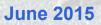
Proposed Environmental Effects Monitoring Programs 2015-2020 Fundy Ocean Research Center for Energy (FORCE)





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Project Team













Executive Summary

Environmental monitoring has been ongoing at the Fundy Ocean Research Center for Energy (FORCE), a demonstration facility for instream tidal energy, since at 2007, when background studies were initiated for the tidal energy demonstration project Environmental Assessment (EA). When the EA was approved by the federal and provincial governments in 2009, a series of environmental effects monitoring programs (EEMPs) were included in the Terms and Conditions of EA Approval. In response, FORCE completed a number of monitoring studies between 2009 and late 2013. The results of the studies undertaken to date along with the original EA are available on the FORCE website (www.fundyforce.ca).

A turbine was deployed at the FORCE site for a short time in 2009. With this exception, no tidal in-stream energy converter (TISEC) turbines have been present at the FORCE site. Consequently, the environmental studies conducted between 2009 and 2015 have largely focused on the collection of background data, rather than on monitoring the effects of turbines. Instead, work has included the construction of the on-shore electrical facility and visitor centre; design, purchase and installation of the submarine cables, and other activities in preparation for turbine deployment. This situation will change with the planned deployment of two cable-connected turbines in late 2015, followed by additional deployments in 2016 and subsequent years.

This report describes new EEMPs that have been prepared on behalf of FORCE, which manages the tidal energy demonstration facility, based on data and lessons learned from the environmental studies conducted to date. The EEMPs are designed to supplement background datasets where needed but are primarily aimed at monitoring the environmental effects of operating turbines. A complementary objective is to identify monitoring techniques that can be successfully applied in the high-flow Minas Passage, based on the principle of "adaptive management".

The EEMPs comprise seven subject areas and are intended to cover initial turbine deployments over the time period 2015 - 2020. The programs are designed to accommodate unforeseen changes in turbine deployment schedules and are adaptive to initial monitoring results. It is also expected that the design and/or methods of certain programs may be updated in later years once early results are known.

Within FORCE's designated Crown Lease Area measuring 1.0 x 1.6 km, FORCE leases to each berth holder a dedicated berth some 200 m in diameter. The berth holder in turn will deploy, operate and test their turbine technologies, which will be connected to the electrical grid through a dedicated subsea cable provided by FORCE. Given these overlapping areas of responsibility, it has been assumed for the purposes of this report that the berth holders will be responsible for monitoring within 100 m of their turbines (the so-called "near field" effects), while FORCE will be responsible for monitoring outside of this zone (the so-called "mid field" and "far field" effects).

Each EEMP is described in a separate chapter. Each program describes past monitoring at the FORCE site and elsewhere around the world (as applicable), as well as the individual program objectives, proposed methods, and monitoring schedules. A discussion of the anticipated challenges is also presented, when applicable.

The EEMPs are intended to be practical, achievable using available technologies, and demonstrative of negative or null effects. Using these EEMPs, FORCE can progressively verify the environmental effect predictions made in the original EA over the next five years. A summary of the programs is presented in the Table below.

Summary of EEMP Objectives and Methods

Subject	Monitoring Objective	Variable/Parameter Monitored or Modelled	Sampling Method	Sampling Location	Sampling Schedule (Period and Frequency)
Lobsters	 To detect a significant change in a population as expressed by a statistical change in lobster catchability. 	 The number and weight of lobster caught per trap. Differences in catchability with distance from the turbine ("distance effects"). Differences in catchability in front/behind vs beside the turbine ("directional effects"); 	 Standard lobster traps deployed at fixed distances from operating turbines. Initially, a double-ring-and-quadrat approach is proposed. If warranted by initial results, the study can be expanded to include Area E and Area W and/or elsewhere for arrays. 	 One ring at 300-350 m from the turbine and one ring at 450-500 m. A total of 24 randomized sample stations, 12 in each ring (6 in each quadrant). 	 All stations are sampled three times to complete one survey; 72 samples per survey (24 stations sampled 3 times). Three surveys are proposed to capture progressive device deployments over time. The actual number of surveys completed will depend on the deployment schedule and initial results. Evaluate results from first 3 surveys, and if more sampling is required around that turbine.
Fish	 To quantify fish distributional changes that reflect behavioural responses to the presence of a deployed TISEC device. To estimate probability of fish encountering a device. 	 Fish density Fish vertical distribution Estimate probability of fish encountering a device 	 Down-looking, vessel-towed hydroacoustic echosounder. Before-After-Control-Impact (BACI) study design. Multivariate analysis (Hotellings T² tests) of fish vertical distributions An encounter probability model 	 9 parallel transects spaced 100 m apart, plus three control transects. Each transect is approximately 1.8 km long 	 Six surveys distributed over six months as was done in 2011-12. Each survey completed over a full tidal and diel cycle (25 hours). Study duration of five years to capture multiple deployments.
Marine Mammals	 Assess <u>direct</u> effects of operational turbine noise: attraction or avoidance. Assess <u>indirect</u> effects due to changes in prey distribution and abundance: attraction or avoidance. 	 Permanent avoidance of the local study area. Permanent avoidance of the near-turbine area (within ~150m). Change in the distribution of a portion of the population: large scale (~50%) decreases or increases in relative occurrence as measured via echolocation activity levels across the local study area, including in the vicinity of operating turbines 	 Deploy 5 C-PODs at multiple sites in the spring to provide an improved baseline data set; redeploy 5 C-PODs in the fall to provide a comparative 'after' data set following turbine deployment(s) 	• at 5 established local study area reference sites.	 2015, 2017 and 2021. Once in the spring and once in the fall. Three months each deployment
			Deploy one C-POD near any occupied Berth	 at 100+m of Berth D and any other occupied berth 	 2015, 2016 and 2017 Once in the spring and once in the fall Three months each deployment.
			 Deploy 1 PAM data logger (AMAR) to provide data to cross-validate C-POD detection data and detect other marine mammal vocalizations 	at FORCE CLA Reference Site West 1 (2015) and East 1 (2017)	 Year 1 2015 & 2017 Once in the spring Nine Months
Physical Oceanography	 None at this time. 	 Demonstration scale project is not anticipated to have a measurable effect on water quality, current and wave profiles, and turbulence. 	 Hydrodynamic modelling can be used to predict when measureable effects, including changes to sediment dynamics, are expected as more turbines are deployed. 	Not applicable	• Pending the results of further modelling, an EEMP can be designed to measure changes in these parameters when needed.
Acoustics	 Establish pre-deployment baseline ambient noise conditions. Use the noise data to verify the EA predictions that suggest noise will not negatively affect marine biota. 	Ambient noise	 Deploy a streamlined moored hydrophone system. Undertake simultaneous drifting hydrophone measurements for comparison and data validation. Alternatively, the hydrophone can be replaced with a drifting noise source emitting at known frequencies. Develop an acoustic noise model 	Within the FORCE CLA	 A deployment period on the order of one to two months to capture noise conditions over multiple tidal cycles.

Subject	Monitoring Objective	Variable/Parameter Monitored or Modelled	Sampling Method	Sampling Location	Sampling Schedule (Period and Frequency)
Marine Benthos	• To identify changes in the occurrence, relative abundance and habitat of benthic species in each berth site relative to reference conditions.	 Change in species occurrence or abundance relative to reference conditions (i.e. pre-deployment and reference site). Change in habitat type/structure in sample sites relative to reference conditions. 	• The vessel would make two or three 100m-long transects across each sample station while recording continuous video segments and taking still photos of the seafloor.	 Sample stations to be located downstream/upstream of the axis of the turbine/array at 150 m and 250 m from the device. Reference sites to be located adjacent to/lateral to the turbine/array at a distance of 150 m from the device. The nearshore sample station would be located in an area containing fine-grained, vegetated habitat. 	 Monitor at each berth prior to and following installation of the turbine(s). Monitoring would occur annually, typically over a two or three day period for a minimum of two years.
Marine Seabirds	• To indirectly assess the potential for direct collision by marine diving birds, or harmful effects caused by their presence, including the potential for displacement of marine wildlife from habitual waters.	 The difference in abundance between sites and between years using density per km² as the unit of measurement. 	 Shore-based survey using Canadian Wildlife survey protocols as in past surveys. 	Observers to concentrate on the device deployment areas, the area between Black Rock and shore (inside Black Rock), and the Minas Passage beyond Black Rock (outside Black Rock) as in previous years.	 Typically 6 hours per observational event; total of 90 hours of observation, or about 16 days annually. Three years; can be extended if warranted

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1.0 **INTRODUCTION**

1.1 Context

The potential environmental effects of tidal in-stream energy conversion (TISEC) devices proposed at the Fundy Ocean Research Center for Energy (FORCE) site have been the subject of scientific research since the Environmental Assessment (EA) was initiated in 2008. An environmental effects monitoring program (EEMP) was made a condition of EA approval of the FORCE test site in 2009 and a number of biophysical studies have been undertaken since then (FORCE 2011; FORCE 2015). These studies were designed to document pre-development conditions, assess instrumentation and data retrieval techniques, and for a limited time when a functioning turbine was present in 2009, monitor environmental effects on certain biophysical components.

The results of baseline studies reveal the challenges associated with monitoring in this high energy environment and point to monitoring approaches, sampling methods and instrumentation that can be used once TISECs are again deployed at the site. Over the past 5-7 years, much of the required baseline data have been collected; the focus now turns to monitoring programs that can successfully assess environmental effects post-deployment, once turbines are again installed in late 2015.

The EEMPs presented here are primarily designed to verify the impact predictions made in the EA (AECOM 2009). They are based on the monitoring requirements first described in the Terms and Conditions of Environmental Assessment Approval (NSDOE 2009).

3.1 The Approval Holder, as part of the project Environmental Management Plan, must develop and implement an environmental effects monitoring program (EEMP). The EEMP must be developed using relevant baseline data and identify appropriate environmental effects indicators. The plan must be developed and implemented in consultation with the project Environmental Monitoring Advisory Committee and shall consider project effects on, but not limited to, the following:

- Fish and lobster
- Marine birds
- Marine mammals
- Acoustics
- Physical oceanography
- Currents and waves
- Benthic environment

These subjects have been combined to form the seven EEMPs presented in this report

- 1. Fish
- 2. Lobster
- 3. Marine Birds
- 4. Marine Mammals
- 5. Acoustics (Noise and Vibration)
- 6. Physical Oceanography (Water Quality, Currents and Waves)
- 7. Marine Benthos

An EEMP has not been developed for the subject of electromagnetic fields (EMFs). The potential environmental effects of EMFs were described as being essentially negligible in the 2009 EA and subsequently were not listed in the Conditions of EA Approval as requiring a topic-specific EEMP. In addition, a detailed literature review on this subject commissioned by FORCE in 2012 concluded that injury or other adverse effects are unlikely to even the most EMF-sensitive marine organisms (Collins 2012; see also Woodruff *et al.* 2013). As recommended in Collins (2012), FORCE will continue to monitor the international research literature regarding the effects of EMFs on marine biota.

1.2 Study Team

To compile the individual EEMPs, SLR Consulting (Canada) Ltd. assembled a team with past experience in the marine renewable energy industry. Team members could both prepare individual subject programs and provide a technical review of other programs. The contributing team members included:

Subject Area	Principal Authors
Fish	Dr. Gayle Zydlewski, Garret Staines, University of Maine
Lobster	Russell Dmytriw, SLR Consulting (Canada) Ltd.
Marine Birds	Dr. Rhys Bullman, Steven Coates, SLR Consulting (UK) Ltd.
Marine Mammals	Dr. Dominic Tollit, Sea Mammal Research Unit, Canada
Acoustics	Craig Chandler, SLR Consulting (Canada) Ltd.
Physical Oceanography	Russell Dmytriw, SLR Consulting (Canada) Ltd.
Marine Benthos	Lisa Isaacman, Fundy Energy Research Network
Senior Technical Review	
Acoustics	Joe Hood, Akoostix/Geospectrum
Instrumentation, Program Design	Dr. Brian Polagye, Northwest National Marine Renewable Energy Center

Table 1-1: Subject Area Authors

1.3 **Objectives**

Globally, in-stream tidal energy projects are developing beyond single unit deployments to larger, pre-commercial and commercial scale arrays, and FORCE is following this development trajectory. As part of its mandate, FORCE is tasked with monitoring and evaluating the environmental effects of the activities undertaken at its site, and reporting on these effects to the public. On behalf of FORCE, the ultimate objective of the project reported here is to design EEMPs that will allow the assessment of environmental effects on critical ecosystems within the FORCE project area and nearby waters over the next phase of turbine deployment. In general, these programs have been designed for the next five years, and are responsive to changes in turbine deployment schedules and adaptable to the ultimate turbine positions within the FORCE Crown lease area (CLA). The four berths and the CLA are presented on **Figure 1-1**.

The results of two primary tasks are presented in this report:

1. Knowledge Synthesis All FORCE-related environmental studies results were assembled, assigned to a subject category and reviewed. At the same time, a targeted literature review was undertaken to identify and obtain recent EEMPs from other marine renewable energy projects as wells as other industry sectors that use EEM that can be applied at the FORCE site. Each EEMP presented here includes a list of references cited to support the particular EEMP. In addition, a broader and more comprehensive Master Bibliography is presented at the end of this report. For ease of use, references are presented alphabetically and are also grouped by subject area. It is hoped that entities engaged to undertake future EEM monitoring can use these recent references to further refine their study methodologies.

2. **EEMP Design** The overarching purpose of each EEMP is to verify the accuracy of the environmental effect predictions made in the EA and maintain compliance with conditions of provincial and federal permits and authorizations. The project team reviewed available monitoring methods and instrumentation to select recommended approaches to future monitoring. In contrast to the research-oriented focus of past work undertaken to characterise baseline conditions, these revised EEMPs are aimed specifically at post-deployment effects monitoring. Subject-specific objectives are presented at the beginning of each EEMP.

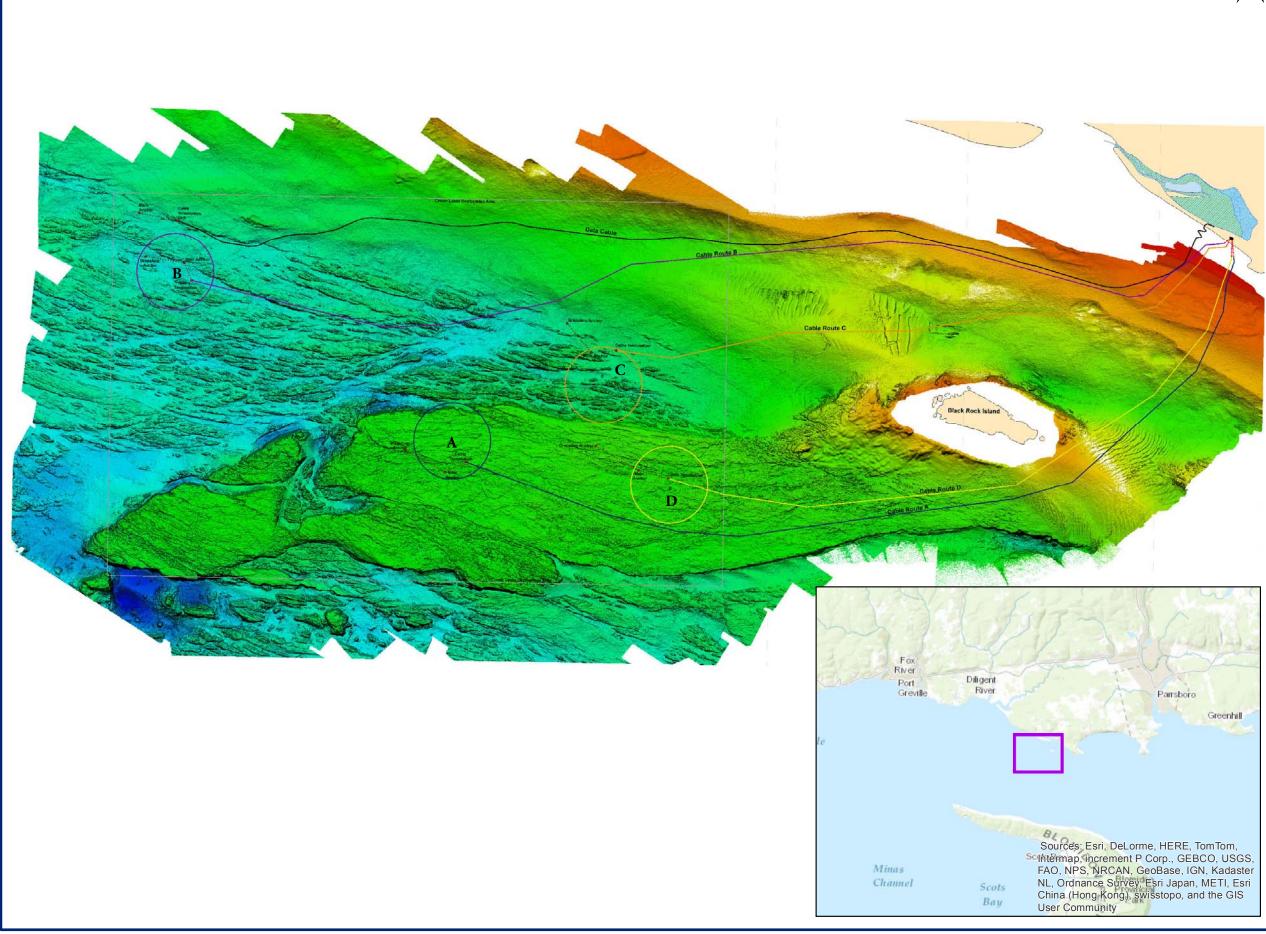
1.4 Methodologies and Assumptions

1.4.1 General Methods

In early March, 2015 project team members presented an outline of most EEMPs to FORCE for review and comment¹.

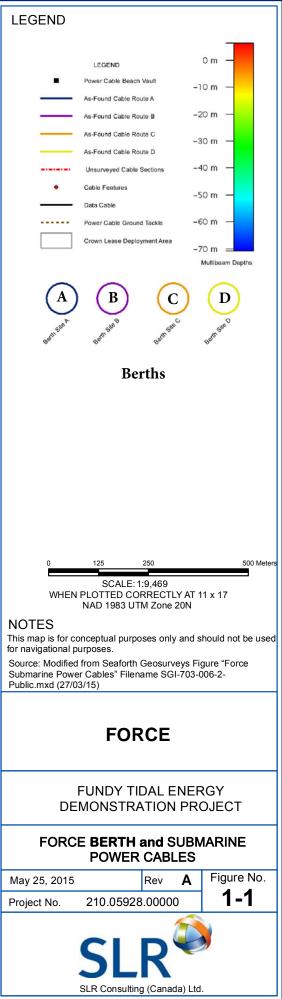
¹ Due to time constraints, outlines for Physical Oceanography and Marine Birds were not presented.

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Parsboro Greenhill



1-6

June 2015 1.0 INTRODUCTION

Following initial discussions with FORCE, FORCE's Environmental Monitoring Advisory Committee (EMAC) and Cape Sharp Tidal Venture², project team members advanced their study designs in draft form for presentation to FORCE, Fisheries and Oceans Canada (DFO), Nova Scotia Department of the Environment, and the joint federal-provincial "One Window" Standing Committee on tidal energy.

At the same time, FORCE updated and sought input from local fishers and First Nation representatives with respect to past monitoring study results and progress on the EEMP mandate. Fishers and First Nation representatives are also present on EMAC and attended EEMP project-related meetings and presentations.

The assembled draft EEMP report and bibliography were submitted to FORCE in late April, 2015. Following review by FORCE and EMAC, the project team presented the revised final report to FORCE by mid-June, 2015.

1.4.2 **Deployment Scenarios**

Four TISEC developer consortiums have been awarded berths within the FORCE CLA. Each berth consists of dedicated 200 m diameter circular space on the seafloor (berths A, B, C or D).

Berth A will host Minas Energy, which is proposing to deploy a 2 MW floating turbine developed by Marine Current Turbines, called the SeaGen F. Berth B is assigned to Black Rock Tidal Power and will be occupied initially by two Triton S36 turbine units, each producing 2.5 MW of power. Berth C will be occupied by three Atlantis AR1500 units, a 1.5 MW turbine proposed by Atlantis working with Lockheed Martin and Irving Shipbuilding. Finally, Cape Sharp Tidal Venture will occupy Berth D. Cape Sharp Tidal is proposing to deploy two Open-Hydro designed open centre turbines, each producing 2.0 MW of power.

The EEMPs are designed to address the effects of turbine operation over a period extending from 2015 to approximately 2020 or slightly beyond. It is currently anticipated that two turbines will be present by the end of 2015 and up to six turbines may be present by 2020. It is currently not possible to predict the exact deployment schedule and so the EEMPs have been designed to be flexible and adaptable to both deployment schedules and ultimate turbine locations. The EEMPs may need to be revisited and updated at a later date to reflect future operational activity.

1.4.3 Approaches to Near Field, Mid Field and Far Field Monitoring

At this stage, the FORCE Tidal Energy Demonstration Project is intended to host individual turbines and small, pre-commercial scale turbine arrays. As its name suggests, the FORCE Demonstration Project is a demonstration scale, rather than a commercial scale tidal energy development. Given the small turbine sizes relative to the Minas Passage and limited scale of the proposed deployments, the 2009 EA predicted that most environmental effects would be difficult to measure (AECOM 2009). This is especially true with respect to potential impacts far removed from the actual turbine sites. Effects are expected to be more difficult to detect with increasing distance from the deployment sites.

² Cape Sharp Tidal Venture is a joint venture between Emera and OpenHydro, formed to deploy OpenHydro-designed turbines at the FORCE site.

Potential impacts or changes that occur very close to the turbine are referred to as "near field" effects, and are generally anticipated within 0-100 m or so from the device. Such effects may include, for example, scouring around the base of the device, colonization of the turbine by benthic organisms, collisions by fish or sea mammals and other effects experienced in the immediate vicinity of the turbines.

Effects in the near field are most effectively monitored by instruments fixed to the TISEC devices themselves. This is so for two reasons. First, the instruments can be cabled to shore through the devices' electrical transmission cables thus overcoming power and data storage limitations. Second, it is difficult and unsafe to approach an operational turbine with instrumentation deployed from the surface. The risk of loss or damage to expensive instruments and the potential for damage to the turbine itself precludes any attempt to measure near field effects in this manner. Unfortunately, the extremely high energy and highly turbid waters of the project area also prevent the effective use of remotely operated vehicles. Since turbine design and operation are the proprietary responsibility of the turbine developer, environmental effects monitoring in the immediate near field (at least as it relates to EEMPs designed for this report) is best conducted by the device owners.

Further removed from the turbine, researchers refer to the "mid field" when describing potential effects approximately 100 m to 1000 m from the turbine. Anticipated effects may include, for example, changes to benthic communities from the wake effects of certain TISEC devices, and behavioural changes to fish, lobster and sea mammals from operational noise or the presence of the device itself. These effects are expected to be more subtle and difficult to detect with increasing distance from the turbine. Nevertheless, these mid field effects are assigned a high priority in the current five-year EEMP design since the environmental effects, if any, from precommercial demonstration scale arrays will be more likely experienced at these distances than farther away. Hence, the mid field is the primary focus of the EEMPs described here as mid field monitoring is the responsibility of FORCE. For certain studies, the mid field extends farther than 1000 m; in general it refers to the area within and around the CLA and Black Rock, loosely termed the project area.

Far field effects refer to environmental impacts that may be experienced or detected outside of the immediate project area. For example, the extraction of tidal energy and its conversion to electricity may have a measurable effect on tidal displacement, tidal currents and sediment or larvae transport, but this will not be measureable at the demonstration scale and so is not a high priority over the next five years. In this report, potential changes to far field physical oceanographic parameters are addressed largely through modelling studies rather than field-based monitoring programs. In contrast, the marine mammal carcass monitoring program described here is designed to detect potential effects in the far field by collecting carcass stranding data from beaches and coves far removed from the project site.

FORCE has proposed a 500 m safety zone around the CLA. FORCE is presently in discussions with and is waiting for feedback from fishers regarding the extent of the safety zone. Lobster is the only species fished commercially in the CLA and FORCE will work with the lobster fishers and manage the safety zone proactively.

1.4.4 Adaptive Management

As noted above, the EEMPs are designed to be flexible and adaptive to the TISEC deployment schedules. In keeping with the "adaptive management" approach used since the beginning of

the FORCE project, modifications to the EEMPs (if needed) can be implemented once the deployment schedule is better known. As more and more turbines are deployed, actual impacts may differ from impacts measured at single devices and the EEMPs can be adjusted to account for this.

Adaptive management is an iterative approach that applies lessons learned from past studies to inform the design of future programs. It also attempts to incorporate changing expectations expressed by regulators, the public and the berth holders. Adaptive management has successfully guided past on on-going tidal turbine testing in Cobscook Bay, Maine since 2008 (ORPC 2012).

1.4.5 International Context

The global marine renewable energy industry has evolved considerably since a Strategic Environmental Assessment was undertaken for the Bay of Fundy in 2008. There are more technically viable prototypes and demonstration-phase tidal energy converters now than in 2008, while certain leading technologies have advanced through testing and grid connection (AECOM 2014). Table 1-2 summarizes the key in-stream tidal energy projects around the world.

Proponent or Project Name	Location	Status
Roosevelt Island Tidal Energy (RITE) Project	East River, New York City	Begun in 2006, Phase III represents the first fully functioning tidal array. When complete, Verdant Energy's 1.0 MW pilot project will consist of an array of up to thirty Generation 5 tidal turbines.
European Marine Energy Centre (EMEC)	Orkney, Scotland	EMEC was established in in 2003 to test both wave and tidal energy technology. EMEC is grid-connected and has tested a number of different technologies.
South West Marine Energy Park (SWMEP)	Lynmouth, UK	The SWMEP is a collaborative development partnership as well as a physical and geographic zone with priority focus for marine technology development, energy generation projects and industry growth.
Pulse Tidal	Humber River Estuary, northern England	Pulse Tidal deployed its Pulse Stream 100 kW generator in the Estuary in 2009.
Marine Current Turbines (MCT)	Strangford Lough, Northern Ireland	MCT is completing the performance evaluation of its 1.2 MW SeaGen design in Strangford Narrows.
Pentland Firth and Orkney Marine Energy Park	Pentland Firth and Orkney waters, Scotland	In 2010, the Crown Estate (a property consortium owned by the UK Crown) awarded development rights to a number of companies for 11 wave and tidal energy projects with a total potential capacity of 1,600 MW.

Table 1-2: International In-Stream	Tidal Energy Projects
------------------------------------	-----------------------

Proponent or Project Name	Location	Status
Électricité de France (EDF) tidal energy demonstration facility	Paimpol-Br´ehat, France	The first 2 MW Open Hydro device was deployed here in August, 2011. This facility has been referred to as the world's first large-scale, grid-connected tidal energy farm and France's first offshore tidal installation.
Ocean Renewable Power Company (ORPC)	Cobscook Bay, Maine	ORPC's TidGen unit is the first grid connected, commercial tidal project in North America and will generate up to 180 kW of electricity.
New Zealand	Parnell Baths, Auckland	New Zealand has committed to developing three, government-funded marine renewable projects as part of their Marine Energy Deployment Fund initiative.
Admiralty Inlet, Pilot Tidal Project, Snohomish County Public Utility	Admiralty Inlet, Washington State	The Project will involve the deployment, operation and evaluation of two 6-meter diameter turbines developed by OpenHydro Group Ltd. While the project will be connected to the grid and produce a modest amount of energy, the primary purpose of the Project research

1.5 Summary

Each EEMP presented as separate chapters in this report meets the primary objectives of the Request for Proposal issued for this work, which are to:

- 1. Recommend methods and instrumentation to quantify environmental effects in the dynamic high current environment of the Minas Passage and surrounding area;
- 2. Explore the possibility of testing the impact predictions presented in the EA for the Project;
- 3. Identify major information and data uncertainties and provide advice on addressing these uncertainties within the proposed monitoring framework, based on a synthesis of the EEM studies completed to date, plus experience gained from EEMPs related to other tidal projects worldwide; and
- 4. Provide a work plan and timeline for the proposed draft EEMP.

The EEMPs are presented in the following order:

- 1. Section 2: Lobsters
- 2. Section 3: Fish
- 3. Section 4: Marine Mammals
- 4. Section 5: Physical Oceanography (Water Quality, Currents and Waves)
- 5. Section 6: Acoustics
- 6. Section 7: Marine Benthos
- 7. Section 8: Marine Seabirds

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Section 2: Lobsters



2.0 SECTION 2: LOBSTERS

2.1 Introduction

2.1.1 **Context**

An Environmental Effects Monitoring program (EEMP) is a stipulation of the September 2009 Approval granted by the Nova Scotia Minister of the Environment to the FORCE project following submission of the Environmental Assessment (EA) in June 2009. The Approval requires the EEM "*identify appropriate environmental effects indicators…and…consider project effects on* (among other subjects) *fish and lobster.*"

Regarding the potential effects of the FORCE demonstration project on lobster, the commercial lobster fishery is the primary focus of study. The 2009 EA notes that "potential adverse effects on the commercial lobster fisheries will be eliminated or minimized to insignificant levels throughout the Project life". The EA goes on to predict "Apart from direct displacement of a limited number of individual lobsters in the immediate Project footprint, there may be indirect effects on migrating lobsters during construction as a result of noise, vibrations, or sediments" (AECOM 2009).

In order to test these predictions, a series of EEMPs focused on lobster "catchability" and movement were undertaken in 2009 and 2010. The ultimate objective of these studies, and the follow-up EEMP described here, is to assess the impact of the FORCE project on lobster catchability; that is, on the number of lobsters entering commercial lobster traps in the vicinity of the Project. This in turn should provide a perspective on the magnitude or significance of Project effects on the commercial lobster fishery.

Project effects may be negative if the turbines demonstrably reduce lobster catches in the local area surrounding the FORCE Crown Lease Area (CLA), or positive if commercial fishing restrictions within the CLA lead to increased populations that in turn migrate to areas where they can be harvested.

Negative effects may result from turbine noise, vibration or other effects that affect lobster survivability at some point in their life cycle (thereby reducing commercial populations), or the turbines may act as a physical barrier affecting lobster movement across the CLA, that is, through an area of restricted commercial activity to areas where fishing is allowed.

Shellfish are reportedly insensitive to underwater noise but sensitive to vibration as it allows them to detect potential predators and prey (Normandeau Associates 2012). However, the lack of a swim bladder such as those possessed in fish means that shellfish are unlikely to be susceptible or at risk from underwater noise impacts associated with tidal devices (NERC 2013).

2.2 Studies Completed to Date

2.2.1 Catchability

Using commercial lobster traps and with the aid of local fishermen, CEF Consultants on behalf of FORCE conducted two lobster catch surveys in fall, 2009 and one survey in spring 2010. The EEMP is based on comparing catchability (i.e., fishing success) before, during and after turbine

deployment within a "test area" where turbine effects may be expected (i.e., within the CLA) and within "control areas" where no turbine-related effects are anticipated (CEF 2010; CEF 2011).

Data were collected in 2009 before and during the commercial fishing season, which corresponded to before and after the fall, 2009 deployment of a turbine jointly managed by Nova Scotia Power Inc. and OpenHydro. Sampling was restarted again in spring 2010, outside of the fishing season while the turbine was still in place but no longer functioning. Over 3000 lobsters were collected and the results were statistically analyzed to determine distribution patterns and trends, both before and during fishing season, as well as before and following turbine deployment.

In general terms, the studies demonstrated where commercial lobster fishing occurs in the vicinity of the Project and concluded that fewer market size lobster are observed in these commercially fished areas. It also showed differences in lobster distribution over the spring and summer, and noted that smaller lobster are more common in shallow water while larger lobster are more widely distributed over a range of depths (CEF 2011).

Catch reductions were noted after the turbine was deployed but no direct relationship between the turbine and reduced catches could be established. This was primarily due the presence of other variables that can affect catchability. Such variables include the displacement of traps to deeper water and the effects of commercial fishing during turbine deployment and subsequent lobster surveys (CEF 2011).

The report authors conclude that lobster catchability study design and methodology are sufficiently robust to collect meaningful data regarding lobster catchability. CEF 2011 concludes "surveys conducted to date provide information on variability of catch within the different areas, at different seasons, with and without the commercial fishery, and at different depths. Review of the data allows an estimate of the number of samples needed to detect a change in lobster catchability at a particular level, e.g., a pre-set change in percent of catch." A follow-up statistical analysis demonstrates how a simple Before After Control Impact (BACI) analysis can be applied to future studies (Bayley 2010).

In summary, the lobster catchability results indicate a statistically significant reduction of lobster catch rate following turbine installation at a distance of 200-300 m from the turbine compared to the control at 500 m. Further analysis demonstrated this was not due to the small sample size, the actual position of the turbine compared to where it was originally proposed when the study was designed, or differences water depth (which also affects catchability as noted above). Given that samples collected within a 6-day period in November 2009 after the turbine was deployed, it is possible that the lower catches were due to the noise or other disturbance associated with turbine installation (Bayley 2010) or other factors such as removal of lobster by the commercial fisheries and/or late fall movement of lobsters out of the area (CEF 2011).

2.2.2 Tagging and Tracking

To determine year round use of Minas Passage and by extension the FORCE site as a corridor by lobsters, Acadia University in 2011 and 2012 undertook a lobster tagging and tracking study using VEMCO acoustic transmitters (Morrison *et al.* 2013). The objectives of the study were:

- 1) To evaluate the transmission range and detection performance of VEMCO acoustic transmitters attached to lobster;
- 2) To determine if the Minas Passage is used as a seasonal migratory pathway; and

3) To examine the level of seasonal exchange and characterize movement, if any, between the Minas Basin and the Bay of Fundy. The study attempted to determine patterns related to timing, route, and speed relative to body size and sex.

A total of 85 lobsters were captured, tagged and released in the central portion of Minas Passage. In total, 27 of 29 acoustic receivers originally deployed were retrieved and the data downloaded. Over the course of the study 33 lobsters (39%) were detected by at least one bottom mounted receiver station.

The studies indicated that VEMCO transmitters affixed to lobsters can in fact be detected by bottom-mounted receivers despite the harsh and acoustically noisy environment. Nevertheless, the study results suggested that the acoustic receivers may have been removed prior to detection of all seasonal movements during the fall-winter 2011 season, leading to an under detection of actual transits through the Passage. Alternatively, the results may indicate that some lobsters moving through the Minas Passage were able to pass by arrays undetected. Receiver efficiency is reduced during periods of high flow speed, and receiver arrays may not have provided complete coverage under all current speeds and over all depth ranges (Morrison *et al.* 2013).

Morrison et al. (2013) concluded that some lobsters in Minas Basin move from east to west through Minas Passage in the late fall / early winter and may move back eastward in the spring. Movement appears to occur preferentially along the northern shore of Minas Passage and through the FORCE test site. Some lobsters may overwinter in Minas Basin. In contrast, limited information regarding their presence and movement was collected outside of Minas Passage. Mean movement rate was observed to be slower in males than in females. Females exhibited a great range of movement speeds than males.

2.2.3 Lobster and Crab Fishery Assessment, EMEC

At the European Marine Energy Centre (EMEC) wave energy test site at Billia Croo, Orkney Islands, Scotland, lobster and brown crab catches by a commercial vessel were recorded on 21 occasions during June to September 2011. Data recorded by Bell *et al.* (2011) included catch rates of legal and undersized individuals and catch composition in terms of species, sizes and sexes.

The study concluded that Billia Croo is a productive fishing area, principally for lobsters, and indeed is under relatively high fishing pressure. The study concludes that (a) the area provides suitable feeding and refuge habitat for lobster, and (b) once designated as a fisheries "no take zone", has the potential to act as a nursery area to both the local lobster fishery and to the Orkney Islands as a whole.

The main lesson presented by Bell *et al.* (2011) for future monitoring is that a significant investment in sampling operations is needed for proper scientific control and optimum data gain from monitoring efforts. The study did not demonstrate cause-and-effect interactions between wave energy devices and lobsters or crabs.

2.3 **Objectives**

The overarching purpose of an EEMP is to verify the effectiveness of mitigation measures implemented by the proponent, the accuracy of the EA predictions, and compliance with conditions of provincial and federal permits and authorizations.

As described in the EA, a significant adverse effect is defined as one that creates a significant alteration to a population (or a portion of it) to cause an unnatural decline or change in the abundance or distribution of the population to a level from which recovery of the population is uncertain, over one generation or more. A positive effect is defined as an improvement in the quality or extent of habitat, or an enhancement of a population such that an increase in that population is evident. The EA goes on to predict that no significant negative effects on the commercial lobster will be experienced.

In order to measure a "significant alteration in a population" so that any negative effects can ultimately be determined, knowledge of the <u>abundance</u> and <u>movement</u> of lobsters in the Minas Passage during various times of the year is needed. Past lobster catchability studies combined with acoustic tagging surveys have provided sufficient background information to establish, in general terms, relative abundance and seasonal movement patterns. Although more work would be useful to further establish population variation and large scale seasonal movement in lobster populations, such information is not needed to statistically measure mid-field effects of turbine operation on lobster catches.

As noted above, past catchability studies have provided useful information on lobster distribution within the CLA and nearby test areas. The EEMP below is designed to answer the question: does the presence of the turbine affect the number of lobster entering the traps? Preliminary results described above suggest that the turbine does, in fact, have such an effect at 200-300 m from the turbine but no effect is detected at 500 m from the turbine. Since these results are preliminary and may in fact be due to perturbations caused during installation (rather than noise, vibration or other effects during operation), additional work is warranted to test this question.

2.4 **Proposed Methodology**

2.4.1 **Overview**

The primary environmental effects variable that should be monitored is the number of lobster caught per trap, combined with (as suggested by DFO 2012) the weight of lobster caught per trap. As in past catchability studies that use standard baited commercial lobster traps, the primary evaluation of effects should use Analysis of Variance comparing catchability at defined distances from the turbine(s).

Current-induced trap movements, trap recovery rates (i.e., trap loss) and the short time window available at slack tide to set or collect traps affects the ultimate study design and, to a certain degree, the utility of the data recovered. Bayley (2010) notes the main weakness with data from CEF 2010 and CEF 2011 is the lack of balance among strata³ and the limited number of replications at each sample site. The methodology below, adapted from CEF 2011 and Bayley 2010, is intended to address these points, to the extent possible.

Despite the limitations and difficulties imposed by the Bay of Fundy marine environment, the lobster catchability studies demonstrated that a simple Before After Control Impact (BACI) study can provide useful environmental effects monitoring data. Bayley (2010) determined the number of samples needed to detect a change in lobster catchability with sufficient statistical

³ A stratum is sampled interval. In this case, distance from the turbine is one type of stratum while water depth is another.

reliability. Based on preliminary results, a reduction in catch of 2 lobsters per trap was considered appropriate.

Given that the EA predictions focus on the commercial lobster fishery, the first priority is to confirm the preliminary results that suggest the turbine may have an effect on lobster catchability. That is, the primary aim is to establish if the reduced catch rate observed at 200-300 m compared to 500 m from the turbine is factual and determine if the observed reduced catch at this distance continues during the extended presence of the turbine. To answer this question, additional sampling is needed while the turbine is present. Drawing from the lessons learned during the 2009-2010 catchability studies, Bayley (2010) proposes a simple, achievable and statistically robust study design that also allows researchers to employ data collected in past studies to support future statistical analyses.

2.4.2 Design A: Mid Field

The text below describes a mid-field EEMP with one turbine at the center of the monitoring program. The study design proposes sample collection from random sample stations located within two rings around the turbine: one ring at 300-350 m from the turbine (called the "treatment ring") and one ring at 450-500 m (called the "control ring"). Both rings would be divided into four quadrats (east, west, north and south) and sample sites would be randomly assigned in each ring within each quadrant. Ideally, the quadrats should be aligned with the tidal current direction so that directional effects in front of and behind the turbine in action can be compared with results in quadrats beside the operating turbine.

The double-ring-and-quadrat approach is proposed to account for possible directional effects due to water currents and noise from the turbine, and to allow for current-induced trap movement. To the extent possible, benthic habitat types mapped in past studies can also be applied to the sample locations to help account for differences in catch rates.

Regarding the total number of sample stations, Bayley (2010) suggests it is important to have a sufficient number of back-up samples to ensure as balanced a design as possible. A total of 24 randomized sample stations, 12 in each ring, is proposed. With two rings (one at 300-350 m and one at 450-500 m), this means six stations in each quadrant.

It is further proposed that **all stations are sampled three times to complete one survey**. Bayley (2010) notes that three replications and six stations per quadrat "would provide good insurance for single losses in locations or site replications, and still retain temporal and spatial replication..."

If all samples could be completed, the total samples per survey would be 72 (24 stations sampled 3 times), meaning 36 samples for the "treatment ring" and 36 samples for the "control ring, which, Bayley notes, provides good power for the main treatment/control effect.

For comparison, the first three catchability surveys, excluding half of the paired trap samples (described below), collected 132, 73, and 147 completed samples, respectively. A balanced design of 72 samples per survey will provide data to evaluate:

- 1. Differences in catchability with distance from the turbine ("distance effects");
- 2. Differences in catchability in front/behind vs beside the turbine ("directional effects");
- 3. Allowance for loss of samples (traps); and

4. Comparability with existing data.

If the results of this study do not detect a statically significant change in lobster catchability, or the effects of a detected change are so low as to ensure that no significant effects on the commercial harvest will be felt, then **the EEMP can be discontinued after at most three surveys.** A full three surveys are proposed to capture progressive device deployments over time. The actual number of surveys completed will depend on the deployment schedule and initial results.

CEF (2010) reports that approximately 15 stations can be sampled routinely in a typical day. More stations can be sampled at lower amplitude tides because the survey vessel can spend more time in the water and traps remain closer to their set location. At extreme high tides, buoys may remain at the surface for less than 30 minutes at each slack tide, allowing recovery of relatively few traps. This experience implies that all stations can be sampled over the course of two days, and that a single survey consisting of three replicates would require a total of 6 days, not including preparation, trap setting and data analysis.

Given that two turbines will be installed in 2015 within Berth D, the study design proposed above can be easily modified to accommodate two turbines within a single berth, as is proposed for Berth D. The two turbines will be located within 200 m of each other since the berth diameter is 200 m, and so can be treated as a single unit. Once the exact placement of the turbines is known, the ring distance can be adjusted to include and effectively represent both turbines.

2.4.3 Far-Field Effects

Second in priority is the question of far-field effects. As Bayley (2910) observes: are there larger scale consequences (i.e., outside of 500 m from the turbine) of the turbine presence?

When 2009 catch data from before turbine deployment are compared to catch data after deployment, preliminary results suggest that no changes to catchability can be detected at 500 m from the turbine. Ideally, future results from the study described above will validate these preliminary findings. If no changes to catchability are found at 500 m then there will be no justification to expand the study outside of that range.

In contrast, if changes are noted at 500 m from the turbine then locations outside the 500 m distance noted above should be sampled over consecutive fall and/or spring seasons when the turbine is operating. This will establish if there are "larger scale consequences of the turbine presence".

Given that a single turbine is extremely small compared to the "proximate far-field zone" (here defined as extending from Cape Sharp to the headland just past Diligent River - a distance of about 8.0 km) it is unlikely that significant effects in the proximate far-field will be detected with only a single turbine in place. Given this, we recommend deferring any far-field studies until three or more turbines are deployed. Once three or more turbines are in place, the study can be expanded as per Design B.

2.4.4 Design B: Far Field

Larger scale, proximate far-field effects may be detected through a continuation of mid-field (turbine area) sampling described above, combined with continued sampling in CEF's Area E (the eastern control area) and Area W (the western control area)⁴.

A similar sampling effort in terms of number of sample stations should be applied to Areas E and W, resulting in 12 randomized sample stations in each control zone (Bayley 2010). Therefore, when undertaking this expanded study to test for far-field effects, a total of 48 stations would be visited per sampling event: 12 each in Areas E and W, plus 24 in the ring-and-quadrat area around the turbines. At 15 stations per days, this would require about 3-4 days of sampling time. Existing sites can be used or randomly selected from. Consistent with Design A, one "survey" would consist of three replicates (i.e., three sampling events), resulting in 144 samples per survey, requiring approximately 12 days of sampling time. Again, at most three complete surveys will be sufficient to demonstrate an effect, should such an effect be present.

In summary, each expanded or proximate far-field survey would sample 12 randomized stations in each of four zones or "strata": Turbine-300m, Turbine-500m, Area E, and Area W. Each site would be sampled (replicated) three times. Bayley (2010) observes this would provide balance, sufficient power, and sufficient redundancy in case of trap losses and trap movement.

The commercial lobster season in the FORCE Project area (i.e., lobster fishing area 35) extends from March 1 - July 31 and from October 15 - December 31. If surveys are undertaken in fall they should be completed before the start of the fishing season in order to avoid any effect of the commercial harvest on catch numbers. Since the fishermen who may be able to help with the survey will be busy during the spring and fall fishing season, it appears that annual surveys should be conducted in September. This should provide sufficient time for lobster populations to stabilize following the spring harvest and allow commercial fishermen who are helping with the study to prepare for the fall fishing season.

2.4.5 Multiple Turbines

At this time, it appears the first two turbines will be deployed in late 2015 in Berth D, while the next turbine will be deployed in 2016 in Berth B, over 1000 m away. The great distance separating these two early turbines suggests there will be limited interference or overlap in environmental effects between them. Given this, they are best monitored as separate installations; study Design A can be applied to the 2016 turbine. In contrast, once either Berth A or C are occupied, study designs should be modified to account for the potential cumulative effects from multiple devices. This is especially important if, as currently anticipated, a fourth turbine is installed in Berth C in 2016.

Once three berths are occupied, the joint effect of multiple turbines can be assessed. Instead of distinguishing distance from turbine on a categorical basis (treatment/control), as implied by the rings in Design A, one can take a continuous approach by expressing samples from each site in

⁴ Bayely (2010) suggests that since most of CEF's Area T (the test area) will be already included in the ring-and-quadrat approach, future work need not continue to sample CEF's established randomized sample sites in this area.

terms of their distance from one or more turbines (Bayley 2010). To accomplish this, a sufficient number of randomly selected sample stations would be selected at different distances from the turbines and accounting for varying water depths.

Given the uncertainty regarding the timing of future deployments, we recommend that planning for future studies designed to address multiple turbines be deferred until short-term study results are known and deployment schedules are further defined. Future designs should also consider how the ultimate "Safety Zone" around the FORCE CLA may positively impact lobster populations outside of the zone.

2.5 **Discussion**

2.5.1 Study Design and Recommendations

These study designs include suggestions proposed in DFO (2012):

- The number of replicate samples is described (three replicates form one survey).
- The monitoring program is designed to assess effects on catchability while the turbines are in operation.
- Catch rates expressed as Kg/trap hauled will also be recorded and evaluated.
- Monitoring activities will be conducted during the out-of-fishing season.

Since the number of lobsters caught per trap-set is not normally distributed⁵, Bayley (2010) recommends that future statistical analyses of study results use Generalized Linear Models (GLM) with a negative binomial distribution rather than the standard log(count+1) transformation that is typically applied to data that is normally distributed.

This proposed design requires new stations to be randomly selected. Since depth is known to be a significant variable, CEF (2012) suggests some stratification by depth be introduced into the station selection to ensure that an adequate balance of depths is sampled.

To increase study efficiency and with the intention of reducing current-induced trap movement, certain stations during past surveys were sampled with pairs of traps connected by a 60 m rope. Statistical analysis indicates the results from the paired samples are not comparable to the non-paired samples (Bayley 2010). The reviewer recommends discontinuing the use of pair traps in future surveys. This also reduces the entanglement safety hazard identified in CEF 2010. The 2009-2010 trap pair data can still be used in future analyses: results for one of the two traps from each pair can be randomly chosen, pooled and then used in statistical analyses.

Difficulties were encountered due to the short time over which the traps could be set and recovered (less than an hour over slack tide) and the time (and expense) required at sea because of low water levels at the wharf. In addition, the strong currents often moved traps from their intimal deployment location, typically approximately 100 m from initial deployment location (but up to 1.0 km). During the first fall 2009 survey, 3 of 51 traps were lost. During the second fall 2009 survey, 7 of 48 traps were lost. During the spring 2010 survey 5 of 28 traps

⁵ "normal" distribution is a statistical term used to describe data that tends to cluster around a central or mean value.

were lost. Analysis of results must take into account both trap loss and trap movement. Planning and cost estimates should factor in a 15% trap loss rate.

It should also be underlined that lobster populations (i.e., relative abundance) are noticeably affected by commercial fishing pressures, whereas the noise and vibration effects of four or five turbines may be very difficult to measure in comparison. Given this, efforts should be made to minimize the effects of the commercial harvest on study results.

2.5.2 Limitations and Other Study Design Considerations

Potential limitations and lessons learned from past work have been described in preceding sections. In addition to those aspects, the three most important factors affecting catch rates are reported to be (CEF 2010):

- 1. soak time;
- 2. lobster size as expressed through carapace length; and
- 3. water depth.

These variables must be considered when designing future studies and analyzing study results.

Soak time is the number of tides between setting and retrieving traps; that is, the length of time the traps are in the water. The study results indicated that lobster catches increased as soak time increased up to a point where catches began to decline as bait was lost, degraded or consumed and/or most of the nearby lobsters had been caught in the trap.

Although soak time is an important variable, it is not useful to reduce trap numbers so that they can all be collected within the same soak time period. Instead, it appears more important to recover as many traps as possible in a robustly designed (i.e., statistically representative) study, even if there are some longer soak times due to delay in retrieving the number of traps required. However, Bayley (2010) suggests that soak time and its square should be considered in future studies and included for analysis if their coefficients are statistically significant.

Lobster catch decreases with increasing depth. Because sampling can vary due to trap loss, consistency of mean depth over the study period should be checked so that depth differences can be accounted for in the statistical analysis, if needed. In addition, lobster size was correlated with their distribution: smaller lobsters are typically found closer to shore in shallower water. The distribution of lobster by size can affect the potential for impact on a particular size group because of the location of turbine deployment, as well as affecting the interpretation of results of catch rates, especially when traps deployed at one depth are moved by currents to a different depth. These factors must be considered when analysing catch results.

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Section 3: Fish



3.0 SECTION 3: FISH

3.1 Introduction

The search for, and interest in, harnessing energy from tidal currents occurs in numerous places around the world. The Bay of Fundy has the most extreme tidal flux of anywhere in the world and is an obvious candidate location for the research and development of TISEC projects. FORCE has constructed a tidal energy demonstration facility near Parrsboro, Nova Scotia within a seabed Crown Lease Area (CLA) measuring 1.0 by 1.6 km. In addition to the research on TISEC devices, an environmental effects monitoring program (EEMP) is required for marine fish interactions.

The following paragraph describes impacts the FORCE project is predicted to have on fish, as presented in the 2009 Environmental Assessment (EA) prepared for the FORCE project:

It is anticipated that marine fish present or migrating through the Project area may experience very limited behavioural changes such as avoidance and aversion, as well as limited mortality and habitat disruption. The extent of these effects is not known given the lack of specific information related to noise generated by the proposed devices, and the background noise in the Project area. By following existing standard construction practices, available guidelines and associated mitigation measures, Project activities and components are not likely to cause significant adverse residual effects on marine fish within the Project area or vicinity (i.e., Minas Passage and Minas Basin). In general, this is due to the relatively small scale of the project, combined with the limited duration and intermittent nature of the Project activities (AECOM 2009).

Possible interactions can occur at different spatial scales relative to the devices, beginning with the near-field. A TISEC device near field interaction could include fish collisions, blade strikes, and/or pressure-induced damage to fish resulting from device cavitation. These events are difficult to capture in real time, especially in the field. There are no field studies where observation of blade strike has been recorded but there are laboratory studies that have documented such interactions (Amaral *et al.* 2015). For the purposes of this EEMP, near field interactions such as blade strikes and collisions are assumed to be the subject of monitoring by the device proponents.

Before attempting to answer the question of whether or not there are actual near field physical interactions (e.g. collisions or blade strikes) it is important to address the larger scale question of whether or not TISEC devices affect overall fish use of the water column at ranges from 10-150 m from the device. At these distances and farther, there are possible indirect large scale effects on fish use of the water column due to the presence of TISEC devices. For example, does fish density change and does fish vertical distribution within the water column change due to the presence of a TISEC device? There has been previous fish research in Minas Passage relative to potential TISEC development (Imrie and Daborn 1981) and one study while a TISEC device was deployed (Melvin and Cochrane 2014). Globally, opportunities to investigate fish interactions with an deployed TISEC device have been sparse (Viehman and Zydlewski 2015). The FORCE project provides a relatively unique situation of deployed devices and the ability to monitor the surrounding fish density responses.

3.2 **Studies Completed to Date**

There have been three hydroacoustic surveys performed to date in relation to fish and TISEC device deployment in the FORCE CLA. The first employed down-looking hydroacoustics with integrated trawl surveys performed by CEF Consultants in 2009-2010 (FORCE 2011). Key findings of the study were:

- Fish were relatively evenly distributed throughout Minas Channel between July and October;
- Spatial differences were noted in gaspereau and dollar fish distributions. Mackerel showed differences in day and night concentrations;
- The FORCE CLA had biomass densities similar to other areas of Minas Channel and was not found to be a specific migration or passage route for any species;
- Correlation between trawl and hydroacoustic biomass estimates was significant but weak due to a few exceptional values, most likely due to the patchiness of schools of herring;
- The major components of finfish biomass in Minas Channel are adult herring entering in June, followed by young herring in later July and August, gaspereau in September, and a broad mix of species leaving the upper Bay of Fundy in October; and
- Biomass is evenly distributed throughout Minas Channel.

Melvin and Cochrane (2015) also used down-looking hydroacoustics in Minas Passage around the time of a TISEC deployment. Key findings of this study were:

- Tidal flows in the area impede traditional sampling methods and instrument deployment approaches;
- Entrained air within the water column restricts use of hydroacoustic technologies at certain times and locations;
- High winds increase the amount of entrained air affecting hydroacoustic data collection;
- Separating entrained air from fish may be difficult and requires manual processing; and
- The use of multi-beam hydroacoustic devices is difficult in high flow tidal areas and quantitative applications are still evolving.

Down-looking hydroacoustics were also used for a survey related to a deployed OpenHydro Ltd. device in the FORCE CLA in 2011 (Melvin and Cochrane 2014). Key findings of this study were:

- Backscatter levels in the Channel and the FORCE CLA site peaked in June from an increase that started in March;
- Adult herring make up late spring- early summer influx of fish;
- Fall backscatter levels rose after a drop in August consistent with emigration of young-ofthe-year spring spawning species; and
- Quantification of hydroacoustics data was hampered by entrained air affecting the top 10-20 m of the water column.

Globally, most site characterization to date has consisted of baseline data collection. There are few international studies of TISEC effects on fish. Broadhurst and Barr (2014) utilized a camera attached to a device deployed by OpenHydro Ltd. at the European Marine Energy Center (EMEC) in the Orkney Isles. Fish were observed during daytime, quantified, and compared to tidal velocity. Fish numbers around the turbine decreased as tidal velocity increased.

A deployed TISEC device, Ocean Renewable Power Company's TidGen®, was monitored in Cobscook Bay, Maine, USA from 2009 to 2013. Preliminary baseline characterization of the site using down-looking hydroacoustics has been performed (Viehman *et al.* 2015) and continued hydroacoustic surveys to test the effects on fish were performed after device installation. This research has been peer reviewed and is an acceptable method for surveying around TISEC device deployments. Additionally, the most recent Annex IV report (Copping *et al.* 2013) references successful case studies implementing hydroacoustics and the Annex IV. There was also an updated report from Annex IV for best practices for environmental monitoring (Copping *et al.* 2014) that specifically cites several acoustic devices as ideal for surveying near TISEC devices including down-looking hydroacoustics.

A recent study (Hammar *et al.* 2013) in Ponta Torres near Mozambique used remote stereo video systems to observe fish in the daytime near a vertical axis hydrokinetic rotor. The authors found that fish avoided the near field of the device. More recently, Viehman and Zydlewski (2015) observed fish behaviour in the near-field of an operational TISEC device deployed beneath a floating barge. They found that fish were less likely to approach the device in the daytime and that fish schools were less likely to approach than individuals. There are additional laboratory studies on impacts that scaled down TISEC devices have on fish (Amaral *et al.* 2015) as well as models describing potential effects (Romero-Gomez and Richmond 2014). While these provide needed information to the research field, continued monitoring near deployed TISEC devices is still needed to properly inform regulators.

Several fisheries surveys have been successfully completed in Minas Passage and other high flow environments using down-looking hydroacoustics (Melvin *et al.* 2014; Melvin and Cochrane 2015; Viehman *et al.* 2015). Hydroacoustic surveys allow for non-invasive, high resolution sampling of nearly the whole water column allowing quantification of fish biomass (Thorne 1983; Burczynski *et al.* 1987). This EEMP proposes mobile down-looking hydroacoustics from a small to medium sized boat following the methods from Melvin and Cochrane (2014).

The primary advantage of hydroacoustics is the ability to measure the distribution and abundance of fish with high spatial (meters) and temporal (seconds) resolution during both day and night in nearly the entire water column. Applications of hydroacoustics are numerous in fisheries science (Kocovsky *et al.* 2013; Mehner *et al.* 2003) and it has been applied to fisheries monitoring associated with tidal power harvest in the US (Viehman *et al.* 2015; Melvin and Cochrane 2015). The reliability of hydroacoustic instruments is also an advantage. Equipment manufacturers produce consistent, durable devices that operate for long periods of time with few interruptions (MacLennan and Simmonds 2005). Hydroacoustics is not without limitations. The technique is limited in its ability (a) to differentiate species and (b) detect fish near boundaries such as the surface, sea floor, or in the immediate near-field (<10 m) of a TISEC device thus making it ideal for mid-field applications. Fish density estimates are possible but precision depends on detailed species composition, length frequencies, and target strength. The technique requires some understanding of the physics of sound propagation in water and staff training to prevent data processing and analysis mistakes (Rudstam *et al.* 2013).

Aside from past successful surveys, there are certain challenges involved with using downlooking hydroacoustics in such a high flow area. The high flow area creates a dangerous environment increasing the risk of collisions with other boats and increased danger in foul weather. As noted, hydroacoustic technology is negatively affected by entrained air in the upper water column as it creates large amounts of noise and can attenuate the signal making fish detection more difficult. This difficulty is often addressed by eliminating a certain amount of the upper water column from processing and analysis (Rudstam *et al.* 2013; Viehman *et al.* 2015). High flow areas like Minas Passage typically have high levels of entrained air due to the high flow combined with high winds. These conditions make sampling with hydroacoustics difficult and even impossible at times. However, there are few methods that have potential for such high temporal and spatial resolution in the high flow environment of Minas Passage; given this, a hydroacoustic approach previously used at this site is proposed for the EEMP.

3.3 **Objectives**

The goal of this EEMP is to describe a means of quantifying fish distributional changes that reflect behavioural responses to the presence of a deployed TISEC device. The objectives of this program are to: (1) test for indirect effects of TISEC devices summed on water column fish density; (2) test for indirect effects of TISEC devices on fish vertical distribution; and (3) estimate probability of fish encountering a device based on fish density proportions in the water column relative to a TISEC's depth in the water column. These objectives will be met using established down-looking hydroacoustic monitoring techniques, Before-After-Control-Impact (BACI) study design, multivariate analysis (Hotellings T² tests) of fish vertical distributions, and an encounter probability model.

3.4 Monitored Variables

Fish Density: Down-looking hydroacoustics provides raw data that can be used to calculate fish density by scaling mean volume backscatter (S_v) by the average scattering cross section (σ_{bs}) or averaging fish tracks per sampled volume. This variable is used to represent fish concentration.

Fish Vertical Distribution: This variable is estimated by dividing the water column into equal depth bins (e.g. 1 m) and calculating the proportion of fish density for each bin. See **Figure 3-1** for an example. This variable is used to represent fish distribution.

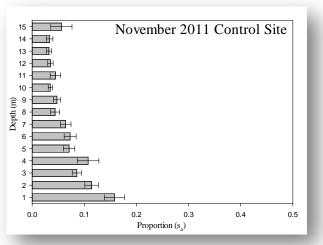


Figure 3-1. Example of the bottom 15 m of the water column showing fish vertical distribution as a proportion of total fish biomass per 1 m of depth. Whiskers represent 1 standard error.

To address the first objective, indirect effects of a TISEC device on monthly fish density estimates (the measured parameter) will be compared using a Before-After-Control-Impact (BACI) design. The "before" component must be estimated from previously collected data from Melvin and Cochrane (2014). The "after" component will be estimated from down-looking hydroacoustics surveys following the methods described in Methodology below. This will provide a statistically defined change in the density of fish at the FORCE CLA after devices are deployed, provided there is such an effect. A control will be used to account for potential annual variability in fish density estimates (Smith 2002). This will inform FORCE of any difference in concentration before and after device installation while accounting for inter-annual variability.

To address the second objective, indirect effects of a TISEC device on monthly vertical fish distributions based on 1 m depth bins measured up from the sea floor will be compared using a Before-After-Control-Impact (BACI) design. This provides fish vertical distribution by 1 m increments (the measured parameter). The "before" component of the study will use the dataset from Melvin and Cochrane (2014). The "after" component will be estimated from down-looking hydroacoustics survey data as described in Methodology below. This will provide a statistically defined change in use of the water column (vertical distribution) by fish in the mid-field at the FORCE CLA relative to a control site, if in fact there is such an effect (Staines *et al.* submitted to European Wave and Tidal Energy Conference (EWTEC) 2015). This in turn will inform FORCE of any change in fish vertical distribution before and after device installation and will account for inter-annual variability with control site comparisons.

To address the third objective, indirect effects of fish water column use at the depth of a deployed TISEC device will be assessed using an encounter probability model. The probability that fish will encounter a deployed device is estimated from two components: 1) the proportion of fish being at the device depth when the device absent; and 2) the proportion of fish being at the device is present. The product of these two estimates will provide a probability of fish encounter (**Figure 2**).

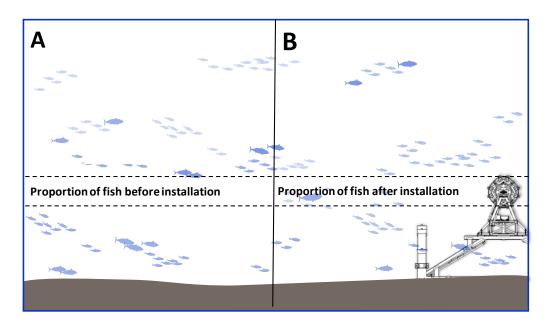


Figure 3-2. Display of part of the water column of a theoretically planned site for TISEC device installation. The dashed lines represent the depth in the water column of interest because it is where the device is located and where potential fish interactions will occur. (A) represents the water column prior to device installation and provides the parameter of fish proportion before installation. (B) represents the water column after device installation and provides the parameter of fish proportion after installation.

3.5 Methodology

3.5.1 Boat Platform and Acoustic Survey System

Previous mobile, down-looking hydroacoustic surveys were performed used an 18.6 m stern trawler (FORCE 2015) and a 15.4 m passenger vessel (Melvin and Cochrane 2014). This EEMP proposes the use of similar sized vessels based on the previous success of these two surveys. A 120 kHz echosounder system consisting of a transceiver and laptop computer housed inside the boat cabin and transducer that is pole mounted on one side of the boat is proposed. The transducer must be mounted deeper than the boat hull to prevent interference with the keel and we recommend mounting the transducer as deep as possible (>2m) to decrease the amount of interference from entrained air at the surface. It is recommended that the transducer be mounted using a pole design attached to the gunwale. The pole mount must be strong enough or supported enough to handle steaming into strong tidal currents during surveys at peak flow. A GPS unit is necessary that provides National Marine Electronics Association (NMEA) serial string data to the laptop computer. System specific software will be necessary for data collection and will come supplied by the echosounder manufacturer. For comparability to the Melvin and Cochrane (2014) dataset we propose a ping rate of 1 s⁻¹. Proper calibration prior to each survey is recommended according to Foote *et al.* (1987).

3.5.2 Survey Description

The FORCE CLA surveys will consist of 9 parallel transects spaced 100 m apart (**Table 3-1**). Each transect is approximately 1.8 km long. Transects are numbered 0-8 starting nearest to shore. The parallel transects within the FORCE CLA will be followed by three control transects

that start at the easterly end of transect 8. Transect Y1 is across the Channel, and the boat will take a southwest bearing across the Channel from the easterly end of transect 8 toward the opposite shore until approximately 30 m depth is reached. From here transect X1 will follow the 30 m contour east to the start of transect Y2 which parallels Y1 back across the channel going north and ending at the westerly end of transect 0 (Figure 3-3). This survey design is repeated until slack tide time.

Surveys should be performed, to the extent possible at speeds between five and ten knots, although speeds up to 12 knots are consistent with Melvin and Cochrane (2014).

Table 3-1. Latitude and longitude in decimal degrees for proposed Minas Channel transects for downlooking hydroacoustic surveys. Transects with an asterisk are for control samples. These transect locations are similar to Melvin and Cochrane (2014) but are slightly longer in length to encompass all berth sites within the FORCE CLA.

Along-Channel Transects	West End		East End	
	Lat	Lon	Lat	Lon
0	45.3725	-64.4409	45.3674	-64.4184
1	45.3717	-64.4414	45.3666	-64.4189
2	45.3709	-64.4419	45.3657	-64.4193
3	45.3701	-64.4424	45.3649	-64.4199
4	45.3692	-64.4430	45.3640	-64.4203
5	45.3684	-64.4435	45.3631	-64.4207
6	45.3676	-64.4439	45.3622	-64.4212
7	45.3667	-64.4444	45.3613	-64.4216
8	45.3658	-64.4449	45.3605	-64.4221
X1*	45.3378	-64.4594	45.3330	-64.4364
Across-Channel Transects	North End		Sout	h end
	Lat	Lon	Lat	Lon
Y1*	45.3658	-64.4449	45.3378	-64.4594
Y2*	45.3674	-64.4184	45.3330	-64.4364

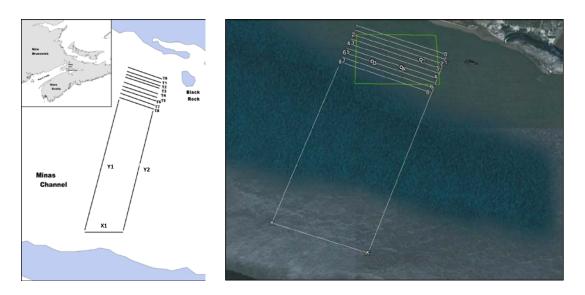


Figure 3-3. (1) Map showing approximate locations of all transects for down-looking hydroacoustic survey. Reproduced from Melvin and Cochrane (2014); and (2) Google Earth view of Minas Passage showing proposed survey transect locations, FORCE CLA, and TISEC device berth sites A, B, and C. The green rectangle is the FORCE Crown Lease Area.

3.5.3 **Schedule**

For the sake of comparability with the Melvin and Cochrane (2014) dataset, this EEMP proposes sampling during the same months on neap tides⁶ as was done by Melvin and Cochrane (2014): six survey events distributed over six different months. The months of May, June, August, September, October, and November will match with the 2011-12 dataset. No surveys are proposed for December through April since these months likely coincide with the lowest water temperatures and lowest fish biomass (Viehman *et al.* 2015; Melvin and Cochrane 2014). July is not surveyed because this month was also skipped in the previous dataset. **Table 3-2** lists proposed 2016 sampling dates based on dates that coincide with neap tides. These sampling dates will capture the immigration and emigration of migratory fish species that occur in Minas Passage and Minas Basin. Resident fish species and those life stages of migratory species that use the project area will also be captured in these surveys.

⁶ The survey can be performed during both neap and spring tides but if data quality is poor enough to preclude its collection during a certain tidal phase then it would be advisable to avoid this time. The survey can begin once a turbine is in place (i.e., there is no need to wait until May, 2016 to begin the program).

Survey	Start date	Start time ADT
1	16 May 2016	9:28 am
2	14 June 2016	8:49 am
3	12 August 2016	8:20 am
4	11 September 2016	8:38 am
5	8 October 2016	6:14 am
6	7 November 2016	5:35 am

Table 3-2 Proposed 2016 Sam	nling Dates Coinciding with Ne	an Tidos Start Timos – High Tido Timos
Table 3-2. TTop03eu 2010 Dall	iping Dates Contouring with the	ap Tides. Start Times = High Tide Times.

Each survey event should consist of a full tidal and diel cycle and therefore last 25 hours. This can be broken up into four separate shifts each around 6 hours. Time between tides when the flow is decreased can be used to change crews and maintain equipment. All surveys should begin on a high tide to ensure that the boat can manage entry and exit from port. Surveying should be limited to calm sea days when wind is less than 10 knots when possible for safety and to maximize data quality.

The EEMP proposes extending this study for five years in an attempt to capture multiple deployments that are planned in the FORCE CLA. The first planned installation will be two open centre turbines in 2015. Additional deployments are anticipated in 2016 through 2020.

Extending this monitoring program over five years will improve the ability to determine potential effects on fish use in and around the FORCE CLA in two ways. First, it is imperative to capture future device deployments to address not only potential effects related to individual device types but also to assess cumulative effects from multiple devices operating at the same time. Second, long-term studies have a higher probability of success because they are less likely to mistake single, novel ecological events as representative. The existence of an effect or lack thereof for several years of surveyed data is stronger evidence when compared to a single year's data. In other words, if there is evidence of a trend for several years as opposed to a single year then that trend is less likely to have occurred by chance alone. Additionally, long-term datasets have the option of time series analysis that can show long term trends and provide evidence for forecasting.

3.5.4 Data Processing

There are several software packages to process hydroacoustics data (e.g., Echoview, Sonar5, Movies+). For processing methods we recommend the informative website: www.acousticsunpacked.org. The surveys in Minas Passage will likely have a major manual processing component to separate the large amounts of entrained air particular to this area. An established method for addressing entrained air at the surface is to eliminate a certain amount of water depth from processing and analysis (e.g. the upper 10 m) (Viehman et al. 2015). Some researchers have had success removing entrained air using a schools detection algorithm in Echoview software.

Additionally, when utilizing subjective manual processing techniques, it is important to include a quality assurance (QA) and quality control (QC) protocol. Ideally, the quality assurance component is an additional person with hydroacoustics data processing experience to take a subsample of processed data and reprocess it to compare to the results of the first person's outcome. A good method for quality control is to find outliers in the final fish density estimates and reference them to the processed data files. Often times a noise spike or other source of signal contamination was missed during manual processing and is included in the fish density estimate. There are numerous other avenues for QA/QC and any the researchers have confidence in should be used.

Most researchers familiar with hydroacoustics will process data to provide density as a metric. Fish density can be calculated by scaling the mean volume backscatter (S_v) by the average backscatter cross section (σ_{bs}) for a sampled volume of water or by determining the number of individual fish tracks for a sampled volume of water. Additionally, using just (S_v) as a metric is also effective (Viehman *et al.* 2015). Using S_v alone provides biomass or relative density as a metric instead of density. For Objective 1, S_v will suffice as a metric for the proposed analysis. However, for Objectives 2 and 3, researchers will need to use area backscatter coefficient (s_a) as a metric for the proposed analyses (Staines *et al.* submitted EWTEC 2015). Researchers with hydroacoustics experience will have knowledge of all of these metrics and their applications.

Based on the objectives of this program, fish density will need to be in two separate forms for the proposed analyses. First, overall fish density estimates for 30 or 60 minute time intervals for the water column are required for the first objective of determining seasonal fish density at the FORCE CLA (hereafter referred to as the impact site) and control sites. Second, fish density estimates for 30 or 60 minute time intervals divided into 1 m depth bins for the water column are required for the second objective of determining seasonal fish vertical distribution at the impact site and control sites (Viehman *et al.* 2015). Objective 1 uses overall fish density of the water column and objectives 2 and 3 use fish density in 1 m depth bins.

3.5.5 Data Analysis

Analysis for Objective 1 would involve a 2-way analysis of variance (ANOVA) based on a before-after-control-impact (BACI) experimental design (Smith 2002). The "before" component will be a previous dataset collected by Melvin and Cochrane (2014) that the aforementioned survey methods are based on. The "after" component of the study could potentially be any year of surveys after TISEC devices have been deployed. The "control" component is taken from the x and y transects of the survey design while the "impact" component is taken from the parallel transects numbered 0-8. The results of a 2-way ANOVA analysis will provide an effect for the before/after component, the control/impact component, and the interaction of the two. A significant interaction effect is evidence of there being an effect of a TISEC device on overall fish density at the impact site (Staines *et al.* submitted EWTEC 2015).

Analysis for Objective 2 should include using Hotellings T² permutation tests to compare the difference between the fish vertical distribution densities of complimentary months of the "before" survey to the "after" surveys for both the control and impact sites. For example, in the "before" survey of Melvin and Cochrane (2014), the month of May in 2012 was sampled. Assume there is an "after" survey performed in the month of May in 2016 after TISEC devices are present. Both of these May samples would be complementary and would be tested for differences. The complementary pair for the impact site transects would be tested and the

complementary pair for the control transects would be tested. If both the impact site and control site had non-significant test results or both had significant test results then that would indicate no evidence for effects from TISEC device presence. However, if only one or the other of the control or impact site has a significant test result then this would indicate possible evidence for TISEC device effects on fish vertical distribution.

Analysis for Objective 3 will involve re-analysis of fish vertical distribution data used in analysis of Objective 2. Determining the probability of encounter of fish with TISEC devices at the impact site will require several data inputs that will all be available after device installation and downlooking hydroacoustic surveys have been completed. The first input required is the depth of a particular deployed TISEC device. Knowledge of this depth is important because this is where expected interaction will likely occur with fish moving into the impact site. The probability that fish would encounter the deployed device is estimated using two probabilities: 1) the probability of fish being at the device depth when the device is not present at the impact site (p_1); and 2) the probability of fish being at the device can be calculated as:

$$p = p_1 * p_2$$

Note that the probability (p_1) of fish being at the device depth can be determined from the Melvin and Cochrane (2015) dataset since most of these data were collected at the impact site when no device was present. In fact, this would be the best estimate of p_1 . Using the control site to determine p_1 assumes that the control site is similar to the impact site. If the control site is to be used to determine the probability of encounter it should be tested for potential differences with the FORCE CLA. These methods would best be undertaken in 2016 or 2017 after site-specific data have been collected and sample sizes are adequate for confident estimates.

3.6 **Discussion**

This EEMP proposes a five year survey that focuses on large scale mid-field effects of fish in and around the FORCE CLA. Near field effects at the turbine are assumed to be the responsibility of the device holder, primarily for safety reasons. Previous studies in the area that relate to this program were reviewed and one recent study was undertaken that will provide the baseline dataset for post-deployment analyses. This EEMP recommends data collection survey techniques, data processing and analysis methods, and interpretation of results.

Lastly, use of the FAST platform⁷ as a component of the EEMP was considered but ultimately rejected. While monitoring devices such as the FAST platform have high potential to collect useful data, there is significant risk of instrument loss or damage associated with deployment. In addition, the as-yet unknown deployment locations and schedule associated with the FAST platform precluded its inclusion in this EEMP. As researchers become familiar with the strengths and weaknesses of the FAST monitoring tool, it will likely prove useful to combine its data streams to monitoring surveys in the future.

⁷ The Fundy Advanced Sensory Technology (FAST) cabled and autonomous platforms are planned for deployment in 2015-16. Please see Section 5.5 (Table 5-1) of the Physical Oceanography chapter for a more detailed description of the FAST platforms' instrumentation.

3.6.1 Limitations and Probability of Success

The probability of success for this study is good. There have been several successful downlooking hydroacoustic surveys performed in the project area. As noted, there are limitations to surveying in this environment. The weather will be a limiting factor (Melvin and Cochrane 2015; Simmonds and MacLennan 2008) with respect to when surveys can or should be performed. The higher the wind speed the more difficult it will be to maintain transect locations and high winds will also increase entrained air near the surface of the water column. The entrained air near the surface, which at times can reach to the sea floor, is likely to be the biggest limitation to this survey design. Although this will not prevent success of a survey and ultimate analyses of data it may limit the use of portions of the data collected during certain surveys. Compared to other techniques available for sampling fish and assessing behavioural changes, we believe hydroacoustics will provide the largest sample sizes covering sources of variation such as tidal and diel cycles and seasonal change.

The FORCE CLA will have specific technical challenges associated with it. The fast tidal flows in the area create a dangerous situation for boating, especially during windy weather. Night time sampling adds another danger to the situation with decreased visibility combined with the fast tidal currents. Safety must be the top priority at all times. In addition to safety concerns, there are challenges to surveying the area with down-looking hydroacoustics.

A pre-emptive test of the existing dataset from Melvin (2014) would allow a specific look at what a typical dataset will entail. Perhaps a subset of data could be made available from Dr. Melvin and processed, analyzed, and interpreted. These results could be provided to FORCE and a more educated decision could be made about moving forward with down-looking hydroacoustics as a method for surveying the FORCE CLA.

Additional fish assessment methods were considered (e.g., trawling and tagging) but each have limitations (monetary or species) that outweigh the limitations of the effects of the turbulent environment on hydroacoustics. Ideally, concurrent trawl samples in the nearby area would provide the best knowledge of ensonified fish species and this is typically standard protocol (Parker-Stetter et al. 2009). Trawling in the Minas Passage, however, is difficult and unsafe. And it is unlikely that berth holders will find trawling near their operating devices acceptable from a safety perspective. The data return with down-looking hydroacoustics combined with the budget proposed will return more of the desired metrics regarding regular fish presence in the region.

3.6.2 Adaptive Management

As long-term studies progress, it is often important to adapt work methods to early results and changes in initial conditions or assumptions. Previous research associated with new TISEC device deployment has shown that initial schedules are rarely followed due to unforeseen circumstances that are inherent in difficult environments. Planned deployment for a particular TISEC device may be delayed and so the fish EEMP associated with that device must be prepared to accommodate these delays. If delays are expected it would still be advantageous to move forward with down-looking hydroacoustic surveys since this would afford another "before" sample set that would be more temporally relevant and could potentially strengthen the proposed BACI design. Additionally, it is important for the groups involved in a TISEC deployment project to stay in communication. An adaptive management team (Jansujwicz and

Johnson 2015) that meets annually is advantageous: as the project evolves all parties know the progression of study results related to the hydroacoustic surveys.

Lastly, the entities performing the surveys should be willing to adapt sampling methods according to what is most successful. The authors have experience using down-looking hydroacoustics to survey fishes relative to the deployment of a TISEC device in Cobscook Bay, Maine, USA. While this experience speaks to the difficulties associated with a high tidal flux environment, it does not necessarily relate directly to Minas Passage. The strong winds and faster tidal flows of Minas Passage may create circumstances that make surveying difficult. There may be weather conditions or tidal stages that are ideal for sampling, and other factors that render other times less rewarding. The personnel performing the surveys must be responsive to these factors and be willing to adapt the surveys to gather quality data that will be suitable for analyses.

3.7 **References**

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Section 4: Marine Mammals



4.0 SECTION 4: MARINE MAMMALS

4.1 Introduction

4.1.1 Stressor Review

This section describes the EEMP for marine mammals and proposes methods and instrumentation to quantify project effects and test EA predictions in the challenging, high current environment of the Minas Passage. This requires a thorough review of past baseline studies and the underlying statistical approach to detecting change due to stressor effects. This section also reviews key results from other monitoring programs relevant to the marine mammal EEMP.

Many of the impacts of TISEC developments are likely to be the same as those associated with more established marine industries, such as oil and gas exploration, construction and extraction. However, there are a number of potential impacts that are specific to these new technologies (e.g., Polagye *et al.* 2011). These have been reviewed in a number of Strategic Environmental Assessment documents (e.g., Faber Maunsell and Metoc 2007; OEER 2008) and regulatory guidance documents (e.g., Isaacman and Daborn 2011; Macleod *et al.* 2011; Sparling *et al.* 2011, 2013). Our understanding of the potential impacts of wave and tidal devices on marine mammals is developing, yet we note that a large degree of uncertainty still surrounds the potential impacts of individual devices, demonstration and commercial scale arrays.

Upon review (e.g., AECOM 2009; SMRU Ltd 2011; Polagye *et al.* 2011), potentially significant stressors of TISEC developments on marine mammals in Minas Passage are primarily:

- a) deterrent effects of noise associated with operational and installation activities;
- b) disruption of communication as a result of increased underwater noise;
- c) indirect effects through changes in prey distribution and abundance; and
- d) direct collision or physical dynamic interaction with TISEC devices.

Individual devices have a relatively small physical footprint so it is unlikely that the presence of single devices or small arrays will pose a significant habitat exclusion risk at a level likely to result in measureable impacts. Effects related to habitat loss due to device presence are therefore considered only relevant for large commercial-scale developments (Polagye *et al.* 2011).

Environmental effects from continuous noise sources are related to sound intensity, signal to noise ratios, spectral frequency and the exposure period, but also contextual factors like the novelty of the sound source (Southall *et al.* 2007; Ellison *et al.* 2012). Harbour porpoise (*Phocoena phocoena*), the key marine mammal species in Minas Passage, use high frequency echolocation clicks to hunt and communicate (Kastelein *et al.* 2002) and are known to be very susceptible to pulsed noise disturbance (Tougaard *et al.* 2009), but few studies have focused on exposure to continuous (non-pulsed) periods of low frequency noise sources such as those emitted by tidal turbines.

It is assumed that turbine sound is likely to vary with power generation state (i.e., more sound will be produced when the turbines are closer to their maximum capacity than around cut-in speed). This variability makes defining a theoretical acoustic 'zone of effect' challenging and was the main reason for using a gradient study design to collect baseline passive acoustic monitoring (PAM) information. The baseline study used hydrophones deployed at seven reference sites both within the FORCE Crown lease area (CLA)(Appendix 1, Figure a), as well as at sites approximately 0.25 km and 1.5 km outside of the CLA boundary (Wood *et al.* 2013). These PAM reference sites are considered to represent the mid field within this report. Near field is considered the area within 100m of each berth.

Predictions based on tidal turbine sound levels for studies related to Snohomish PUD's Admiralty Inlet demonstration project (with two OpenHydro turbines) suggest for much of each tidal cycle, disturbing noise threshold levels (assumed to be a root-mean-square (rms) received sound pressure level (SPL) of 120 dB re 1 μ Pa) may potentially extend to a few hundred metres, with short periods extending beyond 1.5 km at very high operating speeds (Collar *et al.* 2011). Similarly, the MCT SeaGen turbine was estimated throughout normal operation to be audible to marine mammals up to about 1.4 km. Sound levels for individual turbines are not thought to be sufficient for injury to occur (Sparling *et al.* 2013).

For the FORCE study area, this suggests that the present reference sites are fairly well positioned to monitor mid field area effects, noting that only one distant reference site was monitored in baseline studies – the site located mid channel (S2 in **Figure 4-1**). Based on results of the MCT turbine EEMP in Strangford Lough (Kennan *et al.* 2011; SMRU Ltd 2011) and the width of Minas Passage (~5.7 km), the likelihood of passage exclusion (i.e., blocking Minas Passage completely to animal passage) due to acoustic effects is thought very unlikely and this risk is therefore best managed adaptively after effects monitoring have been reviewed.

Installation activities for the purposes of this EEMP are assumed to require less than a few days and thus are in isolation unlikely to cause detectable longer-term significant effects. If future turbine deployment requires longer-term and noisier operations such as piling, studies in Europe provide sufficient information to assess likely construction period effects (Tougaard *et al.* 2009). Harbour porpoises, for example, typically vacate noisy construction sites and return to the area once these construction activities have ceased.

4.2 **Studies Completed to Date**

Within the EA, a significant negative effect to marine mammals was defined as

An unnatural decline, over one or more generations, in the abundance and/or change in the distribution population of a species or portion thereof, permanent avoidance of the area by marine mammals, or a serious injury to or the loss of one or more individuals from an endangered or threatened species (AECOM 2009).

EA impact predictions concluded that FORCE Project activities and components are not likely to cause significant adverse residual effects on marine mammals within the project area or vicinity (i.e., Minas Passage).

To explore the feasibility of testing these EA impact predictions, SMRU Consulting reviewed the available data from past monitoring studies in the area. In general, marine mammal populations are notably often difficult and expensive to monitor due to their low density and wide-ranging,

often cryptic nature. A variety of different marine mammal species have been documented to be historically present in the upper Bay of Fundy and Minas Passage (AECOM 2009). Since 2009, FORCE has undertaken a variety of marine mammal baseline monitoring studies (FORCE 2015). This has included intermittent shore (n=24 days)⁸ and regional vessel-based (n=8 days) observations across 4 years (2009-2012) and a more intensive 24 hour / 7 day, multi-site PAM program (2011-2012 and 2014, n=2,743 days across 7 sites combined, Figure 4-1 & Appendix 1, Figure b). These studies are briefly summarized below.

4.2.1 Baseline Shore and Vessel-Based Visual Surveys

- 2011 and 2012 land based surveys reported 182/189 marine mammal sightings (96%) were harbour porpoise, with five grey seals and two harbour seals also reported. Two vesselbased surveys per year (n=8 overall) undertaken in late-July and late-August in the Minas Passage study area, reinforce the local relative dominance of harbour porpoise in the FORCE project area, but survey design was not considered to use a typical line-transect technique.
- Porpoise land based sightings varied seasonally and occurred more frequently in the vicinity of the FORCE CLA than in the other two comparative areas inshore and east of Black Rock. Porpoises occurred singularly or in small groups of 2-3 individuals, usually seen swimming seaward with the outgoing tidal stream, as well as occasional inferred feeding behaviour.
- The FORCE lease site was 1.3-3.1 km away from the observation platform. This distance requires optimal sighting conditions as a prerequisite to detect harbour porpoise at these ranges.
- Observer data was used to estimate densities of harbour porpoise which ranged from 0 to 1.4 per km² and estimates of the total number of porpoise present in the outer Minas Basin, Minas Passage and Minas Channel during one tidal cycle subsequently ranging from 0 to 42 individuals (FORCE 2015). These density level estimates are lower than those reported in known focal areas of the Outer Bay of Fundy preferred by harbour porpoise (Johnston *et al.* 2005), where tens of thousands of porpoises may be present (NOAA 2010).

4.2.2 Baseline PAM Studies

- C-POD hydrophones, autonomous cetacean echolocation click detectors manufactured by Chelonia Ltd. have been deployed at multiple sites in a gradient design across 4 separate years (Tollit *et al.* 2011, Wood *et al.* 2013, Redden *et al.* 2015), providing overall year-round coverage, but inconsistent seasonal coverage across the seven baseline sites (Appendix 1, Figure b).
- Since 2011, reference sites within the FORCE CLA were temporally well covered (W1 535 days, E1 470 days), followed by S1 (359 days), W2 (219 days), N1 (188 days) and E2 (169 days), while the deepest site at S2 had poor temporal coverage (98 days)(Appendix 1, Figure b). As a consequence, baseline for the FORCE CLA is considered good, but only moderate for the larger study area.

⁸ The use of the letter "n" in this context refers to "number of", as in "the number of days over which studies were conducted".

- No dolphins were detected by C-PODs during baseline PAM studies.
- Porpoise were detected on 98% of days, but echolocation activity data is zero-inflated, meaning there are many parts of each day without porpoise detections (Appendix 1, Figure c). Across all monitoring locations the mean probability of detecting a porpoise was 4.1% (median=0%, 95% CI=0.2-11.8%, IQR=1.4-7.6%).
- General Linear Model (GLM) trend analyses using Generalized Additive Models (GAM) highlight two seasonal periods of increased echolocation detection occurring in the spring (May/June) and to a lesser degree in fall months (mid-October through November) (Appendix 1, Figure d, Redden *et al.* 2015).
- GAM analyses also highlight significantly higher click detection rates at low current velocities with a preference on the ebb tide, at higher tidal heights, during the night time around and after midnight, and in deeper water (Appendix 1, Figure d, Wood *et al.* 2013; Redden *et al.* 2015). Significantly lower activity rates were found at East 2 and North 1 (Appendix 1, Figure c)

4.3 **Data Limitations of Baseline C-POD PAM Studies**

- C-PODs are battery operated and typically last three months, occasionally 4-5 months. Occasional loss of data due to battery connection malfunction occurred until padding was improved in latter deployments. Consequence to EEMP: one C-POD deployment per season of coverage is required. Advice on optimal deployment techniques should be obtained from Acadia University staff.
- Due to internal memory restrictions, non-target noise from sediment movement and moorings resulted in periods of lost recording time in each minute. Across all locations, percent time lost appears linked to short and longer-term tidal rhythms (Wood *et al.* 2013) and averaged 23.2% (median=0%, IQR=0-42%), but large between-site variability is also apparent (Appendix 1, Figures d and e). *Consequence to EEMP: Sites with the FORCE CLA are not prone to high levels of time lost, but certain other monitoring sites used to date are sub-optimal for continued effects monitoring, for example station East 2.*
- SUB-buoy moorings are generally successful in recovering C-PODs, but early baseline studies suffered from a variety of technical difficulties resulting in lost units and data loss. Notably, SUB-buoy mounted C-PODs experience excessive tilt during high flow periods and consequently click detections were considerably lower than on a C-POD located on a stable platform (Redden *et al.* 2015). Consequence to EEMP: SUB-buoys are sub-optimal for collecting reliable porpoise activity data, but appear sufficient to provide comparative beforeafter data if collected systematically over longer periods, noting that monitoring efficiency at certain stages of the tidal cycle will likely be reduced (especially peak spring tides). Use of a bottom moored platform can improve detection rates, but will make comparison difficult with the current baseline data collected using SUB-buoys.
- C-POD calibration is undertaken by the manufacturer, but side-by-side deployments of two C-PODs has highlighted differences in rates of detection-positive minutes in matched timeseries datasets. Consequence to EEMP: More precise calibrations prior to deployment and systematic placement across the study area will improve reliability of temporal and spatial

comparisons, as highlighted in methodology taken by similar studies in European waters (Dahne et al. 2013).

In short duration comparative studies in Minas Passage, C-PODs detected icTalk transmissions (sweep from 120 to 140 kHz, over 0.1s) up to 300 m from the sound source, however, detection efficiency was greatest within 100 m, but reduced at depth-averaged current speeds >1m/s. In contrast, a foam-shrouded icListenHF hydrophone (Oceansonics Ltd.) detected transmissions up to 300 m (>30% efficiency), with 100% detection efficiency at distances up to 150 m, and no apparent reduction in detection performance as current speed increased to 2 m/s (Redden *et al.* 2015). Consequence to EEMP: Detection success of C-PODs in high currents is significantly reduced. Use of alternate data loggers can improve reliability of detection rates, but will make comparison difficult with the current baseline data. Additional cross-validation studies would be valuable, especially to determine porpoise activity levels at high current speed. The interaction between current speed, sediment and flow noise effects and C-POD detection range and efficiency has not to date been fully explored.

4.4 Considerations and Limitations to Assessing EA Predictions

Baseline data collected to date coupled with historical information indicates that only one marine mammal species is present in sufficient numbers to test EA-related distribution or avoidance predictions, namely Harbour porpoise (**Table 4-1**).

Low sighting rates of harbour and grey seals, white-sided dolphins and sporadic sightings of larger whales (mainly long-fin pilot, minke and humpback whale) result in a lack of statistical power to robustly assess change in abundance or distributions or indeed avoidance by these species, even if current baseline monitoring studies were continued or expanded.

Recognizing that only a small portion of the Bay of Fundy Harbour porpoise population utilizes Minas Passage, this EEMP focuses on the more obtainable 'sub-population' level EA predictions. The overall goal is to assess change in mid field area use by Harbour porpoise, including permanent or large scale avoidance/attraction of the FORCE CLA and surrounding mid field study area. Given this goal, we attempt to identify the most appropriate methods to detect change at this scale and establish to what extent current baseline studies can be used to undertake such an assessment.

EA Prediction	Ability to Test EA Prediction	Rationale
Unnatural decline, over one or more		COSEWIC (2006) estimate the population of Harbour porpoise in the Bay of Fundy and Gulf of Maine at 89,700 in 1999, with an unknown trend, and a generation turnover of seven years. Densities in the Upper Bay of Fundy were reported as lower than the Outer Bay of Fundy. The current National Marine Fisheries Service Potential Biological Removal (PBR) estimate is 706, which is presently exceeded by human caused mortality. An unnatural decline is considered for this report as a >30% decrease in population.
generations, in the abundance and/or change in the distribution <u>of the</u> population	Extremely low	Given the relatively small footprint of the FORCE lease site (<2 km ²), the predicted area regularly ensonsified above the 120 dB re 1 μ Pa by operating turbines (Collar <i>et al.</i> 2011) and the small peak number of animals estimated from observer studies to use the general area per day (n=42, <0.05% of regional population), significant population level effects of presently proposed FORCE lease area turbine deployments on the Bay of Fundy and Gulf of Maine population are considered highly unlikely (despite even long-term durations of deployment), and without doubt effects monitoring at this scale (change in overall harbor porpoise population abundance/distribution) is considered infeasible (mainly due to field costs in achieving any statistical power in trend analyses, as well as determining cause and effect pathways, if population level change was detected).
Unnatural decline, over one or more generations, in the abundance and/or change in the distribution <u>of a portion</u> <u>of the population</u>	Low for change in project area abundance. Moderate for large scale change in mid field study area distribution (relative use)	Current PAM or visual baseline studies are not suitable for reliably estimating change in porpoise abundance in the project area through time. PAM baseline studies are believed to have at least a moderate ability to detect large changes in distribution across some of the local area reference sites using porpoise echolocation activity as a proxy for presence and relative use. Change potentially may include increased activity/presence due to fish reefing effects, which likely take time to develop and may also be current speed related (Broadhurst <i>et al.</i> 2014). A more comprehensive PAM baseline across local study area sites will increase probability of detecting changes in distribution.
Permanent avoidance of the area	High	PAM baseline studies highlight an average probability of porpoise detection above 4% and a 95% confidence interval above zero, suggesting the current baseline has a high ability to detect permanent avoidance of the FORCE CLA and mid field study area reference sites.
Serious injury to or the loss of one or more individuals from an <u>endangered or</u> <u>threatened</u> species.	Extremely low	Movement of endangered Right whales through Minas Passage is considered highly unlikely and detecting a dynamic interaction extremely challenging. Until near-field monitoring methods are more proven, the optimal alternative tool to test the EA prediction is presently believed to be via post-hoc investigation of cause of death (C.O.D) of any listed species carcass found regionally.

Table 4-1. Ability to Test EA Predictions for Marine Mammals

A variety of traditional and new methods and tools are available to monitor Harbour porpoise at different scales. **Table 4-2** summarizes the strengths and weaknesses of each approach and reviews their potential applications. The table also references data quality and quantity from baseline information collected to date.

Table 4-2. Monitoring Tools, Baseline Information and Application for the FORCE EEMP

Monitoring Method	Strengths	Weaknesses	Baseline	Cost-Benefit Review
Cabled (multi-) node hydrophone array	Porpoise have high rates of echolocation activity, 24/7/365 coverage potential, potential to track movement and count animals, able to collect noise levels and high resolution cetacean ID and behaviour, no memory limitation so able to collect very long-term data (multiple years). Potential to use FAST platform as a PAM node. Plan to use cabled array on TEL turbine at site in Ramsey Sound.	age potential, nent and count noise levels and n ID and imitation so able o data (multiple FAST platform as e cabled array on amsey Sound.		Considered optimal scientific method of long- term data collection, but high development cost and considered high risk, due to cabling and flow noise issues. Animal tracking methodology unproven in high flow environments or using turbine mounted arrays. Use likely requires research collaboration and co-operation across multiple developers. FAST platform offers option of acting as a cabled 'roaming' reference site node and could cross- validate C-POD data.
Autonomous moored PAM - Data recorders	Porpoise have high rates of echolocation activity, 24/7/365 coverage potential, able to collect ambient noise levels and high quality cetacean ID and behaviour, pre- calibrated, new flow shield designs improving data quality, potential to count animals if multiple sensors deployed. Widely used to monitor odontocete presence.	Porpoise echolocation is narrow beam and short range, moderate unit cost, limited by flow and sediment noise, deployment limit due to high sampling frequency required for porpoises (1-1.5 months), recovery and post-processing required, density and tracking analyses evolving. ICListenHF data required manual post-processing of porpoise detection data.	Yes – short term (3 months using AMARs and ICListenHF).	More reliable data compared to C-PODs but presently very limited baseline available, higher cost, shorter deployment periods possible (or sub-sampling required). Potentially useful to also assess ambient noise and turbine noise. Could cross-validate C-POD data.
Autonomous moored PAM – CPODs	Porpoise have high rates of echolocation activity, 24/7/365 coverage potential, internal data processor for odontocete ID and behaviour with low unit cost. Used at MCT site in Strangford Lough EEMP and for baseline studies in Admiralty Inlet tidal demonstration project and in TEL project in Ramsey Sound. C-PODs, very widely used in offshore wind EEMPs.	Porpoise echolocation is narrow beam and short range. Reliability limited by flow and sediment noise as well as occasional unit failure, reasonable deployment limit due to internal data pre-processing (3-4 months), improved calibration required, recovery required, use of some moorings limits data quality, poor detection range and rates observed at higher current velocities. The optimal statistical	Yes – 3+ partial years – total 2743 days across all sites.	Considerable baseline previously collected across multiple sites in the study area, especially FORCE site. Area use patterns identified to date require confirmation but considered useful for large effect size evaluation of future developments. Limitations identified to date require careful consideration if C-PODs to be used in comparative effects monitoring studies. C-POD data verification studies recommended to cross-validate occurrence patterns.

Monitoring Method	Strengths	Weaknesses	Baseline	Cost-Benefit Review
		analyses to assess trends and minimize auto-correlation effects currently evolving.		
Drifting PAM	Porpoise have high rates of echolocation activity, better coverage of region than single static device, can collect ambient noise levels and cetacean ID, less effected by flow noise, recently used in UK in conjunction with static PAM to assess baseline use.	Short term data, hard to collect data across various tidal states, flow noise effects minimized but not absent, some risk of unit loss, moderate cost, moderate level of post-processing required.	Yes – very short term (few hours). Only used to assess turbine source level.	Considered useful tool to assess turbine source levels and potentially used concurrently with static PAM to assess use of wider area by porpoises.
Land Surveys	Low-moderate cost, multiple species ID, used to assess area use and potentially abundance. Numerous tidal baseline assessments. Newer survey techniques include use of video technology and infrared technology.	Short term data, FORCE CLA 1.3- 3.1km away, limited to daylight and good weather, porpoise cryptic species and difficult to detect in turbulent water and/or long range.	Yes – six 6hr days per year across 4 years (~24 1/2 days)	Current baseline has low power to detect change in use. More focused area observations considered potentially useful as a means to validate PAM seasonal trend data.
Vessel Surveys	Better coverage of local area, multiple species ID, used to assess a use and potentially regional abundance. Often used in regional population surveys.	Short term data, limited to good daylight weather and surface conditions, moderate cost, porpoise cryptic species, speed across ground in high flow areas complicates data analysis, present survey design considered non-standard.	Yes – 2 days per year across 4 years (8 days).	Current baseline has very low power to detect change in use. Not recommended.
Aerial Surveys	Better coverage of region, multiple species ID, used to assess regional use and potentially regional abundance. Often used in regional population surveys.	Short term data, limited to good daylight weather and surface conditions, high cost, porpoise cryptic species.	None known – Outer Bay of Fundy only.	High cost and short term data. Not recommended.
Tag Deployment	High resolution movement information. Mainly used on pinnipeds to date, but porpoise satellite tagging has been successful.	Capture and permit required, high cost, high uncertainty on area used by tagged animal.	No	Logistical constraints and uncertainty in area of use of tagged animal. Not recommended.

Monitoring Method	Strengths	Weaknesses	Baseline	Cost-Benefit Review
Active Acoustics (sonar)	Potentially long-term tool to study near- field interactions, with potential to detect fish and multiple marine mammal species ID. Used to mitigate MCT turbine in Strangford Lough, used in pilot studies at ORPC turbine in Maine, planned to be used to monitor detect interactions with TEL turbine in Ramsey Sound.	Limited field of vision, high unit cost and needs cabling, some systems might be audible to marine mammals and effect behaviour, automated detection systems in development, limited by turbulence, ideal placement to side of turbine to monitor turbine face which potentially limits use of some systems if requirement to place on turbine. Presently unknown if able to determine dynamic interactions.	No – Only mobile fish sonar surveys completed.	Potentially useful tool to understand near-field interactions. However, high cost and value of data to assess porpoise movement near-field to turbines presently uncertain in high flow environments. Ideally, results of ongoing studies should be assessed and future use based on these and adaptive management triggers.
Carcass Stranding Surveys	Low cost, provides confirmed evidence of mortality event, likely local areas for carcass strandings known based on CPOD recoveries, strandings program was part of MCT turbine EEMP.	Difficult to prove cause and effect, access to shoreline, carcass recovery may be required.	Currently only opportunistic.	Opportunistic approach involving local strandings network believed potentially useful as adaptive management trigger.

4.5 **Objectives and Proposed EEMP**

To date, the FORCE environmental monitoring program has not yet monitored the environmental effects of an operational TISEC device, as the OpenHydro device deployed in 2009 was only functional for a few weeks. In order to properly assess the environmental effects of such devices, several turbines will need to be deployed, remain operational, and undergo monitoring over a sufficient period of time (DFO 2012). Marine mammal EA predictions were developed for a minimum of one generation. For Harbour porpoise, this is considered to be seven years (COSEWIC 2006), thereby requiring an EEMP that extends over this period. Logically, monitoring studies can be staggered to allow time for site development of multiple turbines and long-term operations in order to maximize the value of the EEMP.

Effort should be directed towards gathering monitoring data in the near and mid field around individual turbines. Given safety considerations near operational turbines, immediate near field monitoring (considered to be within 100 m) is best undertaken by device owners, rather than through the deployment of moveable equipment from surface by independent monitoring entities. At the same time, broader mid field baseline monitoring programs should be designed to address future 'array level' developments and provide concurrent at consistent data at more distant reference sites. Environmental effects monitoring programs should also be site specific, since the ecosystem characteristics and the key species will vary depending on geographic location, as well as allowing for consideration of the scale of likely stressor effects to key ecosystem components.

The proposed focus of the marine mammal EEMP is to assess long-term effects of two key stressors on Harbour porpoise;

- 1) <u>Direct</u> effects of **operational turbine noise.** Specifically, Harbour porpoises may respond to the acoustic stressors through attraction or avoidance.
- 2) <u>Indirect</u> effects due to changes in prey distribution and abundance. Due to dynamic interactions, prey aggregations (e.g., Russell *et al.* 2014) or near-field avoidance by fish due to acoustic effects (e.g., Viehman and Zydlewski *et al.* 2014), Harbour porpoise may respond to local study area scale prey aggregations through attraction or avoidance.

The assessment of both these direct and indirect stressors is achievable concurrently, as both are potentially monitored through relative changes in porpoise activity and relative site use. Co-ordination with the results of the fish EEMP is ideally required to help determine cause of any identified 'response' effect.

There is no confirmed evidence of tidal turbine strikes or collisions by marine mammals, though monitoring data is very sparse (Kennan *et al.* 2011; Polagye *et al.* 2011; Sparling *et al.* 2013). Given potentially lethal effects of collisions and the lack of data available to assess risk, this EEMP also includes in the short-term opportunistic monitoring for **lethal dynamic interactions** (**collision**), with a long-term adaptive management approach and recommendations for developer-led strike risk modelling assessments. Notably, a carcass stranding monitoring program was initiated as part of the MCT Strangford Lough EEMP and an active acoustics real-time marine mammal detection and mitigation program used to prevent close interactions. Near-field monitoring using active acoustic technology was also proposed to assess near-field dynamic interactions for the Admiralty Inlet demonstration project (Polagye *et al.* 2013) and the

Ramsey Sound Tidal Energy Limited project, however the efficacy of these techniques to detect collisions are not yet proven, and these monitoring efforts largely focussed on species of conservation concern. Collision risk models and strike assessments provide a means to assess the value and need of further detailed investigations of collision risk (Wilson *et al.* 2007; Carlson *et al.* 2014). It is presently assumed individual developers will have a responsibility to assess this device-dependent risk.

Turbine deployment at the FORCE CLA is an incremental process that will occur over a number of years. This EEMP proposal has assumed that two turbines will be deployed at Berth D in the second half (summer/early fall) of 2015, with deployment of 2 additional turbines in two other berths, including Berths B and C, occurring in summer 2016.

4.6 **Primary and Secondary EEMP Objectives**

The primary objectives of the marine mammal EEMP are to assess the following effects:

- 1) Permanent avoidance of the mid field study area during turbine operations.
- Change in the distribution of a portion of the population, specifically large scale (~50%) decreases or increases in relative occurrence (echolocation activity levels) across the mid field study area.

The secondary objectives of the marine mammal EEMP are further to;

- 1) Monitor the regional frequency of stranded carcasses and assess cause of death where possible and maintain an adaptive management approach to new information on collision risk and from C-POD monitoring studies.
- 2) Collect additional PAM data to verify and cross-validate the reliability of C-POD data to determine underlying porpoise activity (across all current speeds) and potential turbine effects.
- 3) Provide recommendations on the potential applications for the FORCE FAST Platform and potential research themes that would increase scientific understanding of the scale of turbine-marine mammal interactions.

4.7 **EEMP Methodology**

The intensity, breadth and associated costs of monitoring efforts developed for this EEMP were discussed within the project team and with members of the EMAC and FORCE team. As a consequence, this report proposes a seven year, flexible and adaptive EEMP that largely focuses on one single species, Harbour porpoise, which consistently utilize the FORCE CLA and are known to have a low tolerance to anthropogenic noise disturbance.

We propose the continued use of C-PODs (deployed on SUB-buoys) which we consider sufficient to detect avoidance and large scale changes in "mid field relative occurrence" (specifically via monitoring long-term rates of echolocation activity). We consider the EEMP has a high probability of success at detecting avoidance and a moderate-high probability of success in detecting changes in mid field occurrence rates exceeding 50% (see Appendix 2 for report analyses of baseline C-POD data).

At a minimum, the EEMP proposes mid field area monitoring using C-PODs at 5 standardized reference sites in years 1, 3 and 7 (Figure 4-1), but this monitoring intensity is adaptive beyond year 3 (i.e., after this 'Phase 1' data has been analysed). In addition, one C-POD will be assigned to each berth as the turbines are deployed and will monitor each berth at 100-150 m distance for fixed periods of time. All C-PODs are deployed for three months in the spring, retrieved and deployed again for three months in the fall to capture periods of peak seasonal occurrence identified in 2011-2014 (Redden *et al.* 2015, Appendix 2).

The primary risk is considered the failure of a C-POD to collect data at berth-specific turbine sites, as well as incomplete seasonal and annual coverage. In addition to these deployments, the EEMP proposes a C-POD calibration study and C-POD data cross-validation study, co-deploying a Jasco Applied Science AMAR PAM data logger (or potentially the FORCE FAST lander with a cabled PAM system) at reference sites within the FORCE CLA, as well as a three year collation of stranded marine mammal reports through co-ordination with Nova Scotia Marine Animal Response Society. A detailed rationale and methodology are detailed below and also summarized in **Tables 4-3 & 4-4.** In summary, for each year the proposed EEMP plans to:

Year 1 (2015):

- a) Deploy 5 calibrated C-PODs at 5 mid field reference sites (Figure 4-1) in spring and fall to provide an improved porpoise occurrence baseline data set at multiple sites in the spring, as well as comparative 'after' data set following summer-fall turbine deployment at Berth D.
- b) Deploy 1 calibrated C-POD within 100-150 m of Berth D (Figure 4-1) in fall to provide a berth-focused mid field porpoise occurrence data set (assumes summer-fall 2015 turbine deployment in Berth D).
- c) Deploy 1 AMAR using shell-type mooring at West 1 (W1, Figure 4-1) in spring to provide PAM data to cross-validate C-POD detection data and detect other marine mammal vocalizations (*notably, the use of the FORCE FAST Platform with a cabled, shrouded, high frequency broadband hydrophone [e.g., ICListenHF] could potentially collect far longer duration acoustic data and is recommended as an alternative).*
- d) Initiate long-term collaboration with Nova Scotia Marine Animal Response Society and local veterinary pathologist. Assess if dynamic interaction adaptive management triggers have been reached (see Table 4-4).
- e) Assess mid field area C-POD data to determine if adaptive management triggers (avoidance or large scale reduction in activity) have been reached (See Table 4-4).

Year 2 (2016):

- a) Deploy 1 calibrated C-POD within 100-150 m of Berth D (Figure 4-1) in spring to provide a focused near-field turbine porpoise activity data-set (assumes summer-fall 2015 turbine deployment).
- b) Deploy 1 calibrated C-POD within 100-150 m of Berth B and each of Berths A and C (if occupied) in fall to provide a berth-focused mid field porpoise activity data-set (assumes summer 2016 turbine deployments).

- c) Continue collaboration with Nova Scotia Marine Animal Response Society. Assess if dynamic interaction adaptive management triggers have been reached.
- d) Assess mid field C-POD data to determine if adaptive management triggers (avoidance or large scale reduction in activity) have been reached.

Year 3 (2017):

- a) Deploy 5 calibrated C-PODs at 5 mid field area reference sites (Figure 4-1) in spring and fall to provide 'after' porpoise activity baseline data-set. Identical C-PODs would be located at the same sites as in year 1. Exact sites locations for West 1 and East 1 should consider final turbine and near-field C-POD placement locations and associated cablings, aiming to deploy >400m away in similar water depth.
- b) Deploy 1 calibrated C-POD within 100-150 m of Berth B and A/C (Figure 4-1) in spring to provide turbine berth-focused mid field porpoise activity data-set (assumes summer 2016 turbine deployments).
- c) Deploy 1 AMAR using shell-type mooring at East 1 (E1, Figure 4-1) in spring to provide PAM data to cross-validate C-POD detection data and detect other marine mammal vocalizations.
- d) Continue long-term collaboration with Nova Scotia Marine Animal Response Society. Assess if dynamic interaction adaptive management triggers have been reached.
- e) Assess mid field C-POD data to determine if adaptive management triggers (avoidance or large scale reduction in activity) have been reached.

Years 4-6 (2018-2020):

a) Monitoring intensity and methods dependent on results from years 1-3 and from other TISEC projects worldwide (e.g., adaptive management approach)(Table 4-4).

Year 7 (2021):

- a) Deploy 5 calibrated C-PODs at 5 mid field reference sites (Figure 4-1) in spring and fall to provide 'after' porpoise activity data-set at timescale of one porpoise generation. Identical C-PODs would be located at the same sites as in year 1. Exact sites locations for West 1 and East 1 should consider final turbine and near-field C-POD placement locations and associated cablings, aiming to deploy >400m away in similar water depth.
- b) Assess if further environmental effects monitoring required.

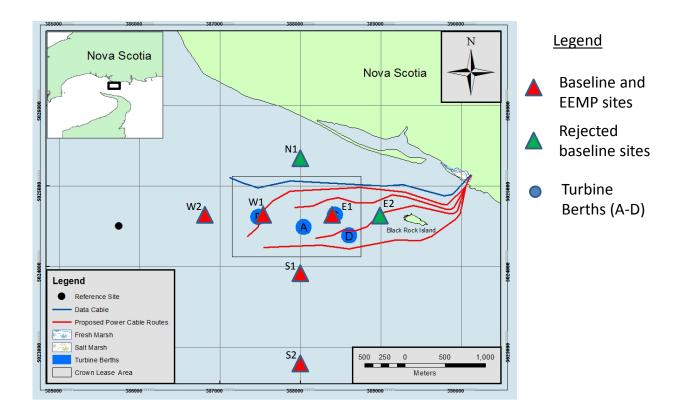


Figure 4-1: Location of past baseline (red and green triangles) and proposed EEMP C-POD monitoring sites in the mid field area (red triangles).

4.8 Supporting Rationale

Further rationale for key components of the proposed EEMP methodology is summarized as follows (see **Tables 4-3** and **4-4** for additional fine-scale details of the EEMP):

• Use of a phased monitoring approach, encompassing a seven year period. Data collection is proposed initially for year one through three (phase 1) and at a minimum in year seven.

Rationale: A phased approach allows for an adaptive management based on early results and maximizes the cost efficiency of the monitoring program. Reference site mid field study area monitoring does not occur in year two to allow additional turbines deployments and operations to occur. Monitoring in year seven is proposed to address potential changes at the generational timescale, as presented in the EA predictions (seven years represents one Harbour porpoise generation). • Use of adaptive monitoring management approach, encompassing adaptive management trigger points (e.g., mid field area avoidance detected, blade strike positively identified through carcass post-mortem) that aim to increase level of monitoring (or mitigation) as significant new information is acquired.

Rationale: Ability to respond to ongoing monitoring results and monitor at the correct scale.

 Systematic and multi-year use of calibrated C-PODs deployed using SUB-buoy moorings, both in the vicinity of at least three different operating turbines and in a five site gradient design across the mid field study area (Figure 4-1). Year 1 monitoring collects additional PAM baseline and monitoring focuses on spring and fall periods, which were identified from baseline studies as the most reliable times to detect large scale effects. Data analysis should include a comparison of pre-installation with post-installation binned Detection Positive Minute metrics using GLM trend analysis, as well as an assessment using Hurdle and Lambert Models (conditional and non-conditional statistical models useful for zeroinflated data-sets).

Rationale: Despite the known limitations of C-PODs moored with SUB-buoys, a comparative multi-site, long-term baseline dataset exists and the underlying trend in porpoise activity (occurrence and relative use) is considered sufficient to meet the primary objectives of the EEMP. GLM models highlight clear patterns in porpoise activity, notably seasonal spring and fall peaks in activity, tidal speed and tidal height signals and also clear diel preferences (Appendix 1). A gradient design to monitor mid field study area provides ability to assess disturbance effects at different spatial distances. Two sites (East 2 and North 1) are not included in this EEMP as they represent suboptimal monitoring sites. Calibrated C-PODs are located consistently at each selected reference site between years.

Additional statistical analyses of C-POD baseline data were undertaken for this report to test the power to detect change in porpoise Detection Positive Minutes (BinDPM) metrics using GLM (GAM-GEE) model trend analyses (Appendix 2). These analyses highlight a betweenyear effect, which, together with between-site (depth related) variability, sporadic temporal coverage at certain reference sites (mainly outside of the FORCE CLA), emphasize the need for the proposed additional period of mid field study area baseline in year one. Secondly, despite time lost issues, analysis of C-POD data collected to date indicates that post deployment changes in porpoise activity on the order of 50% compared to predeployment numbers can be reliably detected in spring and fall, using a similar scale or monitoring (Appendix 2). This is the minimum scale of change that will be needed to invalidate the EA local sub-population prediction that no significant effects are likely.

 Deployment of one high-performance PAM data logger (e.g., autonomous Jasco Applied Sciences AMAR or a cabled PAM system deployed using the FORCE FAST Platform) at West/East 1 reference site within the FORCE CLA, co-located with mid field area C-POD deployments in years one and three. A data sub-sampling protocol is proposed if the AMAR was used in order to minimize deployment, recovery and analytical costs (Table 4-4). Deployment would occur in spring and recovery would therefore optimally be made at the end of autumn, 8 months later. Sub-sampling would not be required if the FORCE FAST lander was used. Rationale: C-POD data verification studies undertaken by Redden et al. (2015) have highlighted that C-PODs deployed on SUB-buoys are prone to certain data collection limitations, particularly at faster water current velocities. Consequently, porpoise activity rates at these faster tidal velocities are considered under-estimated and absolute detection rates uncertain. C-PODs also only monitor and describe cetacean click activity and cannot detect other cetacean vocalizations (e.g., whistles, calls and moans). The use of an alternative PAM data logger is proposed to cross-validate patterns of use described by C-PODs, to determine relative levels of use during periods of faster tidal velocities and to detect other marine mammal vocalizations. The sites at West 1 and East 1 represent sites within the FORCE CLA that have the best coverage and environmental conditions. AMARs have considerable memory capacity and the ability to monitor without sub-sampling at high frequencies required for detection porpoise echolocation activity for ~6 week periods. Subsampling routines are highly flexible and provide the ability for longer term deployments, which can coincide with C-POD related vessel charters. Jasco Applied Sciences have developed moorings capable of collecting acoustic data in high flow environments, including Minas Passage. However, the use of the FORCE FAST Platform is considered preferable for collecting this additional data, given its potential for longer duration monitoring. A broadband, high frequency range and shrouded hydrophone (e.g., ICListenHF) is essential.

• Three year collation of stranded marine mammal reports through co-ordination with Nova Scotia Marine Animal Response Society. Pathological interpretation of cause of death of carcasses where required.

Rationale: Carcass stranding frequencies in the region are presently believed to be low. Data from pre-installation periods can be compared with frequencies post-installation. This method provides a cost-effective means to potentially detect lethal collisions by endangered and threatened species. A notable risk to this plan is cause of death is often difficult to reliably ascertain.

Table 4-3. Summar	y of Proposed	EEMPs Methodology
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 (2015-2017) a) Five C-PODs deployed in the mid field study area (red symbols in Figure 4-1), once in the spring and once in the fall for three months each deployment, 2015, 2017 and 2021 only. b) One C-POD deployed >100 m from Berth D and one >100 m from any other occupied Berth, once in the spring and once in the fall for three months each deployment, 2015, 2017 as necessary. b) One C-POD deployed >100 m from Berth D and one >100 m from any other occupied Berth, once in the spring and once in the fall for three months each deployment, 2015, 2016 & 2017 as necessary. cPOD data verification: 1 PAM data logger (AMAR) co-deployed once for eight months at one FORCE CLA reference site, with sub-sampling protocol to cover spring and fall period, 2015 & 2017 only (potential alternate use of FORCE lander recommended). c.additional C-POD data cross-verification study using AN or cabled FORCE lander and opportunistic assessme 	Phase/Duration	Phase 1 Method Summary	Rationale/Reliability
	Phase 1: 3 years (2015-2017) Phase 2: 4 years (2018-2021) Duration and scale dependent on Phase 1 results, noting as a minimum to include year 7 (2021), additional C-POD deployment across local area as per Phase 1	 C-POD calibration: Pre-deployments each year. C-POD GLM trend analysis: a) Five C-PODs deployed in the mid field study area (red symbols in Figure 4-1), once in the spring and once in the fall for three months each deployment, 2015, 2017 and 2021 only. b) One C-POD deployed >100 m from Berth D and one >100 m from any other occupied Berth, once in the spring and once in the fall for three months each deployment, 2015, 2015, 2016 & 2017 as necessary. C-POD data verification: 1 PAM data logger (AMAR) co-deployed once for eight months at one FORCE CLA reference site, with sub-sampling protocol to cover spring and fall period, 2015 & 2017 only (potential alternate use of FORCE lander recommended). 	 Avoidance effects and large scale reductions/increases i relative use by porpoises is detectable, Additional C-POD baseline in year 1 to improve study area temporal coverage, C-POD deployments on SUB-buoy provide comparable before-after data, Intermittent annual coverage but covers key time periods Baseline reference sites at East 2 and North 1 excluded as considered sub-optimal. Adequate area coverage, but low-moderate risk of C-PO

Table 4-4. Detailed Breakdown of Proposed EEMP Methodology

Objective	Summary of Methodology	Rationale	Probability of Success and Challenges
1) Detect change in berth-specific porpoise probability of occurrence (echolocation activity)	 <u>Variables</u>: Change in occurrence (e.g., GLM echolocation activity trends in Julian Day and Day-Night DPM/10 min). <u>Method:</u> 1 C-POD deployed safely (100-150 m) next to a minimum of 3 turbines (site ideally south of each turbine). <u>Duration</u>: 2 deployments April 15-July15 and September 15-December 15. Other considerations: Calibration of new C-PODs required. C-POD ID should be consistent across sites, or aim to maintain consistent sensitivity. 	• Long-term C-POD baseline occurrence rates within FORCE CLA should allow detection of large changes in activity (occurrence) in the vicinity of each berth.	 Good success in detecting large scale changes due to operating turbines, related to number of turbines monitored. Collaboration with developer required. C-POD failure/loss and near turbine deployment potential risk
2) Detect change in porpoise probability of occurrence (echolocation activity) in the mid field area	 <u>Variables</u>: Change in occurrence (e.g., GLM echolocation activity trends in Julian Day and Day-Night DPM/10 min). <u>Method</u>: 5 C-PODs deployed at key mid field reference sites as in 2011-2014 gradient baseline study area (see red symbols in Figure 4-1). <u>Duration</u>: 2 deployments in years 1 and 3. April 15-July15 and September 15-December 15 Other considerations: Calibration of previously used and new C-PODs required. C-POD ID should be consistent across sites, or aim to maintain consistent sensitivity. 	 Increased baseline study area coverage in year 1. Long-term C-POD baseline rates should allow detection of large scale changes in mid field activity (occurrence). Year 2 gap in monitoring program to permit increased site development. 	 Good success in detecting large scale changes. Lack of monitoring in year 2 reduces effects reporting and probability of detecting effect. C-POD failure/loss potential risk. Assumes robust baseline coverage achieved in year 1. Consideration of turbine deployment locations and cabling in placement of C-PODS within FORCE CLA in years 3 and 7.

Objective	Summary of Methodology	Rationale	Probability of Success and Challenges
3) Collect high quality PAM data to cross- validate C-POD echolocation activity data and detect other marine mammal vocalizations at reference site in FORCE CLA	 <u>Variables:</u> Cross-validation of echolocation activity detection rates per 10 minute individual sampling period. <u>Method:</u> 1X AMAR (or FORCE lander) co-deployed at FORCE CLA reference site (West 1 in year 1, East 1 in year 3). <u>Duration:</u> 1 eight-month deployment in years 1 and 3, April 15-Dec 15, with sub-sampling protocol on high frequency channel designed to sample June 1 – July 1 and Nov. 1 – Dec 1 (10 minutes on, 10 minutes off, 256 kHz sampling rate). Other considerations: Monitor on secondary channel for other cetaceans (including Right whales) and potentially assess ambient noise levels. 	 Improve current understanding of baseline porpoise use at key site. Comparison of C-POD data with alternate bottom- moored PAM methodology Deployment and recovery timed to match C-POD field studies. 	 Good chance of success. Sub-sampling protocol reduces power to compare with C-POD data. Flow noise and AMAR failure/loss potential risk. Potential to replace AMAR with cabled PAM systems and provide longer term cross-validation, but availability of FORCE lander and deployment costs unknown.
4) Assess if any increase in incidence of mortality events of marine mammals in the region can be attributed to collision	<u>Variables:</u> Frequency of regional carcass strandings and cause of death assessment. <u>Method</u> Opportunistic collection of stranded marine mammals through co-ordination with Nova Scotia Marine Animal Response Society. Pathological interpretation of cause of death of carcass. <u>Duration</u> : 3 years (continuous).	 Low incidence of stranded marine mammals to date. Ability to detect unusual mortality events if they occur. 	 Low chance of success, depending on public involvement and assuming predicted low likelihood of events occurring. Inability to determine cause of death (C.O.D.) is a risk. Adaptive triggers should ideally be pre-defined if C.O.D. identified as strike.
5) Possible adaptive management trigger 1: Large scale change in porpoise near-field occurrence	Extend C-POD monitoring duration by one year and consider 2 nd C-POD deployment 400m away from turbine.	 Adaptive management trigger based on Phase 1 analysis with increase in monitoring intensity 	 Definition of biologically meaningful (large-scale change) trigger point. Unknown cost of monitoring plan.

Objective	Summary of Methodology	Rationale	Probability of Success and Challenges
6) Possible adaptive management trigger 2: Large scale change at multiple sites in porpoise study area occurrence	Extend C-POD monitoring duration by one year and consider enlarging study area coverage focussed on area of change	 Adaptive management trigger based on Phase 1 analysis with increase in monitoring intensity 	 Definition of biologically meaningful (large-scale change) trigger point. Unknown cost of monitoring plan.
7) Possible adaptive management trigger 3: COD considered probable strike on 1 endangered species or regulator defined number of other species	EMAC/Regulator review of information required. Review efficacy and future deployment of currently available monitoring systems (including AAM) to assess near-field dynamic interactions. Consider use of acoustic alarms deployed on turbines (Wilson et al. 2013).	 Adaptive management trigger if dynamic interaction stressor risk identified 	 Definition of biologically meaningful trigger point and curren levels of acceptable risk. Unknown cost of monitoring plan.
8) Possible adaptive management trigger 4: External and relevant EEMP studies provide empirical evidence of significant risk to porpoises (or other key marine mammals found in the study area)	EMAC/Regulator review of information required. Acoustic effects: Extend C-POD study area monitoring duration and increase coverage of mid field study area if wide-scale effects documented. Near-field dynamic effects: Review efficacy and future deployment of currently available monitoring systems (including AAM) to assess near-field dynamic interactions. Consider use of acoustic alarms deployed on turbines (Wilson et al. 2013).	 Adaptive management trigger if turbine stressor risk identified and risk considered significant 	 Definition of biologically meaningful trigger point and curren levels of acceptable risk. Issues identified in other studies may be site specific or turbine specific.

4.9 Limitations and Probability of Success

This seven year, flexible and adaptive EEMP focuses on one single species, Harbour porpoise, which consistently utilize the FORCE CLA and are susceptible to anthropogenic noise disturbance. We have reviewed the current baseline datasets and have proposed the continued use of C-PODs (deployed on SUB-buoys) which, despite reported limitations, we consider sufficient to reliably detect avoidance and large scale (>50%) changes in mid field study area relative porpoise occurrence (specifically via monitoring long-term rates of echolocation activity).

The proposed monitoring plan deploys single C-PODs in the vicinity of three different turbine berths (those slated for deployment in 2015 and 2016, if the current schedule is followed) and monitors five other standardized mid field reference sites (Figure 4-1) across two years (2015 and 2017), to provide comparative pre- and post-installation activity and occurrence levels. Only spring and fall seasons are targeted as these were shown to be the optimal time periods to detect change.

The major risks with EEMP are the loss or failure of C-PODs (especially those in the vicinity of the turbines). This risk can be minimized by deploying two C-PODs per turbine deployment. Additional risks are deploying C-PODs relatively close to turbines (risking interactions with cables) as well as the reduced temporal (both annual and seasonal) coverage. Interactions with turbine equipment is minimized by proposed deployments outside of the near field area, i.e., beyond 100 m. We note that coverage of the summer season would not require additional boat charters or C-POD purchases, but would require some additional hardware (e.g., batteries, mooring weights). We have also proposed a C-POD calibration study and C-POD data verification study.

This EEMP does not include an active acoustics (sonar) monitoring system to monitor immediate near-field interactions with turbines in years 1-3. Presently, we are uncertain how effective such systems will be in Minas Passage in detecting dynamic interactions. We advise assessing their utility after AAM data is collected from TISEC studies elsewhere (e.g., studies are planned to take place in Ramsey Sound, monitoring the TEL TISEC device with two Tritech Gemini multibeams). Instead, we propose in years 1-3 to initiate collaboration with the Nova Scotia Marine Animal Response Society to assess if increases in the incidence of mortality events of marine mammals occur in the local region and can be attributed to collision or dynamic interactions. For the purposes of this EEMP we have assumed turbine developers may undertake collision risk modelling, given risks are device-dependent.

Clearly, cabled PAM systems, be they on turbine or on the FORCE FAST Platform, provide very useful monitoring tools for long-term, high quality, near-field or reference site monitoring. We have proposed potential applications for using these deployment strategies, including using them to cross-validate C-POD data. We have also proposed a number of other potential research themes that further broaden the core monitoring plans, but these themes are not considered a pre-requisite to assessing targeted EA predictions (**Table 4-5**). Finally, we have suggested the use of a number of adaptive management triggers, recognizing that these would need further review from key stakeholders and ongoing assessment. These triggers aim to enhance levels of monitoring only if certain significant effects were determined from Phase 1 monitoring. However, use of such triggers does leave uncertainty in final monitoring budget costs.

Table 4-5: Potential research themes aiming to improve baseline coverage, assess the optimal methodology to study near-field interactions and verify the reliability and consistency of the current baseline dataset

Research Objectives	Main Rationale	Methodology
Increased intensity of spatial coverage of PAM monitoring across the larger region.	Only one site captures porpoise activity in deeper water and only two sites within the FORE CLA. No data exists for Minas Basin or the entrance of Minas Passage.	Deploy additional C-POD in FORCE CLA between W1 and E1, at FORCE reference site and in deeper water area, south of FORCE reference site (Figure 4-1). Deploy C-PODs in Minas Basin and entrance of Minas Passage.
Use of C-POD data to compare before-after porpoise 'landmark' buzz sequences (very frequent clicks in click train) to evaluate whether Harbor porpoise are taking direct notice of the turbine during operating and/or idle periods.	Cost-effective use of C-POD data to determine whether porpoise can detect turbines.	This comparison assumes C-PODs are deployed relatively close to turbines. Data from 2011-2014 baseline studies required for comparative purposes.
Test efficacy of standalone and integrated PAM and AMM systems deployed on tidal turbines to better describe near-field interactions and behaviour of porpoises and other marine mammals	The ability to successfully track porpoise fine-scale movement around turbines and assess likelihood of near-field interactions with a tidal turbine has not yet been adequately proven	Use of cabled array of hydrophones and active acoustic systems deployed on or near turbines. 2- 3 hydrophones per PAM nodes are ideally placed >10m apart. AAM systems are thought to be ideally placed facing the side of a turbine rather than outwardly facing.
Improved reliability of PAM data collection, including in high current velocities.	Cross-validation required due to limitations in C-POD data when using SUB-buoys. Ability to collect concurrent ambient noise and other cetacean vocalizations.	Deploy C-PODs and cabled PAM or autonomous PAM data loggers on stable platforms within the FORCE CLA.
Land-based visual observations of the FORCE CLA from land-based monitoring site.	Short-term studies that focus only on the FORCE CLA are considered useful for benchmarking C-POD data (particularly confirming seasonal and tidally related patterns of use).	7-10 day observations in spring, summer and fall seasons, stratified by tidal cycle. Observation days only during optimal weather conditions. Use of reticule binoculars with internal compass for recording location.
Land-based visual observation methodological performance assessment to undertake berth site monitoring within FORCE lease area.	Test the ability of video and theodolite tracking (e.g., Denardo <i>et al.</i> 2001) technology to assess porpoise movement around operating turbines.	Continuous focal animal or focal group sampling (using video-theodolite combination) after initial detection of animals through methodical scans of survey area. Observers would monitor the point of closest approach and directionality (i.e., approach towards the turbine outside of predicted zone of audibility and movement while inside zone of audibility) at various current velocities.
Collision risk modelling.	Use modeling to assess whether collision risk is likely to be sufficiently common to warrant further investigation.	Predicted encounter rates between animals and turbines based on the physical characteristics of the device's moving parts, estimates of local density of marine mammals or on their rate of occurrence near-turbine and their use of the water column and their physical characteristics (swim speed, size).

4.10 Acknowledgements

Thanks to Brian Polagye (University of Washington) and Joe Hood (GeoSpectrum Technologies Inc.) for advice on general EEMP approaches.

4.11 References

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Appendix 1. Figures Cited in Section 3 – Marine Mammals

Figure a: Bathymetric map of study location in Minas Passage and multi-year (2010-2014) hydrophone stations at and near the FORCE test site. FORCE Crown lease area dimensions (rectangle) are 1.0 km x 1.6 km.

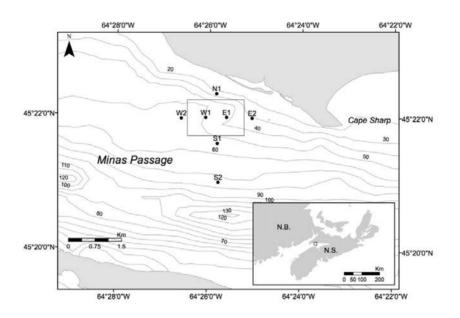


Figure b. C-POD data collected 2011-2014. Sites West 1 (W1) and East 1 (E1) are located within the FORCE Crown lease area (see Figure a).

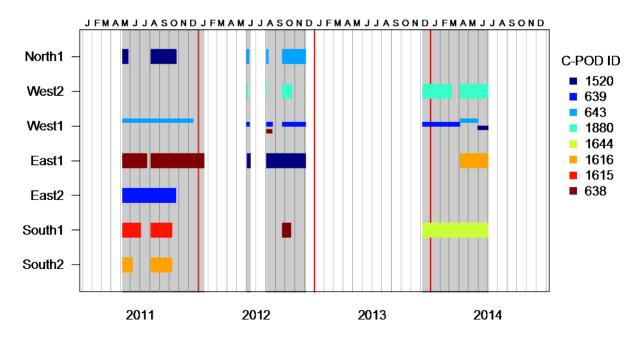


Figure c. Histogram providing percent of the data at each site versus the proportion of positive detections summarised for 10 minute periods (P(BinDPM)=1). North 1 and East 2 have lowest rates of detection and South 2 has the highest rates of detection.

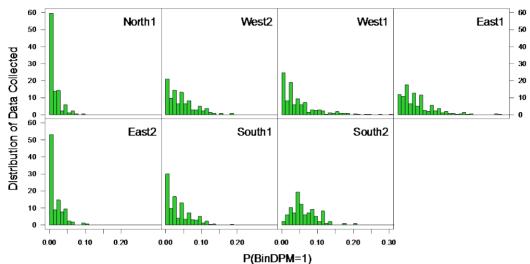


Figure d. General Linear Model GAM/GEE plots of significant covariates and their relationship to porpoise DPM10M, in order of importance (Redden et al. 2015) Shaded areas and error bars represent 95% confidence intervals. Data includes all data collected during 2010-2014. For the Day Night Index, values between 0 (sunrise) and 1 (sunset) indicate daylight, values between 1 and 2 (sunrise) indicate night.

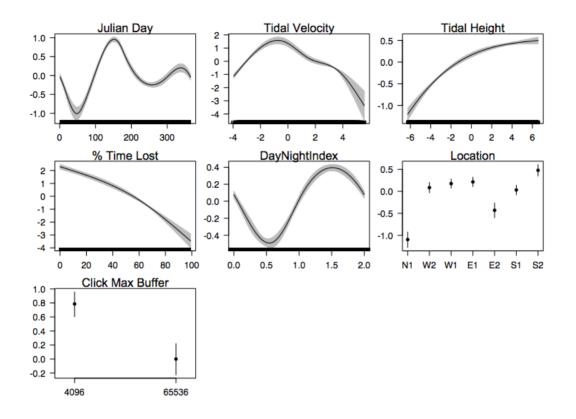
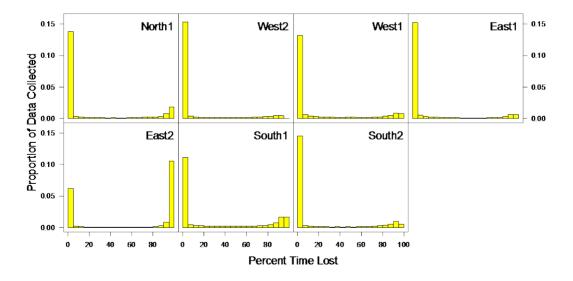


Figure e. Histogram providing proportion of data collected at each site versus percent time lost. East 2 clearly is seen to be the poorest site for reliable data collection.

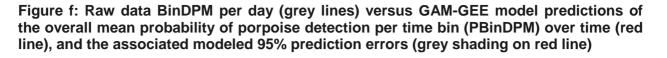


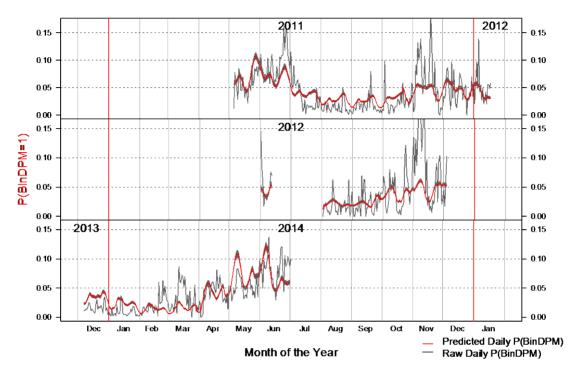
Appendix 2. Statistical Review of C-POD Data and current GLM GAM-GEE model in order to determine power to detect change

A simple power analysis was conducted to investigate our ability to detect turbine effects in this complex system. Two approaches were selected to examine how big an effect on porpoise Detection Positive Minutes (DPM) we might hope to detect using C-POD data. These two scenarios are considered a best case and a worst case scenario of statistical power.

The power analyses were based on the existing 2011-2014 dataset as detailed above (Section 1.2). As the effect of location and C-POD ID could not be resolved due to confounding of these two factors, the analysis is based on the subset of stations that were not identified as outliers in the fit GAM-GEE model and also represent the monitoring sites in close proximity to the FORCE lease area and locations >30-55m in depth (i.e. Included are West and East 1 and 2, and South 1; excluded are North 1 and South 2). The dependent variable in the model presented in the most recent report that analyses this dataset (Redden *et al.* 2015) is a binary variable that denotes a 1, or 0, indicating if there was, or was not, a positive detection of a porpoise in a 10-minute consecutive time bin, "BinDPM". In Figures f and g we define the probability of a positive detection per time bin as P(BinDPM=1).

Our so called 'best case' scenario uses the GAM-GEE model to predict the overall mean probability of porpoise detection per time bin over time, and the associated modeled 95% prediction errors (Figure f). Using the variable BinDPM, we used the fitted model predictions fit to the set of independent covariates that take into account within day variability (and then averaged across day and across location), using the same measured covariates, or design matrix, as described in Redden *et al.* (2015). This means that the predictions generated from this model and plotted in Figure f are conditional on the past observed data inputs of the GAM-GEE model and not an examination of the range of future scenarios.



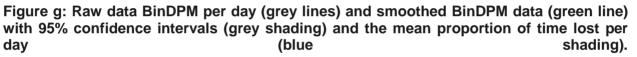


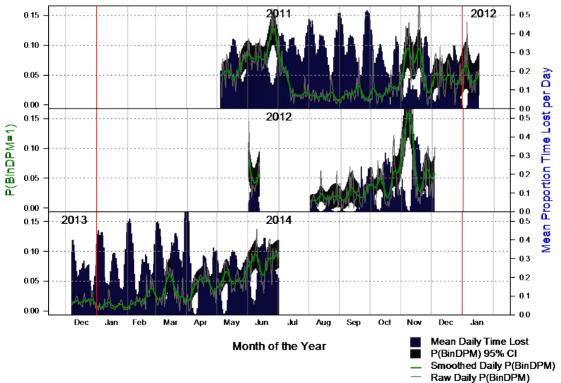
The model predictions plotted in Figure f, have very low uncertainty associated with them. This implies that given the observed set of conditions, the model fits well to the observed P(BinDPM). However, the model is fit with a high degree of flexibility by way of (degree-3 piecewise polynomial) b-spline transformations of the environmental covariates with multiple knots (range: Time Lost=3 to Julian Day=7). This high degree of flexibility, combined with the associated large number of regression parameters relating covariates to BinDPM, ensures that the model can adapt to irregularities within the range of values observed in this dataset, but also limits inference about the theoretical science driving porpoise habitat use. More simply, the present approach increases the accuracy of interpolated values at the cost of the ability to predict outside the data range. Consequently, using the current model to infer sample size, effect size and power for a range of future factors driving porpoise habitat is not presently recommended.

In the present model, the autocorrelation range is assumed to occur over a two hour, or 120 minute, period after which independence is assumed. This de-correlation scale was selected using a data-driven approach that compares the *acf* statistic in R. However, autocorrelation occurs at various scales, for example, the de-correlation scale of tidal velocity acts on a scale of hours, whereas the de-correlation scale of Julian Day likely acts on a more seasonal scale. Due to the complexity of the autocorrelation in long term time-series datasets and the difficulty in accurately and completely modeling its influence on different scales, residual (and unaccounted for) autocorrelation may explain why the prediction error estimates remain small in the present GMA-GEE model. Additional statistical analyses are recommended to address these concerns and to develop an improved predictive model.

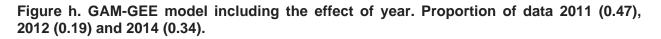
The so called 'worst case' approach looks at the variable BinDPM averaged per day across locations and does not take account of any of the independent variables that explain the within-

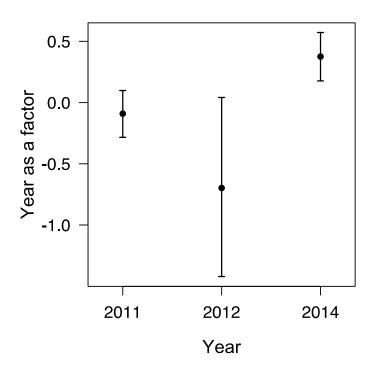
day variability. In other words, we look at how much variability there is in BinDPM within a single calendar day, without considering the fitted model. Because the raw measure of BinDPM is a zero-inflated and highly stochastic measure of the underlying signal of porpoise habitat use in the area, the probability measure and its (binomially-distributed) variance was smoothed across time using a kernel smoother with a bandwidth of 7 days. The result of this analysis is shown in Figure g, and clearly re-highlights the two seasonal peaks occurring in spring and fall. Unlike the GAM-GEE model, the raw data plots of BinDPM do not account for percent time lost per day, which can clearly be seen to be lower during the June and November peak detection periods. However, a simple percent time lost correction factor applied to raw BinDPM data was found to make little difference to the underlying seasonal trend, noting that many bin periods contain no detections. We can conclude that the power to detect decreases (beyond complete avoidance) in porpoise occurrence (activity) in winter and summer months is low, but suggest at peak seasonal periods that a 50% reduction or change should be reliably detectable, using a similar scale of monitoring. Notably new statistical techniques have become available recently that could allow an optimal design of C-POD spatial sampling intensity required to detect a required certain effect (Scott-Hayward et al. 2014), and these techniques could be useful to explore after additional baseline data is collected. In addition, exploration of the use of Hurdle and Lambert Models (conditional and non-conditional statistical models useful for zero-inflated data-sets) to compare pre- and post-installation C-POD data-sets is recommended (Lambert 1992).





Finally, the effect of year was included in the GAM-GEE model and significant year effects were apparent (Figure h), noting however that little temporal overlap occurred between 2014 and 2011-2012.





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Section 5: Physical Oceanography



5.0 SECTION 5: PHYSICAL OCEANOGRAPHY

5.1 Introduction

An Environmental Effects Monitoring program (EEMP) is a stipulation of the September 2009 Approval granted by the Nova Scotia Minister of the Environment to the FORCE project following submission of the Environmental Assessment (EA) in June 2009. The Approval requires the EEMP "*identify appropriate environmental effects indicators…and…consider project effects on* (among other subjects) *physical oceanography (and) currents and waves*".

To the extent possible at the time, the 2009 EA described the physical oceanography of the FORCE project area and predicted, with respect to currents and waves, that "no significant adverse residual effects are anticipated. Effects associated with loss of energy from water flows in the Passage and subsequent impact on sediment deposition will be negligible based on the relative scale of the Demonstration Project and the scale of tidal flow and energy in the Minas Basin".

A series of data collection programs focused on oceanographic measurements were undertaken between 2008 and 2011 at FORCE. The overall objective of these studies was to assess baseline physical oceanographic conditions to aid in turbine design and operational planning. Ultimately, this baseline data can be used to test the predictions made in the EA, once a sufficient number of turbines has been installed to potentially affect the tidal energy system.

5.2 Studies Completed to Date

5.2.1 Water Quality

Envirosphere Ltd. conducted oceanographic measurements in the Minas Passage in 2008 and 2009. A conductivity, temperature and depth profiler (CTD) was deployed in the ebb and flood tides. Temperature, salinity and data regarding turbidity changes with depth were collected (Envirosphere 2009: Envirosphere 2010). Additionally, water samples were collected to asses suspended sediment levels at different depths in the water column and Secchi disk depths were collected during one event to determine transparency. Similar studies were conducted in 2010 and 2011 where samples were collected for suspended particulate matter analysis. Opportunistic measurements of water transparency and temperature were taken from various vessels and are reported in Envirosphere (2011).

Results indicate the FORCE project area exhibits relatively low levels of suspended sediment in the area, compared to Minas Basin where turbidity is much higher. Temperature, salinity and turbidity vary over a small range of values.

5.2.2 **Currents**

Oceans Ltd. in 2008 deployed several broadband acoustic Doppler current profilers (ADCPs) to identify the most appropriate sites for turbine installations based on current flow in the Minas Passage (Oceans 2009a). Further studies were undertaken by Oceans Ltd. in 2010 where two ADCPs were deployed at the OpenHydro berth. High frequency, bottom mounted ADCP measurements were collected at the FORCE berth sites and FORCE cables routes from 2011-2013 by Oceans Ltd. Results indicate that currents reach maximum speeds of 5.2 m/s within the water column and have been measured at 4 m/s at points near the seabed. The results have been used in other studies to model energy availability and identify appropriate TISEC

deployment sites. We underline that there are considerable variations in topographic relief within the CLA; consequently turbulence effects and water column current profiles exhibit significant spatial variability across the CLA.

5.2.3 Wind and Waves

Oceans Ltd. in 2009 described the historic time series of monthly wind speeds and wave heights in vicinity of FORCE site (Oceans 2009b).

5.2.4 Current Modelling (Tidal Flow and Turbulence)

Acadia University researchers in 2012 and 2013 re-analysed existing ADCP data and simulated the tidal system hydrodynamics using a Finite Volume Community Ocean Model.

5.2.5 Summary and Monitoring Status

Given the amount of work already undertaken on the different physical oceanographic components, both Fisheries and Oceans Canada (DFO) and FORCE's Environmental Monitoring Advisory Committee (EMAC) have indicated that additional oceanographic measurements are not needed at this time (DFO 2012; EMAC 2011). We agree with this conclusion and reiterate the prediction made in the EA: measureable effects are not likely given the small number of turbines proposed for the FORCE demonstration facility.

DFO (2012) notes there has been no effort to study far-field suspended particulate matter profiles in Minas Basin. This subject is currently being addressed by studies funded by the Offshore Energy Research Association (OERA), described in more detail below.

5.3 **Objectives**

The primary objective of an EEMP designed for these oceanographic parameters is to verify the predictions made in the EA; namely, that the effects of energy extraction will be negligible based on the small scale of the demonstration project relative to the energy in the tidal system.

To a considerable degree, this prediction has been conclusively demonstrated by hydrodynamic modelling completed by Karsten *et al.* (2011), Sheng *et al.* (2012), Warner *et al.* (2011), van Proosdij *et al.* (2013) and Smith *et al.* (2013). For example, Karsten *et al.* (2011) conclude "the model suggests that about 800 MW of power is available for each 1% reduction in the flow through Minas Passage. Even given the reduction in efficiencies of real turbines, this suggests that hundreds of turbines producing hundreds of MW will results in a minimal, likely difficult to observe, reduction in flow through Minas Passage".

5.4 Methodology

Given past, ongoing, and upcoming projects, this EEMP recommends that hydrodynamic modelling is used as the primary method to predict the number of turbines that may have measurable effects on currents, tides and sediment dispersion within the Bay of Fundy. To the extent that the data may be applicable, modelling can use data collected from instruments on the Fundy Advanced Sensory Technology (FAST) cabled and autonomous platforms planned for deployment in 2015-16. We recommend that the design of future EEMPs for physical oceanographic parameters is deferred until such time as a sufficient number of turbines are

deployed and measureable effects are predicted by hydrodynamic modelling. FAST Instruments and the parameters they will measure are summarized in **Table 5-1**.

We emphasize that the FAST platforms are intended to support FORCE research programs. Because the platforms will be moved around the CLA, and because the instruments are intended for research rather than monitoring, these platforms and their data may not be suitable for use within the EEMPs. Despite this, the data generated at the platforms will be available for use by EEMP managers to the extent that it is useful and applicable.

5.5 **Conclusion**

Installation and post-deployment changes in water quality, current and wave profiles, and turbulence at the FORCE site (berths and cable routes) are not anticipated to have a measurable effect until more turbines are deployed. In the meantime, the use of hydrodynamic modelling can be used to predict when measureable effects, including changes to sediment dynamics, are expected. At that time, an EEMP can be designed to measure changes in these parameters as needed.

Equipment	Application			
Large FAST Platform (not cabled: battery powered)				
	Five beam current profiling system.			
Signature 500 Acoustic Doppler Current Profiler (ADCP)	Currents, Temperature Pressure			
	Turbulence can be derived from the current data.			
	Four beam current profiling system.			
TRDI Sentinel V100 Acoustic Doppler Current Profiler (ADCP)	Currents, Temperature, Pressure			
	Turbulence can be derived from the current data.			
Seaguard Recording Current Meter (RCM) Shallow Water	Multi-frequency Doppler current sensor			
(SW)	Single Point Currents, Conductivity, Temperature, Tide, Turbidity			
ASL Acoustic Water Column Profiler	Fish detection: measures acoustic backscatter returns at multiple ultrasonic frequencies			
	Particle size distribution and volume concentration			
LISST-100X	Also records the optical transmission, pressure and temperature			
Small FAST Platform (Cabled to Shore)				
	Conductivity, Temperature, Depth (i.e., pressure)			
Seabird pumped CTD with oxygen	Dissolved oxygen concentration			
Nortek Acoustic Wave and Current Profiler (AWAC) Acoustic Doppler Current Profiler (ADCP) with waves	Hydroacoustic current meter similar to a sonar: measures current profiles (speed), wave height and wave direction.			
High Definition (HD) Video camera	Real time video			

Table 5-1: Summary of FAST Instrumentation (2015)

Equipment	Application
Fiber optic (FO) multiplexer	For real time data and instrument control
Vemco VR2 acoustic receiver	Bottom mounted acoustic receiver for detecting tagged fish
Autonomous Multi-channel Acoustic Receiver (AMAR) passive acoustic receiver with three hydrophones	A real-time array of broadband hydrophones that will record environmental noise and possibly marine mammals
VECTRON (cabled to shore)	
Multiple Acoustic Doppler Current Profilers (ADCPs) and Acoustic Doppler Velocimeter (ADVs) to approximate water velocity	High resolution, real time measurements of turbulent water flow at turbine hub height

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Section 6: Acoustics



6.0 SECTION 6: ACOUSTICS

6.1 Introduction

It has been established that underwater noise may affect certain benthic organisms, fish, cetaceans and other marine mammals, although the type and intensity of noise generated by the different tidal energy devices is not well understood (Cada *et al.* 2007). This is due to the lack of in-water operating hours on most devices and a related lack of concentrated effort to determine their acoustic characteristics. The noise generated by a given device has the potential to induce behavioural changes on marine wildlife in the near- and mid-field marine environment. The need for baseline acoustic data and characteristic acoustic profiles for tidal turbines is largely recognized by the industry (Pacific Energy Ventures 2012; Garrett *et al.* 2014).

Several studies have demonstrated the potential for adverse effects of noise generated by anthropogenic activities in the subsea environment including marine renewable energy developments (Gill *et al.* 2010; Anderson *et al.* 2011). Marine mammals, cetaceans and fish, particularly those with swim bladders, may be sensitive to increased noise levels (**Table 6-1**). Fish rely on sounds to communicate, forage, find a mate, and defend themselves. Eggs and larvae may be more susceptible to noise sources since they have no avoidance capabilities (Degraer *et al.* 2013).

Organism	Noise Threshold	Source
Fish	 192 dB (1 μPa) – transient stunning; 	Turnpenny and Nedwell
	 200 dB (1 μPa) – internal injuries; 	1994
	• 220 dB (1 $\mu Pa)$ – egg/ larval damage; and	
	• 230 – 240 dB (1 µPa) – fish mortality	
Harbour porpoise	Avoidance displayed at levels exceed 140 dB re 1 uPa (broadband)	Southall <i>et al</i> 2007
Cetaceans and Pinnipeds	120 dB (re 1 μPa) is considered Level B harassment under the US Federal Marine Mammal Protection Act	PUD 2012
Lobsters		NERC 2013
	None	PUD 2012
Seabirds		RPS 2011
	No data	Leopold and Imares 2009.
		Turnpenny and Nedwell 1994

Table 6-1: Noise Sensitivities of Select Marine Biota

The tidal turbines proposed for installation at the FORCE demonstration site have large, moving parts and will naturally generate noise. Additional noise will be generated during installation, maintenance and retrieval. Installation in particular presents the possibility of significant (but temporary) noise levels during the placement of gravity base foundations, moorings and especially monopiles (Degraer *et al.* 2013). While no monopiles are planned at this time, it is possible that such foundations will be used in the future deployment of arrays of certain devices.

Within the 2009 EA, no specific noise level was identified as excessive or likely to cause significant impact. Instead, "significant impacts" with respect to noise are defined in relation to avoidance by, or injury to, marine birds, marine mammals, benthos and fish (AECOM 2009). Nevertheless, an EEMP to address noise is required as a condition of provincial and federal approval of the 2009 EA. The approval requires that the EEMP "*identify appropriate environmental effects indicators...and...consider project effects on* (among other subjects) *acoustics.*"

To compare noise levels between devices and predict effects on marine biota, two critical data sets are needed: (a) the spatial and temporal distribution of ambient noise and (b) turbine device noise levels, often referred to as the device "noise profile" or "source levels". These levels can be assessed by conducting measurements of ambient noise and device broadband and narrowband source levels. At this time, device developers have not so far provided information on their device noise profiles, although the industry appears to be moving in this direction. The International Electrotechnical Commission Project Team 62600-40 (IEC PT 62600-40): *Acoustic Characterization of Marine Energy Converters* is currently preparing a standard for the acoustic characterization of Marine Energy Convertors, with publication expected in the next two years. For the purposes of this EEMP, we assume that each device source noise profile will be collected by the developer early in the deployment and the data will be shared with FORCE.

At the FORCE site it is impractical to measure sound levels at all locations and depths. Moreover, hydrophones deployed on the sea bottom measure noise at a single, near bottom point, which may not provide sufficient information to characterise sound conditions at depths frequented by fish and marine mammals. To overcome these limitations, acoustic modelling can be used over the longer term to predict sound levels at all locations, which in turn are verified by targeted point measurements undertaken to validate the model predictions.

Noise is particularly amenable to numerical modelling given adequate data related to physical oceanography, baseline noise levels, and turbine acoustic characteristics. Acoustic impact models have been successfully developed at other marine energy sites and used to retire risks associated with noise (Ward 2014).

While it is not anticipated that the noise generated by the initial demonstration-type turbine deployments at the FORCE site will have significant impact on marine biota due to their limited scale (AECOM 2009), noise data collected at the demonstration stage will provide information that can be used to predict effects on marine biota, further refine the fish and marine mammal EEMPs, and support an acoustic model over the longer term.

6.2 **Studies Conducted to Date**

To date, acoustic monitoring at the FORCE site has fallen into two categories:

- Detection of marine wildlife (described in the Fish and Marine Mammal EEMPs); and,
- Measurement of ambient and tidal device noise.

For the latter, two different methods have been tried at the FORCE site with different outcomes. Attempts were made in 2008 to collect acoustic data from the site using drifting hydrophones prior to the deployment of the OpenHydro turbine in 2009, and again while the OpenHydro device was in the water in late 2009. On both occasions, a hydrophone was suspended from a vessel and was allowed to drift through the target area. This method was determined to be ineffective due to interference from vessel hull and surface noise (FORCE 2013). By way of contrast, the use of drifting hydrophones attached to a buoy system (as opposed to a vessel) resulted in the successful collection of turbine acoustic data in Strangford Lough, UK in 2014 (Schmitt *et al.* 2015).

A second attempt to collect acoustic data at the FORCE site was made in 2011. In this program, hydrophones moored to the seabed were employed to measure ambient noise (Martin and Vallarta 2012). The initial device was lost, but subsequent trials of a new mooring design in 2012 demonstrated the effectiveness of a streamlined, high-flow mooring located on the ocean bottom combined with an acoustically-transparent cover and lacking parts that can generate noise. This system, a fixed autonomous recorder with a sheltered internal hydrophone, measured ambient noise and was reportedly able to identify the noise generated by tidal turbines at levels that may disturb marine life, and distinguish that noise from ambient levels (Martin and Vallarta 2012). These conclusions have not yet been tested in the presence of an operating turbine. It should also be underlined that these tests were relatively short duration (about two weeks) and did not fully characterise the ambient noise environment over multiple tidal cycles.

The Ocean Renewable Power Company (ORPC) in 2011 developed and employed a drifting spar buoy noise measurement system to undertake pre-deployment acoustics surveys in Cobscook Bay, Maine. ORPC successfully measured noise generated from their reduced scale "beta unit" in 2011 (ORPC 2013) but have not so far undertaken post-deployment noise measurements of their full scale TidGen® unit (ORPC 2014).

In 2014, noise measurements were made of the Schottel STG turbine at the QUB tidal test site in Portaferry, Northern Ireland (Schmitt *et al.* 2015). Measurements were taken using both drifting and vessel-fixed hydrophones. Study results indicated the fixed hydrophone recorded a considerable amount of low frequency extraneous noise attributed to current flow around the instrument, whereas this effect is reduced when the hydrophone is allowed to drift. More effort in the field is required to collect data from a drifting hydrophone, and this data in turn requires considerably more processing to account for the hydrophone movement relative to the turbine (Schmitt *et al.* 2015). Despite this, the study concludes "Constant running, free spinning and braking (of the turbine) can be readily identified" when current speeds are 1-2 m/s.

While limited acoustic data were acquired at the FORCE site during the 2008-2012 hydrophone deployments, additional monitoring programs will likely be conducted over the next 1 to 5 years. The Small FAST Platform slated for deployment in 2015 will be equipped with an AMAR passive

acoustic receiver with three hydrophones to monitor ambient noise. This device will be cabled to shore and in theory can be used to measure noise levels around operating turbines. A disadvantage of the Small FAST Platform is its current design: if the instrument is not sufficiently shielded and/or the platform designed to minimize current flow noise, excessive extraneous noise may be generated. Effective design is critical to ensuring that useable data are collected.

In summary, a fixed autonomous recorder with a sheltered internal hydrophone as developed by Martin and Vallarta (2012) appears able to differentiate turbine source noise from ambient sounds. At the same time, the authors conclude this system can accurately measure turbine sounds at levels that may disturb marine life. The AMAR equipped Small Fast Platform can also potentially be used to collect pre- and post-deployment noise data, although its deployment schedule and overall research objectives have not yet been established. Importantly, the platform must be designed to minimize secondary noise effects if these data are to be useful.

The primary data gaps related to noise are the limited ambient noise data collected to date, the lack of operating turbines that can be subjected to noise assessment, and device specific "noise profiles" that must be provided by the device developers.

6.3 **Objectives**

While it is unlikely that noise from single devices will have a significant effect on marine wildlife, there is a need to:

- More fully establish pre-deployment baseline conditions; and
- Use the noise data to eventually verify the EA predictions that suggest noise will not negatively affect marine biota.

For the purposes of this EEMP, we assume the acoustic characteristics of specific devices, including absolute broadband and narrowband source levels across their operating range, will be measured or determined by the device owners and this information will be shared with FORCE.

6.4 Methodology

In general, a drifting hydrophone that is acoustically isolated from its conveyance will provide better quality data than a hydrophone moored on the seabed or rigidly attached to a structure such as a turbine. Logistically, however, the deployment and collection of drifting hydrophones over a sufficient time period to adequately characterise the acoustic environment is highly labour intensive and this method requires additional effort to process measurements (Schmitt *et al.* 2015). Together, these factors can make drifting programs designed to establish baseline conditions and fully characterise the noise profile of an operating turbine more expensive than moored programs. Given this, moored hydrophones are proposed in this EEMP but drifting hydrophones are suggested as a means to verify and validate data collected by a moored system.

In general, locating the hydrophone close to the device will improve the quality of measurements by increasing the measurement signal to noise ratio and simplifying requirements for acoustic channel modelling. Safety is the critical factor in determining how close a hydrophone can be deployed to an operating turbine. Deployment of a fixed hydrophone

within 100 m of an operating turbine is optimal. This near-field monitoring within 100 m of the turbine is the responsibility of the berth holder.

In order to achieve the objectives outlined above, the following activities are proposed:

1. Collect ambient noise data

- Deploy a streamlined moored hydrophone system. A deployment period on the order of one to two months should be considered to capture noise conditions over multiple tidal cycles.
- There is some evidence to suggest that shielded, streamlined hydrophones may in fact under-measure noise due to the actual shielding designed to reduce extraneous flow noise. To determine the accuracy of such a moored system, simultaneous drifting hydrophone measurements can be undertaken by FORCE for comparison and data validation. Alternatively, the hydrophone can be replaced with a drifting noise source emitting at known frequencies. The accuracy and sensitivity of the moored system can then be verified based on this noise source.
- Data generated from the moored hydrophone and the drifting hydrophone or drifting noise source should be used by FORCE to develop the acoustic noise model (see below).

2. Employ the Small FAST Platform to collect noise data

- To the extent practical (given the other instruments on board) the cabled Small FAST Platform should be designed to be acoustically quiet in high currents so that the data can be used to characterise ambient and turbine noise. The Platform deployment schedule and position should be coordinated with EEMP managers to maximize the utility of the data collected.
- Data generated from the FAST Platform should be used to expand the acoustic noise model (see below). This dataset is critical to the model since it will presumably be long term in nature and be representative of multiple locations as the Platform is moved around.

3. Resources permitting, develop an acoustic model

- Determine model outputs required to assess potential noise effects on marine wildlife (see below). Seasonal variations will likely be included in these requirements.
- Determine specific data requirements for the model and examine means of acquiring that data through ongoing research (e.g., FAST platforms) and future EEMP activities.
- Use acoustic data to calibrate and validate the model.
- Source level data obtained from berth holders over the next five years can be used in the acoustic model to predict cumulative effects and reduce the need for ongoing measurements in the field.

6.5 Acoustic Modelling

As noted above, an acoustic model is both predictive and cost effective over the long term. Developing an acoustic model for the FORCE site would be challenging due to both the physical oceanography and the input data requirements. However, a model would allow quantification of noise levels at various locations and depths throughout the site and inform the assessment of potential impacts on marine wildlife as more and more turbines are deployed. The model would also allow predictions of cumulative noise levels generated by arrays of tidal devices.

The effort required for modelling would almost certainly be less than the effort required to collect similar information from the site using in-water acoustic measurements. Once constructed, the model can predict noise over a wide range of times, tidal conditions, locations and water depths.

Some model input requirements can be met through the use of existing data or assumptions, and certain data may not be required depending on the final model design. The following is an overview of the information typically required to model noise within an area such as the project site. Much of the information below is already available, while other data must be generated on site.

- 1. To assess transmission loss:
 - a) Obtain data regarding sea state/waves (surface roughness to understand acoustic scattering);
 - b) Obtain sound velocity profiles over the area of interest. This will change with season and to some extent between day-night due to surface heating. Sound velocity is a function of temperature, salinity, and pressure. It can be measured directly using a sound velocimeter or calculated from salinity, temperature and depth measurements collected by a conductivity, temperature and depth (CTD) instrument. These data have already been collected for the site but may need to be augmented using instruments on the FAST Platforms.
 - c) Assess in-water attenuation if needed. This is normally only important for high frequencies several kHz and up.
 - d) Characterize bottom depth and the sea bottom profile. Detailed bathymetry already exists for this site.
 - e) Characterize the bottom type, which provides values for model parameters such as compressional and sheer sound velocity and attenuation, potentially for several layers (e.g. gravel over bedrock).
- 2. Collect ambient noise data. Ambient noise is required to understand masking, provided there is a need to compute signal to noise ratios at a particular receptor location.
- 3. Obtain or measure turbine acoustic characteristics: The narrowband and broadband source levels described above are critical model input parameters.
- 4. Finally, develop an understanding of the marine organism's sensitivity as a function of sound frequency to assess potential noise impacts to marine biota. This would include, for example, the hearing or vibration sensitivity for all species of interest.

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Section 7: Marine Benthos



7.0 SECTION 7: MARINE BENTHOS

7.1 Introduction

Marine benthos, for the purposes of this EEMP, refers to marine organisms (excluding fish and lobster – addressed by other EEMPs) living on the seafloor and their habitat.

According to predictions made in the 2009 Environmental Assessment (EA), the "Project activities and components are not likely to cause significant adverse residual effects on marine benthos within the Project area or vicinity" (AECOM 2009).

Impacts of tidal energy development on benthos, particularly in extreme high flow environments such as at the FORCE site, are largely unknown although several studies (described below) have been undertaken to assess changes to benthic habitats in the vicinity of tidal turbines.

Mechanisms of tidal project-induced changes to benthic communities may include (Broadhurst and Orme 2014):

- Disturbance/destruction of habitat / individual organisms due to installation activities;
- Change in hydrodynamics and sediment dynamics due to presence and operation of project infrastructure leading to changes in benthic habitat and communities; and
- Benthic organism interactions with artificial structures (colonization, artificial reef effects, avoidance).

Based on results of previous benthic surveys, it does not appear that the FORCE site provides critical or rare benthic habitat for fish or invertebrates (Morrison and Redden 2013). Species and habitats present in the FORCE site are common throughout the Minas Passage. Moreover, the demonstration project site covers only a small fraction of the Minas Passage and available similar habitat. Species present in the FORCE area are adapted and tolerant to a highly dynamic and variable environment. It is likely that local, limited changes to hydrodynamics and seafloor conditions, if any, due to the demonstration-scale tidal energy project would be within natural variability and thus changes to benthos would not be detectable.

Given that no operating turbines have been installed in the FORCE site long enough to assess the potential impacts to the benthic environment, a basic, directed monitoring program is justified to verify the EA predictions. An intensive monitoring program is not recommended at this time given the characteristics of the local biotic community and habitat, and limited scale of the demonstration project.

7.2 **Studies Completed to Date**

Geophysical multi-beam and sidescan sonar surveys of the FORCE test site, Nova Scotia Power/OpenHydro turbine site and a reference site were conducted between 2007 and 2011. The focus of the surveys was to characterize geophysical features in support of turbine and cable route siting (Seaforth Geosurveys 2009, 2011a, b, 2012; Fader 2011).

Surveys of benthic habitat and biodiversity involving video and photographic surveys, as well as limited grab sampling, were completed in 2008 and 2009 in association with the environmental

assessment of the FORCE test site (Berths A, B, C and their cable routes and the nearshore zone by Black Rock) and in 2011 over the Nova Scotia Power/OpenHydro turbine site following turbine removal (Envirosphere 2009, 2010a,b,c; Fader 2011).

In 2011, the 2008-2009 video/still photography was further analysed to provide a more detailed characterization of the benthic communities in Berth and Cable Routes A, B, and C (Morrison and Redden 2013). The analysis concluded:

"Several habitat types were observed in the FORCE test area: exposed volcanic bedrock, exposed sedimentary bedrock, regions characterized by partial cover by loose sediment (gravel, cobble, and/or boulder), and regions fully covered by loose sediment. The surveys detected a low number of species present in the FORCE lease area and cable routes. *Halichondria panicea* (yellow breadcrumb sponge) is the most abundant species observed in the FORCE lease area. Other commonly observed macrofauna from video stills include two species of seastar, *Asterias vulgaris and Henricia sanguinolenta* (bloodstar) and *Urticina felina* (northern red anemone). No "at risk" species were observed in the videographic records; however, some unique forms were observed, probably a result of local adaptations to the harsh conditions. The cable routes and shallow regions of the FORCE test area (<15 m) support seaweeds, macroalgae and greater amounts of fine grained, sandy sediment. In deeper areas (>25 m), few species of macrofauna are present, limited to sessile epifauna or epifauna with limited mobility"

Based on our review of past studies, some of the challenges and limitations of the previous surveys were:

- Limited number of sampling sites,
- Issues with poor image quality,
- Difficulty in species identification,
- Grab sampling yielded few specimens given the hard-bottomed seafloor,
- Inability to adequately survey certain habitat types (slopes, under rocks, sediments) using available techniques (cameras could not view these areas),
- Inadequately representative control site; and
- Benthic habitat/biodiversity surveys of Berth and Cable Route D have yet to be conducted.

Additional data would be useful to develop a more accurate and comprehensive picture of the baseline natural spatial and temporal variability of the benthic community. However, as noted by Morrison and Redden (2013):

"Given the observed low biodiversity of macrofauna and the prevalence of encrusting yellow breadcrumb sponge, these findings suggest that it is unlikely that the installation of TISEC infrastructure will negatively impact the benthic community in the FORCE lease area. It can be expected that the increase in habitat heterogeneity created by the installation of infrastructure will increase both the diversity and overall biomass of macrofauna associated with the seafloor in the turbine test area"

7.3 International Monitoring Programs

Beyond baseline site characterization, benthic EEMPs at other marine energy sites, and at sites of other marine activities (e.g. oil & gas platforms), have been limited to date. At most sites, benthic monitoring has focused on habitat impact and recovery following construction/installation activities and/or biofouling of support structures and cables (e.g. Saunders *et al.* 2011; Polagye 2013; ORPC Maine 2014). The majority of these EEMPs have utilized video/still photography collected by divers using hand held equipment.

There are two key examples of broader benthic EEMPs for operating tidal devices. The first example is the program implemented for the SeaGen tidal turbine, currently installed in Strangford Lough, Northern Ireland. The program consists of two elements both involving the use of hand held video cameras deployed by divers (Royal Haskoning 2011):

- 1. A rapid general video sweep of the supporting structure and structure/seafloor interface for colonizing organisms and scour/erosion.
- 2. A transect aligned along the downstream axis of the turbine with fixed sample stations established at distances of 20m, 150m and 300m from the turbine plane of rotation. A reference station was also identified at a distance of 50m to one side of the device. At each station, five 0.25m² quadrats are assessed by a diver. Each square is sequentially captured by video using a slow panning motion.

In the second example, Broadhurst and Orme (2014) conducted a multi-year benthic habitat assessment of an operating OpenHydro turbine at the European Marine Energy Centre (EMEC) in the Orkneys. The habitat assessment program used grab sampling and video tows to evaluate potential changes to benthic communities. The video tows involved continuous recording along 500m horizontal transects placed at distances of 200m, 400m and 600m from the device and a control site located outside of the project area.

Both programs revealed detectable differences within the vicinity of the operational marine tidal energy device, over time. The OpenHydro program showed increased species diversity and compositional differences within the device site, compared to the control site. Broadhurst and Orme (2014) suggested that the changes were likely the result of localized artificial reef effects and natural temporal variation. The SeaGen program detected compositional differences at all downstream sample stations over time, but the changes were similar among all stations and at the reference site. The device foundation was colonized by species assemblages similar but slightly different to those present on the seafloor pre-installation. Royal Haskoning (2011) concluded that the "observed changes are a result of a combination of normal seasonal variation and a natural process of species competition and succession".

However, Broadhurst and Orme (2014) noted that "small-scaled studies such as this (in terms of number of device replicates and control sites surveyed), could misinterpret wide-scale environmental impacts associated with large development plans."

Past experience collecting baseline data in the Bay of Fundy demonstrates it is difficult to remain "on station" when attempting to follow a cross current or horizontal linear transect, even at near-slack tide. For this reason, approaches that use vertical transects (aligned with the current) or discrete sampling stations are proposed below.

Benthic Monitoring Guidelines

In 2011, Scottish Natural Heritage and Marine Scotland commissioned the development of a set of guidelines for survey and monitoring in relation to marine renewables deployments in Scotland. This set includes a volume dedicated to benthic habitats (Saunders et al. 2011). While never finalized, these draft guidelines are widely cited by monitoring programs and provide a comprehensive overview of feasible and cost-efficient best practices for monitoring benthos at tidal energy sites.

"The overall effects of a single or multiple tidal devices would, as for wave devices, be most effectively monitored by a combination of broad-scale acoustic mapping and random drop-down image sampling.... Because of the expected strong directional component of any impact, which will be sharply orientated along the direction of current flow, the greater part of the post-installation and operational monitoring can be concentrated in a relatively narrow area directly downstream (for half a tidal cycle) of the axis of an individual device. With a relatively homogeneous seabed, a transect-based approach covering one downstream/upstream side of the device is likely to be sufficient for impact monitoring, providing that a reference station of similar faunal composition can be located outside the identified impact zone. The reference station need not be particularly distant and could simply be located laterally to the device at a sufficient distance to be confidently beyond any influence from the tidal turbine. In practice this is likely to be no more than 50 - 100m" (Saunders *et al.* 2011, pg. 63-64)

7.4 **Objectives**

7.4.1 **Primary Objective 1 – Within the Berths**

At this project scale, it is likely that any detectable disruption to the benthos will be limited to the berths, and most likely to the immediate vicinity of the turbines within the berths.

While the predicted risk of any change to the benthic ecology within the berths is low, this prediction should be tested. Monitoring downstream of each turbine/array is necessary given that different turbine designs may interact differently with the system's hydrodynamics and seafloor habitats.

In order to verify that the demonstration-scale tidal energy project is *not likely to cause significant adverse residual effects on marine benthos* (as predicted in the EA), the overall objective of the EEMP is to identify changes that may be attributable to the project, if any, in the occurrence, relative abundance and habitat of benthic species in each berth site relative to reference conditions. Reference conditions in this case are pre-deployment conditions at each berth site as well as at a designated reference site outside of areas that may be affected once turbines are deployed.

7.4.2 Variables to be Monitored

- Change in the occurrence (i.e. loss or addition of a species) of one or more species in the sample sites relative to reference conditions (i.e. pre-deployment and reference site).
- Change in the relative abundance (increase or decrease in number of individuals or percent biomass coverage, depending on type of organism) of one or more species in the sample sites relative to reference conditions (i.e. pre-deployment and reference site).
- Change in habitat type/structure in sample sites relative to reference conditions (i.e. predeployment and reference site)

7.4.3 Indicators of Change

- Change detected in a sample site over at least 2 sample periods/seasons;
- Changes cannot be directly explained by natural variability or other influences; and
- Change not consistent with reference sites.

7.4.4 Ancillary Objective 2 – Nearshore Around the Cables

The nearshore environment is a much lower priority compared to the berths where turbines will be deployed. Previous surveys have found patches of benthic habitat supporting seaweed and algae communities in nearshore areas of certain berth sites and cable routes (particularly Cable B). These areas may provide important habitat for fish, larvae and marine invertebrates, many of which may not be visible in video/still surveys (hiding amongst vegetation, living in sediment).

The cable footprint on these habitats is small. At the current scale of development, it is unlikely that the impacts on hydrodynamics, which could influence marine benthos, will be detectable beyond the berth sites. However, at some scale of development, effects of energy removal may influence sediment transport, erosion and deposition patterns in the Minas Passage, which could affect the vegetated, nearshore habitats. Initiating an early monitoring program will provide a robust baseline and "track record" of changes in benthos as more turbines are installed. Monitoring these habitats would also serve as an early indicator of potential far-field impacts.

In order to assess the significance of changes in the nearshore that may be induced by the turbines and the presence of four subsea electrical cables, a secondary priority is to monitor changes in nearshore seaweed and algae communities and habitat relative to reference conditions (i.e. pre-deployment and reference site).

7.4.5 Variables to be Monitored

- Change in the occurrence (i.e. loss or addition of a species) of one or more species in the sample site relative to reference conditions (i.e. pre-deployment and reference site)
- Change in the relative abundance (increase or decrease in number of individuals or percent biomass coverage, depending on type of organism) of one or more species in the sample site relative to reference conditions (i.e. pre-deployment and reference site)

• Change in habitat type/structure in sample site relative to reference conditions (i.e. predeployment and reference site)

7.4.6 Indicators of Change

- Change detected in sample site over at least 2 sample periods/seasons
- Changes cannot be directly explained by natural variability or other influences
- Change not consistent with reference sites

7.4.7 **Objective 3 – Opportunistic Monitoring of Colonization**

Turbines, cables and other tidal energy support structures may provide vertical relief surfaces and shelter for colonizing biofouling/epi-fauna organisms. The impact of these new habitat structures could have positive or negative effects on native biodiversity. Given the existing harsh environment and low species diversity, the overall risk of negative effects to the marine environment from colonization is low.

Nevertheless, the increased habitat structure could support increased productivity of native species in turn affecting benthic communities in surrounding habitats, with trickle down effects on other marine organisms (e.g. fish; artificial reef effects).

Alternatively, the introduction of artificial structures and increased vessel traffic could introduce and support non-native (and potentially invasive) species, which could spread to surrounding habitats. While there was little evidence of biofouling on the gravity base of the NSPI/OpenHydro turbine after a year in the Minas Passage (Fader 2011), yearly variability is high and different types of structures may offer more favourable conditions for colonization (e.g. with cavities or sheltered areas). Thus, it would be useful for both developers and FORCE to understand the rate and pattern of colonization on different structures by different organisms.

The objective of this opportunistic monitoring is to gauge epi-fauna growth on and use of turbines and support structures and the potential effect on overall biotic community in FORCE site. Opportunistic monitoring is the responsibility of the berth holder.

7.4.8 Variables to be Monitored

- Change in occurrence of species on turbine/support infrastructure and cables (loss or addition of a species)
- Change in relative abundance of a species (increase or decrease in number of individuals or percent biomass coverage) on turbine/support infrastructure and cables

Possible Indicators of Change

- Diversity and relative abundance of colonizing species differ from pre-installation benthic species
- Evidence of scour or sedimentation around support structures that may provide habitat for benthic species

- Presence of non-native species
- Evidence of movement of organisms to adjacent sites

7.5 Monitoring Approach

The proposed approach is adapted from previous FORCE benthic habitat/biodiversity surveys, Saunders *et al.* (2011), Broadhurst and Orme (2014) and Royal Haskoning (2011) with consideration of the unique conditions encountered in the Minas Passage/FORCE site.

7.5.1 Vessel-Mounted Drop-Down Video / Still Photographic Surveys

7.5.2 Sample Site Locations

For Objective 1 monitoring would occur in <u>each berth prior to and following installation of the turbine(s)</u>. Monitoring would occur once per year, typically over a two or three day period. Sample stations (described below) would be located downstream/upstream of the axis of the turbine/array as per Saunders et al. (2011). Reference sites can be located adjacent to/lateral to the turbine/array at a distance of at least 100 m from the device, provided the sites consist of a similar faunal composition to the sample stations (Saunders et al. 2011). The sites selected should represent the typical habitat structure and species composition in the area. It may be prudent to add sample sites if needed to encompass different broad habitat types/depths, communities or special features.

For Objective 2 at least one nearshore sample station would be located in an area containing fine-grained, vegetated habitat.

Exact sample locations will depend on the final turbine position within each berth⁹.

For Objective 3 the "sample site" used to assess colonization on the turbine is naturally the turbine itself.

7.5.3 Survey Design

For statistical purposes, a standard randomized survey design is preferred. A Before-After-Control-Impact (BACI) approach is likely the most effective method (e.g., Smith 2002). Whatever protocol and design is chosen, the study should be replicable and consistent from year to year to allow inter-annual comparisons. An accurate positioning system, using differential GPS, is essential to log the location of sample points and permit comparison of

⁹ Benthic surveys have not been conducted in Berth and Cable Route D. It is likely that the biotic and habitat composition in this Berth and Cable Route will reflect that of the rest of the FORCE site. Given limited resources, a full survey of these areas is not necessary for the monitoring program, as long as baseline conditions of the sample and reference sites are surveyed prior to turbine deployment. However, it may be prudent to conduct preliminary surveys to confirm that there are no unique habitat features or species that need special monitoring consideration, as well as to identify preferred locations for sample and reference transects for monitoring.

sample locations over time. However, even with GPS, wire angle in these water depths will make it difficult to know when the drop camera is over "exactly" the same area of seabed.

Two possible approaches are outlined below. In the first approach, defined sample stations in the vicinity of the turbine are visited on a number of occasions. In the second approach, linear transects are established and revisited during subsequent surveys.

Approach 1

Within each berth, three fixed, georeferenced sample stations would be established directly upstream or downstream of the axis of the turbine/array at distances of 150 m and 250 m from the device/array. At least one reference station will be established lateral to/to one side of the turbine/array at a minimum of 150 m (minimum to ensure no influence from the device) from the device/array. At least one sample station will be established in a nearshore site (Objective 2).

The vessel would make two or three 100 m-long transects across each sample station while recording continuous video segments and taking still photos of the seafloor (e.g. see Saunders *et al.* 2011). This is the preferred approach since the sample station is fixed and the vessel can move at will across the target station.

Approach 2

In each berth, vessels will follow two or three fixed, georeferenced transect lines directly downstream of the device/array and running parallel to the flow from a distance of approximately 100m (or closet safe distance) to 200 m from the device/array (or to the boundary of the berth). For reference sites, vessels will follow two or three fixed, georeferenced 150m long transect lines running parallel to the flow (transects should be out of impact zone i.e. no closer than 50m from the device/array). At each site, the vessel will use standard drop-down video/still photography protocols to record the seafloor along the transect (see Saunders *et al.* 2011).

Nearshore monitoring and reference sites will follow a similar approach, with vessels running two or three transects of 100 m (depending on size of habitat zones).

This approach is less preferred due to the difficulty of remaining "on station" when following a linear track.

7.5.4 Frequency/Schedule

Surveys at each of monitoring and reference area would be conducted annually, and if possible in conjunction with other monitoring activities to reduce costs. According to Saunders *et al.* (2011) "a drop-down video/still monitoring programme incorporating annual sampling should be sufficient to establish whether change due to anthropogenic influence has occurred".

At least one survey should be conducted **prior to** device installation, especially in Berth D, which has not been previously surveyed. However, it is recommended that sampling should start immediately at all sites, regardless of the anticipated deployment date. This will require discussing the likely position of the turbine/arrays with the berth holders. The more years of baseline data, the better the understanding of natural variability and thus the ability to determine project-related impacts.

To ensure suitable image quality, surveys should occur during slow water periods (Saunders et al. 2011). Previous surveys found best results at 45-60 minutes prior to and after slack water (Envirosphere 2009, 2010a,b,c). To maximize the amount and quality of data collected, it is recommended that surveys be conducted during mid-late summer when flows and turbidity are low and biological productivity is highest. This follows the recommendations by investigators of previous benthic studies, who noted that many images taken in winter and spring had to be discarded due to poor image quality caused by high flows and turbidity (Morrison and Redden 2013). Given low productivity and species diversity in the project site and difficult conditions for this type of equipment, surveys in other seasons are unlikely to add sufficient information to warrant the expense.

Previous experience suggests that approximately two days (eight slack tide periods) will be needed to adequately photograph four sample stations.

7.5.5 **Objective 3- Epi-fauna Colonization**

This is the most likely change in benthic organisms to be detectable. However, given the harsh environment and reported low species diversity, the overall risk to the marine environment from the colonization effect is low. Thus monitoring of this mechanism should be done on an opportunistic basis.

Given safety concerns, we do not propose to operate drop-down video/still cameras near turbines and mooring lines. Instead, data on epi-fauna on turbine/support structures should be collected whenever possible. Opportunities include:

- Take advantage of any inspection activities the berth holders will be conducting of their infrastructure. For example, FORCE could use images collected during camera inspections of the turbines/support structures to identify changes in species occurrence and relative abundance. Another opportunity to inspect epi-fauna growth and to collect samples would be when infrastructure is removed for maintenance purposes.
- Given the low relief and small surface area, it is unlikely that cables will provide significant additional habitat for organisms or will act as a major barrier to movement. However, to confirm this, video/still surveys of benthic communities along cable routes could be conducted opportunistically in conjunction with any FORCE cable inspection activities. This will provide information on how benthic and other organisms growth, use and behave around the cables (e.g. do organisms seem to avoid or be attracted to cables).

7.5.6 Data Analysis

Robust semi-quantitative and/or qualitative analysis will be sufficient to assess change in these indicators (Saunders *et al.* 2011). The small sample sizes, limited number of replicates and difficulty of re-sampling exact locations may limit the applicability of full statistical analyses. Given this, the EEMP described above is less resource intensive than a typical Before-After-Control-Impact study.

Ultimately, data analysis will depend on the amount, nature and quality of the data collected, but both (semi-) quantitative statistical analyses and qualitative assessment should be considered. Techniques employed should be consistent from year to year, allowing for some flexibility due to any improvements in techniques. Statistical approaches used in the international studies cited above can be reviewed for their utility with FORCE data sets (e.g., multivariate statistical analysis [ANOSIM]; non-parametric Wilcoxon signed rank test on frequencies). As noted above, a semi-qualitative approach will most likely be applicable to these data.

7.6 **Discussion**

7.6.1 Adaptive Management

It is prudent to initiate a monitoring program at the early stages of the project to facilitate adaptive management by providing a robust baseline and "track record" of changes in benthos as more turbines are installed. As the project footprint grows, it is uncertain how far the hydrodynamics of the system can be altered before changes in near-field or far-field marine benthos manifest and become a concern. Hydrodynamic modelling, as recommended in the Physical Oceanography EEMP, is proposed as a means to understand the likely effects of progressive energy extraction as more turbines are installed.

If no impacts at the sample sites are detected after two years of monitoring, there may be a case for scale-down or deletion of benthic monitoring of the FORCE site at the 5-20 MW scale. If persistent changes at the sample sites are detected, which may be attributable to the project, it may be advisable to expand the monitoring program. The response will depend on the nature, magnitude and location of the changes. For example, given the relatively small size of the project in comparison to the total size and energy of the Minas Passage, it is unlikely that any impacts to benthos will be detectable beyond the immediate wake of the turbines. However, if impacts are seen, it may be advisable to add more sampling sites outside the berth area.

7.6.2 Limitations and Probability of Success

The proposed approaches should be sufficient to detect change in the monitored variables over time, if evident, and thus address the overall objective of the EEMP.

However, due to limitations of video/still camera equipment, species in certain habitats may be missed or under-reported (Saunders *et al.* 2011; Morrison and Redden 2013). This includes species in areas with high current speeds and turbidity, steeply-sloping or vertical rock faces, as well as organisms living under rocks or within the seaweed and algae beds or finer sediment habitats.

Nevertheless, the proposed approach is the most feasible option, and is supported by best practices literature. Moreover, the previous benthic surveys in the FORCE site using video/still photography have yielded good results and there is local experience/expertise in the use of this equipment in the Minas Passage and analysis of these types of data.

Alternative approaches have been used successfully at other marine energy sites, including the use of remotely operated vehicles (ROVs) or divers. These allow for a greater degree of accuracy, higher quality images and the ability to manoeuvre beneath vegetation and view slopes and angled surfaces; however, these techniques are unsuitable and unsafe for the high flow conditions in the Minas Passage (Saunders et al. 2011).

Acoustic approaches are commonly used for initial site characterization (Saunders *et al.* 2011). A recent study explored the feasibility of using sonar to monitor change in benthos (both physical and biological) over time in the slower waters in the outer Bay of Fundy (see Brown *et*

al. 2014). However, it is not recommended for FORCE at this time since more work is needed to refine data analysis, it has yet to be tested in extreme conditions and would likely be prohibitively expensive and resource intensive compared to video/still photographic techniques.

Another commonly used approach for benthic monitoring is grab sampling (Saunders *et al.* 2011). Morrison and Redden (2013) recommended that video-grabs be attempted to collect samples around rocky and steep sloped features and in vegetated, finer sediment areas, where cameras are less effective. However, feasibility of this approach in the Minas Passage is uncertain and past grab sampling efforts in the project area have yielded few specimens (Morrison and Redden 2013). This approach is mostly utilized and effective in lower energy, soft-sediment habitats (Saunders *et al.* 2011).

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Section 8: Marine Seabirds



8.0 SECTION 8: MARINE SEABIRDS

8.1 Introduction

One of the key objectives of the Fundy Tidal Energy Demonstration Facility is:

To develop monitoring techniques and methodologies for TISEC devices in the tidal environment (AECOM 2009).

The EEMP for marine birds described here has been developed in an attempt to confirm the impact predictions made with respect to the Project as well as to confirm the appropriateness and effectiveness of any mitigation undertaken. The program has been designed with reference to bird surveys previously undertaken at the site, existing guidance on survey methods and monitoring programs for tidal energy projects that are currently being undertaken both in Canadian and Scottish waters (see RPS 2010; Jackson and Whitfield 2011 and Robbins 2012). Ultimately however an adaptive management approach that allows for "flexible decision making that can be adjusted as outcomes from management actions and other events become better understood" is proposed for this program (FORCE 2015).

If results indicate that suggested mitigation is insufficient or ineffective, then either these mitigation measures will be modified and/or additional mitigation will be developed and implemented. This approach recognizes the unique environment of the Minas Passage, and as well the uncertainty with respect to the potential for environmental effects associated with the new tidal in-stream energy conversion (TISEC) technologies (AECOM 2009).

8.2 **Potential Impacts on Marine Birds**

There is a range of wave and tidal energy generation devices in production or in testing around the world and these devices differ greatly in their design, size and deployment state; which in turn changes how they can potentially impact on birds. There is currently very little operational experience or empirical evidence concerning how wave and tide devices may affect birds. To a large extent then, the potential effects of wet renewable technologies on birds are currently hypothetical, unproven and based on a combination of comparison with other marine activities (shipping, oil, offshore wind farms) and perceived risks (Grecian *et al.* 2010).

8.2.1 Construction Related Impacts

Such impacts relate mostly to temporary increased turbidity potentially affecting the visual ability of a diving seabird to forage and sub-surface and airborne noise from increased vessel traffic. In the typically turbid waters of Minas Passage, this potential effect is unlikely to result in behavioural changes to marine seabirds.

Although there is no evidence that diving seabirds use auditory signals to navigate underwater or become disorientated by marine noise, birds are sensitive to airborne and underwater noise and this could temporally displace birds from the vicinity of construction activities. Other potential impacts during construction include disturbance and displacement, habitat change, night time illumination and water contamination (Jackson and Whitfield 2011).

8.2.2 **Operational Related Impacts**

Underwater collision risk with tidal turbines can be informed by hypothetical calculations of how much time birds are estimated to occupy the same water space as a turbine rotor and making various assumptions (Wilson *et al.* 2007). However, such models may not be realistic without taking into account avoidance and evasion behaviour by diving birds. There are currently no measures of these parameters, and there are considerable practical difficulties in obtaining them. Given that underwater visibility and light intensity at the turbine depths are likely to be low, it is possible that diving birds may not normally detect rotors until they are very close, possibly too close to take evasive action. Although some marine mammals use active acoustics to detect underwater obstacles, there is no evidence that diving birds do likewise (Jackson and Whitfield 2011).

Other key impacts are likely to involve disturbance, displacement, habitat change, barrier effects and lighting impacts.

Navigation lights on fixed marine structures or on service vessels have the potential to attract or disorientate flying birds at night and interfere with normal navigation behaviour. Bright lights, especially red lights, can be a serious problem for migrating birds in certain weather conditions, at times leading to disorientation and, occasionally, large mortality events (Percival 2001). Given the scale of wet renewable developments, effects of navigation lights may be small but probably no greater than those for offshore wind farms. Lighting on vessels during any nocturnal maintenance or construction work is liable to present a more marked concentration of a potential spatial impact, albeit restricted temporally (Jackson and Whitfield 2011). Disoriented birds are prone to circling a light source and may deplete their energy reserves and either die of exhaustion or drop to the ground or water where they are at risk of predation (SLR 2015).

Future monitoring should address bird activity at night to determine if vessel and turbine lighting have an adverse effect on their behavior. The EA suggested that crews onboard project vessels should monitor evidence of bird collisions, particularly during night activities (AECOM 2009). Although sea bird collision risk is considered to be low, it is nevertheless recommended to reduce the potential effect of lighting on migrating birds. One option is to ensure lighting will be kept at low heights to reduce the chance of illuminating migrating birds as they pass through the area (JWEL 2004).

8.2.1 Summary

The EA findings predict limited short-term, localized changes to marine bird habitat use in the project area as a result of noise associated with vessel traffic, particularly for installation and decommissioning. Despite an anticipated increase in vessel traffic, the risk of direct mortality from collisions by marine birds is considered to be negligible and any effect would relate to disturbance and displacement related impacts. Additionally, the installation of turbine devices and electrical cables was not expected to have substantive residual effects on food sources or marine habitat for marine birds (AECOM 2009). The EA concludes that project activities and components are not likely to cause significant adverse residual effects on marine birds within the Project area or vicinity.

8.3 Studies Completed to Date

8.3.1 Marine Birds in the Study Area

The abundance and diversity of seabirds and migratory waterfowl and waders is described in detail in AECOM (2009), FORCE (2011) and FORCE (2014). It is known that the Bay of Fundy supports significant populations of coastal seabirds and other waterfowl and that Minas Basin in particular is important for migratory shorebirds during mid-July to mid-November, when many species pass through the Minas Passage and use both shoreline and offshore areas near the project site.

8.3.2 *Methodology*

In order to establish baseline conditions and then test the EA predictions, a series of EEMPs for marine birds were undertaken from 2008 to 2014. The purpose of these studies was primarily to collect pre-deployment (baseline) data on seabird presence, abundance and activity using visual survey techniques.

From July 2008 shore based vantage point surveys and offshore boat based surveys have been undertaken in the Minas Passage study area. The findings of these surveys are described in the annual monitoring reports and summarised in FORCE (2014). The 2011 monitoring program consisted of six one-day shore-based observational surveys (March-April & December) of the Minas Passage study area and two vessel-based surveys (late July and late August) in the Minas Passage study area and outer Minas Basin and Minas Channel. In 2012, there were six, one-day shore-based observational surveys (June-August) and three vessel-based surveys in mid-July, late July and early/mid-August. Vessel-based surveys employed observation protocols in CWS (2007).

Shore-based surveys ran from approximately high tide through the 6-hour period of the outgoing tide. For the boat based surveys, survey times were stratified across the tidal cycle. Observation protocols used during this study were based on the CWS (2007) and Wilhelm *et al.* (2008). A 'snapshot' sampling approach was used for flying birds, although all flying birds seen in the observation period were counted. Watches of 5-minute duration were conducted every 10 to 15 minutes in most locations and continuously (every five minutes) at the FORCE test site. The observer monitored the 300 m wide strip of water and air approached by the vessel, alternating sides on successive cruises. Information recorded included counts, species identification, age class and distance from the vessel. Observation conditions were generally good.

8.3.3 Key Findings 2009 -2014

- Moderate to low concentrations of seabirds are found at the FORCE site relative to the rest of the Bay of Fundy.
- The spring and fall migration periods are identified as the peak times when the individual abundance of and species diversity were at their highest in the Minas Passage.
- Diving birds such as the common loon and black guillemot occur frequently in the area but overall abundances are low to moderate. Deep divers (common murre and razorbill) are relatively uncommon and low in abundance (FORCE 2015).

 Diving birds were found at the FORCE site throughout the year, the majority of which dive to depths between 10 and 40 meters. Some species of diving birds observed were capable of diving to depths of 100 m (FORCE 2015).

Overall, low densities of seabirds and waterfowl are present in Minas Passage and Minas Channel, which suggests that this area may not be an important foraging or loafing area for a wide range of species. Diving species, including common loon, northern gannet, and black guillemot were not found to be abundant suggesting that the likelihood of interactions with tidal turbines may be relatively low.

The past observational monitoring of marine seabirds, therefore, has provided a comprehensive data set which used standardized field procedures and data interpretation guidelines. This methodology is recommended for use as the primary field investigation method in the new EEMP.

8.4 Limitations and Data Gaps

Although observational monitoring studies of marine seabirds have been ongoing since 2009 and provide a comprehensive data set using standardized field procedures and data interpretation guidelines, there are some limitations in the surveys to date which may lead to a lowered ability to detect any potential impacts of the turbine deployment:

- Shore based surveys have not been undertaken on a consistent basis between years. Different survey periods have been used in different years;
- Vessel based surveys have also been undertaken in different months between years and survey transects have differed or have not been undertaken using a set of fixed transects;
- Abundance counts have only been collected from one side of the vessel and are unadjusted i.e. they have not been analyzed using distance (Buckland *et al.* 1993), potentially leading to reduced abundance counts;
- No comprehensive data on diving species such as behavior, diving depth and frequency of diving behavior in the vicinity of turbine infrastructure has been collected for the purpose of collision risk or encounter rate modelling.

To address these limitations some adjustments and additions will be made to future surveys to take into account the requirement for robust pre and post deployment data. However, as much as possible the future methodologies will remain the same for effective comparison of results. There will be a stronger focus on the deployment site itself where any potential impacts of the turbines may be measurable.

8.5 **Objectives**

To date, bird studies have not been undertaken in the presence of a functioning tidal turbine; turbines are proposed for deployment beginning in late 2015. The potential for direct collision by marine diving birds with tidal energy devices, or harmful effects caused by their presence, including the potential for displacement of marine wildlife from habitual waters, are the primary considerations addressed in this EEMP. In order to get as accurate a picture as possible

regarding the presence and behaviour of marine birds in the vicinity of operating devices, data needs to be collected both underwater and at the sea surface (Marine Scotland 2014).

The main objective of this EEMP is to obtain robust site-specific species abundance and behaviour data which can be used to establish whether the installation, presence and operation of tidal energy devices causes displacement of surface-visible wildlife from habitual waters, and to identify any discernible changes to wildlife behaviour.

The EEMP proposed here extends previous monitoring programs and aims to:

- Obtain more data with respect to the occurrence and movement of bird species in the vicinity of the Project site to verify the existing findings of shore and boat based surveys; and
- Within the bounds of the current survey protocols, confirm EA predictions related to the avoidance and/or attraction of birds to vessels and tidal turbines.

Should resources permit, potential improvements to the current program may include:

- The use of automated cameras to record 'at turbine' bird behavioural interactions outside of those hours targeted by visual observers.
- The additional collection of behavioural information to parameterise the diving bird collision risk model of Grant *et al.* (2014).

Future studies of marine birds should continue to monitor:

- Changes in habitat use, movement or migration patterns associated with turbine use, noise or vessel traffic;
- Signs of an unnatural decline or change in abundance and/or distribution, over one or more generations;
- Signs of changes in foraging and/or social behaviours;
- Emerging technologies used at other sites to enhance current monitoring methods.

8.6 Methodology

8.6.1 Monitoring Approach

Post-deployment monitoring studies at the FORCE site will aim, where necessary, to be more focused than the pre-construction baseline surveys already described. The focus will be on those species identified in the pre-deployment assessment process to be of concern although overall, bird densities in the Project area were found to be rather low in the context of the broader spatial distributions of birds within the Bay of Fundy. FORCE (2011) notes that:

Low to moderate in densities of seabirds relative to other coastal areas of Nova Scotia were observed at the site, but a high diversity of species use the area throughout the year. No preference for, or avoidance by, seabirds and waterfowl of the turbine installation site were noted. The continuing monitoring programme will aim to quantify the magnitude of any changes and provide evidence to demonstrate whether such changes, should they arise, can be attributed to the tidal energy development or whether they have occurred for other reasons.

Jackson and Whitfield (2011) note that post deployment monitoring studies should provide information on:

- Changes to the abundance, distribution or behaviour of species considered to be of high or medium conservation importance;
- The extent to which predicted adverse effects such as disturbance and collision mortality are realised; and
- The extent to which, over time, species affected by disturbance and displacement habituate to the presence of a development.

The extent to which the post deployment monitoring program may be successful in detecting the effects of the turbines on birds in the Minas Passage depends largely on its ability to address the questions in **Table 8-1**.

Baseline Conditions Question	EEMP Monitoring Question	Method Differences/Comments	
Which species occur in the survey area (i.e. the site and its vicinity)?	Does species composition significantly change following construction /operation?	None.	
What is the abundance of the species?	Does abundance of species significantly change following construction /operation?	None subject to effort considerations required to detect change in key interests.	
How does abundance vary spatially across the survey area?	Does spatial distribution of species significantly change following construction /operation?	None subject to effort considerations required to detect change in key interests.	
How does abundance vary temporally (seasonally especially, time of day and state of tide may also be relevant)/	Does temporal patterns of occurrence of species significantly change following construction /operation?	None subject to effort considerations required to detect change in key interests.	
Which habitats do birds use (surface, mid- water, seabed, air-space etc.)?	Does habitat selection at a development site significantly change following construction /operation?	None	
Why do birds use a survey area and at which life-cycle stages are they present (i.e. what is their behaviour and purpose for being there)?	Do species significantly change their behaviour or reasons for using the site following construction /operation?	None	
What are the origins of birds using the study area (where do they breed, what other areas do they use, i.e. connectivity)	Not relevant as unlikely to change in response to a development	Standard surveys of distribution and abundance are unlikely to provide good information on connectivity to breeding sites. This subject is best addressed by tagging studies.	
What human activities occur in the study area and how do birds respond to them (e.g. vessel traffic, fishing)?	How do human activities at the site change following construction/operation (be they associated with the development or not), and what behavioural changes occur in response?	None subject to effort considerations required to detect change in key interests. It is important to collect data on other human activity so that the effects of changes to this can be factored into monitoring analyses.	

Table 8-1: EEMP Information Requirements

Baseline Conditions Question	EEMP Monitoring Question	Method Differences/Comments	
Does a study area have any habitat features that appear to be particularly important to birds (e.g. tide races, sheltered bays, nest sites)/	Do features identified as important in baseline surveys continue to be so?	None subject to effort considerations required to detect change in key interests.	
Not relevant to Baseline Conditions	Do species initially affected by displacement show habituation to the development with time?	Time series data are required to show habituation. Standard survey methods likely to be suitable.	

(source: Jackson and Whitfield 2011).

8.6.2 Study Design

It is essential that the survey and monitoring program is fit for purpose, providing information that is scientifically robust and credible to inform decision making. The survey design will be informed by the results of the previous pre-deployment baseline surveys and by the requirements of the project itself. It is expected therefore that there will be a continuation of the existing survey programme with some refinements and scope for flexibility where possible.

Although the study will need to be repeatable year on year, a degree of flexibility is required as the use of a site by marine birds is often highly variable and this can make it difficult to attribute changes to a particular cause (such as a single turbine deployment in the marine environment). If scientifically valid conclusions are to be drawn concerning the effects of development, study design must take into account natural variation and change due to other causes. If this is not done then the monitoring results are likely to be of little value as they are likely to lack the power to either detect change or identify the causes (Jackson and Whitfield 2011).

The post-deployment monitoring study will target the development site and the appropriate nearby areas already identified in the baseline surveys. The inclusion of a buffer around the main survey area will provide information on the birds using the area immediately surrounding a development.

As this project is 'near-shore' (<4 km) and <5 km² in total area, a buffer of at least 1 km is proposed.

8.6.3 Sampling Frequency

The timing of shore-based survey visits will be planned so that they are as temporally representative as possible, including the three main temporal cycles: time of day, time of year and state of the tide. Although time of day is not generally regarded as a controlling factor for marine bird surveys, survey work will as far as possible be evenly distributed through the day from dawn to dusk where daylight hours allow.

Bird surveys are generally undertaken at monthly intervals throughout the year but although there is variation between species, many marine birds follow a broadly similar annual timetable with regard to breeding, moulting, migration and wintering. Therefore, the survey timetable can reflect this, dividing the year up into periods based around the main annual stages, resulting in a survey that is less than monthly in frequency (**Table 8-2**).

Year Period	Description	Approximate Dates January and February	
1	Mid winter		
2	Late winter	February and March	
3	Early breeding season	April – mid May	
4	Mid breeding season	Mid May – mid June	
5	Late breeding season	Mid June – end July	
6	Post breeding/moult	August to mid September	
7	Autumn	Mid September – October	
8	Early winter	November and December	

Table 8-2: Example Periods for Marine Bird Surveys.

(source: Jackson and Whitfield 2011). Note: survey can begin at any time of the year but all sample events should be completed.

For the post deployment seabird EEMP, monitoring will be conducted throughout the year, based on the year periods described in Table 8-2. The annual program is shown on **Table 8-3**. The full methodologies for shore and boat based surveys are given in FORCE (2011) and will be continued where relevant for consistency and repeatability.

The broader survey area has already been characterised in terms of the spatial abundance of marine birds; these data are sufficient to provide the wider contextual picture of the avifauna surrounding the deployment site. As such no further boat surveys are proposed at this stage unless it is required that such surveys provide a continuous picture of bird abundance and distribution in the Minas Channel. If boat surveys are to continue then a more powerful survey approach should be adopted that takes into account missed observations and those out of range of the observer. These surveys would cover the same general area as previous but would adopt a fixed transect approach so distance sampling can be effected (see Buckland *et al.* 1993) and would follow the methodology recommended by Camphuysen *et al.* (2004). Data analysis would follow the Before/After/Gradient or BAG method outlined in Jackson and Whitfield (2011).

8.6.4 **EEMP Field Surveys**

As noted above, the current observational monitoring of marine seabirds has provided a comprehensive four-year, pre-deployment data set using standardized field procedures and data interpretation guidelines. However, no turbines have so far been installed for a sufficient time to monitor its effects on marine seabirds. The recommended EEMP builds on this program.

Demonstration-scale tidal turbines will be deployed in phases over the next five years or so. Given the differing designs (and hence the potential for differing effects on marine seabirds) the proposed EEMP is designed to be flexible and adaptive to different turbine forms, deployment schedules and results from early studies.

The proposed EEMP begins once the first two bottom-mounted Cape Sharp Tidal Venture turbines are installed in late 2015 and extends through 2016 when the surface piercing Black Rock Tidal device (and the bottom mounted Atlantis device) are slated for installation. Since additional turbines will be installed on the Black Rock device in 2017, this program can be extended, should initial results warrant this extension. Similarly, the EEMP can be adapted to monitor effects of the Minas Tidal device, once information regarding the final design and deployment schedule is known.

The EEMP will seek to repeat and augment the previous surveys undertaken between 2009 and 2012 but will focus on the deployment area more specifically. It is recommended that the survey be <u>undertaken for a minimum of three years post deployment</u>, depending on the actual turbine deployment schedule.

8.6.5 Shore Based Surveys

To account for the variability in the temporal span of shore based surveys between 2009 and 2012 it is proposed that future post deployment shore based surveys are repeatable and carried out <u>during the same months on a year by year basis</u>. The surveys will monitor the FORCE Project area including the FORCE test site, the area between Black Rock and shore (inside Black Rock), and the Minas Passage beyond Black Rock (outside Black Rock) as in previous years.

The pre-deployment surveys have identified specific periods of high abundance and diversity (albeit between years) with steady increases in abundance from Spring to early Summer (March to July) with a peak in June. After a period of low to moderate abundance between July and October numbers peaked again in the Fall in early November when local populations were supplemented by migratory movements through the study area. There were however data gaps with little information for the months of January, February, late August, September and October.

The EEMP shore based surveys will be focussed during the periods given in Table 8-2 to cover the whole annual cycle giving a <u>total of 90 hours of observation</u>, or about 16 days annually (**Table 8-3**).

Year Period	Month	Number of Surveys
1	January	1 (6 hours)
1-2	February	1 (6 hours)
2	March	1 (6 hours)
3	April	2 (12 hours)
3-4	Мау	2 (12 hours)
4-5	June	2 (12 hours)
5	July	1 (6 hours)
6	August	1 (6 hours)
6-7	September	1 (6 hours)
7	October	1 (6 hours)
8	November	2 (12 hours)
8	December	1 (6 hours)

Table 8-3: Marine Seabird Survey Schedule

Note: survey can begin at any time of the year but all sample events should be completed.

To ensure consistency with past studies and allow before-and-after deployment data set comparison, shore-based surveys should be undertaken from approximately high tide through the 6-hour period of the outgoing tide. Observation protocols should ideally mirror those described in CWS (2007) and Wilhelm *et al.* (2008) for consistency with previous work. In addition to following the monitoring protocols referenced above, observers should be instructed to record abnormal concentrations of seabirds suggestive of fish kills that may have resulted from turbine operation. It is recommended that the surveyors take a 30 minute break after the first three hour period to help prevent observer fatigue. The vantage point locations will remain the same.

A post deployment tidal site monitoring programme has been underway at the EMEC tidal test site at Fall of Warness, Eday in the Orkney Islands of Scotland. The survey effort here has been considerable, with some 909 hours of land based observations undertaken over the course of a single year. The method however is tried and tested and it is prudent to collect data is a similar fashion for the sake of maintaining a relatively standard approach to EEMPs at similar projects. With a view to informing any modelling approaches, it is recommended that the bird survey methods adopted by EMEC (2013) are used here.

The following information should be recorded for every seabird sighting made during the scans. Records should be limited to birds that are on the water or that or hovering directly above it (within a few metres), ensuring that the grid square to the location on the water below hovering birds is recorded. In this case the grid adopted is a 500m x 500m grid to ensure that surveys are carried out in a consistent in a methodical fashion, ensuring the whole study area is covered.

- DATE Date of the watch.
- TIME Time of the sighting.
- SIGHTING EQUIPMENT The equipment used to sight the bird(s).
- GRID SQUARE The grid square to which the sighting was allocated.
- NUMBER OF SPECIES As birds often form mixed groups, provide the number of species within each group.
- SPECIES The species sighted. As it is often difficult to distinguish birds to species levels, the option is given to enter 'Unidentified '. Further details can be provided in the COMMENTS section.
- NUMBER Estimated total number of birds (regardless of species) in the group.

Details of the following bird behaviors should also be recorded. Any combination of them can be included.

- DIVING FROM FLIGHT One or more birds diving underwater from a hovering or flying position.
- DIVING FROM WATER One or more birds diving underwater from a position on the water surface.
- SWIMMING AT SURFACE The birds are making progress at the surface.
- STATIONARY AT SURFACE The birds are stationary at the surface.
- COMMENTS Any other relevant information about the sighting should be included here. This may include details such as a record of the age or sex classes of the birds (i.e., if there are any relatively small animals in the group or if there are predominantly males or females), and interactions with the turbines (resting, nesting, collisions, etc.).

8.6.6 Exposure Time Population Modelling

Exposure time population modelling (ETPM) is an alternative approach to assessing collision risk to diving birds, although ETPM is an effects monitoring program in itself.

The data collected from the shore based surveys may be used to inform this type modelling but it is anticipated that only diving species that are present in reasonable numbers can be included in the approach outlined below:

The main aim of this approach is as follows:

- To develop a population model, from which thresholds of 'acceptable' additional mortality can be estimated.
- To estimate exposure time in order to derive collision probabilities per unit period of time which correspond to the mortality thresholds generated by the population model.
- To consider the associated mortality and collision probability estimates to determine the most likely range and the risk that these could lead to a population level impact at a given scale.

The methodology for assessing exposure time during the breeding and non-breeding seasons is described in detail in Grant *et al.* (2014). The example formula for the breeding season is given here:

T = FPUHS

Where:

Fj is the mean number of foraging trips made by an individual within period j.

Pj is the proportion of these foraging trips being made to the development area in period *j*.

Uj is the mean number of dives on each foraging trip during period j.

Hj is the mean length of time during each dive spent at vulnerable depths (i.e. the same

depths as the moving parts of the devices) during period *j*.

S is the proportion of the water at vulnerable depths, occupied by the parts of the devices with which the birds might collide (e.g. turbine blades).

The modelling outputs are expressed in terms of the collision rate required to achieve a threshold level of additional mortality, as opposed to producing an actual figure for the number of collisions that are predicted to occur within a given time period, as is typical of more standard approaches to collision risk modelling (Band *et al.* 2007). The subsequent interpretation of outputs from the exposure time model is based upon a subjective assessment of whether the required collision rate is likely to occur or not.

8.6.7 Data Analysis

In previous survey reports i.e. FORCE (2011) the data has been analysed using two way analyses of variance (ANOVAs) that has considered the difference of abundance between sites

and between years using density per km² as the unit of measurement. A similar method is proposed to assess any potential site specific effects, ensuring that where count data are not normally distributed (as is likely) then these data are either transformed to normality or an equivalent tool for non-normally distributed data should be used. Such a tool may include for example Mood's median test or a Kruskal-Wallis test.

8.7 Alternative Monitoring Studies

AECOM (2009) has assessed that project activities are not likely to cause significant adverse residual effects on marine birds within the project area or vicinity. The current observational monitoring program is providing a comprehensive data but could be supplemented with an automated camera to gain further insight to seabird populations including potentially vulnerable diving seabird populations.

Automated cameras could provide complementary data to the existing observational monitoring program for seabirds, as well as marine mammals at the FORCE site and surrounding area. Cameras would be installed on existing above-water turbine infrastructure. Predictions of seabird behaviour can be extrapolated from previous studies from other sites to the FORCE site where:

- Seabirds would use infrastructure for roosting behaviour;
- Infrastructure would be used more in the summer months than winter months; and,
- Other factors such as time of day, tides or wind would affect seabird behaviour near turbine infrastructure.

Previous studies have used in-situ digital stills, programmed to collect data every 5 minutes supplemented with tidal data from nearby buoys to correlate infrastructure usage with tidal conditions. It would be anticipated that technical difficulties may be encounter during the study period including but not limited to camera malfunction due to weather or a physical strike, exceeding data storage on the unit or loss of power the camera unit. During a similar study, technical difficulties were not noted and the study was considered a relatively efficient way to collect seabird data (Jackson 2014).

In order to provide appropriate coverage of the Minas Basin and the FORCE site, it is anticipated that multiple camera locations would be installed. Cameras would be used year round, ensuring that the equipment is accessed and receives regular maintenance. Personnel would also need to manage and tabulate large sets of data to compile and analyze marine bird photographs.

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Section 9: EEMP Summary

9.0 SECTION 9: EEMP SUMMARY

This section summarizes the EEMPs created for each of the seven subject areas.

- 1. Fish
- 2. Lobster
- 3. Marine Birds
- 4. Marine Mammals
- 5. Acoustics (Noise and Vibration)
- 6. Physical Oceanography (Water Quality, Currents and Waves)
- 7. Marine Benthos

For ease of reference, **Table 9-1** summaries the objectives and methods of each EEMP. **Table 9-2** attempts show how each EEMP would be deployed on a year-to-year basis. The actual schedule of each EEMP will depend on a number of factors including weather conditions, device deployment, vessel availability, etc. Despite the uncertainty, Table 9-2 can be used to help plan and schedule multiple EEMPs so that cost efficiencies may be found in compiling cost proposals, vessel and equipment rental, staff time or other aspects of the programs.

As noted in the Introduction, the EEMPs are designed to be flexible and adaptive to the TISEC deployment schedules. In keeping with the "adaptive management" approach used since the beginning of the FORCE project, modifications to the EEMPs (if needed) can be implemented once the deployment schedule is better known. As more turbines are deployed, actual impacts may differ from impacts measured at single devices and the EEMPs can be adjusted to account for this.

FORCE's experience has demonstrated "the ongoing challenge...of how to detect and measure any potential effects resulting from only one or a small number of operational turbines and natural variations in the ecosystems..." (FORCE 2015). The EEMPs provide systematic approaches to detecting environmental changes that can be attributed to the turbines. The results of these studies can be used by FORCE, their Environmental Monitoring Advisory Committee, the general public, regulators and the berth holders to first measure and then assess the likely environmental effects of their tidal energy devices.

Subject	Monitoring Objective	Variable/Parameter Monitored or Modelled	Sampling Method	Sampling Location	Sampling Schedule (Period and Frequency)
Lobsters	 To detect a significant change in a population as expressed by a statistical change in lobster catchability. 	 The number and weight of lobster caught per trap. Differences in catchability with distance from the turbine ("distance effects"). Differences in catchability in front/behind vs beside the turbine ("directional effects"); 	 Standard lobster traps deployed at fixed distances from operating turbines. Initially, a double-ring-and-quadrat approach is proposed. If warranted by initial results, the study can be expanded to include Area E and Area W and/or elsewhere for arrays. 	 One ring at 300-350 m from the turbine and one ring at 450-500 m. A total of 24 randomized sample stations, 12 in each ring (6 in each quadrant). 	 All stations are sampled three times to complete one survey; 72 samples per survey (24 stations sampled 3 times). Three surveys are proposed to capture progressive device deployments over time. The actual number of surveys completed will depend on the deployment schedule and initial results. Evaluate results from first 3 surveys, and if more sampling is required around that turbine.
Fish	 To quantify fish distributional changes that reflect behavioural responses to the presence of a deployed TISEC device. To estimate probability of fish encountering a device. 	 Fish density Fish vertical distribution Estimate probability of fish encountering a device 	 Down-looking, vessel-towed hydroacoustic echosounder. Before-After-Control-Impact (BACI) study design. Multivariate analysis (Hotellings T² tests) of fish vertical distributions An encounter probability model 	 9 parallel transects spaced 100 m apart, plus three control transects. Each transect is approximately 1.8 km long 	 Six surveys distributed over six months as was done in 2011-12. Each survey completed over a full tidal and diel cycle (25 hours). Study duration of five years to capture multiple deployments.
Marine	 Assess <u>direct</u> effects of operational turbine noise: attraction or avoidance. 	 Permanent avoidance of the local study area. Permanent avoidance of the near-turbine area (within ~150m). Change in the distribution of a portion of 	 Deploy 5 C-PODs at multiple sites in the spring to provide an improved baseline data set; redeploy 5 C-PODs in the fall to provide a comparative 'after' data set following turbine deployment(s) 	• at 5 established local study area reference sites.	 2015, 2017 and 2021. Once in the spring and once in the fall. Three months each deployment
Mammals	 Assess <u>indirect</u> effects due to changes in prey distribution and abundance: attraction or 	y distribution and decreases or increases in relative	 Deploy one C-POD near any occupied Berth 	 at 100+m of Berth D and any other occupied berth 	 2015, 2016 and 2017 Once in the spring and once in the fall Three months each deployment.
avoidanc	avoidance.		 Deploy 1 PAM data logger (AMAR) to provide data to cross-validate C-POD detection data and detect other marine mammal vocalizations 	at FORCE CLA Reference Site West 1 (2015) and East 1 (2017)	Year 1 2015 & 2017Once in the springNine Months
Physical Oceanography	 None at this time. 	 Demonstration scale project is not anticipated to have a measurable effect on water quality, current and wave profiles, and turbulence. 	 Hydrodynamic modelling can be used to predict when measureable effects, including changes to sediment dynamics, are expected as more turbines are deployed. 	Not applicable	• Pending the results of further modelling, an EEMP can be designed to measure changes in these parameters when needed.
Acoustics	 Establish pre-deployment baseline ambient noise conditions. Use the noise data to verify the EA predictions that suggest noise will not negatively affect marine biota. 	Ambient noise	 Deploy a streamlined moored hydrophone system. Undertake simultaneous drifting hydrophone measurements for comparison and data validation. Alternatively, the hydrophone can be replaced with a drifting noise source emitting at known frequencies. Develop an acoustic noise model 	Within the FORCE CLA	 A deployment period on the order of one to two months to capture noise conditions over multiple tidal cycles.

Table 9-1: Summary of EEMP Objectives and Methods

Subject	Monitoring Objective	Variable/Parameter Monitored or Modelled	Sampling Method	Sampling Location	Sampling Schedule (Period and Frequency)
Marine Benthos	• To identify changes in the occurrence, relative abundance and habitat of benthic species in each berth site relative to reference conditions.	 Change in species occurrence or abundance relative to reference conditions (i.e. pre-deployment and reference site). Change in habitat type/structure in sample sites relative to reference conditions. 	• The vessel would make two or three 100m-long transects across each sample station while recording continuous video segments and taking still photos of the seafloor.	 Sample stations to be located downstream/upstream of the axis of the turbine/array at 150 m and 250 m from the device. Reference sites to be located adjacent to/lateral to the turbine/array at a distance of 150 m from the device. The nearshore sample station would be located in an area containing fine-grained, vegetated habitat. 	 Monitor at each berth prior to and following installation of the turbine(s). Monitoring would occur annually, typically over a two or three day period for a minimum of two years.
Marine Seabirds	• To indirectly assess the potential for direct collision by marine diving birds, or harmful effects caused by their presence, including the potential for displacement of marine wildlife from habitual waters.	 The difference in abundance between sites and between years using density per km² as the unit of measurement. 	 Shore-based survey using Canadian Wildlife survey protocols as in past surveys. 	Observers to concentrate on the device deployment areas, the area between Black Rock and shore (inside Black Rock), and the Minas Passage beyond Black Rock (outside Black Rock) as in previous years.	 Typically 6 hours per observational event; total of 90 hours of observation, or about 16 days annually. Three years; can be extended if warranted

Table 9-2: Summary of EEMP Scheduling

Subject	2015	2016	2017	2018	2019	2020	Con
Lobsters	Fall: One Survey (2- 3 weeks)		Fall: One Survey (2-3 weeks) following new device deployment		Spring: One Survey (2-3 weeks) following new device deployment		 One survey consists of sampling all stations The actual number of surveys will depend of
Fish	Late Summer or Fall	Late Summer or Fall	Late Summer or Fall	Late Summer or Fall	Late Summer or Fall	Late Summer or Fall	 Each annual program consists of six survey Each survey completed over a full tidal and Study duration of five years to capture multi
	Spring (3 months) Fall (3 months)		Spring (3 months) Fall (3 months)			2021: Spring (3 months) 2021: Fall (3 months)	 Five C-PODs at reference sites in 2015, 20 Once in the spring and once in the fall. Three months each deployment
Marine Mammals	Spring (3 months) Fall (3 months)	Spring (3 months) Fall (3 months)	Spring (3 months) Fall (3 months)				One C-POD at 100+m from each occupied Once in the spring and once in the fall Three months each deployment.
	Spring (9 months)		Spring (9 months)				• 1 PAM Data Logger (AMAR)
Physical Oceanography							 Pending the results of further modelling, an the certain physical parameters when needed
Acoustics	Summer (1-2 months)						To capture ambient noise conditions over m
Marine Benthos	Summer/Fall (2-3 days)	Summer/Fall (2-3 days)	Summer/Fall (2-3 days)		Summer/Fall (2-3 days)		 Monitor at each berth prior to and following Monitoring would occur annually for a minin
Marine Seabirds	Fall	Summer	Summer				 Typically 6 hours per observational event; to Three years; can be extended if warranted

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9-6

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