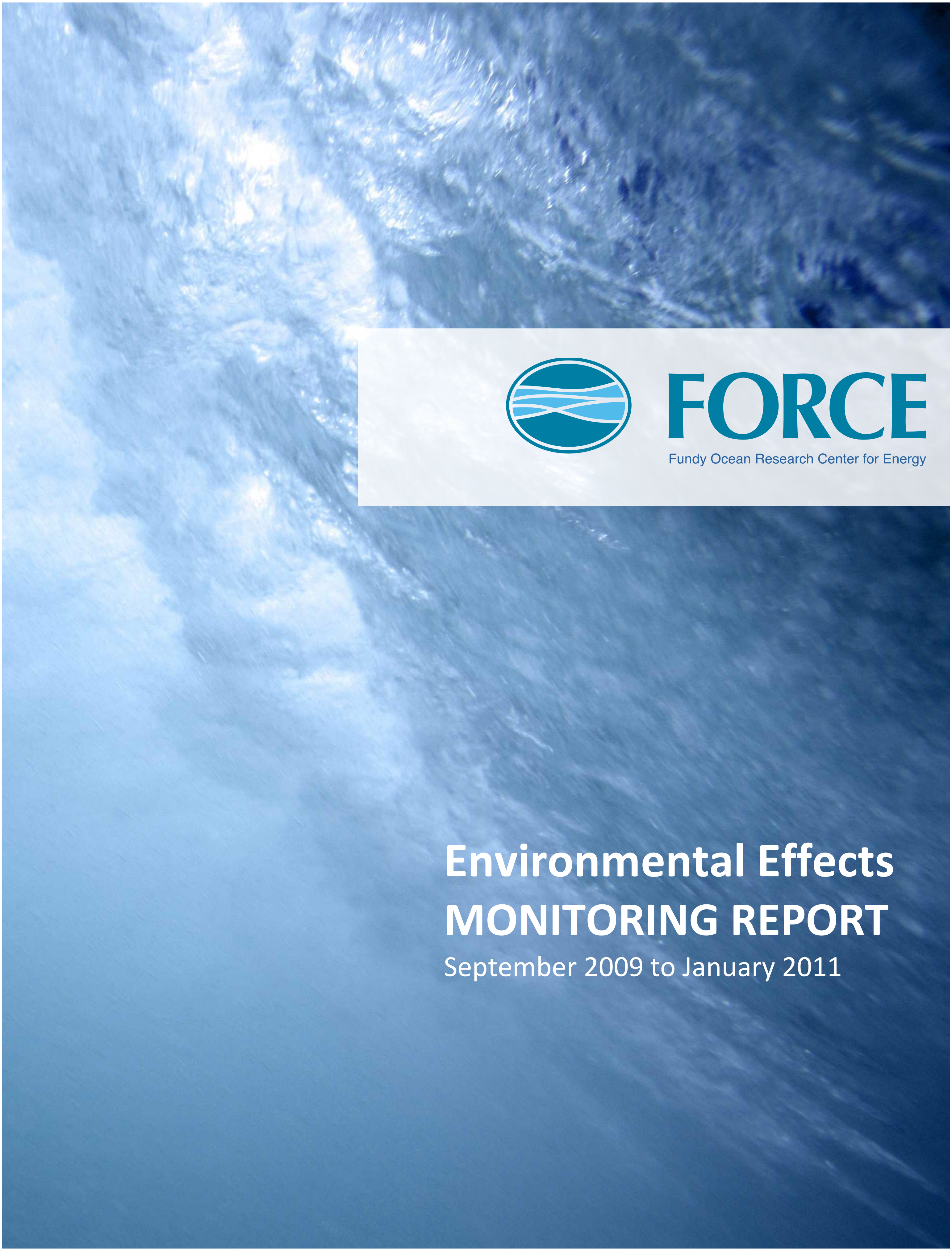

FORCE

Fundy Ocean Research Center for Energy

Environmental Effects MONITORING REPORT

September 2009 to January 2011

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ACKNOWLEDGEMENTS

FORCE would like to thank and acknowledge the important contribution of Envirosphere Consultants Limited in providing the critical third party technical review of FORCE's first Environmental Effects Monitoring report. We would also like to acknowledge the scientific and engineering consultants who conducted important work on behalf of FORCE, including: Acadia University, Atlantic Marine Geological Consulting Limited, BioIdentification Associates, CEF Consultants Ltd., Envirosphere, Seaforth Geosurveys Inc., and Sea Mammal Research Unit Limited. As well, we are grateful for the technical input and review provided by Nova Scotia Power Incorporated in the preparation of this report. This report was completed October 2011.

EXECUTIVE SUMMARY

This report fulfills reporting requirements for environmental monitoring at the FORCE Minas Passage Tidal Demonstration Site, under the Fisheries Act Authorization (Fisheries and Oceans Canada (DFO)) and Condition 3.1 of the provincial Environmental Assessment (EA) Approval for the project, by summarizing the key results of the Environmental Effects Monitoring Program (EEMP) from the commencement of the program in late September 2009 to January 2011. The EEMP has covered the early development of the project including the deployment of the first tidal turbine installed at the site by Nova Scotia Power Inc. (NSPI)/OpenHydro (OH) from November 12, 2009 until December 14, 2010.

The Environmental Effects Monitoring Program focuses on monitoring the effects of the marine environment of installation, operation, and removal of turbines and cables—environmental monitoring of onshore components of the project are dealt with under separate approval processes. The objective of an EEMP is to test the environmental impact predictions identified in the EA study. Components of the EEMP were proposed in the Project's Environmental Management Plan (EMP), and approved in principle by DFO and the Nova Scotia Department of the Environment (NSE). The final EEMP was modified based on advice from an independent Environmental Monitoring Advisory Committee (EMAC), established as a requirement of the provincial EA Approval and Fisheries Act Authorization. All reports documenting field studies and background information collection for the EEMP and covered in this report are provided in the Appendices.

An "adaptive management" approach has been used in implementing the EEMP, that is, one that reviews activities and outcomes continuously and modifies them periodically to reflect new information as well as the results of assessments of outcomes relative to objectives. Regulators, and EMAC, recognized the novel and exploratory nature of many of the monitoring activities—Minas Passage is a unique environment which presents challenges for monitoring due to its high currents and tidal range. Most of the monitoring approaches used for the EEMP, although often derived from conventional protocols, were applied for the first time in the challenging environment of Minas Passage.

Environmental monitoring at the tidal demonstration site began shortly after approvals for the project were received, and in advance of the installation of the NSPI/OpenHydro turbine on November 12, 2009. The turbine was installed successfully with no environmental impacts observed for the process. In place, the turbine and instrumentation initially operated successfully, but communication with the turbine through an acoustic link failed soon after deployment. Monitoring equipment mounted on the turbine recorded engineering parameters for the turbine, and made physical oceanographic measurements, including currents, for about three weeks before the devices eventually failed on December 4, 2009. Subsequently the turbine remained in place for over one year, during which turbine blades and some instrument

modules were lost. Presence of the structure at the site for over a year, as well as the subsequent recovery operation, provided an opportunity for several of the monitoring studies to look for environmental impacts—no adverse environmental impacts were observed. The findings represent an important step in understanding interactions between tidal turbines and the environment.

In summary, the EEMP has collected useful information, both focused on determining possible impacts of the tidal turbine, as well as on obtaining background environmental data for the Minas Passage; and has provided the opportunity to investigate the application of a variety of monitoring approaches and technologies in the challenging Minas Passage environment. Some of the main findings of the EEMP studies are as follows:

Seabirds and Waterfowl: 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.

Marine Mammals: Harbour Porpoise is the predominant marine mammal identified in the Minas Passage area based on observational surveys from shore and vessels as well as passive acoustic monitoring of porpoise and dolphin calls in the vicinity of the turbine and in a reference area. Use of passive acoustic monitoring in the project demonstrated that this technology is a useful tool for future real-time and long-term monitoring at the site.

Fish: Echo-sounder and mid-water trawl surveys demonstrated the presence, relative abundance, and seasonal movements of a wide range of fish species—both those expected to occur and highlighted in a literature review conducted as part of the EEMP—which use Minas Passage through the summer and fall. Species occurring at the site included: Atlantic herring, dollar fish (*Peprilus triacanthus*), Atlantic mackerel, gaspereau, smelt, lumpfish, sea raven, summer flounder, winter skate, tomcod, silver hake, red hake, walleye pollock, striped bass, dogfish and Threespine stickleback. Atlantic herring, dollar fish, mackerel, gaspereau, smelt and lumpfish were most consistently caught. Movements of fish species of interest in the Inner Bay of Fundy including striped bass, Atlantic sturgeon, and American eel, were demonstrated through the successful use of acoustic tags as part of a monitoring program which FORCE in part supported to include the Minas Passage. Acoustic tagging will likely be used as a monitoring technique in future, before and after the turbines are deployed.

Lobster: Studies of lobster catch were undertaken prior to, and after turbine deployment, as well as before and during lobster fishing season, in a survey designed to detect changes in catch reflecting turbine installation and other environmental parameters. The survey provided baseline information on lobster abundance over a broad area and variations in the vicinity of the installed turbine. Overall, lobster catch did not reflect differences which could be attributed to the tidal turbine installation although one of the comparisons showed a lower catch within a 200-m radius of the turbine. This result is preliminary in that other factors could have been involved in the result but it has provided an effects hypothesis which can be tested in future monitoring at the site.

Public and Citizens' Monitoring: No observations of unusual sightings of, or damage to, fish, seabirds or marine mammals attributable to the project, were made by the public or other users of the Minas Passage (e.g. fishers) during the study period.

Deployment and Recovery of NSPI/OpenHydro Turbine: The turbine was successfully deployed and recovered without environmental consequences, and no bio-fouling or damage to the turbine structure resulting from the deployment occurred. A side-scan sonar and towed video survey completed after turbine recovery, indicated no changes in bottom characteristics at the turbine and reference sites, with the exception of 1-m diameter pits in the bedrock surface caused by two legs of the turbine support structure, and some unidentified debris on the seabed thought to be part of the damaged turbine.

Real-Time Fish Monitoring: Although one of the objectives of the EEMP was to accomplish real-time monitoring for fish and marine mammal behavior and/or avoidance near operating turbines, limited suitable technology or methodology is available, and consequently, effective real-time monitoring has not been done to date. An exception is the passive acoustic monitoring of porpoise and dolphin vocalizations, which has the potential to determine effects of project activities on behaviour of these animals. Finding or developing suitable technology is an ongoing objective for this Project, and other Tidal In-stream Energy Conversion (TISEC) projects around the world.

The knowledge gained from the studies conducted to date will be employed in projects undertaken in future as part of the EEMP for the Tidal Demonstration Project.

1. INTRODUCTION

This report was prepared by the Fundy Ocean Research Center for Energy (FORCE), with input from Nova Scotia Power Inc. (NSPI), based on the Environmental Effects Monitoring Program (EEMP) initiated in late September 2009 and continuing through January 2011. Components of the EEMP were proposed in the Project's Environmental Management Plan (EMP) dated October 16, 2009, and approved in principle by DFO and the Nova Scotia Department of the Environment (NSE). The monitoring activities described in this report extend from late 2009 to January 2011, including pre-deployment and deployment monitoring of the first Tidal In-stream Energy Conversion (TISEC) unit by NSPI/OpenHydro, which was installed from November 12, 2009 until December 14, 2010.

Prior to the commencement of the EEMP, the Project had been assessed under a joint federal–provincial Environmental Assessment (EA) review process and was subject to regulatory approval in accordance with respective legislation. The project received provincial EA approval on September 15, 2009, and FORCE was required to meet Terms and Conditions provided by

Nova Scotia Environment (NSE) as part of the approval for the project. In February 2010, the federal responsible authorities for the environmental assessment determined that the project would not likely result in adverse environmental effects, thereby allowing them to take a course of action in relation to the project. In 2010, an addendum to the EA was prepared to account for additional funding that was provided by Natural Resources Canada through the Clean Energy Fund and changes to the onshore portion of the project.

The purposes of this Report are three-fold:

- To summarize the results of the FORCE EEMP as per the Terms and Conditions of the provincial Environmental Assessment Approval for the project dated September 15, 2009;
- To fulfill the requirement of an "as built" report under Fisheries Act Authorization #08-HMAR-MA7-00223035 issued by DFO on October 7, 2009 to NSPI for the deployment, operation and recovery of the turbine; and
- To provide a public record of the environmental effects monitoring program completed by FORCE during the deployment of the NSPI/OH turbine.

Background environmental information and Environmental Assessment Predictions for the project are available in the EA Registration Document, while Terms and Conditions for the provincial EA Approval for the project are available by viewing either the NSDOE EA website at http://www.gov.ns.ca/nse/ea or the FORCE website at www.fundyforce.ca. Additional information collected after the receipt of the provincial EA Approval is available in the EA Addendum Report, which is also available at the FORCE website. A summary of the EA Impact Predictions noted above are provided in Appendix A of the present report.

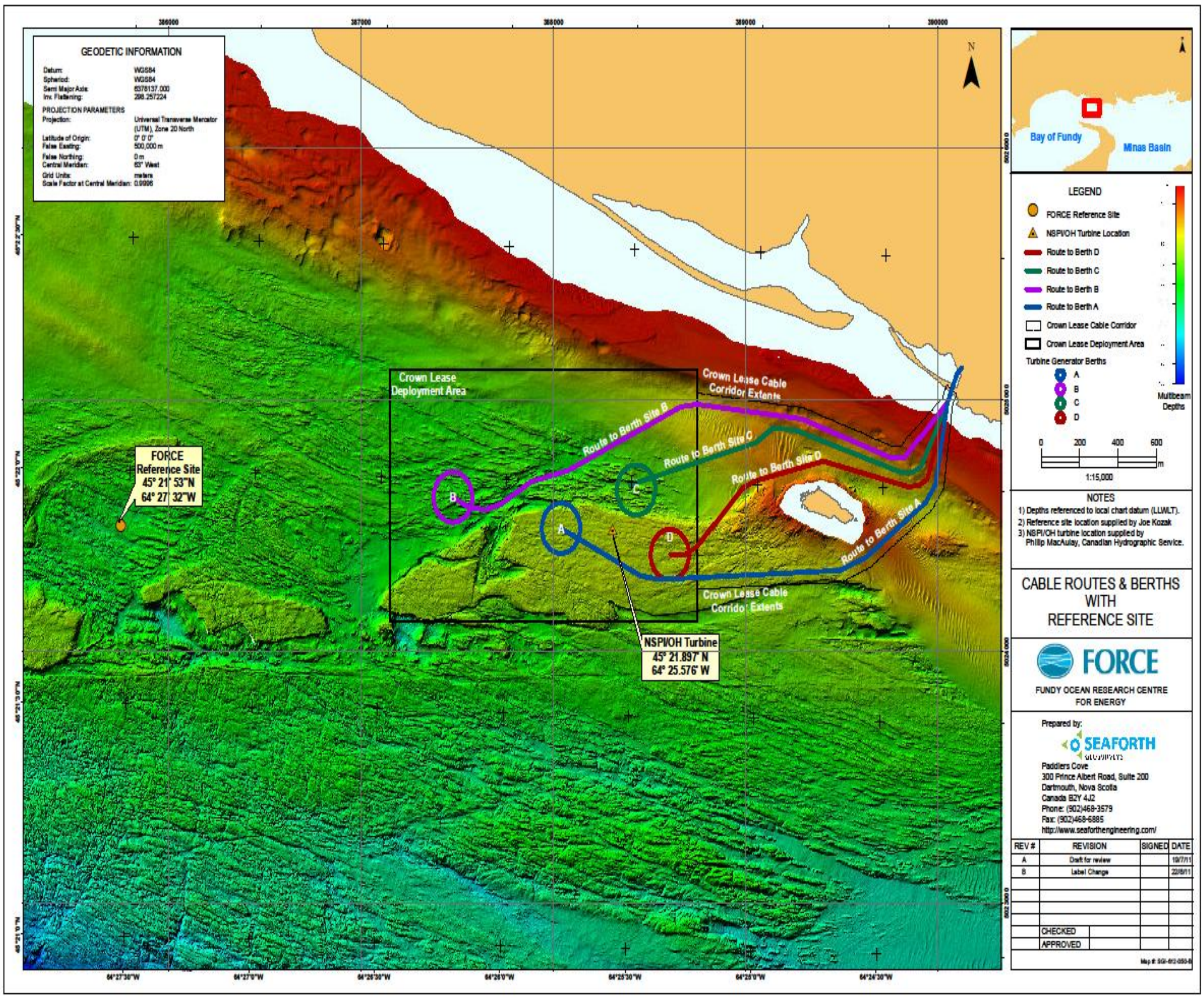
2. PROJECT DESCRIPTION

The Fundy Tidal Energy Demonstration project is managed by the Fundy Ocean Research Center for Energy (FORCE). Presently, the Project consists of four undersea berths for TISEC subsea turbine generators, four subsea cables (to be installed) connecting the turbines to land-based infrastructure, an onshore transformer substation, and power lines connecting to the local power distribution system. The marine portion of the project is located in a Crown Lease Area, 1.6 km by 1 km in area, in Minas Passage near Black Rock, and the onshore facilities are on leased lands on the West Bay Road approximately 10 km West of Parrsboro. A detailed description of the Project is available in the above-noted EA Registration Document and the EA Addendum document on the FORCE website. The initial project description did not include a fourth sub-sea grid-connected berth site within the approved Crown Lease area (Berth D, Figure 1), which FORCE developed at the request of the Nova Scotia Department of Energy subsequent to the EA Approval.

After the Project was approved, monitoring at the site began, which bracketed the deployment of the first TISEC turbine on November 12, 2009 by NSPI/OpenHydro; construction of land-based facilities began in February 2010. The marine cables are presently scheduled to be installed at the site in the spring of 2012, with two to three turbines to be deployed in the latter part of 2012.

Figure 1 shows the Fundy Tidal Energy Demonstration Facility in the Minas Passage, including the marine demonstration area and berth sites, cable routes, onshore facilities, the location of the EEM Reference site, and the location at which the NSPI/OH turbine unit was installed, which will be referred to in the following sections.

Figure 1 – Project Location – Berth Sites, Cable Routes and EEM Reference Site



3. ENVIRONMENTAL EFFECTS MONITORING PROGRAM (EEMP)

An Environmental Effects Monitoring Program (EEMP) measures specific parameters in the environment during the course of the project, to test assumptions or predictions of the effects of the project on the environment. At its most basic, EEM seeks to establish or disprove a cause-effect relationship between a specific project activity and a specific environmental effect.

FORCE's EEMP was required as part of the EA Terms and Conditions for EA Approval. The EEMP was carried out in cooperation with NSPI, as many of the monitoring activities applied to the broader project area and the NSPI turbine site. NSPI was also required to meet monitoring and reporting requirements under a Fisheries Act Authorization from DFO.

In consideration of the challenging environment of the Minas Passage, as well as the limited commercially available and reliable monitoring methodologies for such an environment, it was recognized by regulators and Environmental Monitoring Advisory Committee (EMAC), that the EEMP for the Demonstration Project should use an adaptive management approach. Adaptive management is a decision process that promotes flexible decision-making that can be adjusted as outcomes from management actions and other events become better understood. The adaptive management approach recognizes the unique and severe physical environment of the Minas Passage and the need to coordinate research data collection and reporting between researchers. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Simply stated, adaptive management is an iterative process of planning and implementing an action, monitoring, evaluation, and making adjustments as needed.

Biophysical and environmental parameters selected for monitoring were based on a proposed EEMP identified in the Project's Environmental Management Plan (EMP), and approved in principle by DFO and NSDOE. The final EEMP implemented during the NSPI/OpenHydro deployment period was modified based on advice from the Environmental Monitoring Advisory Committee (EMAC) for the project, established as one of the conditions of the provincial EA Approval in order to provide impartial scientific advice to FORCE. The EMAC consists of independent science experts and stakeholders, including fishers and First Nations representatives, as well as provincial and federal regulators who participate as observers. The full set of EMAC's recommendations on the EEMP, and FORCE's responses are available at the FORCE website at: www.fundyforce.ca.

The EEMP was implemented by a number of consultants working on behalf of FORCE. As well, to maximize funding and to optimize delivery, several of the EEMP surveys funded by FORCE were expansions to monitoring research projects already underway and supported by the Offshore Energy and Environmental Research Association (OEER). The final EEMP for the project is summarized in Table 1, which shows the various field components of the Plan for the period of September 2009 to January 2011.

Table 1 - Summary of the Environmental Effects Monitoring Program – September 2009 to January 2011

EEM PARAMETER	LOCATION	METHOD	TIMING
Seabirds	Minas Passage & Demo Area	From shore & vessel observations – CWS Standard protocol	7 surveys from shore – May-Nov 2010; 2 surveys from vessels – July/Aug 2010
Marine Mammals	Minas Passage & Demo Area	From shore and vessel observations – Standard protocol	Same as above
	Demo Area & vicinity of NSPI/OpenHydro turbine	Passive acoustic monitoring – 3 deployed C-POD hydrophones	Aug– Nov 2010
Lobster Fishery	Demo Area & control sites	Catch & release –catch rate comparison between test & control areas	3 Surveys -Sept/Oct 2009; Nov 2009; May/June 2010
Fish Movements	Minas Passage	Echo-sounder/mid-water trawl netting from vessel	2 surveys -Apr/May, 2010 (no netting) 13 surveys/101 net tows – June to Nov, 2010
	Demo Area & vicinity of NSPI/OpenHydro turbine	Acoustic tagging / tracking –Acoustic telemetry receiver lines & VEMCO transmitter fish tags	July-Nov 2010
Acoustic Environment (Noise)	Vicinity of NSPI/OpenHydro turbine site	Suspended recording hydrophone (vessel/drifting)	Dec 2009 & May 2010
Benthic and Scour	Reference Site & NSPI/OpenHydro Turbine site	Side-scan sonar/video	After recovery of turbine – completed Jan 2011
CTD and SPM	Minas Passage	Standard Sampling protocols - from vessels	Samples collected Jul/Aug/Oct 2010 & Jan 2010

During the monitoring program, FORCE and Offshore Energy Environmental Research (OEER) Association co-sponsored a Workshop in Wolfville, Nova Scotia in October 2010 to review research and monitoring needs for tidal energy development. The workshop included invited experts, and the outcomes confirmed the validity of key topics for monitoring as previously identified in other reviews (for the workshop report, go to www.offshoreenergyresearch.ca). An important priority and challenge identified by the workshop was the need for real-time monitoring of fish and marine mammal behaviour and movement in the vicinity of turbines, as well as interactions with them; a topic which is the subject of ongoing research around the world. Thus, although it remains a goal of the FORCE EEMP to apply real-time monitoring of turbine interactions of fish and marine mammals, reliable and effective methodologies remain in the developmental stages. Under the 2010 EEMP, this type of monitoring was limited to passive acoustic monitoring of porpoise and dolphin vocalizations. In addition, research on the application of 2D/3D sonar devices by DFO to monitor fish movements near turbines, funded by

the OEER and partially funded by NSPI, was initiated in 2009 and is still underway. Project descriptions of the tidal research underway can be found at:
http://www.offshoreenergyresearch.ca/Home/TidalEnergyResearch/tabid/386/Default.aspx

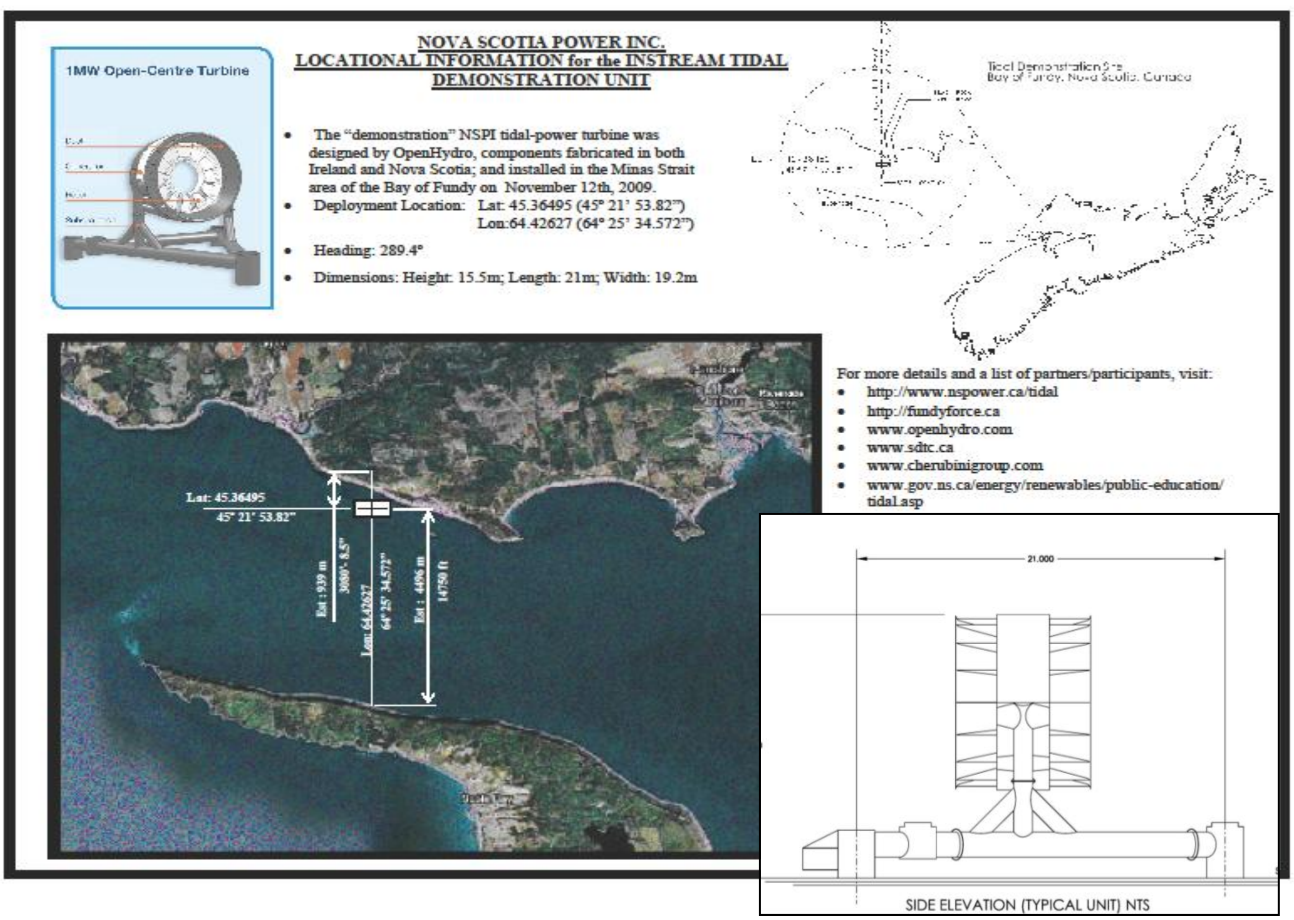
4. DEPLOYMENT AND RECOVERY OF THE NSPI/OH TURBINE

This section provides information on the NSPI /OpenHydro turbine deployment and recovery operations, including FORCE's observations, to provide context for the environmental effects monitoring efforts for the period of September 2009 to January 2011.

A report prepared by NSPI on the Deployment and Recovery of the NSPI/OpenHydro turbine is provided in Appendix B. The NSPI document describes activities, and also provides a discussion on "lessons learned" from the perspective of deployment and recovery, and instrument communications issues.

The NSPI/OpenHydro turbine is a 1 MW shrouded, open-centre, horizontal axis design with 12 blades, each 2 metres in length with a 5 metre open centre. The open centre and shrouded blade design is expected to minimize impacts on marine mammals, fish and seabirds, and also avoids the use of lubricating oils and thus reduces potential for chemical pollution. Figure 2 provides additional specifications of the NSPI/OpenHydro turbine and deployment.

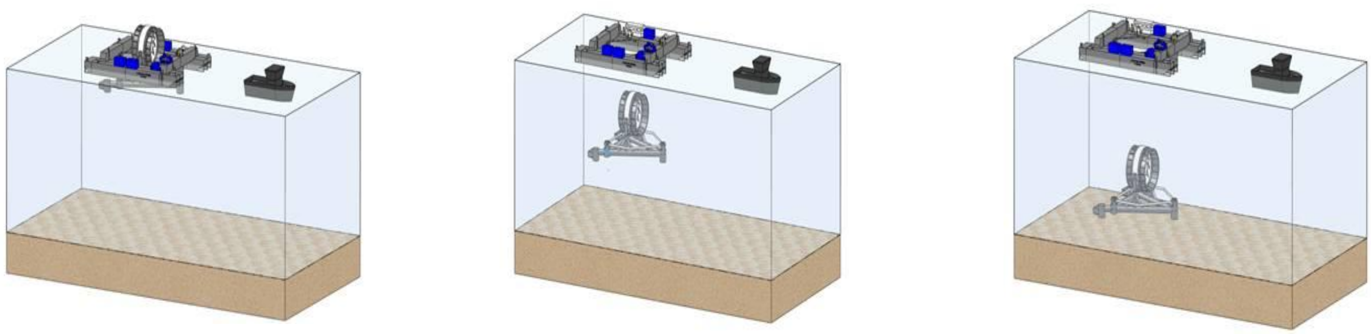
Figure 2 – Location and Specifications for NSPI/OpenHydro TISEC Unit



The NSPI/OpenHydro turbine was mounted on a steel subsea base, referred to as the Gravity Based Structure (GBS) or Subsea Base (SSB), which was built at Cherubini Metal Works in Dartmouth, Nova Scotia. The GBS weighed 400 metric tons and the turbine 50 metric tons, for a total assembly weight of 450 metric tons. The turbine on the structure was equipped with a load bank for dissipating generated electricity as heat (a subsea cable was not available to remove generated electricity—subsea cables will not be installed until 2012), along with battery packs to operate the monitoring and data logging equipment, and monitoring devices including data loggers, three Acoustic Doppler Current Profilers (ADCP), strain gauges, and an acoustic modem to allow transmission of collected data for regular downloading and analysis.

The turbine assembly was deployed using the specially-designed OpenHydro Installer barge (see Figure 3), which was pre-tested in the Bedford Basin, prior to moving the turbine assembly and barge to the Minas Passage location.

Figure 3 - Description of Turbine Installer Barge and Deployment Process



Notes for Figure 3:

The OpenHydro Installer barge is a special-purpose vessel built by OpenHydro for the sole purpose of deploying, recovering and transporting the OpenHydro Tidal Turbine Generator Unit in a marine environment known for extreme tidal forces. As such, this barge has features and specialized interfaces with the Unit that are not on a standard sea-faring barge.

Successful maneuvering of the Unit is contingent on the use of these unique features, as is the safety of the equipment and personnel involved. Any proposed alternative to this OpenHydro Installer barge must be able to demonstrate the following capabilities:

1. The barge is 32.8 meters long by 23.3 metres wide and capable of supporting the Tidal Turbine Generator Unit.
2. The Open-Centre "moon pool" design allows the 10 m diameter Unit to be raised out of the water, and allow personnel a stable access work platform in which to assess and service the Unit and associated sensory equipment.
3. The "moon pool" features a flood lighting system to permit work and visual contact with the Unit 24 hours per day to ensure the efficiency and safety of activities.
4. The barge is equipped with ball-and-taper lifting mechanisms manufactured by First Subsea (http://www.ballgrab.co.uk) to mate with the three engineered 20 inch diameter lifting attachment points on the Unit's Gravity Subsea Base.
5. The barge features a lifting frame assembly to guide and mate the ball-and-taper lifting mechanisms to each of the lifting attachments points on the Subsea Base simultaneously.
6. Cable drum winches on the barge have a minimum cable length per winch of 105 m, and a working lifting capacity of 120 tonnes. In addition, each winch is equipped with its own controls, weight-on-line load cell technology and line payout monitoring equipment.
7. The barge features line handling and retrieval equipment hydraulic and video lines required between the barge and the lifting frame.
8. The barge is equipped with bolted sea-fastening attachment point system which mates to the Unit's Gravity Subsea Base as required by the Insurers for approval of towing activities.

9. Land surveying class GPS geographic locating equipment and satellite communication with antenna is used to position the Unity within a 1 degree variance within the predominate tidal flow directions.
10. The barge is equipped with Gemini underwater sonar imaging manufactured by Tritech International (http://www.tritech.co.uk/index.htm) for accurate positioning of the Unit.
11. The barge features a VHF marine radio base station.
12. An underwater video camera, with wide screen display equipment on deck, allows personnel to visually monitor the Unit for some distance under water during deployment and recovery activities.

4.1 Deployment

The NSPI/OpenHydro turbine was installed at Berth C (refer to Figure 1), allocated for the deployment through mutual discussions with FORCE and participating parties tidal device providers. Based on an evaluation of bathymetry and geological considerations at the site, the project team identified a location which was acceptable for deployment. The turbine assembly was deployed on November 12th, 2009, and placed within 0.6 metres of the engineered location. The deployment location as shown in Figure 1 was located on a bedrock plateau at 28.8 metres below mean low water (42.3 metres below mean high water), at Lat: 45° 21.897' N Long: 64° 25.576' W. Turbine and instrumentation were functional immediately after deployment, but communication was never re-established although attempts were made on several occasions. NSPI/OpenHydro also made several attempts to observe the turbine assembly, and in March 2010, using 2-D and scanning 3-D sonar, a first indication of damage—the possible loss of turbine blades—was detected. Based on this information, and the ongoing inability to communicate with the unit, NSPI/OpenHydro decided to recover the turbine assembly in the fall of 2010, approximately one year earlier than planned. Future deployments when cables are in place will utilize data capabilities through the cables and will not require acoustic communication.

One of the goals in deployment and subsequent recovery of the turbine was to avoid disruption of the lobster fishery at the site. The complex logistics of the project resulted; however, in this objective not being met—both the deployment and recovery of the turbine unit occurred during the fall lobster season. As they would normally do in any circumstance involving marine activities in areas with an active lobster fishery, the NSPI/OpenHydro team worked with local lobster fishers to ensure minimum disruption to the fisheries activities during the deployment and recovery operations, and engaged local fishers in designing and executing the deployment and recovery operations. Local fishers' vessels were also employed as standby and safety vessels—their input and assistance during the process was instrumental throughout.

4.2 Recovery

The NSPI/OpenHydro turbine unit was successfully retrieved on December 16, 2010. The recovery utilized the same OpenHydro Installer Barge used for deployment. Upon retrieval, the turbine blades and center ring, as well as the acoustic modem were no longer attached, but otherwise the remaining structure did not show signs of damage. Further detailed evaluation is required, but the initial assessment indicated that the turbine was not strong enough to withstand the tidal forces experienced in the Minas Passage. NSPI/OpenHydro later indicated that the current regime measured by the Acoustic Doppler Current Profiler on the device, was stronger than the baseline measurements provided in advance, and that the turbine had been under designed for the tidal forces involved.

After recovery, the barge and turbine assembly were moved to Saint John, New Brunswick and stored over the winter, until favourable weather conditions allowed transport to Dartmouth. The barge and turbine assembly were moved to Cherubini Metal Works in Dartmouth in May, 2011. Downloading of the data from the unit was completed, and a detailed analysis is still underway. Initial analysis of collected data indicates that the turbine was operational for approximately 3 weeks, until December 4, 2009.

4.3 Environmental Monitoring Activities During Turbine Deployment, Operation, and Recovery

Environmental monitoring during the turbine deployment was a cooperative effort between FORCE and NSPI. Both organizations have specific monitoring requirements; FORCE has an EEM Plan approved by regulators for the demonstration site as a whole, while NSPI has requirements specific to the berth location where the turbine was installed. The monitoring undertaken is complementary, but in some cases additional monitoring was undertaken by NSPI specific to the site of the deployed turbine. Results were presented in the relevant study reports.

As a condition under the Fisheries Act Authorization issued to NSPI for the turbine deployment, NSPI was required to submit environmental monitoring reports to Fisheries and Oceans Canada (DFO) on a regular basis. NSPI submitted reports to DFO on: March 17, May 21, June 22, July 23, August 16, September 28 and October 27, 2010, and the Deployment and Recovery Report on June 23, 2011.

A FORCE representative observed turbine deployment and recovery operations, and inspected the turbine unit onshore on June 3, 2011 at the Cherubini facility. The inspection covered only the turbine mount, since the GBS portion of the assembly was below the water level. During recovery and after subsequent inspection, the unit did not show evidence of bio-fouling or algae growth, strike marks or scrapes, or any entangled fishing gear or debris. Subsequent discussions with NSPI and OpenHydro representatives confirmed that there was no significant bio-fouling on the GBS at the time of recovery.

Due to the high currents, water depths, and turbidity, the use of video or photography for monitoring proved difficult. NSPI attempted to use video to determine the condition of the turbine, with limited results. Video mounts on the turbine unit during the deployment were not possible; video cameras were attached to the lifting frame and OpenHydro Installer Barge; however, during the recovery operation, and provided useful information.

No real-time monitoring for fish or mammal movements around the turbine was attempted during the installation period, although passive acoustic monitoring of marine mammals (porpoises and dolphins) using porpoise click detector moorings, tested during the monitoring program in the vicinity of the turbine and in a reference area (see Section 5 and report in Appendix D) collected relevant information, and may be a useful tool in future. No fish or marine mammals were seen during the various operations related to the turbine deployment. Real time monitoring of fish and marine mammals in turbulent areas with high currents such as the Minas Passage is an ongoing challenge, not only for the FORCE project, but for other TISEC projects around world.

5. SUMMARY OF MONITORING STUDIES

Various EEM studies were undertaken during the period covered by this report—from September 2009 until January 2011. This section provides an overview of the studies, and the study reports are presented in the Appendices.

As they were completed, interim and final reports were provided to the EMAC for ongoing review and advice, and to assist in making recommendations for the 2010 and 2011 EEMPs. Interim monitoring reports were also provided to DFO by NSPI as required under the Fisheries Act Authorization, as noted in Section 4.3. All complete reports for field studies and background information carried out under the *aegis* of the EEMP are presented in the Appendices, and are available to the public, as is this full report, on the FORCE website.

Environmental monitoring continues to be a challenge at the site because of the lack of instruments and methods capable of dealing with the turbulent, high current tidal environment of the Minas Passage. In addition, many of the studies were hampered by the limited availability of vessels to deploy and retrieve instrumentation or run survey routes.

5.1 Seabirds and Waterfowl

To gather information on seabirds and waterfowl in the vicinity of the tidal demonstration site, FORCE carried out baseline and first-year monitoring studies in 2008 and 2009 respectively. As part of the EEMP, a series of one-day shore-based observational surveys for seabirds at the Fundy Tidal Power Demonstration Site were carried out from May to November 2010. As well, two vessel-based surveys reaching from the outer Minas Basin to Cape Spencer were undertaken to provide additional baseline data and environmental monitoring information to assess potential impacts of the project. The shore-based surveys took place in May (1, 13 and 27) and on June 12, October 23, and November 13 and 22, 2010, and vessel-based surveys took place on July 19 and August 18, 2010 (see report Appendix C).

Thirty-two species of water-associated birds were observed from shore in the vicinity of the demonstration facility, with Herring Gull, Great Black-Backed Gull, Common Eider and Red-Throated Loon the most common and abundant species. The greatest number of species occurred during fall migration in late October and early November (October 23 and November 13 surveys), but no migration peak was observed in May, and the expected peak spring movement of birds through the area may have occurred earlier.

Ten species were observed in vessel surveys which included parts of Minas Basin, Minas Passage and Minas Channel, including Herring Gull, Great Black-Backed Gull, Ring-Billed Gull, Double-Crested and Great Cormorant, Common Eider, Black Guillemot, Northern Gannet, Wilson's Storm Petrel and Common Loon.

No pattern was observed in the local distribution of birds in several sub-areas of the installation site (between Black Rock and shore; in Minas Passage outside Black Rock; and in the turbine installation ("Crown Lease") area. Greatest concentrations of birds were observed in late-May to early-June in the inshore area extending between Black Rock and shore (Great Black-Backed & Herring Gulls dominant); in the turbine installation area in mid-November (Red-Throated Loons dominant); and in Minas Passage during October 23 and November 22 surveys (Common Eider, Herring Gulls and Red-Throated Loons dominant).

The shore-based component of the survey showed a fall peak in migrants but a spring peak, which was expected to occur, was not demonstrated, suggesting either that it occurred earlier in the year than the period covered by the survey or that it is not as pronounced at the site as in other areas. Loons were the principal family of water-associated birds targeted by spring and fall observations in the study, since they are known to migrate through the area and they feed by diving and consequently may potentially interact with turbines. Because of their likely occurrence in the area in winter, their winter occurrence in the area is a potential data gap. Surveys extending earlier in the spring to capture the spring migrants, as well as in mid-March and December, may be sufficient to document the winter occurrences of alkyd species.

Generally, seabird densities in the study area measured in 2009 and 2010 are slightly lower than or comparable to densities for other Nova Scotia waters. Densities were lower than typical seabird densities in coastal and shelf areas in Nova Scotia waters although peak densities can be comparable to those from adjacent areas of the Bay of Fundy. The 2010 observations, combined with those of earlier baseline and monitoring studies carried out by FORCE, continue to suggest that the tidal demonstration site is not exceptionally important in terms of seabird and waterfowl abundance in the Inner Bay of Fundy.

5.2 Marine Mammals

Marine mammals, which include whales, dolphins, porpoises and seals, occur in the Inner Bay of Fundy and could potentially be impacted by turbine operations, either directly by contacting tidal devices or through impacts on food species. Monitoring during the tidal demonstration project has consisted primarily of on-shore and ship-board observational studies, done in conjunction with the seabird surveys. As well in 2010, an acoustic monitoring program, using porpoise 'click detectors' moored at the FORCE Tidal demonstration site, was used to study porpoise and test the feasibility of using the technology for future monitoring. Both study approaches identified the importance of Harbour Porpoise as the dominant marine mammal species at the site; only occasional white-sided dolphins, and seals have been seen at the site, and no confirmed whale sightings have been made during the surveys. The lack of sightings of whales reflects the low overall abundance and frequency of occurrence of these species in the area.

5.2.1 Vessel and Shore-Based Observations

Shore-based surveys undertaken at the Minas Passage shore installation provided information on the occurrence of Harbour Porpoise (*Phocoena phocoena)* in the study area in spring and fall—showing that the species occurred on most days and usually several times per day—as well as providing some insight into movement and activity patterns (see report Appendix C). Most observations were made on ebbing tides between high tide and low water and all individuals were swimming with the tide and at the surface. No particular association of Harbour Porpoise was noted with the proposed location of tidal turbines.

Harbour porpoise were only observed incidentally as part of the shore-based seabird surveys and the surveys represent only a snapshot of daily activities through the tidal cycle. In addition, the lack of summer to early-Fall observations at the study site, as well as observations in the late-March to early-May period, is a gap in assessing the overall pattern of abundance of Harbour Porpoise at the site. The daily movements of Harbour Porpoise are part of a larger pattern involving adjacent areas of Minas Basin and Minas Channel and also likely interactions with fish movements in the area, little of which can be determined from point observations at the study site. The observations have provided information on local behaviour and distribution which may be valuable in assessing project impacts. Harbour Porpoise may therefore be an important indicator species at the site meriting additional observational effort in future.

Vessel surveys in Minas Passage and Channel conducted in July and August 2010 were less effective at detecting Harbour Porpoise. Five Harbour Porpoise and no other species were observed in the two surveys combined, but similar surveys the previous year were more successful, in particular identifying various species of marine mammal including an unconfirmed sighting of a whale and sightings of White-Sided Dolphins in the area.

5.2.2. Mammal – Passive Acoustic Monitoring

The Passive Acoustic Monitoring (PAM) study, which was an expansion to an existing OEER-funded project, involved a continuous, approximately 3 month passive acoustic monitoring study for dolphins and porpoises (10 August to 23 November 2010) during the NSPI/OpenHydro tidal turbine device deployment in Minas Passage (see report Appendix D). This acoustic monitoring approach records the sounds of porpoises and dolphins (clicking sounds produced for echolocation of prey and communication) and later analyzes them to provide information on the identity of the species, their abundance, timing, daily patterns, and characteristics, providing information on use of the area and the animals' behaviour.

Comparisons can be made of behaviour (as monitored by the sounds produced by the species) in the vicinity of a turbine compared with 'control' sites at some distance from it, thereby showing potential impacts of turbine operation. Three C-PODs (autonomous, cetacean echolocation click detecting hydrophones) mounted on "SUB B3" streamlined instrument buoy moorings were included in the deployment, positioned in close proximity (150 metres east and west) of the turbine, while a third 'control' device was positioned 700 metres west of the turbine site. One of the devices near the turbine failed early in the deployment, while the two remaining C-PODs (east of the turbine and the control site) recorded click data continuously until the batteries expired (89 and 92 days post-deployment). The failed C-POD collected one day of data before stopping and its mounting SUB-buoy was recovered damaged, although the recording failure was determined to be due to an internal instrument fault.

The study confirmed the ability to collect long-term (3-month), high quality, cetacean click and temperature data from moored C-PODs in the Minas Passage, proving the ability of the instrumentation to provide useful baseline monitoring data on Harbour Porpoise behaviour including daily and seasonal patterns, and differences between turbine and control sites. The study answered questions over interferences with other acoustic instrumentation, showing no interference either by concurrent use of Vemco acoustic transmitters and receivers (fish tracking study), or from depth sounders of fishing vessels, which were discriminated by the C-POD analysis. Harbour porpoises were the only members of the groups of cetaceans (dolphins and porpoises) the C-PODs are designed to detect – no dolphin species were detected. Harbour Porpoise was commonly present (93% of days) but the relative abundance indicated by click detections was relatively low, and varied significantly with time of day (highest at night), and with month (highest in September) but showing no variation with location (i.e. between the turbine and control sites). Some click patterns were; however, different between the turbine and control sites. A power spectrum analysis suggested that Harbour Porpoise occurrences followed the tidal cycle but without clear association with either the falling or rising tide. The species was detected regularly through the late summer, but did not appear to spend significant time there (suggesting mainly transit through Minas Passage) but areal coverage of the instruments was not particularly large to detect other activities such as foraging which may occur in the area.

In summary, C-PODs were found to be effective in monitoring cetacean presence. Harbour Porpoises were detected regularly through late summer and autumn but did not (with a few exceptions during neap tides in September and October) appear to spend significant time periods around either the turbine or the control site (suggesting transit through Minas Passage or local foraging in areas out of detectable range). Presence was higher at night at both sites. No statistical evidence of the presence of the turbine attracting or repelling porpoise was found, but when porpoises were present, behavior (based on click train parameters) appeared to differ between the two sites.

5.3 Distribution and Abundance of Lobster

Commercial fishing for lobster is important in Minas Channel, and is one of the few commercial fisheries in the FORCE Tidal Demonstration area. The objective of this study was to provide baseline information on lobster abundance expressed as catch rates and to determine if changes resulted from the tidal energy program. The study, referred to as a catch or catchability study, consisted of setting commercial lobster traps within test and control areas in the vicinity of the tidal demonstration site. Three surveys, two in the fall of 2009, before and bracketing installation of the NSPI turbine, and one in the spring of 2010 while the turbine was in place, have been conducted to date. The study report in Appendix E summarizes the key results from the surveys.

The surveys focused on the FORCE Tidal demonstration site and 'control' areas located to the east and west, which were selected to represent areas unaffected by turbine installation. Locations were randomly selected within the areas and standard lobster traps modified with additional weight to resist tidal currents were used. At the request of NSPI/OpenHydro, the study also included stations located in the vicinity of the NSPI/OpenHydro turbine, at roughly 200 and 500 m distance, to determine differences in catch rates which might reflect turbine effects. The overall study determined patterns of catch and composition in the three areas (demonstration site and East and West Controls) and assessed differences among areas, seasons, depths, and levels of fishing activity (the timing of the baseline surveys spanned the pre-season of the lobster fishery (first survey) and during the fishery (2nd and 3rd surveys)). The findings and all results were analyzed statistically to determine patterns and trends, and an independent statistical review of results was carried out to assess the validity of the statistical approach and findings, as well as to provide recommendations for design improvements. In its execution, the study was adaptive and the approach was modified to respond to the tidal environment to optimize the effort and ensure efficient deployment and recovery of traps. Activities included efforts to maintain standard soak times (the length of time the traps were in the water), experimentation with the use of paired traps, repositioning of traps moved by the tide, adjustments for loss of traps, and efforts to manage efficient recovery and deployment. Sources of variability included survey timing, water depth, habitat type, number and types of sampling site locations, trap movement and soak time.

Some broad general conclusions were reached by the study, which has provided a useful baseline for future monitoring at the site, including providing a statistical basis for refining the designs of monitoring programs. In general, the study found that catch was comparable between the Eastern Control, Tidal Demonstration site, and West Control area. Catch rates in the spring (2010 following turbine deployment) were markedly lower than the two fall surveys, and catch rates were higher nearer to shore and consequently in shallower water. Size composition of the catch in three size classes, favoured small lobster in shallower water and thus near shore; large lobster were widely distributed with no correlation with depth. In addition, the distribution of lobster by sex and reproductive state (whether females were berried or not) did not appear to vary spatially. Catch rates were greater the longer traps were in the water. In the only correlation with project activities found in the catchability study, lobster catch was found to be lower 200 m from the turbine than at 500 m distance. This outcome could not be linked to specific turbine effects, as the study was not designed to account for other factors such as variation in the substrate or position in relation to subsea features, but provides guidance for design of further studies at the site.

The independent statistical review concluded overall that the project results and design were valid statistically, but suggested improvements to increase the ability of the design to measure catch parameters and monitor changes.

5.4 Fish Surveys – Distribution, Abundance and Movements

The Inner Bay of Fundy is an important feeding and nursery area for marine and estuarine fish and Minas Passage is migratory pathway for most species. However the high tides and currents, as well as availability of research funding have hindered work on determining the utilization of the Passage. Consequently, patterns of behaviour, distribution and movement of fish in the study area are imperfectly known, but essential for assessing impacts of tidal turbines. Therefore EMAC placed a high priority on studies of fish in Minas Passage. Efforts supported in whole or in part by FORCE have been highly successful. Work included a background literature, which updated information on the occurrence and migration of fishes in the Minas Passage (see Appendix F). NSPI/OpenHydro conducted a short-term hydroacoustic survey without a trawl component in April and May 2010. FORCE also undertook an extensive hydroacoustic and mid-water trawl survey of Minas Passage (Appendix H) in 2010 which determined species composition, abundance, timing and distribution of fish. FORCE also funded an expansion of OEER-supported acoustic tagging studies to monitor the movements of key species including Striped Bass, Atlantic Sturgeon, and American Eel tagged in coastal areas of Minas Basin and rivers entering it. Finally, FORCE supported a project, focused on the use of drift nets as a monitoring tool, which resulted in a July 2010 drift net deployment in the Blomidon-Minas Passage area (Appendix G). Summaries of the fish surveys are presented below.

5.4.1 Fish Distribution and Abundance in Minas Passage – Hydroacoustic and Mid-Water Trawl Surveys

A hydroacoustic (echo-sounder) fish survey was conducted from a small (18.6 m) commercial stern trawler approximately bi-weekly from June to October of 2010 in Minas Passage, spanning the FORCE Tidal Demonstration Site (Appendix H). Hydroacoustic surveys use sound or backscatter reflected from the swim bladders of fish in the water column to estimate the abundance, biomass and distribution (depth and location) of fish under the vessel. Receiving equipment is calibrated to enable accurate measurements of the intensity of backscatter to be converted to an estimate of fish density or acoustic biomass. An echo sounder cannot determine the identity of the species present without independent verification, typically done by using trawls or nets to catch the fish. In the present study, a mid-water trawl was used to capture fish identified in the hydroacoustic record. The present survey was highly successful, providing a detailed background data set for assessing potential for tidal impacts.

The hydroacoustic fish survey was intended to identify seasonal changes in fish distribution both spatially and vertically in the water column. Initial survey trials to develop protocols were carried out in June 2010 with approximately bi-weekly surveys conforming to a consistent methodology conducted from July to October. The NSPI/OpenHydro turbine was in place within the tidal power lease area during these surveys.

Species occurring at the site, determined from mid-water trawls included: Atlantic herring, dollar fish (butterfish, *Peprilus triacanthus*), Atlantic mackerel, gaspereau, smelt, lumpfish, sea raven, summer flounder, winter skate, tomcod, silver hake, red hake, walleye pollock, striped bass, dogfish and Threespine stickleback; and occasional krill (a planktonic shrimp-like crustacean) were also sampled. Atlantic herring, dollar fish, mackerel, gaspereau, smelt and lumpfish were most consistently caught. At times, predominately bottom species, such as sea raven, summer flounder, and winter skate were caught well above the bottom. Gadoid (cod-like) fishes, including tomcod, silver hake, red hake, and pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm fork length). A large striped bass and large dogfish were caught on September 17 and October 26 respectively, and a dogfish was also caught in the initial June survey. No species listed under the Species at Risk Act were caught during any survey work in 2010.

The relative abundance of different species of fish changed seasonally. Herring by far outnumbered all other species caught in the spring, dominating the catch especially in June and early July. In October, when most herring are thought to leave Minas Basin, herring still made up the largest single component in most tows, but were much less abundant than earlier in the year (about 7% of the June average).

The quality of the data generated by the hydroacoustic survey system was considered good and there was reasonable consistency between catch data and the acoustic record, with samples of fish captured and species identified in the areas of fish abundance identified by acoustics. The correlation between acoustic biomass and the catch in the mid-water trawl was only moderate, however, in part because of the patchiness and dominance of herring during some of the surveys, but also thought to be because of the varying currents and turbulence in the Minas Passage, preventing good alignment of the mid-water trawl and the vessel hydroacoustic echo sounder.

Some key findings from the study were:

- Surveys found that fish were relatively evenly distributed throughout Minas Channel between July and October.
- Both acoustic and tow data indicated a relatively even distribution of biomass throughout Minas Passage, with little spatial differences or concentration by species. The tidal power lease area had fish biomass similar to other parts of the cross section of Minas Passage and therefore does not appear to be a specific migration or passage route for any species.

- Major differences between tow and acoustic estimates of biomass were most probably a result of differences in abundance and patchiness of herring as well as reflecting the difficulty in adequately positioning trawls to sample fish seen on the hydroacoustic system.
- The major component of finfish biomass in Minas Passage is adult herring moving into the area in June, followed by young herring in later July and August, gaspereau in September, and a broader mix of species leaving the upper Bay of Fundy in October.
- Tidal conditions were not a significant predictor of biomass, but the strong tidally-induced currents may have increased the variation and range in spatial and vertical fish distributions.
- Fish were acoustically observed moving upwards in the water column at night, but catches were higher during the day, suggesting visual cues, such as the fish seeing trawl doors, leading to escape behaviour into the net, increasing catch efficiency.

5.4.2 Fish Movement - Acoustic Tagging/Tracking

An important new technology for monitoring the activities of fish in the ocean—use of acoustic tags—has been applied to the problem of determining fish movements in the vicinity of the FORCE Tidal Demonstration Site. FORCE contributed to a project funded largely by the OEER which implanted acoustic transmitters in Striped Bass, Atlantic Sturgeon, and American Eel in Minas Basin and rivers feeding into it (Appendix I). Underwater acoustic telemetry receivers (hydrophones to listen for distinctive acoustic signals of the tags) deployed across the Minas Passage at Cape Sharp, and in near-shore areas of the Minas Basin during July to November 2010, recorded the unique acoustic signals transmitted by tagged fish near the receivers, to track the movements of these species.

Funding from FORCE allowed the implanting of VEMCO acoustic transmitters in an additional 50 Striped Bass (120 fish were tagged in total—80 Striped Bass, 30 Atlantic sturgeon, and 10 eels). Striped Bass were captured by angling and tagged in the Stewiacke River in early May, 2010, or near the Gaspereau River mouth in early August; while Atlantic sturgeon were tagged after capture during August from shallow Minas Basin waters (Delhaven/Cornwallis mouth area and Walton area) using a bottom trawler chartered from Delhaven. Eels were captured using fyke nets set in the Shubenacadie River near Enfield in early October. Preliminary results have shown a high success rate for the project, with high post-surgery survival for all species, and significant detections by receivers in Minas Passage Sixty-six per cent of tagged bass crossed through the line of receivers at Cape Sharp, and 31% were detected in the NSPI/OpenHydro turbine berth area. Of the 10 eels tagged in October, three were detected as they migrated out of Minas Basin and one of these was detected near the NSPI/OpenHydro turbine site. All but two of the 30 tagged Atlantic sturgeon were detected, with 21 and 8 sturgeon detected by the line at Cape Sharp, and the turbine receiver array, respectively.

This application of the technology was successful and will continue to be employed and expanded in 2011 to gather further information on fish movements in the FORCE Tidal Demonstration area.

5.5 Ambient Marine Noise

Noise monitoring, both ambient baseline and during operation of tidal turbines, has been identified as an important objective of environmental monitoring at the FORCE demonstration site.

In addition to measuring noise levels, which may potentially influence marine mammals, operators have been interested in determining noise signatures near an operating turbine. Both FORCE and NSPI/OpenHydro have attempted to obtain underwater noise levels at the site. Early in the project, on September 24, 2008, FORCE deployed a suspended hydrophone from a drifting vessel with motors off in Minas Passage for a baseline survey in the FORCE lease area; and conducted a post-deployment survey in the vicinity of the NSPI/OH turbine berth site on December 2, 2009 with the vessel under power. NSPI/OpenHydro subsequently conducted a survey at the turbine berth site conducted using “drifting” suspended hydrophones on May 11, 2010.

Sound level data from both sets of surveys were later determined by an independent consultant engaged to be unreliable, indicating that sea state and turbulence interferences were a problem in the generated data. Overall, the noise level data collected on the three surveys was considered inconclusive; and therefore, no further analysis has been undertaken. In consultation with DFO, FORCE agreed to undertake a more detailed baseline noise survey after the removal of the NSPI/OpenHydro turbine and prior to the deployment of any other turbines at the site. This work is scheduled to be completed in 2011.

5.6 Seabed Environment and Scour Survey

In January 2011, a side-scan sonar and towed video camera survey was conducted at the Reference Site and at the location of the NSPI/OpenHydro test deployment site, to determine conditions on the bottom after the recovery of the turbine assembly (see report - Appendix J). Sonograms and side-scan sonar mosaics were interpreted, compared and contrasted with previously collected multi-beam bathymetry and derived backscatter and slope imagery, to determine both natural change and possible effects of the turbine placement, operation, and removal over a one year time frame. The analysis showed no detectable seabed change at the Reference Site since the original data was collected over 5 years ago. The seabed consists predominantly of exposed sedimentary bedrock ridges projecting from intervening flat regions of gravel with boulders.

No change in the seabed at the turbine site was observed in the survey, with the exception of a several metre long linear piece of seabed debris, possibly remains of the turbine blades or center-ring, as well as small imprints believed to have been left by two of the feet of the GBS. The turbine was placed on a broad, resistant, exposed volcanic basalt platform, and two of the feet of the gravity platform appear to have created 1-m diameter depressions in this bedrock surface. No other changes in the morphology or gravel distributions of the seabed were detected and no fine-grained sediments occur both in the near-field and far-field that could have been disturbed by the turbine.

5.7 Physical Oceanography

Oceanographic measurements (See Appendix K) were made on vessels of opportunity in Minas Passage in July, August, and October 2010 and January 2011, to obtain information on water transparency, suspended sediment, and water temperature. A standard Secchi disk deployment was used to measure transparency; surface water samples were taken by bucket for laboratory measurement of suspended sediments; and surface temperature was measured to an accuracy of 0.1 º C using a thermometer calibrated to a U.S. National Institute of Standards (NIST) standard. Several of the observations coincided with overpasses of an ocean remote-sensing satellite and the information was provided to the Bedford Institute of Oceanography to contribute to the data set used to calibrate the satellite sensors.

Observations were consistent with the seasonal pattern based on earlier observations for the site, which includes high transparency and low suspended sediment levels in summer, reaching low transparency and higher suspended sediment levels in winter.

Sea surface temperature showed a late-summer peak, ranging from 16.3 -17.4ºC. in August to a low of 3.5 - 4.1º C. in January; and suspended sediment levels ranged from 3.3 to 6.2 mg/L in July - August to levels of 9.4 to 12.5 mg/L in January. Secchi Depth, a measure of water transparency, ranged from 2.75 to 3.5 m in July and August respectively to a low of 1.5 m in January 2011. These findings are consistent with previous studies and no further monitoring is anticipated for these parameters.

6. ADDITIONAL OBSERVATIONS

FORCE established a 1-888 number in October 2009 both as an inquiry line, but also to report any usual environmental occurrences in the study area and to identify concerns, complaints and any other issues raised by the public and others in the area communities. The organization also established the Community Liaison Committee (CLC) as another mechanism for the local community to provide feedback, identify questions and concerns on the project. As well, the CLC is a mechanism to provide ongoing updates on the project to the local community.

It was anticipated that if any usual incidents did occur, such as fish kills, mammal and any unusual seabird activity, etc. in the marine demonstration area, these would be reported to FORCE via the 1-888 number and/or the CLC, to the federal and provincial regulatory agencies.

FORCE consultants working on vessels or from shore for the EEM studies were available to note any unusual events or occurrences; but no unusual incidents or occurrences were observed during the deployment period.

The Marine Animal Response Society (MARS) was also contacted on a regular basis to determine if there were any reported mammal strandings or mortalities in the Minas Passage area during the deployment of the NSPI/OpenHydro turbine. One fin whale mortality was reported in the Minas Basin - Minas Channel area while the turbine was in place, but MARS determined that the mortality was not related to the presence of the turbine. No other occurrences were reported to MARS in the Minas Channel area during the turbine deployment period.

7. CONCLUSIONS

The planned field studies proposed under FORCE's EEMP, were successfully implemented and reports completed. However, in many cases the monitoring methods and instruments for measuring environmental effects in the Minas Passage are still a work-in–progress, and require additional research.

The turbine was only operational for a short period of its deployment. However, the 450 metric ton turbine assembly was in the water for over one year, and, the EEM program did not detect any adverse impacts. The EEMP did gather additional environmental background data and information for the Minas Passage area, and enabled the testing of a variety of monitoring technologies and methods.

Based on the adaptive management approach, the lessons learned were valuable and will be incorporated in the design of future EEM studies. As there will be no turbines deployed in 2011, the 2011 EEMP will be focused on gathering additional background information and the ongoing testing of monitoring methodologies. EMAC has provided FORCE with recommendations for the 2011 EEMP, which along with FORCE's response, is available on the FORCE website. As well, FORCE will continue to work with others, such as the OEER, to identify and implement research on monitoring approaches in the Minas Passage.

8. APPENDICES

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX A

Environmental Impact Predictions

Environmental Impact Predictions - Fundy Tidal Energy Demonstration Project

Linkage between EEMP and Environmental Impact Predictions

The following Table summarizes the linkages between the identified **EEM program** and the environmental impact **Predictions** from the EA Registration Document. It also lists the **Significance Criteria** used to evaluate these predictions.

Page citations in Table are from: Volume 1: Environmental Assessment, Fundy Tidal Energy Demonstration Facility, AECOM 2009

EEM Program Component	Significance Criteria	Prediction
Lobster Catch Study	A significant adverse effect on commercial fisheries is defined as one that is likely to cause any one or both of the following: 1.) An unmitigated or non-compensated net financial loss to Commercial Fisheries as a result of the Project. It is understood that a net financial loss must be discernable outside the range of normal inter-annual variation in landings experienced by fishers for a variety of non-Project related reasons. 2.) Uncompensated damage to fishing gear or vessels. An adverse effect that does not meet the above criteria is evaluated as not significant. A positive effect on commercial fisheries is defined as an enhancement of opportunities for commercial fisheries which results in an increase in harvests, revenues and/or profitability. p 189 Section 6.9.2	Potential adverse effects on the commercial lobster fisheries will be eliminated or minimized to insignificant levels throughout the Project life. This will accomplished by working with the local lobster fishers to ensure ongoing and timely communication related to construction, maintenance, monitoring and decommissioning activities in order to minimize interference with lobster fishing seasons. The issuance of Notices to Mariners and updated charts and coordinates for turbine and cable locations, and the use of a 300 m radius fisheries/safety exclusion area around the turbines will decrease the likelihood of interaction between vessels and fishing gear with the Project infrastructure. The proposed fisheries/safety exclusions zones will be small compared to the available fishing grounds within the Minas Passage/Channel area. However, it is recognized by FORCE that a baseline lobster catch program operated over several fishing seasons will likely be required to determine if there is an effect on lobster catches and profitability for individual fishers. Gear damage losses that can be demonstrated will be addressed through compensation on a case by case basis, following international protocols. P 192 Section 6.9.6
		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. P. 149, section 6.2.4
Fish Migration, Fish Behavior,	A significant adverse effect on Marine Fish and Water Quality is defined as one that creates a significant alteration to a	It is anticipated that marine fish present or migrating through the Project area may experience very limited behavioral changes such as avoidance and aversion, as

studies, CTD and SPM,	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. Original population levels may not be re-established by natural recruitment (reproduction and immigration from unaffected areas). A significant population effect on fish habitat may alter the quality or extent of valued habitat physically, chemically, and/ or biologically, such that there is a decline in the species diversity of the habitat. This effect may be demonstrated by a decline in abundance and/or change of habitat components (i.e., sediment quality, food resources, water quality, and riparian vegetation). An adverse effect that does not meet the above criteria is evaluated as not significant. A positive effect on Marine Fish and Water Quality is defined as an enhancement in the quality or extent of habitat, an increase in species diversity, or an enhancement of a population such that an increase in that population is evident, or such that natural mortality is reduced p 144, section 6.2.2	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. P 153 Section 6.2.6 The fundamental knowledge required to assess the environmental effects of TISEC on marine fish does not currently exist; consequently, building the research knowledge base among the scientific community of the Bay of Fundy represents a valuable asset that will amplify the potential for this region to become a global centre of excellence in marine energy developments (Jacques Whitford et al. 2008). It is acknowledged that there is a degree of environmental risk involved in Project development that cannot be completely eliminated due to this lack of knowledge. Monitoring and follow-up, described previously, will be an integral part of confirming the predictions of this assessment, informing future commercial developers and will provide opportunities for further research on the Minas Passage, the Project and potential interactions. 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. P. 154 section 6.2.6
Acoustic Environment	Significance criteria for the Acoustic Environment is defined by potential interaction with Marine Birds and Mammals, Benthos, Fish and the Commercial fishery.	Project related vessels used in all Project phases could result in increased noise levels which may cause fish to exhibit localized temporary avoidance behavior in the area of the vessels. p 145 section 6.2.3 Increased noise (magnitude, frequency, duration and character) above background levels resulting from construction or decommissioning (including increased vessel traffic), may result in short or long-term changes to behavior and habitat use, injury or mortality of marine fish. Once the construction and decommissioning phases of the Demonstration Facility are complete, the disruption to marine fish will be related primarily to noise and vibration produced by turbine operations. P 144, section 6.2.3
Currents and Waves	Significance criteria for the Acoustic environment is defined by potential	No significant adverse residual effects are anticipated to be likely;

	interaction with Marine Fish and Water Quality, Recreational and Commercial Fishing, Marine Benthos, Marine Mammals, Marine Birds, and the Intertidal Environment.	• Marine Fish and Water Quality: P. 154 section 6.2.6 • Recreational and Commercial Fishing: P. 149, section 6.2.4 • Marine Benthos: P 142, section 6.1.6 • Marine Mammals: p 165, section 6.4.6 • Marine Birds: p 164, section 6.4.4 Turbine operation could potentially result in changes to the patterns of sediment distribution, which in turn may have an environmental effect on marine fish and invertebrates; however, this issue is not well understood. If a significant fraction of the kinetic energy is removed (i.e., commercial scale tidal facility), the overall effect in Minas Basin may include reduction in turbulent mixing, changed patterns of current movement within the Basin, and hence changed patterns of sediment distribution. Deposition characteristics outside the natural variability of an area will cause changes to the water column and, in turn, water quality. Such deposition may also cause changes to the local seabed, sediment dynamics and ecology of the area. Sediment properties affect the benthic organisms that inhabit them, and consequently the fish and other species that feed upon them. The distribution and abundance of marine fish species are largely a function of sediment properties, which could potentially be changed as a consequence of tidal power development. 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 (Jacques Whitford et al. 2008). p. 140 section 6.1.4
Marine Birds and Mammals	A significant effect to marine birds is defined as an unnatural decline or change in abundance and/or distribution, over one or more generations, of a population of a species or portion thereof, permanent avoidance of the area, serious injury to or the loss of one or more individuals from an endangered or threatened species, the loss of its critical habitat, or any substantial change in migration patterns.	There is expected to be some 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 the increase in vessel traffic, the risk of direct mortality from collisions for marine birds is considered to be extremely low. Additionally, installation of turbine devices and cables is not expected to have substantive residual effects on food sources or marine habitat for marine birds.

	Natural recruitment may not re-establish the population, or any populations or species dependent upon it, to its original level within several generations. An adverse effect that does not meet the above criteria is evaluated as not significant. A positive effect to marine birds is defined as a measurable population increase or enhancement in the quality of habitat for marine related bird species. P. 161 section 6.4.2	p 164, section 6.4.4 Project activities and components are not likely to cause significant adverse residual effects on marine birds within the Project area or vicinity. p 164, section 6.4.4
	A significant effect to marine mammals is 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. Natural recruitment may not re-establish the population, or any populations or species dependent upon it, to its original level within one or more generations. An adverse effect that does not meet the above criteria is evaluated as not significant. A positive effect to marine mammals is defined as one that results in a measurable population increase and/ or enhances the quality of critical habitat. p.155, section 6.3.2	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). p 165, section 6.4.6
	A significant adverse effect on all marine species at risk as listed in Schedule 1 of SARA as Extirpated", "Endangered" or "Threatened" or listed by the Nova Scotia Endangered Species Act as "Endangered" or "Threatened", is defined as a non-permitted contravention of any of the prohibitions stated in Sections 32-36 of SARA, or in contravention of any of the prohibitions stated in Section 13 of the	Project activities and components will not cause significant adverse residual effects on Marine Species at Risk within the Project area or vicinity (i.e., Minas Passage and Minas Basin). p. 172,section 6.5.6,

	Nova Scotia Endangered Species Act. A significant adverse effect on marine species at risk but not under the protection of SARA or the Nova Scotia Endangered Species Act (i.e., listed in SARA but not as “Extirpated”, “Endangered” or “Threatened” in Schedule 1; listed as “Species of Special Concern” within Schedule 1 of SARA; or ranked as “S1”, “S2”, or “S3” by ACCDC and also ranked “red” or “yellow” by NSDNR) is defined as an alteration of marine habitat physically, chemically, or biologically, in quality or extent, in such a way as to cause a change or decline in the distribution or abundance of a viable population that is dependent upon that habitat, such that the likelihood of the long-term survival of these population(s) is substantially reduced, the direct mortality of individuals or communities such that the likelihood of the long-term survival of these population(s) is substantially reduced, or in the case of marine species at risk listed in Schedule 1 of SARA, noncompliance with the objectives of management plans (developed as a result of Section 65 of SARA) that are in place at the time of relevant activities. A positive effect on marine species at risk is defined as an increase in populations and/or diversity of species at risk, or an enhancement in the quality of critical habitat for species at risk. P. 166, section 6.5.2	
Benthic Habitat and Scour	A significant adverse effect on marine benthos is defined as a physical, chemical, or biological alteration of benthos, in quality or extent, to such a degree that there is a decline in abundance and/or change in distribution of benthos, beyond which natural recruitment (reproduction and immigration from unaffected areas)	The fundamental knowledge required to assess the environmental effects of TISEC on currents and therefore sediments and marine benthos does not currently exist; consequently, building the research knowledge base among the scientific community of the Bay of Fundy represents a valuable asset that will amplify the potential for the Maritime region to become a global centre of excellence in marine energy

	would not return that population, within a generation or more, to its former level. Such a change could result in alterations in sediment nutrient cycling, community structural complexity, biotic interactions, habitat pattern, population dynamics and ultimately genetic diversity. An adverse effect that does not meet the above criteria is evaluated as not significant. A positive effect on marine benthos is defined as an enhancement in benthic quality, increase the species diversity, or increase the area of the valued benthic habitat. p. 137, section 6.1.3	developments (Jacques Whitford et al. 2008). It is acknowledged that there is a degree of environmental risk involved in Project development that cannot be completely eliminated due to this lack of knowledge. Monitoring and follow-up, described previously, will be an integral part of confirming the predictions of this assessment, informing future commercial developers and will provide opportunities for further research on the Minas Passage, the Project and potential interactions. 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 benthos within the Project area or vicinity (i.e., Minas Passage and Minas Basin). P 142, section 6.1.6

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX B

In-stream Tidal Report – NSPI Report

DEPLOYMENT AND RECOVERY
OF THE
OPENHYDRO IN-STREAM TIDAL TURBINE

June 20, 2011

Nova Scotia Power Inc.
P.O. Box 910
1874 Barrington Street
Halifax, NS B3J 2W5

1. Introduction

The following is a summary of the NSPI/OpenHydro tidal turbine fabrication, testing, deployment and recovery in the Bay of Fundy.

The two major components of the In-Stream Tidal Turbine assembly (hereafter referred to "the Assembly") are the Turbine itself, and the steel Subsea Base (hereafter referred to as the "SSB"). The Turbine was fabricated at the OpenHydro facility in Ireland, while the SSB was fabricated at Cherubini Metal Works in Dartmouth, NS. The Turbine and OpenHydro Installer Barge (hereafter referred to as "the Barge"), were transported to Cherubini for assembly with the SSB. The Barge was designed and fabricated for use in deployment and recovery of the Assembly and of a specialized modular design allowing transport.

2. Site Selection

NSPI was awarded Berth "C" in which to deploy the Assembly. Evaluation of bathymetry data for Berth "C" allowed the project team to identify an area which was acceptable for deployment. Key desirable characteristics for the deployment location include: fairly flat, level, and with a minimum amount of loose bottom material. A location with these characteristics greatly simplifies both the design of the SSB and deployment operations. OpenHydro and NSPI utilized ADCP information from numerous sensor deployments, conducted 3D and 2D imaging sonar sweeps of the site, and used surface ADCP sensors to assist in micro siting.

3. Data Collection

As the FORCE subsea cable was not yet installed when NSPI intended to deploy the Assembly in late 2009, a communication system was included to allow on-board data collection to be transmitted for ongoing analysis. Design and integration of this communication module had significant technical challenges due to the harsh environment it would be immersed in for an anticipated two years. Initially viewed as a possible setback, this "wireless" test apparatus concept has drawn positive attention of the industry to the point that other OpenHydro projects such as EDF adopted a similar approach with regards to their first contracted Unit with OpenHydro. The absence of a cable also provided flexibility as to siting, and additional re-location capability. A Tritech Acoustic Modem receiver and transmitter were used during this deployment.

While communication with this acoustic modem failed shortly after deployment, data was collected for various timeframes over the deployment duration of the Assembly on data loggers that recorded the output of the three ADCP's, strain gauges and turbine performance. The ADCPs were manufactured by Nortek Aquadopp. Two were installed horizontally to measure the upstream and downstream current velocities. A third was oriented vertically, to gather information on tidal current speed through the water column, independent of the turbine.

The data logger recorded turbine performance by measuring the mean three phase AC voltage for each coil group on the load banks of the Turbine using a passive circuit located in the data logging enclosure. RPM was calculated from the AC voltage from one of the coil groups using a frequency transducer. The output power can then be calculated from the voltage and current measurements (P = VI) (power could also be calculated from either the voltage or current measurements).

4. Testing

The Assembly underwent a "test tow" in the Bedford Basin on October 26th, 2009 to evaluate the lifting mechanism, communication with the acoustic modem, data collection system integrity, towing behavior, and other components.

5. Deployment

During the licensing process, a local barge services company submitted a formal pleading to Transport Canada regarding the importation of the Barge. This company was concerned about loss of local work, and felt they had the capability to provide the service. The NSPI Project Manager met with representatives from the Company, following which the pleading was withdrawn.

After receiving all necessary permits and licenses for necessary for deployment and completing the testing above, the Assembly was successfully deployed in the Bay of Fundy on November 12, 2009. The deployment team followed the operating plan devised by OpenHydro, and placed the Assembly within 0.6m of the engineered location. Communication with the Assembly was also confirmed after deployment.

This location was reported by NSPI to the departments of Transport Canada and Navigable Waters on November 19th, 2009. Numerous "Notices to Mariners" containing the coordinates and project information were distributed shortly afterward.

Due to the unpredictability of weather, there was always a risk that deployment could be delayed. Safe ports and procedures were in place to ensure safety of equipment and crew in the case of inclement weather. This is also true of the recovery operations.

6. Operation

Some time after deployment, communication with the Assembly via the on-board acoustic modem ceased which resulted in no data being recovered via this modem. After a number of efforts to observe the Assembly and evaluate its condition though 2-D and scanning 3-D sonar, camera, and ADCP monitoring, Nova Scotia Power Inc. and OpenHydro decided to recover the Assembly in the fall of 2010, one year earlier than originally planned.

7. Recovery

As licensing for the Barge had expired, NSPI and OpenHydro went through the process again, and again there was a pleading submitted by a local company. Following discussions with representatives from the company, the pleading was withdrawn.

The recovery operation utilized the same OpenHydro Installer barge used to deploy the Assembly in 2009. The initial attempt in mid-November of 2010 was called off due to high winds and delayed until the next acceptable tidal phase for recovery (neap tide). Recovery was completed successfully on December 16, 2010. As with the deployment, OpenHydro had prepared a method plan for the recovery that proved to be both realistic and efficient, and all operations proceeded successfully.

Recovery operations confirmed that the Assembly did not move over the course of its deployment. In addition, a study completed by Atlantic Marine Geological Consulting Ltd. saw no detectable change to the marine environment in the vicinity of the deployment location. Upon recovery, no evidence of impacts was evident on any part of the Assembly or SSB. Biofouling has not been observed after this deployment; the Assembly and SSB appeared clean of growth at the site (from video) and after retrieval (from close inspection in person).

Due to windy and icing conditions in the region in December of 2010, the Assembly was towed to St. John, New Brunswick. No adequate weather window presented itself, and the decision was made to store the Assembly in St. John until the spring, when more favorable weather would allow for safe passage for the tug and barge to Dartmouth, Nova Scotia.

8. Evaluation

The major structural components of the Assembly appear to be in excellent condition, but the turbine blades and acoustic modem are no longer attached. Loss (vs. fracture) of the blades is an indication that the mechanism holding the blades in place was not sufficient to withstand the tidal forces experienced in the Minas Passage. The original collected tidal data indicated lower tidal velocities which translated into forces being significantly underestimated. Preliminary evaluation indicates the blades were likely lost during a predicted major tidal event that occurred after the deployment.

Further analysis of the data collected and a forensic investigation of the machine itself will confirm what forces and velocities were experienced and what impact these forces and velocities had on the Assembly.

The delay in towing from St. John, NB (where it weathered the winter), to Dartmouth, NS has delayed any thorough forensic analysis of the Assembly. The Assembly has recently been returned to Cherubini Metal Works in Dartmouth, NS where a thorough evaluation will be completed. Data downloaded from the data logger is currently undergoing analysis by OpenHydro. Results of all evaluations will be incorporated to improve and optimize future designs.

9. Lessons Learned

The SSB was a large proportion of the project costs, and while it successfully demonstrated the design (ie. held the Turbine in place during the deployment), further evaluation of the subsea base using data collected from strain gauges during deployment will allow design optimization.

Ballasting the SSB also proved to have some challenge due to the viscosity of materials involved. Project personnel worked together to identify an alternative which was employed successfully.

Tidal forces were significantly greater than predicted, resulting in loss of the turbine blades. Evaluation of the data recorded will confirm forces experienced, and what modifications to the design are required prior to redeployment in the environment.

Communication with the acoustic modem failed, and while the modem was no longer present when the Assembly was recovered, it is not clear when this device was lost. Future designs with on-board communication will ensure all exposed equipment is better protected.

The project team had not planned to do visual or physical monitoring of the Assembly as part of the original project plan. As such, arranging for appropriate resources when communication was lost with the acoustic modem was challenging, including vessels, equipment and personnel.

When communication failed, a number of techniques were employed to try and view the Assembly and determine what had taken place. Many of these techniques were not successful due to the high velocities and amount of sediment in the deployment location which severely limited underwater visibility.

10. Going Forward

NSPI remains confident in the development of tidal energy and, assuming further analysis confirms the feasibility of this technology, anticipates re-deployment in the near future. The physical detailed inspection of the components that comprise the turbine, venturi and subsea base will be performed over the coming months. This information will play a critical role in the development of OpenHydro's next generation of tidal turbine designs.

Authorized by: ______________________________

Mark Savory, VP of Technical and Construction Services
Nova Scotia Power Inc.
Project Sponsor

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX C

Seabird and Marine Mammal Survey 2010

Marine Mammal and Seabird Surveys

Tidal Energy Demonstration Site — Minas Passage, 2010

Submitted to:

Fundy Ocean Research Centre for Energy (FORCE)

Submitted by:

Envirosphere Consultants Limited
Windsor, Nova Scotia

January 2011

Authors: Patrick L. Stewart, Fulton L. Lavender and Heather A. Levy

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EXECUTIVE SUMMARY

The Province of Nova Scotia and the Fundy Ocean Research Centre for Energy (FORCE) are presently developing a tidal energy demonstration facility in the Minas Passage area of Nova Scotia's Bay of Fundy. Water-associated birds (seabirds, waterfowl and shorebirds) and marine mammals (seals, dolphins and porpoises, and whales) are important components of the marine ecosystem in Minas Passage that may potentially interact with tidal devices. To gather information on marine mammals and seabirds in the vicinity of the tidal demonstration site, FORCE carried out baseline and first-year monitoring studies in 2008 & 2009 respectively. From May to November 2010, a series of one-day shore-based observational surveys for marine mammals and seabirds at the Fundy Tidal Power Demonstration Site, as well as two vessel-based surveys reaching from the outer Minas Basin to Cape Spencer, were undertaken to provide additional baseline as well as environmental monitoring information to assess potential impacts of the project. Shore-based surveys took place in May (1, 13 & 27) and on June 12, October 23, and November 13 & 22, 2010, and vessel-based surveys took place on July 19 and August 18, 2010.

Thirty-two species of water-associated birds were observed from shore in the vicinity of the demonstration facility including: seabirds (Double-Crested Cormorant, Great Cormorant, Herring Gull, Black-Backed Gull, Iceland Gull, Laughing Gull, Lesser-Backed Gull, Ring-Billed Gull, Mew Gull, Black Guillemot, Northern Gannet, Razorbill, Horned Grebe, Red-Necked Grebe, Black-Legged Kittiwake, Atlantic Puffin, Thick-Billed Murre and Common Murre); and waterfowl (Common Eider, American Black Duck, Mallard, Harlequin Duck, Long-Tailed Duck, Canada Goose, Common Loon, Pacific Loon, Red-Throated Loon, Surf Scoter, Black Scoter, White-Winged Scoter, Red-Breasted Merganser and Common Merganser). The greatest number of species occurred during fall migration in late October and early November (October 23 & November 13 surveys), but no migration peak was observed in May, and the expected peak spring movement of birds through the area may have occurred earlier. Ten species were observed in vessel surveys which included parts of Minas Basin, Minas Passage and Minas Channel, including Herring Gull, Great Black-Backed Gull, Ring-Billed Gull, Double-Crested

and Great Cormorant, Common Eider, Black Guillemot, Northern Gannet, Wilson's Storm Petrel and Common Loon. Densities of seabirds measured in vessel surveys were comparable to those observed in 2009, and overall were slightly lower than or comparable to densities in other Nova Scotia coastal and offshore waters.

Herring Gull, Great Black-Backed Gull, Common Eider and Red-Throated Loon were the most common and abundant species, with Great Black-Backed and Herring Gulls dominant in terms of numbers in the spring-early summer (May-June), and Herring Gulls dominant in July-August, shifting to a greater importance of Common Eider and Red-Throated Loon and low abundance of Great Black-Backed Gull in the Fall. Great Black-Backed Gull, which was the most abundant seabird during May, was replaced in dominance by Herring Gull in June through August, and by Common Eider in October. Red-Throated Loons were present during migration in May and in Fall (late-October-November), and were particularly abundant in November.

No pattern was observed in the local distribution of birds in several sub-areas of the installation site—(between Black Rock and shore; in Minas Passage outside Black Rock; and in the turbine installation ("Crown Lease") area. Greatest concentrations of birds were observed in late-May to early-June in the inshore area extending between Black Rock and shore (Great Black-Backed & Herring Gulls dominant); in the turbine installation area in mid-November (Red-Throated Loons dominant); and in Minas Passage during October 23 & November 22 surveys (Common Eider, Herring Gulls and Red-Throated Loons dominant).

Harbour Porpoise (*Phocoena phocoena)* occurred frequently from early May to late November with the exception of mid- to late-May, and a single Grey Seal (*Halichoerus grypus)* was observed on November 13th. Harbour Porpoise occurred typically in groups of 2-3 individuals with the largest group containing four individuals; highest numbers were observed on May 1, and November 13 and 22 when abundance averaged one animal per 30-minute observation period. Individual Harbour Porpoise occurred with about the same frequency in the three operational subdivisions of the study area (inside Black Rock, outside Black Rock (Minas Passage) and 'turbine area' (the area seaward of Black Rock towards the Minas Channel and Cape Split)), usually swimming seaward with the outgoing tidal stream.

1 INTRODUCTION

Seabirds and marine mammals are important components of the marine ecosystem, and in the context of tidal power development, they have the potential to interact with tidal turbines and be affected by associated activities. The location of the tidal energy demonstration site is known to support various seabird, waterfowl and marine mammals species common to coastal environments in Atlantic Canada; however detailed information that can be used in monitoring and impact assessment is not available for the site. Preliminary shipboard surveys for seabirds and marine mammals were carried out in July and October 2008 as part of geophysical cruises to the area to obtain information on occurrence and species composition at the site (Envirosphere Consultants Limited 2009a). A comprehensive survey program was established in 2009, with single day-long seabird surveys conducted in June, July, August and September 2009 to provide additional baseline information for the assessment of potential impacts and for the development of an environmental monitoring program for the project (Envirosphere Consultants Limited 2010). Subsequent review of the results of the first year monitoring report by the Environmental Monitoring Advisory Committee (EMAC) for the project, as well as regulatory agencies, led to recommendations for the collection of additional information on bird species, particularly diving species such as loons, during the Spring and Fall migration periods, which were not represented in sampling in the 2009 monitoring program. This report presents the results of a modified monitoring protocol which includes a series of shore-based, day-long observations of seabirds and marine mammals in the waters in the vicinity of the tidal power demonstration site, as well as two vessel-based surveys carried out in July and August 2010 to repeat surveys done at the same time of year in 2009.

2 METHODS

Shore-Based Surveys

Shore-based surveys were carried out at the site on May 1, 13 & 27; June 12; October 23, and November 13 & 22, 2010. Surveys were done by Mr. Fulton Lavender, an experienced seabird and marine mammal observer, assisted by Mr. Matthew MacLean, Environmental Technologist, Envirosphere Consultants Limited, except on May 1 and November 22 when Patrick Stewart, M.Sc., Senior Biologist, Envirosphere Consultants Limited, assisted. The observer team arrived on site at approximately high tide and observations were made during the approximately 6-hour period of the outgoing tide. Observations were made by eye and using a tripod-mounted, 22x magnification spotting scope for the observer, as well as 8 x 40 or 10 x 50 binoculars, for both principal observer and the assistant. For the first survey (May 1), observations were made from the top of the beach berm in the mid-section of the beach at the site; for the remaining surveys the observation point moved to the top of the berm on the east end of the beach where there was shelter from the wind to stabilize the spotting scope on the several occasions when the winds were moderate. This location provided a good view of all the areas of interest, in particular of the turbine installation area (Figure 1a). The observer scanned the entire study area several times during successive 30-minute periods, noting all birds seen and location, maturity, as well as activities (flying, on water, feeding etc.), providing an estimate of total number of unique bird species per period. For subsequent analysis and interpretation, the average number of birds of each species per period based on all 30-minute periods was used to summarize bird and marine mammal occurrence on each survey.

Vessel-Based Surveys

Day-long surveys for marine mammals and seabirds were carried out from a chartered lobster boat (Ed and Fred Huntley, Scots Bay), departing from Scots Bay in early morning just before high tide on July 19 and August 18, 2010[1] and returning with the tide in the evening. Surveys were carried out by Fulton Lavender, assisted by Matthew MacLean, the same team used for the shore-based surveys. Surveys were done under generally good observation conditions although it was foggy on August 18 up to 1300 hrs (visibility <300 m, 14%; 0.3-0.5 km, 43%; and >0.5 km 42.8% of 5-minute periods). Surveys covered areas including parts of Minas Basin extending from approximately off Parrsboro, and along the central to north sides of Minas Passage and Minas Channel extending to Cape Spencer (Figure 1b). A standard watch for seabirds was carried out modeled after the Canadian Wildlife Service protocol (Wilhelm *et al.* 2008) but omitting 'snapshot' sampling for flying birds[2], although all flying birds seen in the 5-minute period were counted. Watches of 5-minute duration were carried out while the vessel was in motion, every 10 to 15 minutes. One of the five-minute observation periods every 30 minutes was always done on the port side of the boat as a standard, although this distinction was not needed for subsequent analysis. The observer monitored a strip of water and air 300 m wide approached by the vessel, on the port side for the July survey and starboard side for the August survey, recording information on counts, identification, stage (adult, immature, juvenile etc.), distance (distance classes as required in Wilhelm et al. (2008)), as well as on birds observed beyond 300 m. At the beginning of each observation period, the observer's assistant recorded the time, vessel coordinates, heading, speed, wind-speed, and weather conditions. All data was recorded in notebooks and subsequently transferred to the CWS standard form for a moving vessel survey (Wilhelm et al. 2008). At the same time, the observer carried out continuous watches with binoculars for marine mammals, and any sightings by the vessel crew were investigated. A protocol and reporting forms used by DND-MARLANT for marine mammal observations, including the MARLANT Whale identification Guide (Envirosphere Consultants 2006) were on board for use in identification. After this data is used in this project, the data will be given to the Canadian Wildlife Service and to Fisheries and Oceans Canada for inclusion in respective seabird and marine mammal databases.

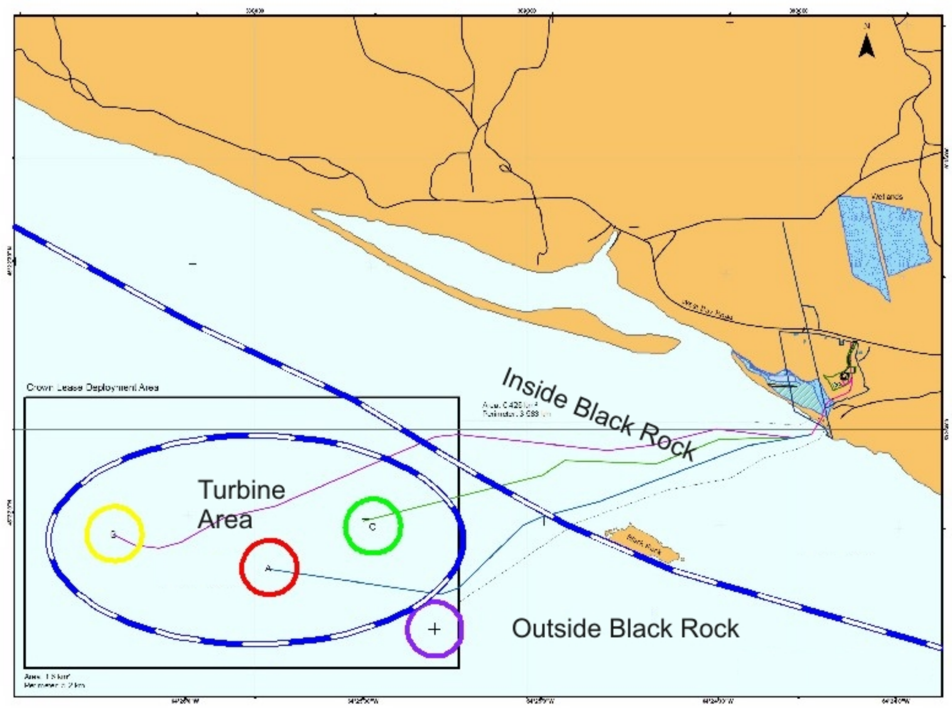

Figure 1a. Study area for shore-based surveys, showing project location and major subdivisions.

[1] Survey times were chosen to catch a high tide early in the morning to allow a full tidal cycle during daylight hours.

[2] The 'snapshot' is an instantaneous count of flying birds within a 300 m radius of the observer and was omitted. All flying birds were included in the normal sampling routine, however, although the density estimate obtained is likely to be higher than if the 'snapshot' approach was used.

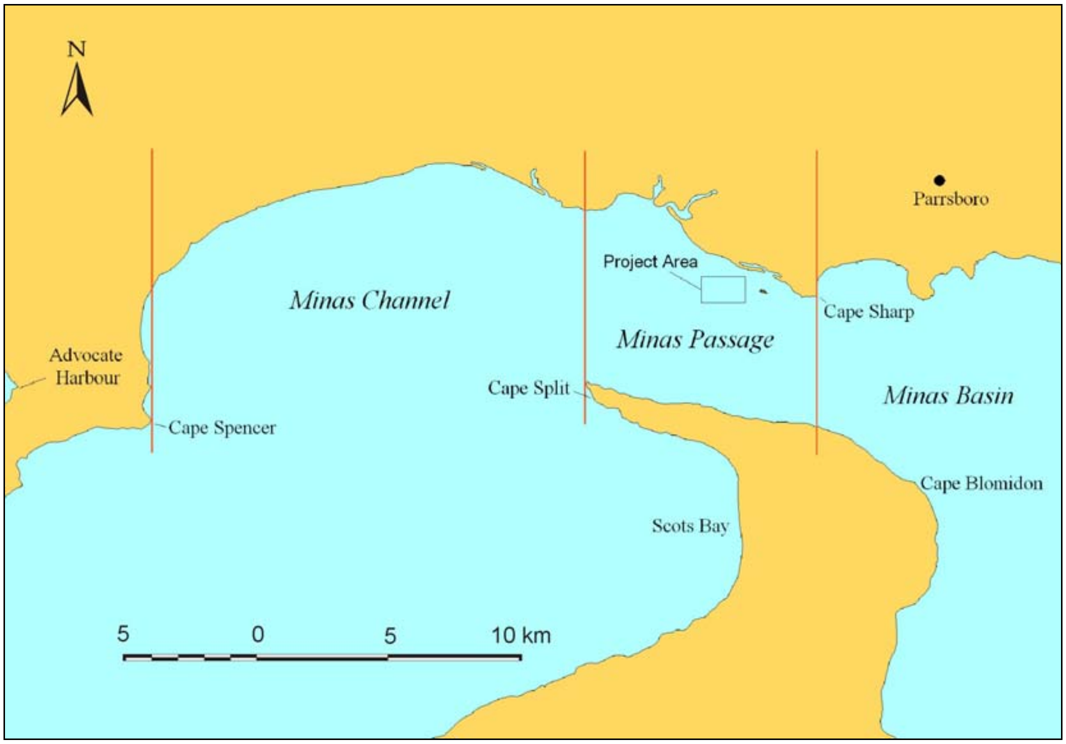

Figure 1b. Study area for vessel surveys, showing project location and major subdivisions.

The survey route (Figure 2) was designed to provide coverage not only of the study site but also of areas to the east (Minas Basin) and west (Minas Channel) since these areas are likely to have seabird distributions which will overlap the tidal demonstration site; to cover nearshore areas as well as along the axis of Minas Passage-Minas Channel; and also to cover daily movements of birds within the general area (e.g. for feeding)[3]. A survey lasted typically from early morning to evening, from one high tide to the next, allowing transects at the project site to be done before the peak ebb and repeated after the peak flood, thereby reducing the amount of time steaming against the tide. After sampling at the project site, the boat steamed with the peak tidal flow to Cape Spencer, where it waited until the tide reversed, and then cruised back again to the survey origin. For the purposes of data analysis, the study area was divided into three sub-areas: Minas Passage was between Cape Sharp and Cape Split; Minas Basin was east of Cape Sharp; and Minas Channel the area west of Cape Split (Figure 1b). Compared to 2009, sampling included traveling further into Minas Basin to better balance the survey effort there with that expended in the other areas.

A detailed 'zig-zag' grid of transects was also included as part of the survey to provide focused information on the tidal installation site which is included in the overall analysis but not specifically analyzed in this study (Figures 3 & 4). Difficulties in repeating the grid by different operators of the vessel in July and August resulted in a different pattern in the two months; however it demonstrated a closely-spaced grid pattern could be carried out if such site-specific monitoring of the site is required in future. The increased sampling effort in this grid biases the abundance and species composition estimates for Minas Passage as a whole in this report to more closely reflect the characteristic seabird community at the installation site.

[3] The survey design was reviewed by D. Fifield, CWS, St. John's, NL, prior to implementation.

For each observation period, the distance traveled based on beginning and end coordinates of the period, as well as based on heading and ship speed, was calculated. The two were highly correlated and the distance based on coordinates was used for subsequent analysis[4]. Seabird densities are estimated and presented in several different ways in this report: as total numbers of birds or numbers of individual species observed in 5-minute observation periods (maps); as a spatial density estimate based on numbers seen 'in transect' (i.e. in the 300 m band on the side of the track traversed by the ship, and therefore the most quantitative estimate); as well as total or individual species abundances per kilometre (includes all birds seen within and outside of the 300 m quantitative observation band and which typically includes more species than the area estimate)[5]. Abundance expressed per unit area is a more accurate estimate of density of offshore birds' although it may exclude some species. Because 'snapshots' were not done (the 'snapshot' is a procedure to observe flying birds at one point in time and therefore avoid the possibility that they would fly back into the area during the observation period and be recounted), the density of flying birds may be overestimated in this survey (e.g. Wilhelm et al. 2008).

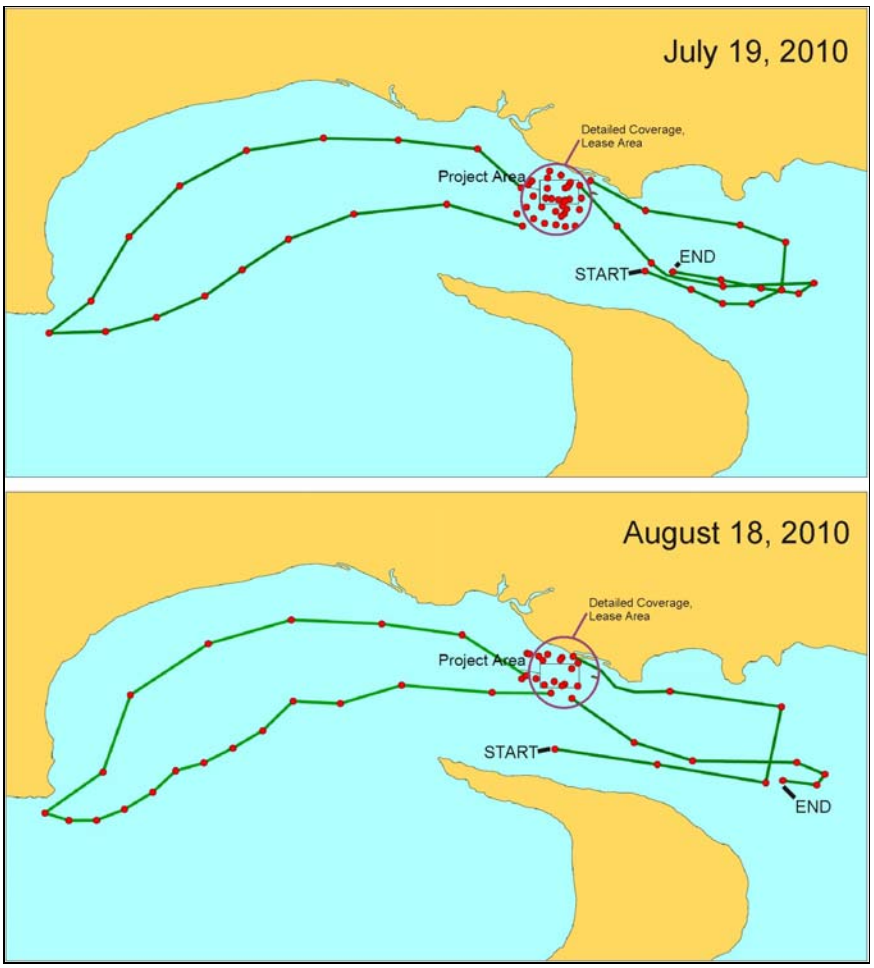

Figure 2. Survey route for July and August seabird surveys in 2010. Points indicate locations of start points for 5-minute observation periods during seabird and waterfowl survey.

[4] In 2010, the recorded geographic position of the start points of the survey were more reliable than in 2009, because an assistant to the seabird observer was provided, and reduced or removed recording errors for speed, heading, and geographic coordinates compared to 2009.

[5] Observed abundances were not adjusted for birds 'missed' which is a phenomenon of reduced ability of the observer to see all the birds as distance from the vessel increases, and hence numbers reported in this report slightly underestimate true density.

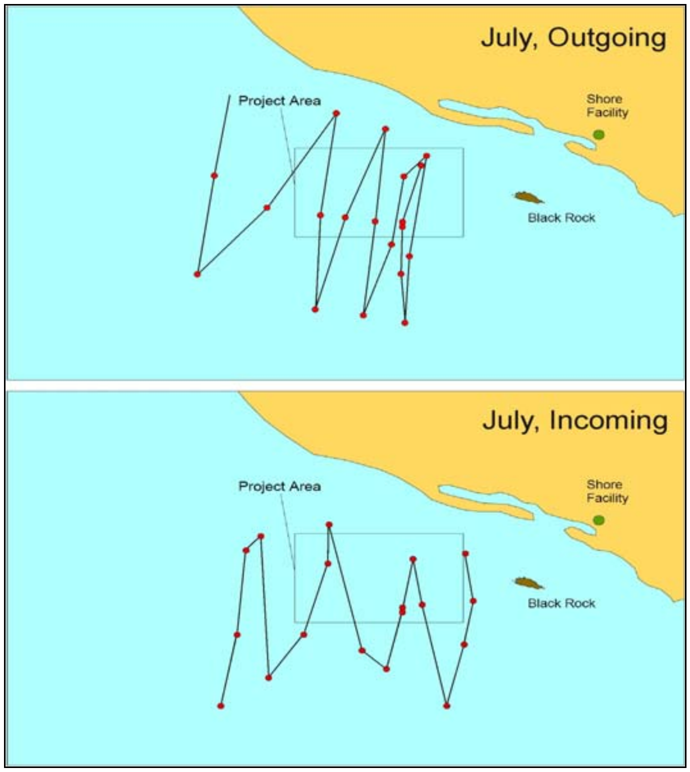

Figure 3. Survey route for July and August seabird surveys in 2010. Points indicate locations of start points for 5-minute observation periods during seabird and waterfowl survey.

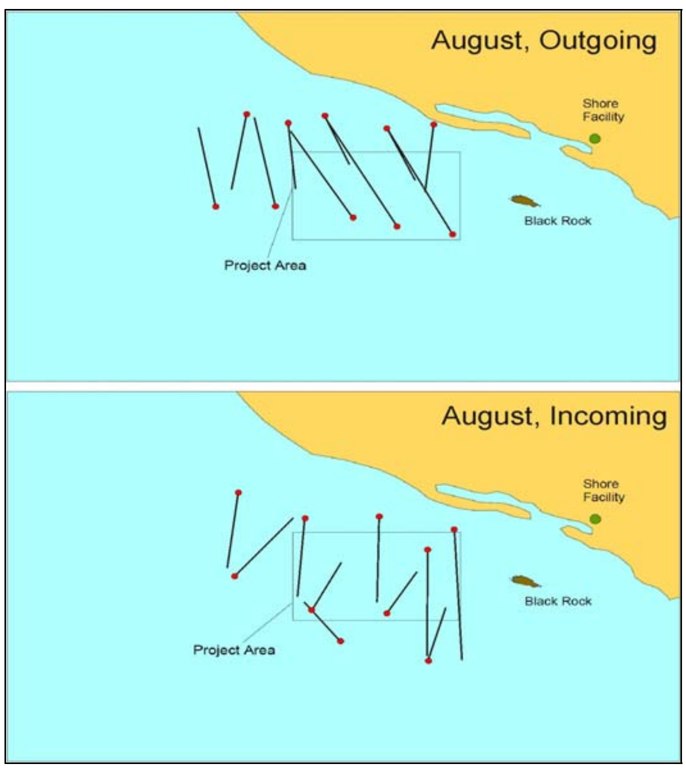

Figure 4. Survey route for July and August seabird surveys in 2010. Points indicate locations of start points for 5-minute observation periods during seabird and waterfowl survey.

3 RESULTS AND DISCUSSION

3.1 Marine Mammals

Two species of marine mammals, the Harbour Porpoise (*Phocoena phocoena)* and the Grey Seal (*Halichoerus grypus)* were observed in the surveys. Harbour Porpoise was by far the dominant species (43 individuals observed), versus only one Grey Seal, the latter seen only in the shore-based survey on November 13. Most of the sightings occurred during the shore-based observations, with only five Harbour Porpoise recorded on the two vessel surveys (Table 1; Figure 5). Harbour Porpoise occurred in the study area throughout the observation period with the exception of mid- to late-May (May 13 and 27) (Figure 5) and highest numbers of sightings were made on May 1, and November 13 and 22, at those times averaging about one animal per 30-minute observation period (Figure 5). A high of seven animals was observed, however, moving through the area in a half-hour period on May 1. There did not appear to be an association of the movements with time of day although most individuals were observed from mid- to late in the observation period (typically mid- to late afternoon or early evening)(Figure 5).

Harbour Porpoise were typically observed in groups of 2-3 individuals with the largest group containing four individuals. The porpoises were nearly always swimming in the direction of the outgoing tide[6]. The only exception was one group of 4 individuals sighted during the vessel survey on August 18, which were heading northeast (further into Minas Basin).

Individual Harbour Porpoise occurred with about the same frequency in the three operational subdivisions of the study area (inside Black Rock, outside Black Rock (Minas Passage) and ‘turbine area’ (the area seaward of Black Rock towards the Minas Channel and Cape Split)) (Figure 5). All the individuals were swimming seaward with the outgoing tide and appeared to pass through individual areas by chance, depending on their position in the tidal current stream leaving Minas Basin.

Both Harbour Porpoise and Gray Seal are known to occur in the Bay of Fundy and were expected to occur in the study area, but their relative abundance and seasonal occurrence was unknown, as there were few previous recorded sightings for the area. Compared with 2009, fewer Harbour Porpoise were observed on the vessel surveys (only five individuals compared with 19 individuals in the July-August surveys for 2009). No other species were observed in the vessel surveys, compared with three other species (Harbour Seal, White-Sided Dolphin, and an unidentified whale) in 2009. Shore-based surveys (which were not conducted in 2009), in contrast, showed Harbour Porpoise to be relatively common in the Minas Passage at the tidal demonstration site. The species is a small porpoise found in Atlantic coastal areas in the summer to fall. It is commonly taken as by-catch in gill nets (Caswell et al. 1998) which is one of many threats to the survival of local populations, including the Bay of Fundy/Gulf of Maine population. The Northwest Atlantic population of the species is listed as a Species of Concern by COSEWIC and the status is *Threatened* under the Federal *Species at Risk Act*. Grey Seal is a large coastal seal species, which is common in Atlantic Canada.

[6] Observations were coordinated with the tidal cycle, capturing the period from the high tide to low tide, and the water flowed from Minas Basin to Minas Passage.

Table 1. Marine mammal observations during seabird and marine mammal surveys, Minas Basin, Minas Passage and Minas Channel, May – November 2010.					
Date	Time (ADT)	Survey Component	Location[1]	Species	Number
May 1, 2010	1637 - 1707	Shore	45 22.26 64 24.35	Harbour Porpoise	7
	1707 - 1737	"	"	Harbour Porpoise	3
May 13, 2010	--	Shore	45 22.21 64 24.22	None Observed	--
May 27, 2010	--	Shore	"	None Observed	--
June 12, 2010	1200 - 1230	Shore	45 22.21 64 24.22	Harbour Porpoise	1
	1230 - 1300	"	"	Harbour Porpoise	2
	1330 - 1400	"	"	Harbour Porpoise	3
	1530 - 1600	"	"	Harbour Porpoise	2
July 19, 2010	1758 - 1803	Vessel	45 19.76 64 17.92	Harbour Porpoise	1
August 18, 2010	1812 - 1817	"	45 20.10 64 18.00	Harbour Porpoise	4
October 23, 2010	1500 - 1530	Shore	45 22.21 64 24.22	Harbour Porpoise	1
	1600 - 1630	"	"	Harbour Porpoise	1
November 13, 2010	945 - 1015	Shore	45 22.21 64 24.22	Harbour Porpoise	1
	1015 - 1045	"	"	Harbour Porpoise	3
	1115 - 1145	"	"	Harbour Porpoise	1
	1215 - 1245	"	"	Grey Seal	1
	1245 - 1315	"	"	Harbour Porpoise	1
	1315 - 1345	"	"	Harbour Porpoise	2
	1415 - 1445	"	"	Harbour Porpoise	3
	1445 - 1515	"	"	Harbour Porpoise	2
	1515 - 1545	"	"	Harbour Porpoise	1
November 22, 2010	1300 - 1330	Shore	45 22.21 64 24.22	Harbour Porpoise	2
	1400 - 1430	"	"	Harbour Porpoise	3
	1430 - 1500	"	"	Harbour Porpoise	2
	1530 - 1600	"	"	Harbour Porpoise	2
1. Observation point for shore survey.					

3.2 Seabirds, Waterfowl and Shorebirds

3.2.1 Vessel-Based Surveys

3.2.1.1 Survey Effort

Measures of seabird and marine mammal abundance as well as species diversity are influenced by sampling effort. Total numbers observed, as well as number of species occurring (species diversity), are positively correlated with sampling effort, while the quality of abundance estimates (e.g. numbers per kilometre or numbers per unit area) are typically improved by additional sampling effort. Important variations in sampling effort in the present survey included: differences in effort between areas, and differences in intensity of sampling (number of observation periods per unit distance or unit area). In the present study, there were differences in effort between Minas Basin and the other areas (Minas Basin lower and Minas Passage and Minas Channel with a similar level of sampling effort (Figure 6 and Table 2) (due to the shorter distance traveled in Minas Basin)). Differences in sampling effort affect comparisons between study areas, with areas having lower effort having lower species diversity and higher variability than other areas. These differences introduced by sampling effort would tend to obscure the natural differences between these areas that the analyses are trying to detect.

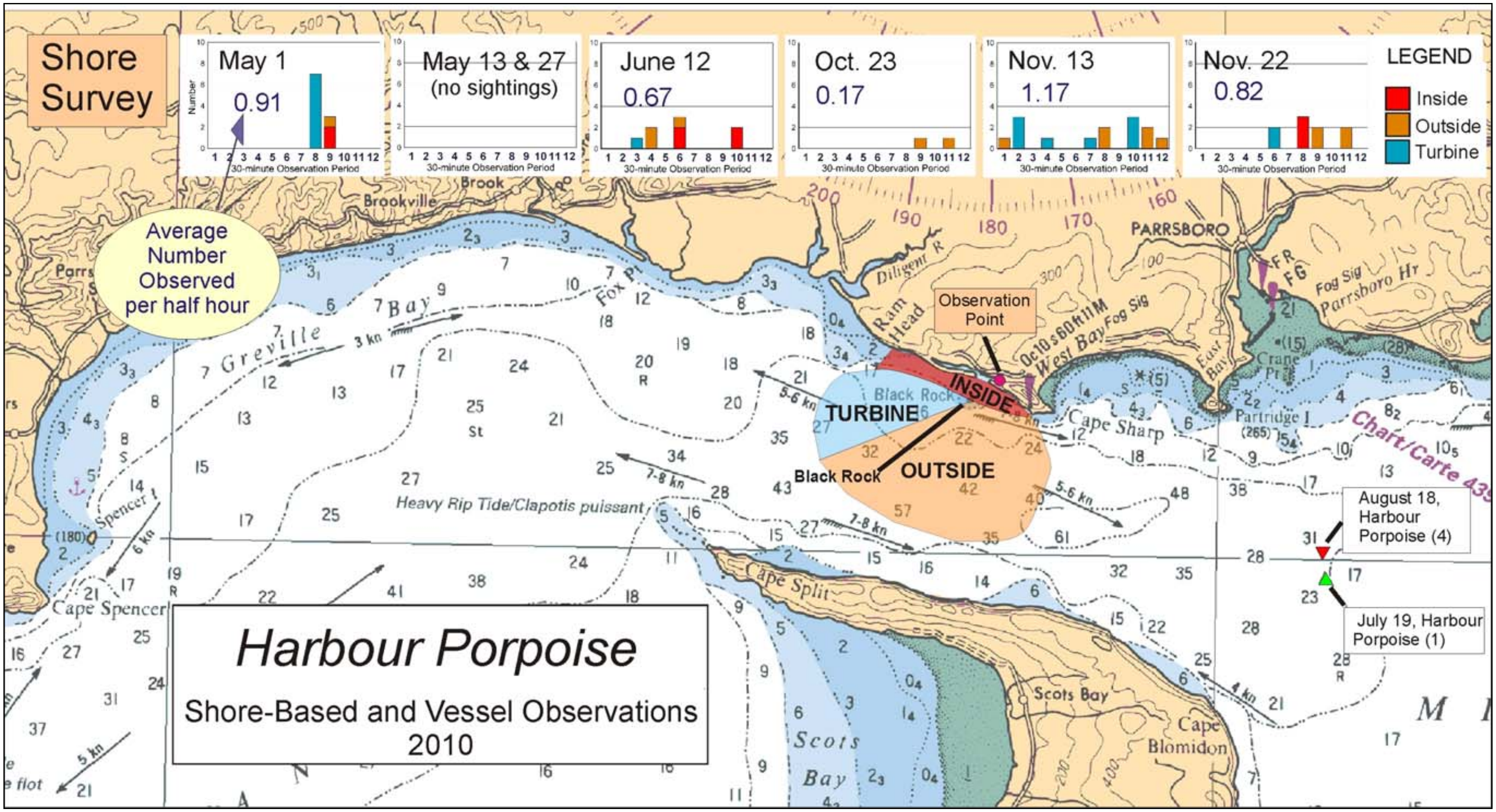

Figure 5. Sightings of marine mammals from shore observations, May-June and October-November, 2010, and from vessel surveys, July and August, 2010. Approximate area viewed from shore is shown and terms describe sub-areas used in the text.

Sampling effort was similar between months (July and August) in terms of number of 5-minute observation periods (Figure 6 & Table 2) and distance surveyed (Table 2), as well as between Minas Basin and Minas Channel in both months and overall. Sampling effort in Minas Passage was higher than the other areas, reflecting the extra sampling on the grid of observation lines run across the tidal demonstration site. Effort was lower overall than in July and August, 2009, resulting from a lower sampling frequency[7]. Effort in Minas Basin, which had been relatively low compared to the other areas in 2009, was increased over June and September 2009 values by extending the cruise route further into the Basin, although it was still lower than in July & August 2009 because of the difference in sampling frequency noted above.

Both surveys had good observation conditions, although the August survey had a lower visibility before noon due to the presence of fog. Lower visibility, while not greatly impacting quantitative observations within 300 m of the vessel, would affect (reduce) the total number of sightings.

Table 2. Observation Effort, Seabird and Marine Mammal Survey of Minas Basin, Minas Passage and Minas Channel, July and August, 2010.

		Distance Traveled (km)	
	Overall	July	August
Minas Basin	22.41	11.46	10.95
Minas Passage	54.06	31.89	22.17
Minas Channel	30.17	15.63	14.54
Total	106.64	58.98	47.66
	Overall	Area Sampled[1] (km^2)	
Minas Basin	6.72	3.44	3.29
Minas Passage	16.22	9.57	6.65
Minas Channel	9.05	4.69	4.36
Total	31.99	17.69	14.30
	Overall	Number of Observations (5-minute periods)	
Minas Basin	25	15	10
Minas Passage	60	38	22
Minas Channel	32	14	18
Total	117	67	50

1. Observations ‘in transect’ (i.e. within 300 m band parallel to one side of vessel).

[7] In the July-August surveys in 2009, sampling took place nearly continuously, at about twice the rate as in June & September 2009 and July-August 2010. This would have been unsustainable because of the potential for errors and overloading the observer, so a more modest rate was used in 2010.

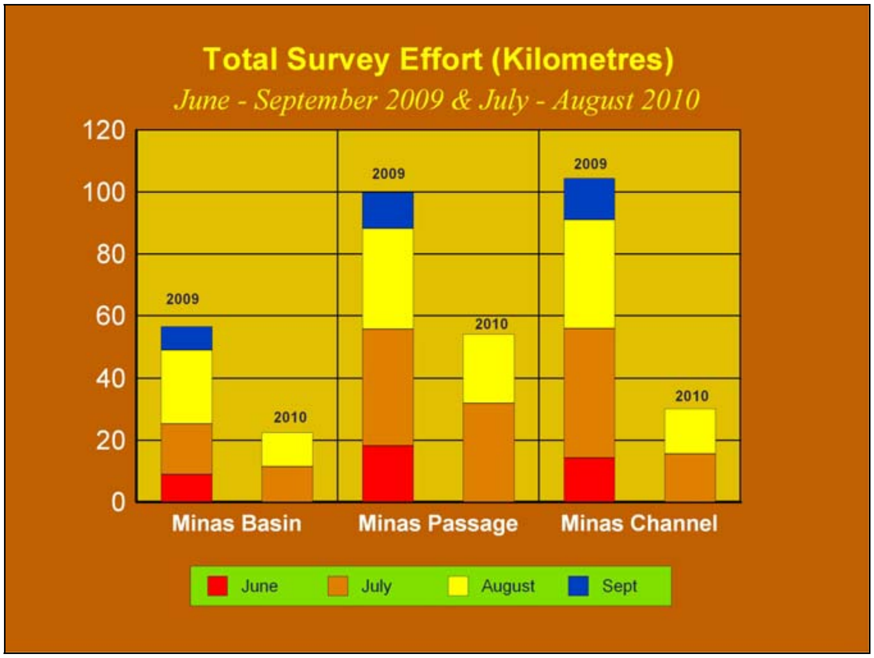

Figure 6. Distance surveyed (kilometres), June to September, 2009 and July & August 2010.

3.2.1.2 Species Composition

Overall, 161 seabirds and waterfowl in 10 species were sighted during the vessel surveys (Figures 7-9 and Tables 3-5). Most sightings were in Minas Passage, about twice the number seen in Minas Basin and Minas Channel. Herring Gull (*Larus argentatus)* was the most abundant and common bird (48.4% of sightings, occurring in 35.0% of observation periods, Table 3) and dominating in both July and August (Table 3-5, Figures 9 & 10). Common Eider (*Somateria molissima*), a coastal seaduck species, was next in abundance in both months (14.4% and 21.1% of individuals in July & August, respectively), but was not common, one flock of 15 occurring in July and one of 12 birds in August (1.5% and 2% of observation periods, respectively). Great Black-Backed Gull occurred in moderate abundance in both surveys (6.7% and 8.8% of individuals in July & August, respectively, and 10.4 and 6.0% of observation periods); and three species occurred in moderate abundance in individual surveys—Northern Gannet (14.4% of individuals and 7.5% of observation periods in July; Wilson's Storm Petrel, an oceanic species only occasionally likely to occur in the area (12.5% of sightings, 16.4% of observation periods in July); and Ring-Billed Gull (15.8% of sightings and 12% of observation periods) in August. Common Loon (*Gavia immer)* occurred occasionally as single sightings in both July and August surveys; and Double-Crested and Great Cormorant, and Black Guillemot were observed in low numbers in the August survey.

Differences between 2010 and 2009 in seabird abundance determined by the vessel surveys included a reduced number of species and total number of sightings in 2010, although density estimates of birds were similar in 2010. Compared to 2009, bird species diversity was lower, with two fewer species observed in 2010. A core group of species which occurred in both years were: Herring Gull, Great Black-Backed Gull, Ring-Billed Gull, Double-Crested Cormorant, Common Eider, Common Loon, Black Guillemot and Northern Gannet. Great Cormorant and Wilson's Storm Petrel occurred only in 2010, and Pacific Loon, Greater Shearwater, Red Phalarope and White-Winged Scoter occurred only in 2009. The number of sightings was also lower in July and August 2010 than in 2009 (69.1% of 2009 overall and 80.0% and 55.3% for July and August, respectively); however sightings adjusted for effort (numbers per kilometre) (Figure 8, Tables 3-5) were comparable overall to 2009, although some differences in individual areas and months occurred. Differences included: higher densities (seabirds per kilometre) in

July 2010 in Minas Basin and Minas Passage; lower densities for August 2010 in Minas Passage; and higher densities in August 2010 in Minas Channel compared to 2009 (Figure 8).

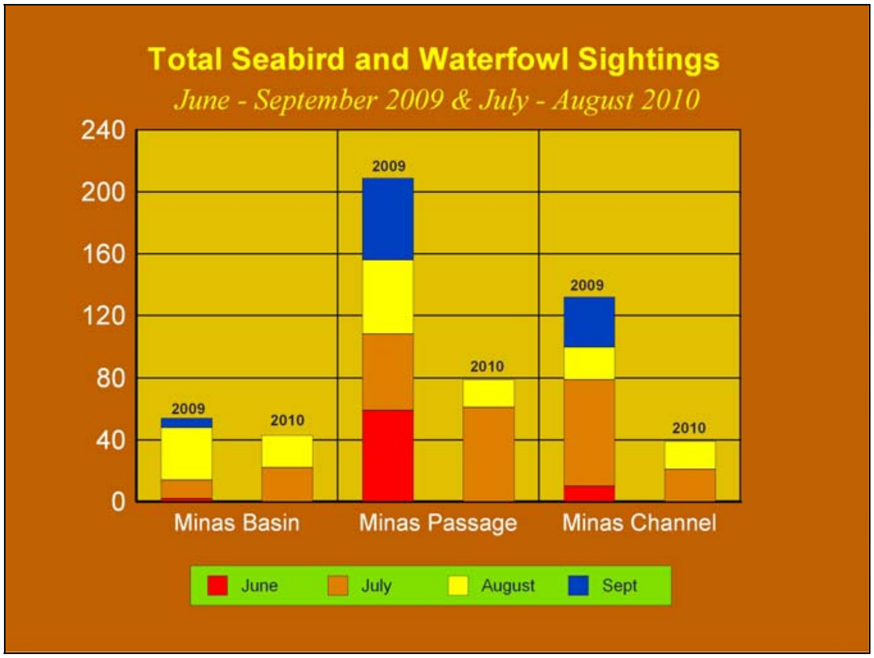

Figure 7. Summary of numbers of sightings of seabirds and waterfowl by area and month, from vessel surveys, June to September, 2009 and July & August 2010.

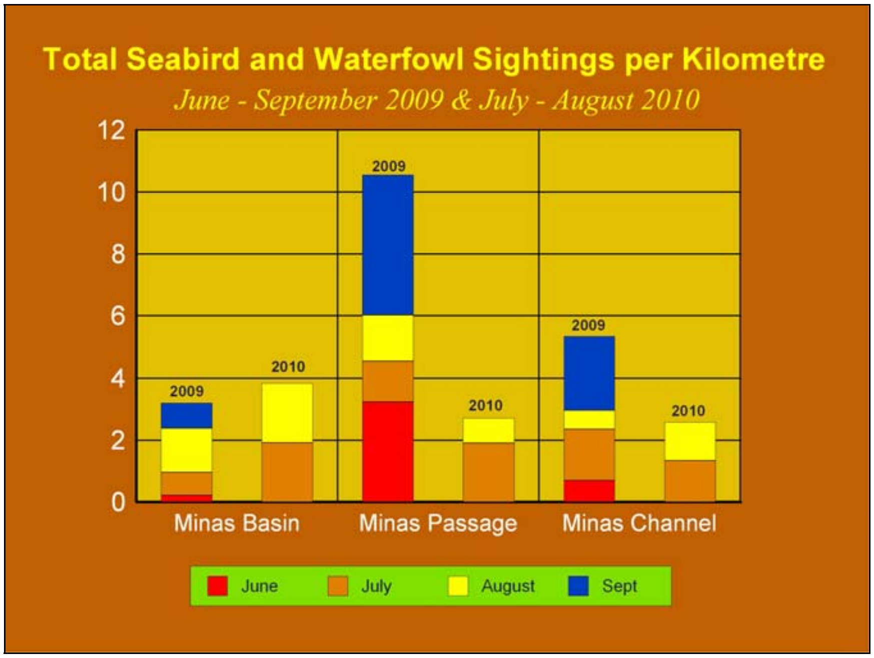

Figure 8. Summary of numbers of sightings of seabirds and waterfowl by area and month, from vessel surveys, adjusted for effort (kilometres surveyed) June to September, 2009 and July & August 2010.

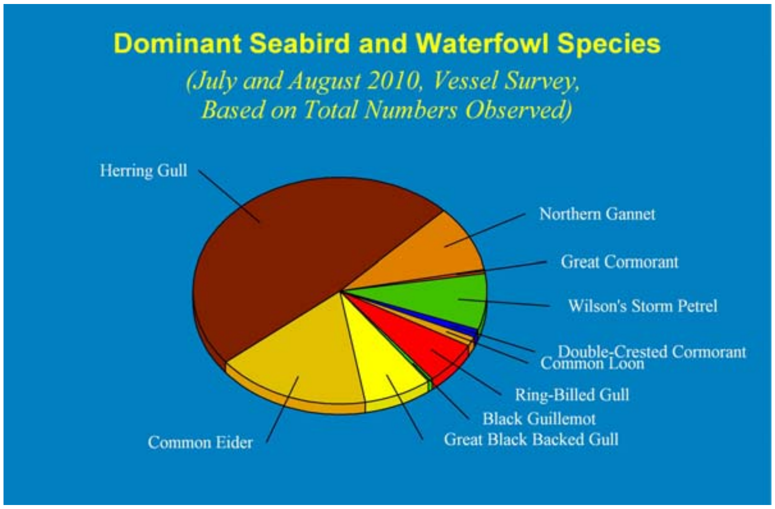

Figure 9. Species composition and relative abundance of seabird and waterfowl species observed in Minas Basin, Minas Passage and Minas Channel on vessel surveys, July & August, 2010.

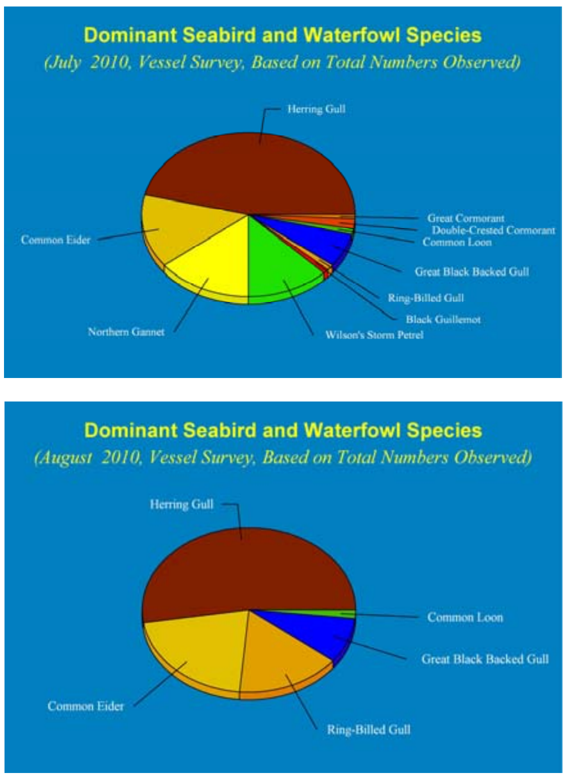

Figure 10. Species composition and relative abundance of seabird and waterfowl species by month, obtained in vessel surveys of Minas Basin, Minas Passage and Minas Channel, July & August 2010.

3.2.1.3 Distribution and Abundance

Overall Abundance

Overall abundance of seabirds and waterfowl observed in vessel surveys, expressed either per kilometre or per square kilometre, was similar in both July and August in Minas Basin and Minas Channel; and higher in July than in August in Minas Passage (Figures 11-12)[8]. Highest average abundance reached 4.0 birds per km^2 in Minas Passage in July and lowest in Minas Channel in both July and August (1.7 and 1.6 birds/km^2, respectively)(Figures 11-12 & 15; Tables 3-5).

Abundance was similar between years, with a tendency for abundance in terms of individuals per kilometre to be higher in 2010 than in 2009 (Figure 13), while density expressed as birds/km^2 was comparable between years (Figure 14).

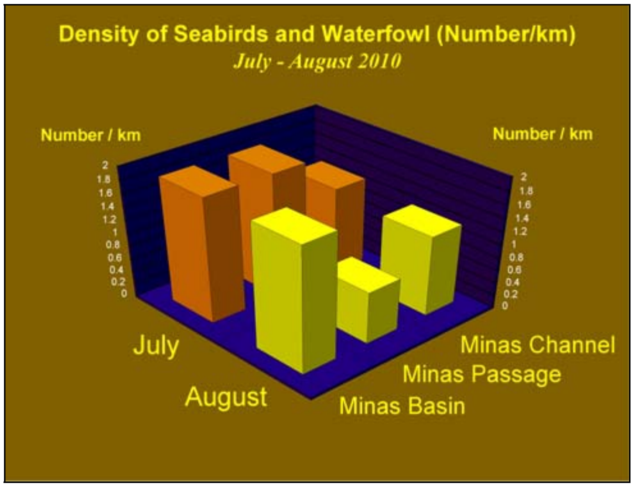

Figure 11. Abundance of seabirds and waterfowl (number/kilometre), July & August, 2010.

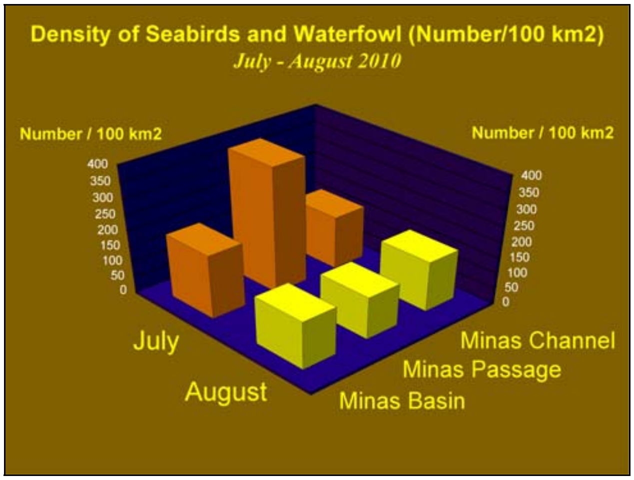

Figure 12. Abundance of seabirds and waterfowl (number/100 km^2), July & August 2010.

[8] The measure of "number per km" includes all birds seen, typically extending to 500 m or more from the vessel, while the measure "number per km^2" refers only to birds observed within 300 m of the side of the vessel on which observations were made.

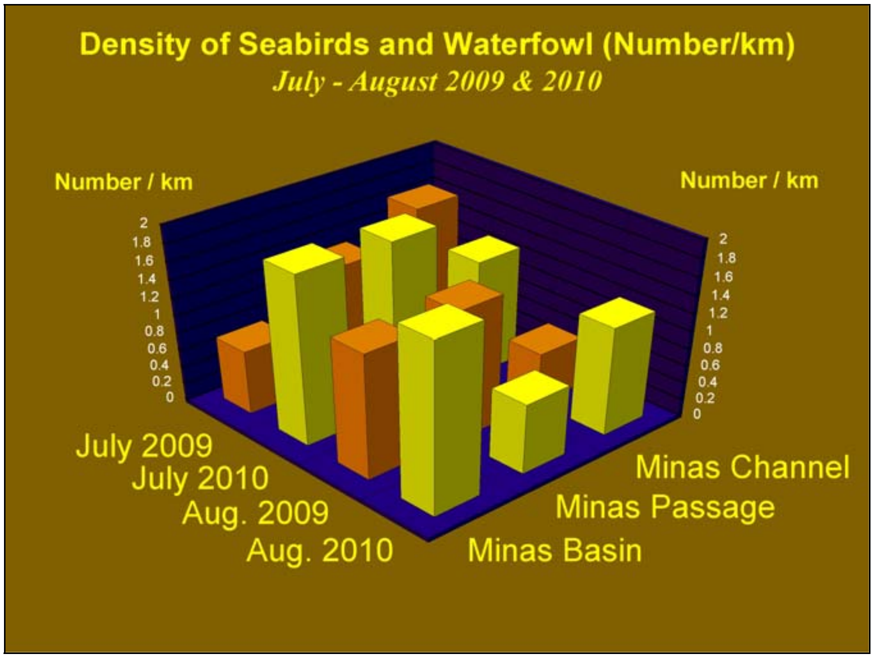

Figure 13. Abundance of seabirds and waterfowl (number/km) in vessel surveys, July & August 2009 & 2010.

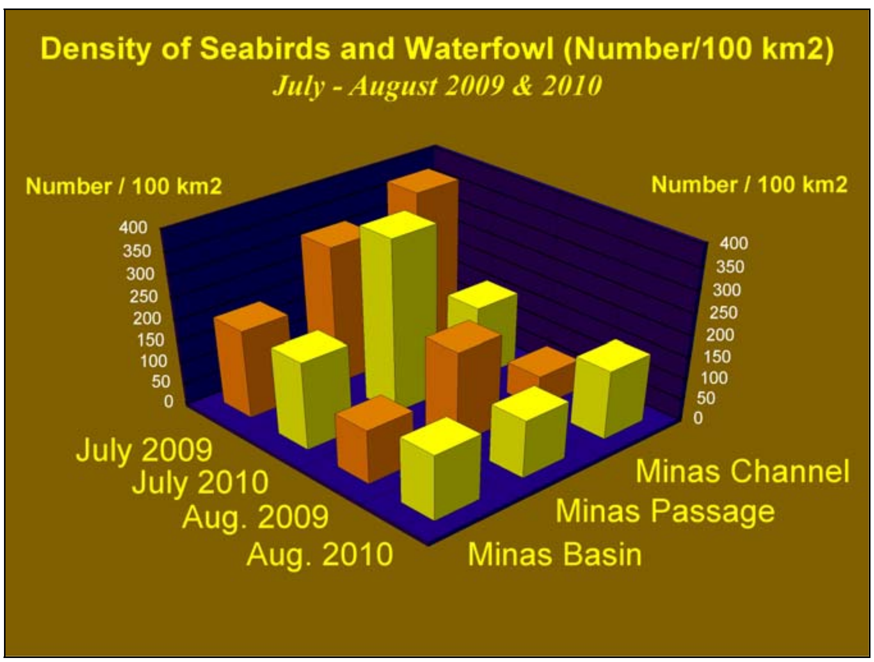

Figure 14. Abundance of seabirds and waterfowl (number/100 km^2) in vessel surveys, July & August 2009 & 2010.

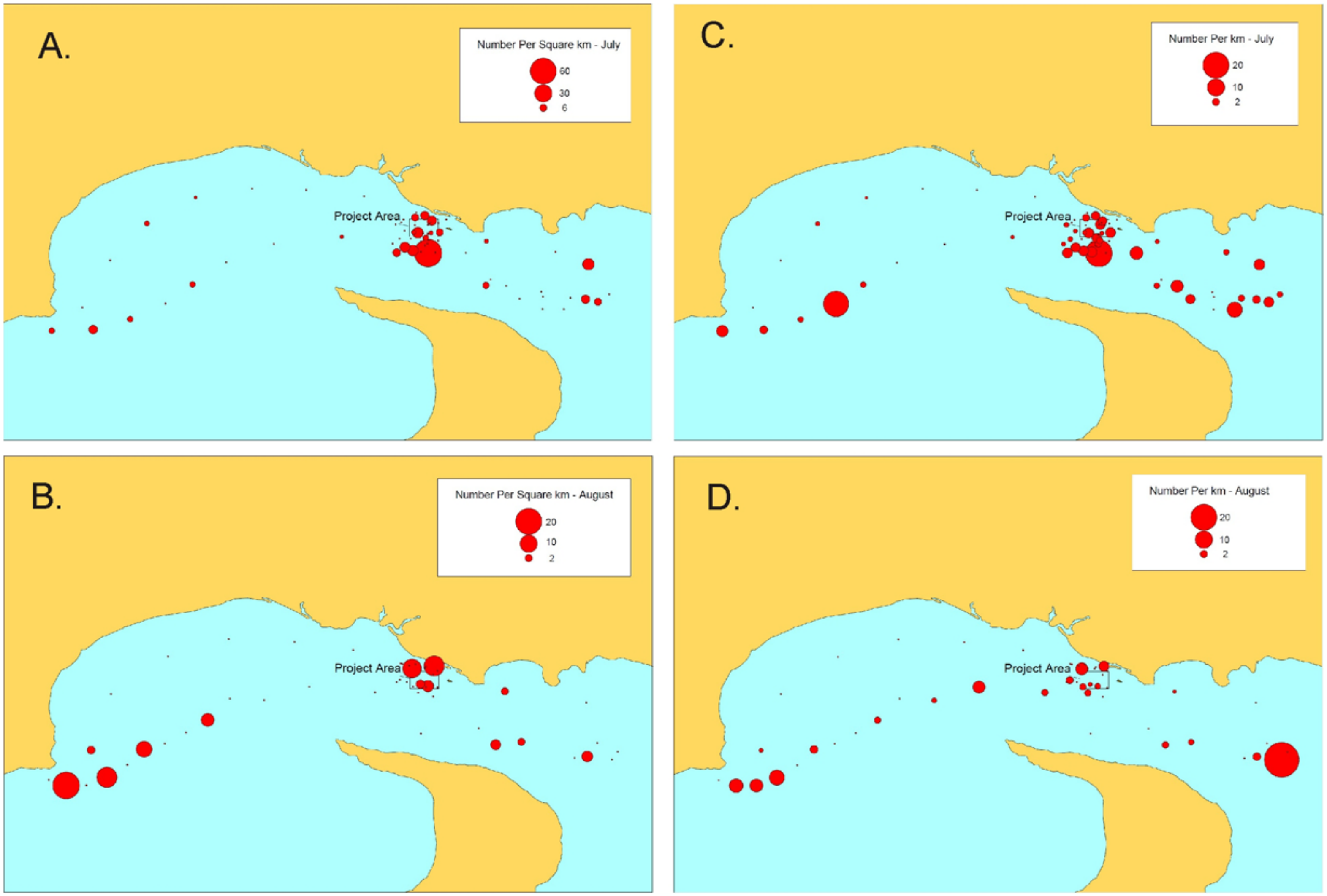

Figure 15. Overall abundance of seabirds and waterfowl in Minas Basin, Minas Passage and Minas Channel, July and August, 2010. A & B, individuals per square kilometre; C & D, individuals per kilometre.

Table 3. Abundance of seabirds in Minas Basin, Minas Passage and Minas Channel, July & August, 2010. Number of 5-minute observation periods: Minas Basin = 25; Minas Passage = 60; Minas Channel = 32. Number of immatures/juveniles shown in brackets.

Area	Total, All Species	Great Black-Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Wilson's Storm Petrel	Great Cormorant	Northern Gannet	Ring-Billed Gull
	Total Number Observed										
Minas Basin	43	3	0	20 (5)	0	12	1	4[2] (2)	0	1 (1)	2
Minas Passage	79	7 (2)	2 (1)	37 (8)	0	15	0	9[2] (1)	1 (1)	3[2] (1)	5 (1)
Minas Channel	39	2 (1)	0	21 (4)	2 (2)	0	0	0	0	11 (11)	3 (3)
Total	161	12	2	78	2	27	1	13	1	15	10
	Number / Kilometre										
Minas Basin	1.92	0.13	0.00	0.89	0.00	0.54	0.04	0.18	0.00	0.04	0.09
Minas Passage	1.46	0.13	0.04	0.68	0.00	0.28	0.00	0.17	0.02	0.06	0.09
Minas Channel	1.29	0.07	0.00	0.70	0.07	0.00	0.00	0.00	0.00	0.36	0.10
Overall	1.51	0.11	0.02	0.73	0.02	0.25	0.01	0.12	0.01	0.14	0.09
	Number Observed within 300 m survey area [1]										
Minas Basin	12	0	0	8	0	0	1	3	0	0	0
Minas Passage	47	0	1	26	0	15	0	3	0	0	2
Minas Channel	15	1	0	12	2	0	0	0	0	0	0
Total	74	1	1	46	2	15	1	6	0	0	2
	Number of Seabirds per 100 km^2										
Minas Basin	178.49	0.00	0.00	118.99	0.00	0.00	14.87	44.62	0.00	0.00	0.00
Minas Passage	289.82	0.00	6.17	160.33	0.00	92.50	0.00	18.50	0.00	0.00	12.33
Minas Channel	165.71	11.05	0.00	132.57	22.09	0.00	0.00	0.00	0.00	0.00	0.00
Overall	231.31	3.13	3.13	143.79	6.25	46.89	3.13	18.75	0.00	0.00	6.25
Month	Observations	Frequency of Occurrence (% of observation periods)									
July	67	10.4	1.5	37.3	1.5	1.5	1.5	16.4	1.5	7.5	1.5
August	50	6.0	0.0	32.0	2.0	2.0	0.0	0.0	0.0	0.0	12.0
Overall	117	8.5	0.9	35.0	1.7	1.7	0.9	9.4	0.9	5.1	6.0

1. 300 m band on one side of survey vessel.
2. Maturity unknown.

Table 4. Abundance of seabirds in Minas Basin, Minas Passage and Minas Channel, July 19, 2010. Number of 5-minute observation periods: Minas Basin = 15; Minas Passage = 38; Minas Channel = 14. Number of immatures/juveniles shown in brackets.

Area	Total, All Species	Great Black-Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Wilson's Storm Petrel	Great Cormorant	Northern Gannet	Ring-Billed Gull
	Total Number Observed										
Minas Basin	22	3	0	12 (2)	0	0	1	4[2] (2)	0	1 (1)	1
Minas Passage	61	3	2 (1)	28 (5)	0	15	0	9[2] (1)	1 (1)	3[2] (1)	0
Minas Channel	21	1	0	8 (5)	1 (1)	0	0	0	0	11 (11)	0
Total	104	7	2	48	1	15	1	13	1	15	1
	Number / Kilometre										
Minas Basin	1.92	0.26	0.00	1.05	0.00	0.00	0.09	0.35	0.00	0.09	0.09
Minas Passage	1.91	0.09	0.06	0.88	0.00	0.47	0.00	0.28	0.03	0.09	0.00
Minas Channel	1.34	0.06	0.00	0.51	0.06	0.00	0.00	0.00	0.00	0.70	0.00
Overall	1.76	0.12	0.03	0.81	0.02	0.25	0.02	0.22	0.02	0.25	0.02
	Number Observed within survey area[1]										
Minas Basin	7	0	0	3	0	0	1	3	0	0	0
Minas Passage	38	0	1	19	0	15	0	3	0	0	0
Minas Channel	8	1	0	6	1	0	0	0	0	0	0
Total	53	1	1	28	1	15	1	6	0	0	0
	Number of Seabirds per 100 km^2										
Minas Basin	203.64	0.00	0.00	87.28	0.00	0.00	29.09	87.28	0	0	0
Minas Passage	397.20	0.00	10.45	198.60	0.00	156.79	0.00	31.36	0	0	0
Minas Channel	170.61	21.33	0.00	127.96	21.33	0.00	0.00	0.00	0	0	0
Overall	299.55	5.65	5.65	158.25	5.65	84.78	5.65	33.91	0	0	0

1. 300 m band on one side of Survey Vessel.
2. Maturity not known.

Table 5. Abundance of seabirds in Minas Basin, Minas Passage and Minas Channel, August 18, 2010. Number of 5-minute observation periods: Minas Basin = 10; Minas Passage = 22; Minas Channel = 18. Number of immatures/juveniles shown in brackets.

Area	Total, All Species	Great Black-Backed Gull	Double-Crested Cormorant	Herring Gull	Common Loon	Common Eider	Black Guillemot	Wilson's Storm Petrel	Great Cormorant	Northern Gannet	Ring-Billed Gull
	Total Number Observed										
Minas Basin	21	0	0	8	0	12	0	0	0	0	1
Minas Passage	18	4	0	9	0	0	0	0	0	0	5
Minas Channel	18	1	0	13	1	0	0	0	0	0	3
Total	57	5	0	30	1	12	0	0	0	0	9
	Number / Kilometre										
Minas Basin	1.92	0.00	0.00	0.73	0.00	1.10	0.00	0.00	0.00	0.00	0.09
Minas Passage	0.81	0.18	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.23
Minas Channel	1.24	0.07	0.00	0.89	0.07	0.00	0.00	0.00	0.00	0.00	0.21
Overall	1.20	0.10	0.00	0.63	0.02	0.25	0.00	0.00	0.00	0.00	0.19
	Number Observed within Survey Area[1]										
Minas Basin	5	0	0	5	0	0	0	0	0	0	0
Minas Passage	9	0	0	7	0	0	0	0	0	0	2
Minas Channel	7	0	0	6	1	0	0	0	0	0	0
Total	21	0	0	18	1	0	0	0	0	0	2
	Number of Seabirds per 100 km[2]										
Minas Basin	152.18	0.00	0.00	152.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minas Passage	135.34	0.00	0.00	105.27	0.00	0.00	0.00	0.00	0.00	0.00	30.08
Minas Channel	160.44	0.00	0.00	137.52	22.92	0.00	0.00	0.00	0.00	0.00	0.00
Overall	146.87	0.00	0.00	125.89	6.99	0.00	0.00	0.00	0.00	0.00	13.99

1. 300 m band on one side of survey vessel.
2. Maturity unknown

Abundance of Gulls

Herring Gull

Herring Gull was the most abundant seabird overall and the most commonly observed in the study area during the vessel surveys in July-August 2010. The species is a common, annual breeder, nesting on islands and seacliffs along the Bay of Fundy. It is primarily a scavenger/ omnivore, which feeds at the water surface. Herring Gull abundance is often linked to human activities and associated food sources in coastal areas. Herring Gull occurred in both surveys, and was highest in abundance in Minas Passage in July (2.0 birds per km^2) showing similar lower abundances for both months in Minas Basin and Minas Channel (Figure 16). Lowest abundance was 0.9 birds per km^2 in Minas Basin in July. Herring Gull abundance per kilometre was higher in July in both Minas Basin and Minas Passage, and highest in August in Minas Channel (Figure 17). Most individuals were adults with immatures and juveniles making up about a fifth of numbers (July, 20.8%, and August, 23.3%)(Tables 3-5). The species was observed in all areas in both months (Figure 18).

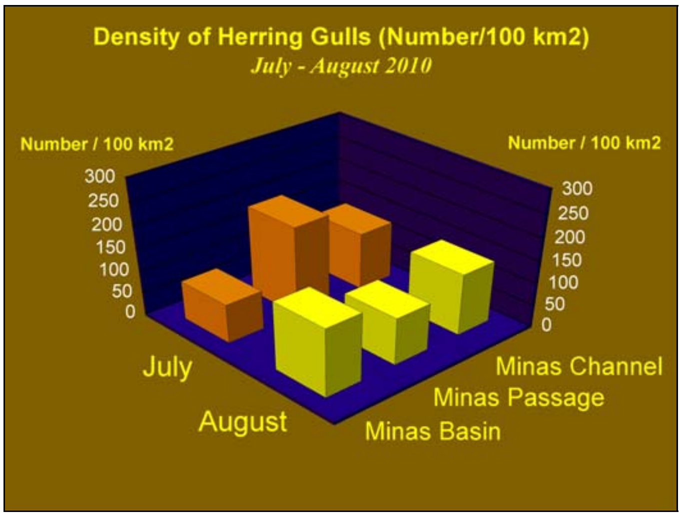

Figure 16. Density of Herring Gulls (number/100 km^2), July & August, 2010.

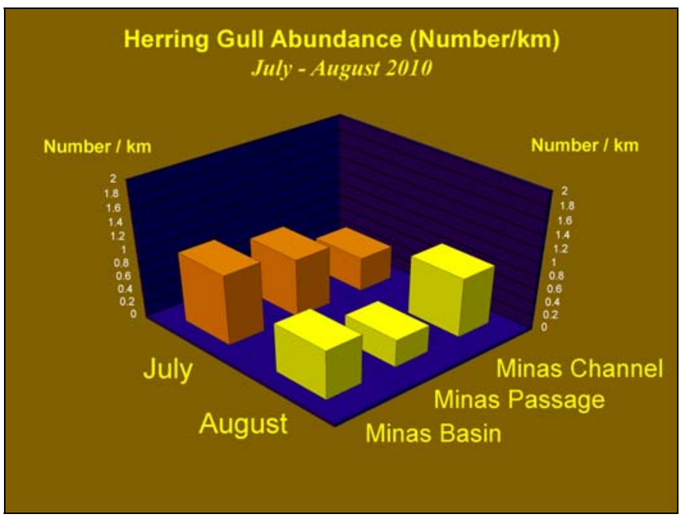

Figure 17. Abundance of Herring Gulls (number/kilometre), July & August, 2010.

Great Black-Backed Gull

Great Black-Backed Gull occurred occasionally in low abundance in all areas in both July and August surveys (Figure 18). Abundance was similar between months, but the species was not seen in Minas Basin or Minas Channel in August. Highest abundance was 0.3 birds per kilometre in Minas Basin in July and lowest 0.1 birds per kilometre in Minas Channel in both July and August (Tables 3-5). Abundances in Minas Passage and Minas Channel were similar between years (0.1 to 0.2 birds per kilometre) and abundance in Minas Passage was highest of both years in July 2010 although most variable (the species was not sighted in Minas Basin in August 2010). All 'Black-Backs' sighted in July were adults but immatures/juveniles accounted for 60% in August (Tables 3-5). The species is a common annual breeder in Atlantic Canada, which nests on islands and seacliffs along the Bay of Fundy, feeding mainly by scavenging along shores and at the water surface.

Ring-Billed Gull

Ring-Billed Gull occurred occasionally in low abundance, observed in Minas Basin in July and in all areas in August (Tables 3-5)(Figure 19). Highest abundance was 0.2 birds per kilometre in August (Minas Passage and Minas Channel), with a lower abundance in Minas Basin (0.1 birds per kilometre) in both July and August (Table 3). The species was also more common and abundant in August in 2009 surveys, at similar densities (0.1 to 0.2 birds per kilometre), although it was not sighted in Minas Channel. Both adults and immatures/juveniles were observed, with immatures and juveniles occasionally important (July, 0%, and August, 44.4%)(Tables 3-5). Ring-Billed Gull is a common annual migrant and occasional summer resident, feeding typically at the water surface.

Abundance of Miscellaneous Seabird and Waterfowl Species

Common Eider

Common Eider occurred occasionally, with sightings of one small flock in each of the surveys, once in the middle of Minas Passage near the tidal demonstration site in July (15 individuals) and once in Minas Basin in August (12 individuals)(Figure 19). In contrast, the species occurred in smaller groups or singly in July and August 2009, with most individuals sighted in Minas Passage near the tidal study site and several sightings in Minas Basin in July. Densities in 2010 ranged from 0.5 birds per kilometre (Minas Basin, July) to 1 per kilometre (Minas Passage, August) (Tables 3-5) compared with densities of 0.1 to 0.3 individuals per kilometre in 2009 (Envirosphere Consultants 2010). All of the individuals observed were adults. Common Eider is a common breeder on islands and shorelines of the Bay of Fundy. The species typically feeds on molluscs such as mussels, which it finds in intertidal and upper subtidal areas. Eider can dive to medium depths and occasionally deeper to reach shellfish beds.

Double-Crested Cormorant

Double-Crested Cormorant is a resident of the area, nesting in colonies in Minas Basin and on Cape Split, and relatively common in inshore waters, but only two individuals were seen on the combined surveys, in July in the vicinity of the project site (Figure 20). Overall densities were less than 0.1 birds per kilometre compared with 0.1 to 0.3 birds per km observed in 2009. The species is a common annual breeder, which nests on islands and seacliffs along the Bay of Fundy, feeding by diving for fish to shallow to medium depths and occasionally deeper.

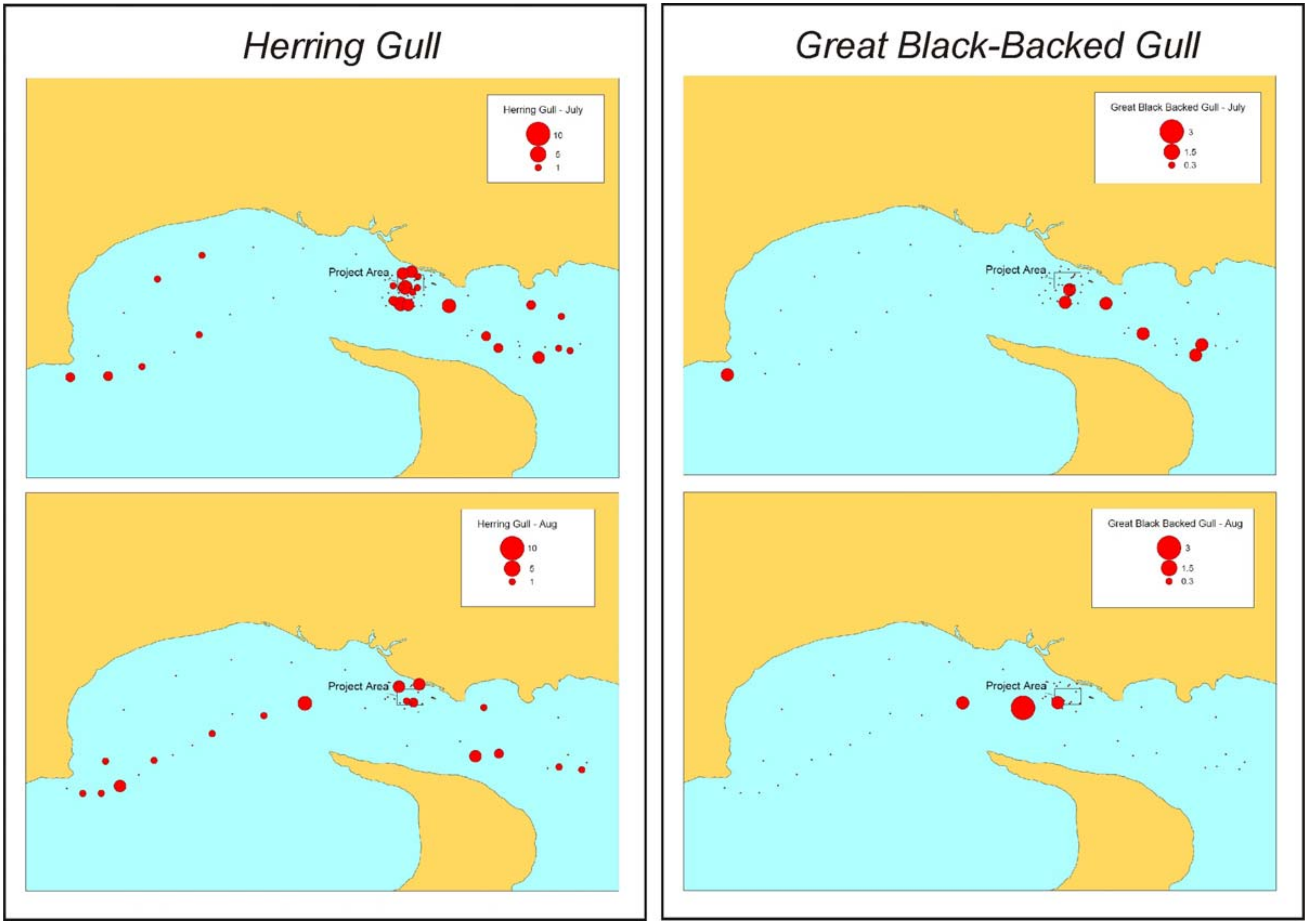

Figure 18. Distribution and abundance (individuals per 5-minute observation period) of Herring Gull and Great Black-Backed Gull in Minas Basin, Minas Passage and Minas Channel, July & August 2010. Area shown is Crown Lease, which contains berths for tidal device installation.

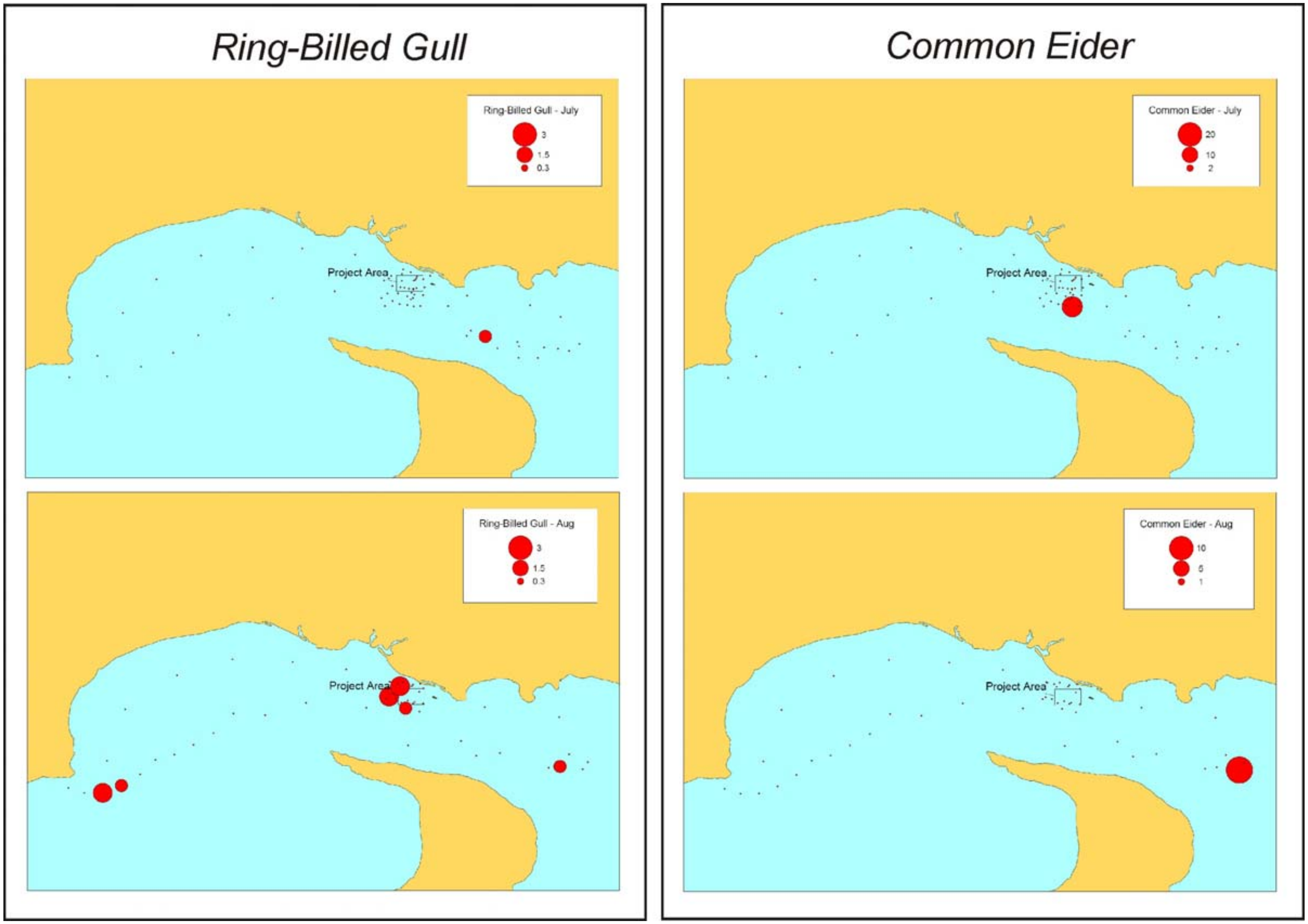

Figure 19. Distribution and abundance (individuals per 5-minute observation period) of Ring-Billed Gull and Common Eider in Minas Basin, Minas Passage and Minas Channel, July & August 2010. Area shown is Crown Lease, which contains berths for tidal device installation.

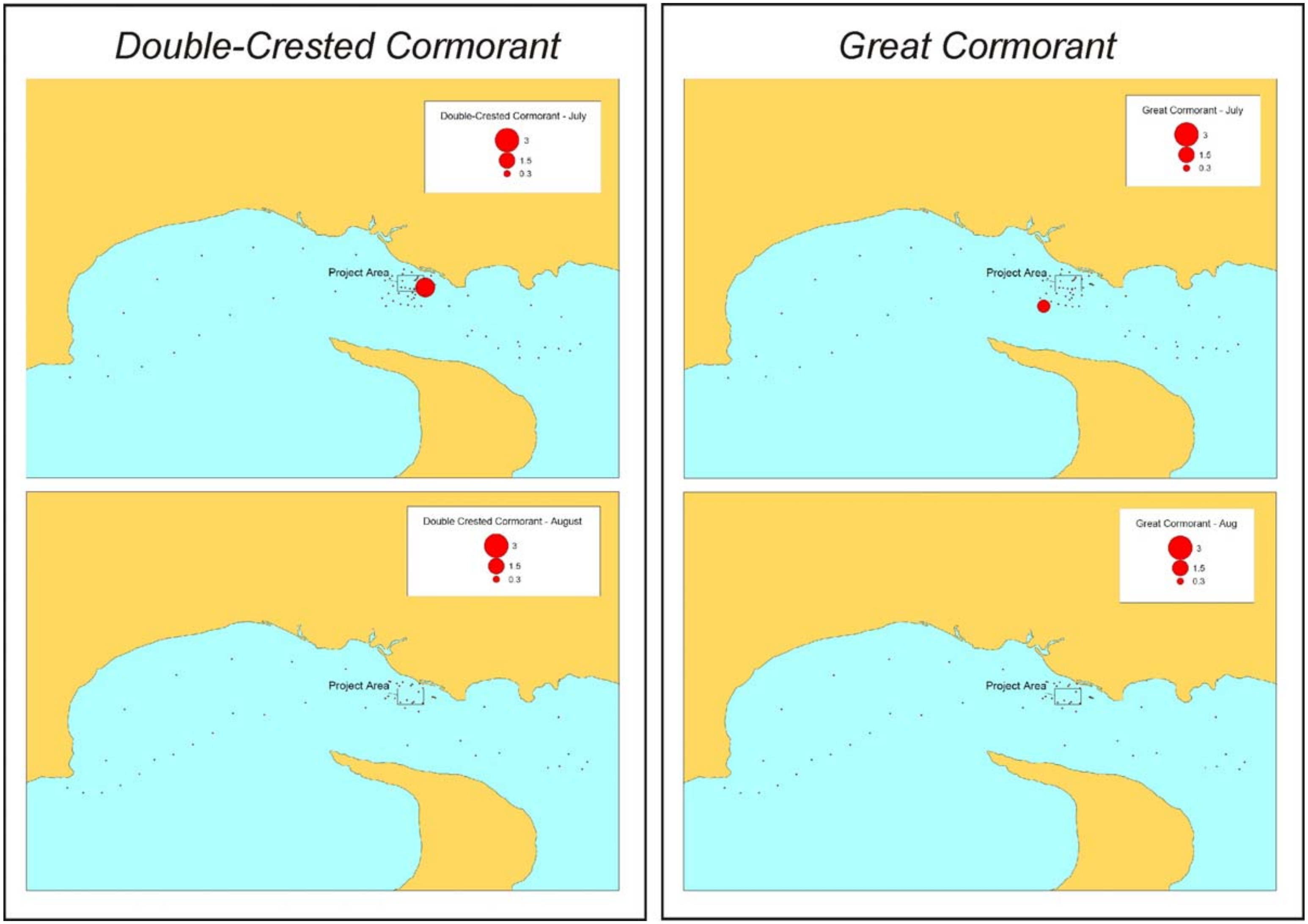

Figure 20. Distribution and abundance (individuals per 5-minute observation period) of Double-Crested Cormorant and Great Cormorant in Minas Basin, Minas Passage and Minas Channel, July & August 2010. Area shown is Crown Lease, which contains berths for tidal device installation.

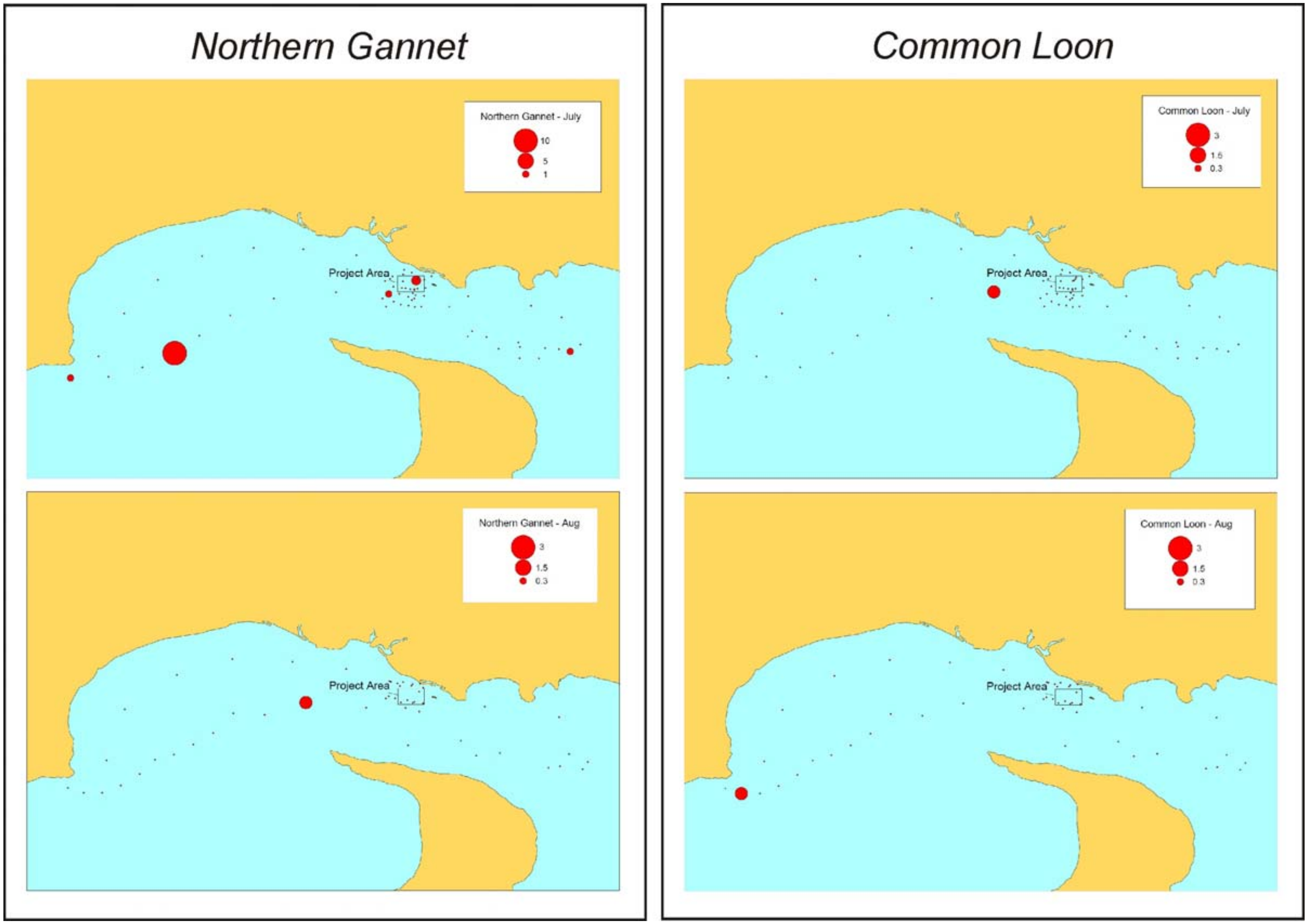

Figure 21. Distribution and abundance (individuals per 5-minute observation period) of Northern Gannet and Common Loon in Minas Basin, Minas Passage and Minas Channel, July & August 2010. Area shown is Crown Lease, which contains berths for tidal device installation.

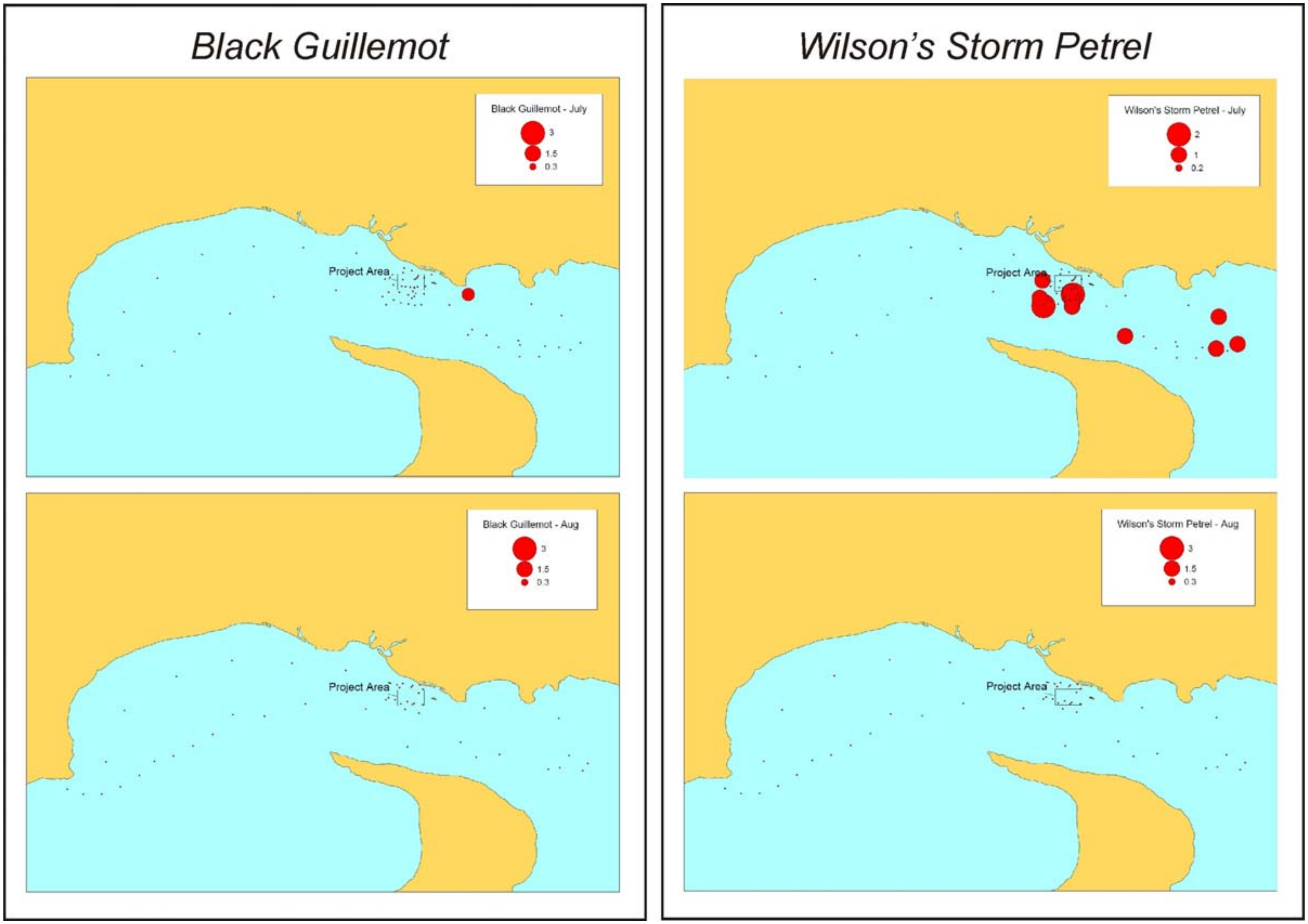

Figure 22. Distribution and abundance (individuals per 5-minute observation period) of Black Guillemot and Wilson's Storm Petrel in Minas Basin, Minas Passage and Minas Channel, July & August 2010. Area shown is Crown Lease, which contains berths for tidal device installation.

Great Cormorant

Great Cormorant breeds in Atlantic Canada and occurs occasionally in the study area. A single immature individual was obseved in the middle of Minas Passage near the tidal demonstration site in July (Figure 20). No individuals of this species were observed in surveys in 2009.

Northern Gannet

This species normally migrates through the area to colonies on the Gulf of St. Lawrence, but the Inner Bay of Fundy may support immatures and late migrants. Northern Gannets, principally immature stages, occurred in moderate numbers in all areas in the July survey, but were not observed in August (Figure 21). Highest concentrations were observed in Minas Channel (0.7 individuals per kilometre) and lower but similar concentrations of 0.1 individuals per kilometre occurred in Minas Basin and Minas Passage. The species was not as abundant in July 2009, with only a single individual observed in Minas Channel, but was more abundant in August 2009 (0.1 to 0.15 individuals per kilometre in Minas Channel and Minas Passage respectively, and 0.2 individuals per square kilometre in Minas Passage) (Envirosphere Consultants 2010). Most of the individuals, all of which were observed in July, were immature. Northern Gannet is a common annual migrant and summer resident. Feeding is by diving from great heights to medium and shallow depths to fish.

Common Loon

The species is typically a common coastal resident in the study area, but was uncommon in the 2010 surveys, with single immature individuals observed in Minas Channel in each of the two surveys (Tables 3-5, Figure 21). The species is an annual breeder on inland lakes and is a summer resident on the Bay of Fundy. Common Loon forages by diving and swimming underwater to catch fish, diving mostly to medium depth, but occasional very deep dives are possible.

Black Guillemot

A single Black Guillemot was observed in Minas Basin in July and none were seen in the August survey (Figure 22). The species had been more common and abundant in July 2009, occurring in all the study sub-areas, and occurring in all time periods (Envirosphere Consultants 2010). Black Guillemot is a common annual breeder on seacliffs and in coastal rocks along the Bay of Fundy, and feeds on fish, diving to shallow to mid-depth.

Wilson’s Storm Petrel

Wilson’s Storm Petrel is a common oceanic species found in offshore continental shelf waters in summer, and can pass through the Bay of Fundy during migration or be transported in by storms. The species was observed frequently in Minas Basin and Minas Passage in July (Tables 3-5, Figure 22). Densities were from 0.3 to 0.4 individuals per kilometre and 0.3 to 0.9 individuals per square kilometre in Minas Passage and Minas Basin respectively (Tables 3-5). Maturity of most of the individuals could not reliably be determined, but some of the individuals were immatures. No Wilson’s Storm Petrels were observed in 2009.

3.2.2 Shore-Based Survey

3.2.2.1 Survey Effort

Sampling effort was similar between shore-based surveys (May to November) with 12, 30-minute observation periods per day (11 on May 1st). Observation conditions varied through the May – November period, which will have affected the results. Ideal survey conditions were overcast days with negligible to slight winds—most of the surveys met these conditions[9]. Overcast conditions were present for the May 1, May 27, October 23 and November 22 surveys, which allowed for greater visibility of birds species at greater distances. Surveys conducted on sunny days (May 13, June 12 and November 13) would have had lower visibility of species due to surface reflections but were still considered to be acceptable.

3.2.2.2 Species Composition

Overall, 1736 seabirds and waterfowl in 32 species were sighted during the shore-based surveys. Seabirds occurring at the site included: Double-Crested Cormorant, Great Cormorant, Herring Gull, Black-Backed Gull, Iceland Gull, Laughing Gull, Lesser-Backed Gull, Ring-Billed Gull, Mew Gull, Black Guillemot, Northern Gannet, Razorbill, Horned Grebe, Red-Necked Grebe, Black-Legged Kittiwake, Atlantic Puffin, Thick-Billed Murre and Common Murre (Table 6). Waterfowl included: Common Eider, American Black Duck, Mallard, Harlequin Duck, Long-Tailed Duck, Canada Goose, Common Loon, Pacific Loon, Red-Throated Loon, Surf Scoter, Black Scoter, White-Winged Scoter, Red-Breasted Merganser and Common Merganser. The highest diversity of bird species occurred during fall migration in late October and early November (October 23 & November 13 surveys) in which 23 and 25 species, respectively, were observed compared with 12-17 species observed during surveys earlier in the year (Figure 23). This was the first time that quantitative shore-based surveys were carried out at the tidal power demonstration site, although some observations were made during terrestrial bird surveys in June-Sept 2009 (Envirosphere Consultants 2009b)[10].

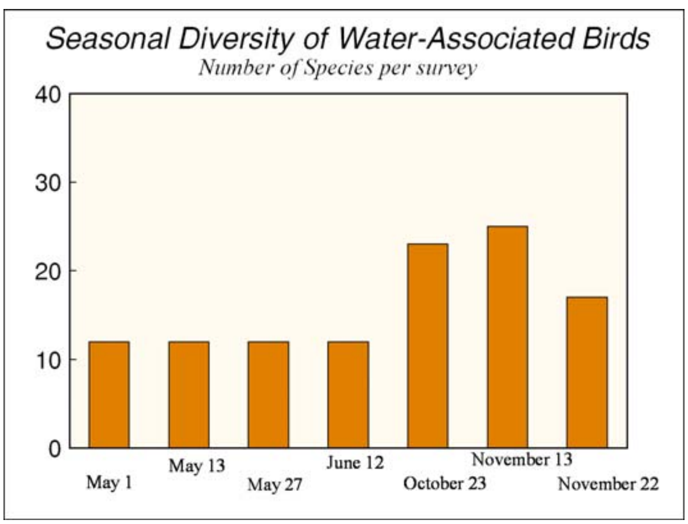

Figure 23. Number of species observed on shore based surveys, May – November 2010.

[9] Visibility on May 13 was reduced because of moderate wind and wave conditions, although visibility was otherwise good; while visibility on June 12 was reduced by glare from sunny conditions and slight winds (15 – 20 km/hr).
[10] Species noted in waters off the site were Herring Gull, Great Black-Backed Gull, Common Eider, Common Loon, Double-Crested Cormorant, and Black Guillemot.

Table 6. Seabirds observed at Black Rock Tidal Power Demonstration Site, May 1 to November 22, 2010, in shore-based surveys.		
Species Code	Common Name	Scientific Name
Waterfowl		
RTLO	Red-Throated Loon	*Gavia stellata*
COLO	Common Loon	*Gavia immer*
PALO	Pacific Loon	*Gavia pacifica*
ABDU	American Black Duck	*Anas rubripes*
COEI	Common Eider	*Somateria mollissima*
WWSC	White-Winged Scoter	*Melanitta fusca*
SUSC	Surf Scoter	*Melanitta perspicillata*
BLSC	Black Scoter	*Melanitta nigra*
RBME	Red-Breasted Merganser	*Mergus serrator*
COME	Common Merganser	*Mergus merganser*
HADU	Harlequin Duck	*Histrionicus histrionicus*
LTDU	Long-Tailed Duck	*Clangula hyemalis*
MALL	Mallard	*Anas Platyrhynchos*
CAGO	Canada Goose	*Branta canadensis*
Seabirds		
DCCO	Double-Crested Cormorant	*Phalacrocorax auritus*
GRCO	Great Cormorant	*Phalacrocorax carbo*
GBBG	Great Black-Backed Gull	*Larus marinus*
HEGU	Herring Gull	*Larus argentatus*
ICGU	Iceland Gull	*Larus glaucoides*
LAGU	Laughing Gull	*Larus articilla*
LBBG	Lesser Black-Backed Gull	*Larus fuscus*
RBGU	Ring-Billed Gull	*Larus delawarensis*
MEGU	Mew Gull	*Larus canus*
RAZO	Razorbill	*Alca torda*
HOGR	Horned Grebe	*Podiceps auritus*
BLKI	Black-Legged Kittiwake	*Rissa tridactyla*
NOGA	Northern Gannet	*Morus bassanus*
BLGU	Black Guillemot	*Cepphus grylle*
RNGR	Red-Necked Grebe	*Podiceps grisegena*
ATPU	Atlantic Puffin	*Fratercula arctica*
COMU	Common Murre	*Uria aalge*
TBMU	Thick-Billed Murre	*Uria lomvia*

3.2.2.3 Distribution and Abundance

Overall Abundance & Diversity

Great Black-Backed Gull, Herring Gull and Common Eider were the most common species observed in shore-based surveys at the site with Great Black-Backed and Herring Gulls dominant in terms of numbers in the spring-early summer (May-June) with Common Eider becoming important in the early summer (June) survey (Figures 24 & 25). Although Great Black-Backed Gull was the most abundant seabird during May surveys, it declined in importance through the remainder of the year. Herring Gulls also declined in importance in Fall (October-November), while Common Eider and Red-Throated Loons increased in importance. Red-Throated Loons, which were present in most surveys, were also particularly abundant during November 13 & 22 surveys which captured their Fall migration period (Figure 25).

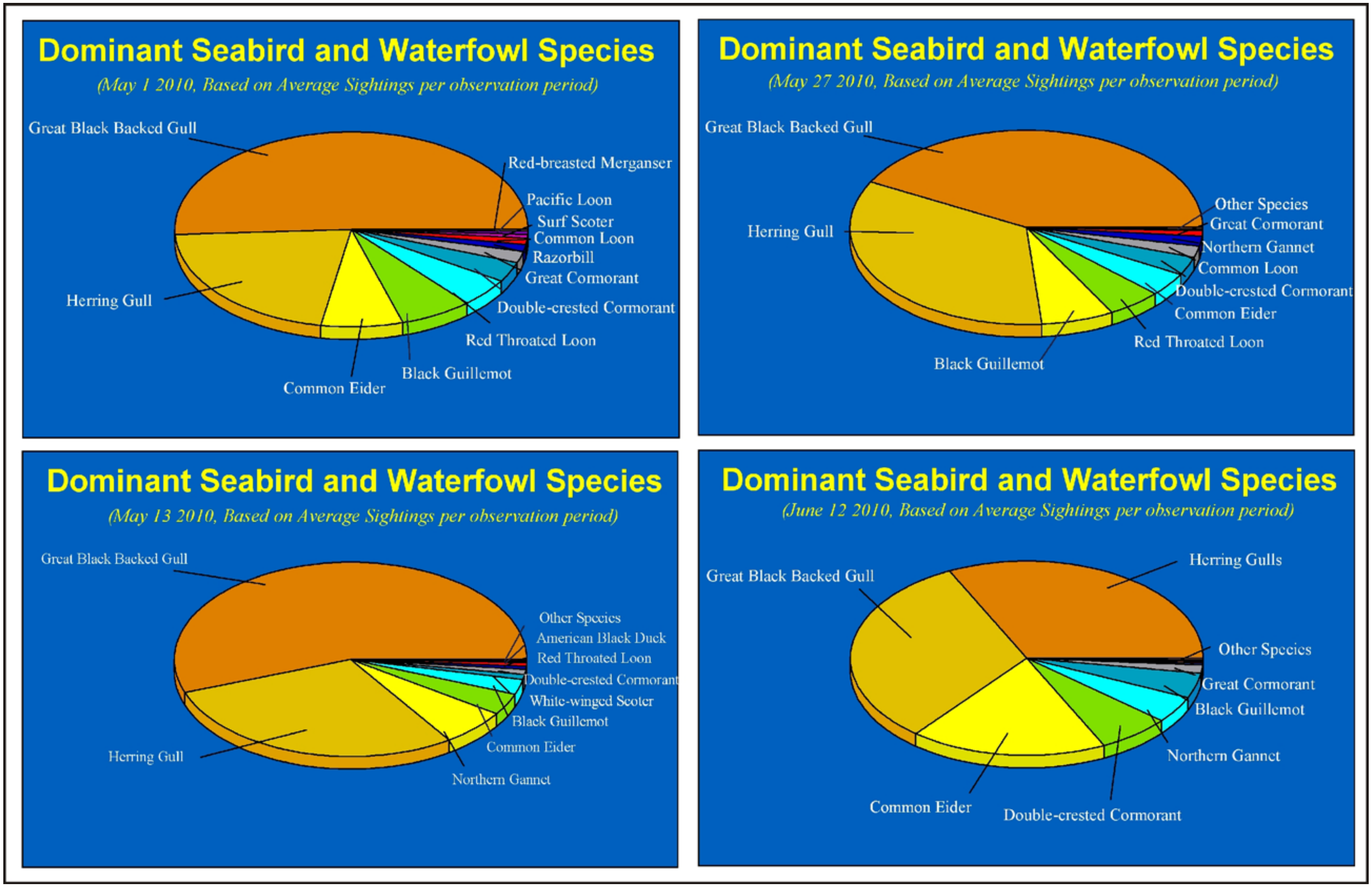

Figure 24. Dominant species of seabirds and other waterfowl at the Fundy Tidal Demonstration Site in late-Spring to early-Summer, obtained in shore surveys on May 1, 12, 27 & June 12, 2010.

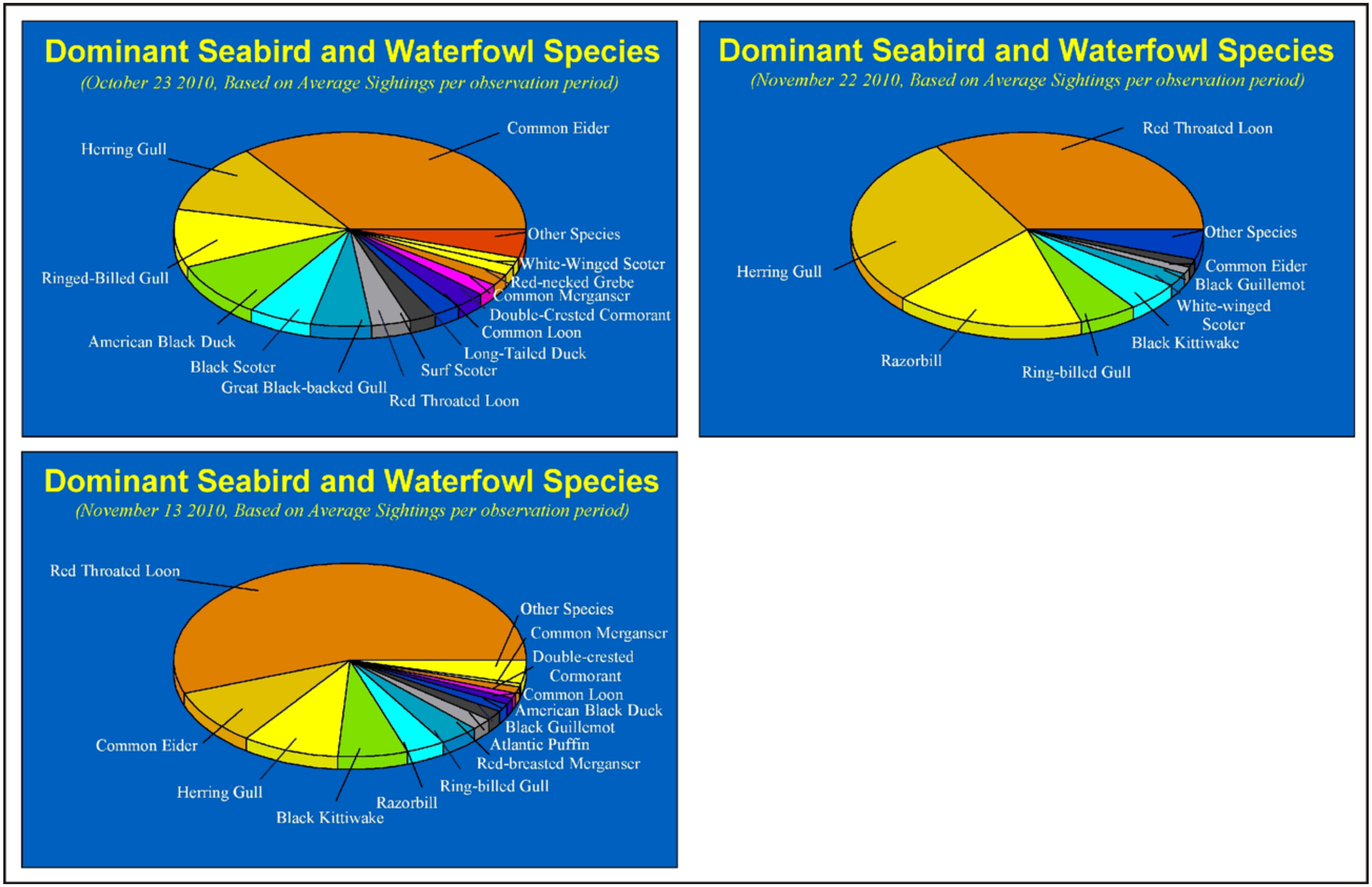

Figure 25. Dominant species of seabirds and other waterfowl at the Fundy Tidal Demonstration Site in late Fall, obtained in shore surveys on October 23 and November 12 & 22, 2010.

Overall abundance of birds was moderate in spring-early summer, reached a peak in mid-June and was moderate in May (May 1st & 27th) (Figure 26) when dominant species were Great Black-Backed & Herring Gulls (Figure 24). Abundance was low in October and in late November, but showed a large peak concentration of migrating Red-Throated Loons in early November (November 13th). Greatest concentrations of birds were observed between Black Rock and shore for the May 27 & June 12 surveys (Great Black-Backed & Herring Gulls dominant); within the proposed turbine development site on November 13th (Red-Throated Loons dominant); and in Minas Passage ('Outside' Black Rock) during October 23 & November 22 surveys (Common Eider, Herring Gulls and Red-Throated Loons dominant)(Figure 26)[11].

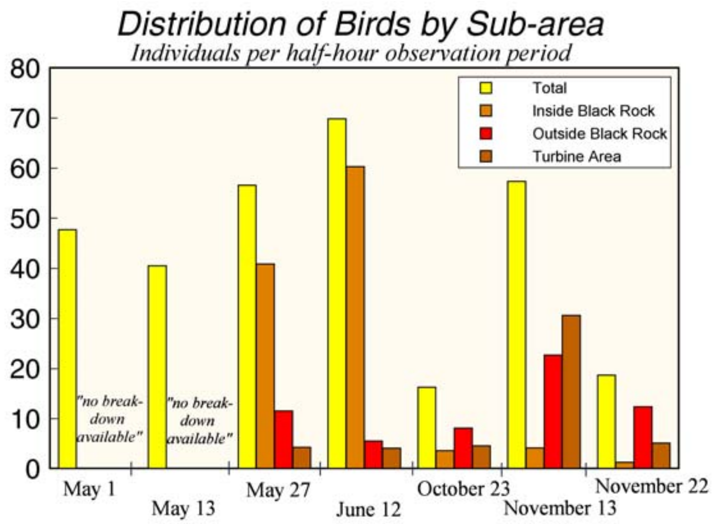

Figure 26. Abundance of seabirds and other water-associated birds (individuals per 30-minute observation period) at the FundyTidal Power Demonstration site, May – November 2010.

Abundance and Seasonal Occurrence of Gulls

Gulls were commonly seen at the site. In total seven gull species, (Great Black-Backed, Herring, Iceland, Laughing, Mew, Lesser Black-Backed and Ring-Billed Gull) were observed with Great Black-Backed and Herring Gull the most abundant gull species and the most abundant bird species overall. Mew and Laughing Gull were each only observed once (November 13 & June 12 surveys, respectively) (Figure 27).

Great Black-Backed Gull—Great Black-Backed Gull was the most abundant gull species overall and was observed during all surveys (Figure 27). It was the most abundant and dominant seabird during May surveys (42-55% of sightings) though numbers declined significantly in the October and November surveys (~6% and 0.3-0.9% of sightings, respectively) (Appendix A).

Herring Gull—Herring Gull was the second most abundant gull species and was observed during all surveys (Figure 27). It was the dominant and most abundant species in June (32% of sightings, averaging 22.5 individuals sighted per observation period), and was second or third most abundant bird species in all other surveys. Lowest abundance occurred during the October survey (11.8% of sightings) (Appendix A).

[11] A breakdown of bird abundance by area was not available for May 1st & May 13th surveys.

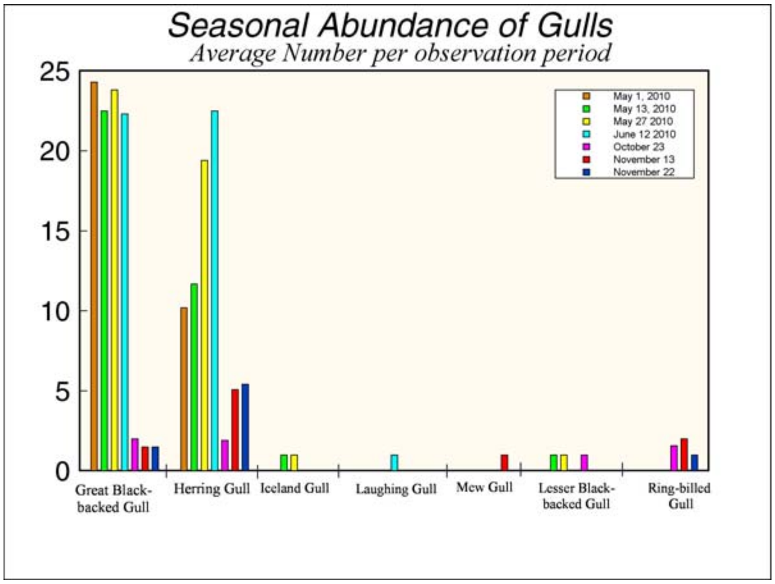

Figure 27. Abundance of gulls at Fundy Tidal Power Demonstration site, May-June and October-November, 2010.

Iceland Gull—Iceland Gulls migrate into the Bay of Fundy in late Fall and leave by late spring, except for a few immature and sub-adults which become summer residents. The winter resident population is less abundant than in past due to climate change (winters are warmer). The species was observed only once on each of the May 13 & 27th surveys and consequently was not a dominant in the community at the site (0.2 & 0.14% of sightings per survey, respectively) (Figure 27)(Appendix A).

Laughing Gull—Laughing Gull breed at the mouth of the Bay of Fundy and occasionally appear further up the Bay following surface 'bait' fish species. This species is an uncommon but regular stray to Nova Scotia, often occurring after storms originating to the south (it is our common 'Hurricane Gull'). Laughing Gull was observed once (June survey) and subsequently was low in abundance and dominance (0.08 per observation period, 0.11% of sightings)(Figure 27) (Appendix A).

Mew Gull—The European Mew or Common Gull appears in Nova Scotia waters as a rare but regular stray from the east via Newfoundland. The species is seen on the Atlantic coast of Nova Scotia most years from Cape Breton to Cape Sable Island, but is seen less frequently on the Fundy shore (there are fewer than ten records). The number reported each year is small, mainly as Spring and Fall transients or Winter residents. One Mew Gull was observed on the November 13th survey (0.08 individuals per observation period, 0.14% of sightings) (Appendix A).

Lesser Black-Backed Gull—The Lesser Black-Backed Gull is an uncommon transient that may breed here. It has been recorded in all seasons including as a winter and summer resident in small numbers. The species was observed during 3 of 7 shore-based surveys (May 13th & 27th and October 23rd) in low abundance and dominance (0.08 per observation period, 0.2, 0.14 and 0.49% of sightings on each survey respectively) (Appendix A).

Ring-Billed Gull—Ring-Billed Gulls occur near the coast and around offshore islands when not breeding; but are found inland on freshwater lakes, ponds, marshes during the breeding season. They feed on insects, crustaceans, mollusks & invertebrates along the shore, and sometimes pirate food from other species. They occurred occasionally in moderate abundance and dominance during October & November surveys (9.7, 3.5 and 5.4% of sightings) (Appendix A).

Abundance and Seasonal Occurrence of Waterfowl

Waterfowl (ducks & geese, scoters, and mergansers) were also commonly observed at the study site. Of the eleven waterfowl species seen, Common Eider was the most prevalent—present during all surveys with greatest and least concentrations observed on June 12 and November 22, respectively (Figures 24, 25 & 28). Other species including American Black Duck, White-Winged Scoter, Surf Scoter, Black Scoter, Red-Breasted Merganser, Common Merganser, Harlequin Duck, Long-Tailed Duck, Mallard and Canada Goose were observed occasionally and in low concentrations.

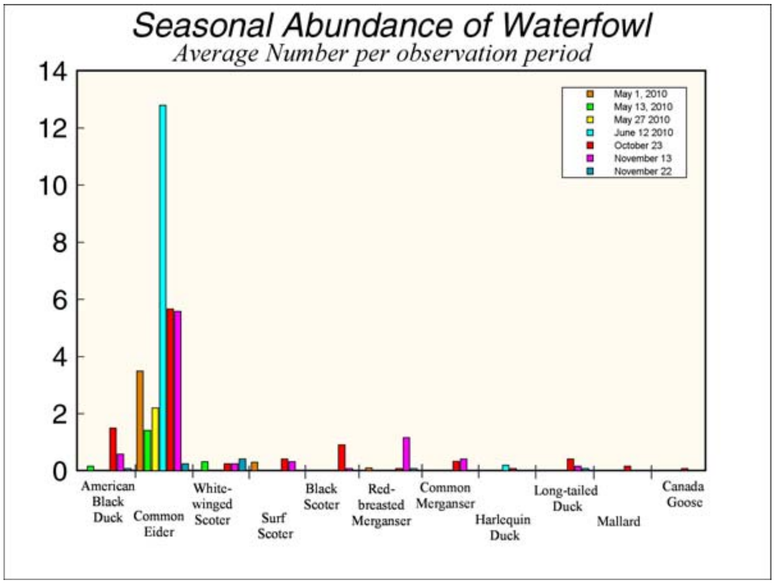

Figure 28. Abundance of waterfowl at the Fundy Tidal Power Demonstration site, May-June and October-November, 2010.

Common Eider—Common Eider was common and abundant in all shore-based surveys and was one of the overall dominants at the site (Figures 24, 25 & 28). It peaked in abundance in June (Figure 28), but was also abundant during the October and November 13 surveys (35% and 9.7% of sightings respectively) (Appendix A).

American Black Duck—This species breeds in, and migrates through, the area in Spring and Fall and is commonly present in winter. It is often seen feeding on tidal flats, and is known to rest on open salt water, occasionally far from shore. American Black Duck occurred occasionally in surveys (mid-May, October and November). It was the fourth most abundant species in the October survey (9.2% of sightings) and present in low abundances and dominance (0.42 to 1.0% of sightings) in the other surveys (Figures 24, 25 & 28)(Appendix A).

White-Winged Scoter—This scoter commonly migrates through the area in Spring and Fall, and regularly winters in moderate numbers. The species feeds over sea ledges and along shorelines, diving to the bottom for shellfish. White-Winged Scoter occurred in low abundances during mid-May, October and November surveys, and was one of the lesser species in terms of dominance (ranging from 0.4 to 6.2% of sightings in the seven surveys) (Figures 24, 25 & 28)(Appendix A).

Surf Scoter—This scoter commonly migrates through the area in Spring and Fall and regularly winters in moderate numbers. Surf Scoter feeds over sea ledges and along shorelines, diving to the bottom for shellfish. The species occurred in low abundance (0.58 - 2.6% of sightings) in early May, October and early November surveys (Figures 24, 25 & 28) (Appendix A).

Black Scoter—Black Scoter commonly migrate through the area in spring and fall and regularly winter in moderate numbers. They feed on shellfish, which they find on the seabed of sea ledges and along shorelines. The species occurred in low abundance (0.92 & 0.08 individuals per observation period) and was relatively abundant in October and early November surveys (5.7% & 1.7% of sightings) (Figures 25 & 28) (Appendix A).

Red-Breasted Merganser—Mergansers breed in, and migrate regularly through, the inner Bay of Fundy in Spring and Fall. The Red-Breasted Merganser is common in moderate numbers in shallow coastal areas, and feeds by diving for fish in shallow water. Red-Breasted Mergansers were occasionally seen in low abundance and low dominance (0.19 - 2.0% of sightings) during early May, October and November surveys (Figures 24, 25 & 28)(Appendix A).

Common Merganser—Mergansers breed in and migrate regularly through the area spring and fall. The Common Merganser is rare to uncommon in salt water except where rivers and streams enter the ocean. They are known to feed by diving for fish in shallow water. Common Merganser was observed during the November 13th survey only when it was in low abundance and dominance (0.73% of sightings) (Figures 25 & 28) (Appendix A).

Harlequin Duck—This species migrates in small to moderate numbers through the area in spring and fall, and regularly winters in small numbers along Atlantic shores. It feeds on shellfish along rocky shorelines, diving to moderate depths. The species is listed federally as a species of Special Concern under the *Species at Risk Act.* Harlequin Duck was observed in low numbers in two of the seven surveys (June and October) (0.24 & 0.49% of sightings respectively) (Figures 24, 25 & 28) (Appendix A).

Long-Tailed Duck—This species is a common migrant through the area in Spring and Fall in moderate to high numbers, and is normally abundant in Winter. It dives for small shellfish along shorelines and in shallow bays with sandy bottoms. Long-Tailed Duck were present during fall migration (October-November) in low abundance and were a minor component of the waterfowl community at the site (0.3-2.6% of sightings) (Figures 25 & 28) (Appendix A).

Mallard—American Mallard breeds in, and migrates through, the area in Spring and Fall. The species is an uncommon sight in coastal areas, where it feeds on tidal flats. Mallards were observed during the October survey only, and in small numbers (0.17% of individuals & 1.0% of sightings per observation period) (Figures 25 & 28) (Appendix A).

Canada Goose—Canada Geese breed in and migrate through the area routinely in moderate to large numbers, and the species is a regular winter resident. It feeds in crop fields near the ocean and on mudflats, and is often seen resting on salt water while waiting for the tide to recede. Only one Canada Goose was observed in the shore-based surveys (October survey) and it was a minor species overall (0.5% of October sightings) (Figures 25 & 28) (Appendix A).

Abundance of Loons

Three loon species (Red-Throated, Common and Pacific) were observed during the shore-based surveys, with Red-Throated Loons most abundant, followed by Common Loon and then Pacific Loon.

Concentrations of Red-Throated Loon peaked with the November 13, 2010 survey, dominating numbers of all other seabird and waterfowl species (Figures 24, 25 & 29).

Red-Throated Loon—The Red-Throated Loon migrates through the area spring and fall. It is common and abundant at times, wintering in small numbers. It feeds on small fish at various depths, including the deepest water. It was observed during all surveys and was the most abundant and dominant bird species during the November surveys (31.9 & 6.3 individuals per observation period, and 33 - 56% of sightings). Numbers were significantly lower in other surveys (0.2 – 5.0% of sightings) with the lowest abundance occurring during the June survey (0.17 individuals per observation period) (Figures 24, 25 & 29)(Appendix A).

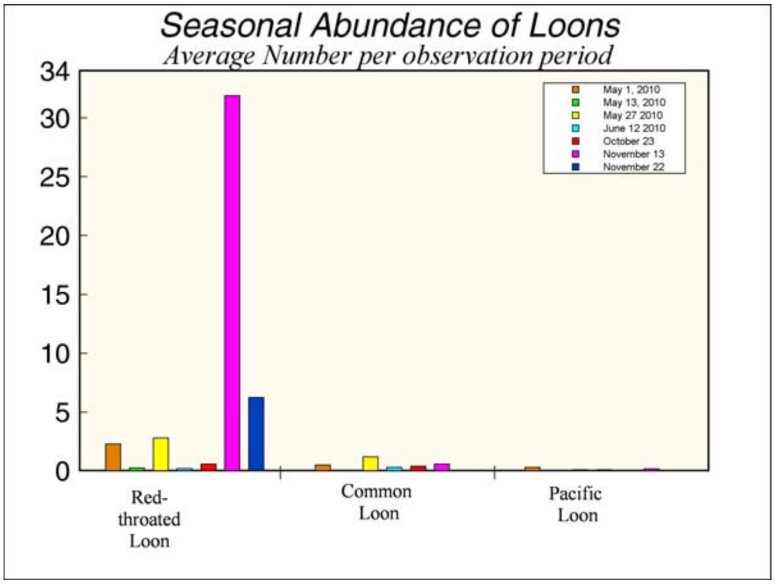

Figure 29. Abundance of loons at the Fundy Tidal Power Demonstration site, May-June and October-November, 2010.

Common Loon—Common Loon were observed during all surveys with the exception of May 13th. The species occurred in generally low abundance (0.08 - 1.17 individuals per observation period) and low dominance (0.36-2.1% of sightings) with the greatest abundance occurring in October and the lowest in late November (Figures 24, 25 & 29)(Appendix A).

Pacific Loon—This species migrates through the area in Spring and Fall. It is rare at all times, and occasionally overwinters. Pacific Loon feeds on small fish at various depths but mainly in deepest water. It was observed in four of seven surveys (May 1, May 27, June 12 & November 13) in low numbers (0.08 - 0.27 per observation period), but was most abundant during the May 1 survey (0.27 individuals per observation period) (Figures 24, 25 & 29)(Appendix A).

Other Seabird Species

Various other seabird species were observed during most surveys, some of which were relatively abundant, while some occurred only occasionally. Species which were more important in terms of numbers and frequency of occurrence included: Double-Crested Cormorant, Great Cormorant, Northern Gannet and Black Guillemot. Several species including Razorbill, Horned Grebe, Red-Necked Grebe, Atlantic Puffin, Common Murre, Thick-billed Murre and Black-Legged Kittiwake, were present only occasionally and in generally lesser numbers; however flocks of Black-Legged Kittiwakes and most of the alcid species (e.g. Razorbill) occurred in the Fall migratory period (November 22) (Figures 24, 25 & 30).

Double-Crested Cormorant—Double-Crested Cormorants were observed during all surveys with the exception of the late November survey. Numbers were greatest during May (1 & 27) and June surveys (1.5 - 4.5 individuals per half hour observation period). This cormorant was the fourth most abundant species observed during the June survey (6% of sightings) (Figures 24, 25 & 30) (Appendix A).

Great Cormorant—This species breeds in and migrates through the area in small numbers in Spring and Fall, and also winters in moderate numbers. The Great Cormorant is known to dive deeper and feed further offshore than other cormorant species. Great Cormorants were observed during all surveys with the exception of the late November survey. Numbers were greatest during May (1 & 27) and June surveys (0.58 - 1.1 individuals per half hour) (Figures 24, 25 & 30) (Appendix A).

Northern Gannet—Northern Gannet occurred fairly commonly during the study, observed during four of the seven surveys. Abundance of Northern Gannet peaked in June (3.1 individuals per observation period) and it placed as third (6% of sightings) and fifth (4.4% of sightings) most dominant species for the May 13 and June 12 surveys, respectively (Figures 24, 25 & 30) (Appendix A).

Black Guillemot—Black Guillemot were observed during all surveys with varying abundances (0.08 - 3.18 individuals per observation period), with greatest numbers in May 27th (3.8 individuals per period) and least in October 23 (0.08 individuals per period). It was the third and fourth most abundant species (6.6% & 6.7% of sightings) during May 27 and May 1 surveys respectively (Figures 24, 25 & 30) (Appendix A).

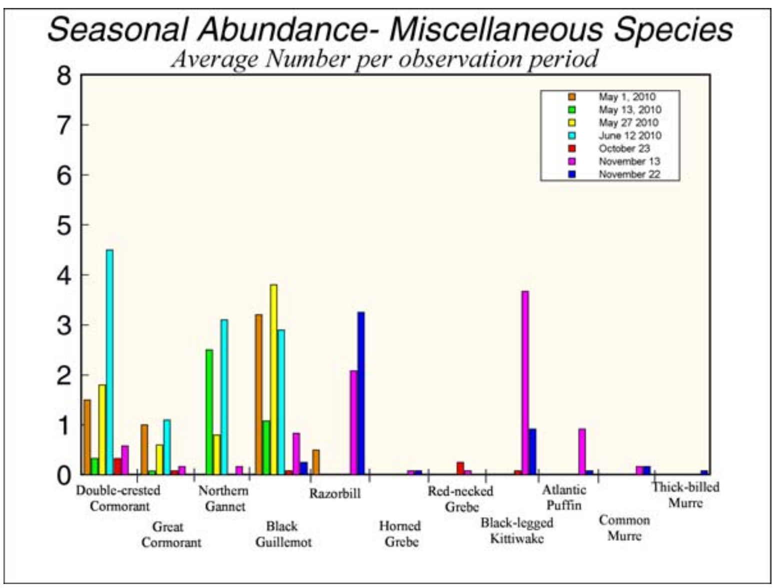

Figure 30. Abundance of miscellaneous seabird and waterfowl species at the Fundy Tidal Power Demonstration site, May-June and October-November, 2010.

Razorbill—Razorbill, a member of the Alcid family, breeds in the Bay of Fundy where it maintains a fairly stable population in the southwest end of the Bay. Populations are highest in the Winter, when numbers are augmented by northern migrants. The species feed on small fish and will sometimes dive to considerable depths to capture prey. Razorbill was observed during May (1st) and November (13th & 22nd)

surveys in moderate abundances (0.55 - 3.25 individuals per observation period). It was the third (17% of average sightings per survey) and fifth (3.6% of average sightings per survey) most abundant species in November 22 and 13 surveys, respectively (Figures 24, 25 & 30) (Appendix A).

Horned Grebe—Horned Grebe is a small waterfowl species which migrates through the area in Spring and Fall. The species is marginally common to uncommon, and sparse to moderately abundant in numbers in winter, feeding on small fish at all depths. Horned Grebe occurred in low numbers, represented by a single individual (0.08 per observation period) during November surveys (Figures 25 & 30) (Appendix A).

Red-Necked Grebe—This species migrates through the area Spring and Fall, and are marginally common to uncommon, and sparse to moderately abundant in numbers in Winter, feeding on small fish at all depths, but mainly in deep water. The species occurred in low numbers and abundance (0.08 & 0.25 individuals per observation period) during early November and October surveys, respectively, and were not observed in other surveys (Figures 25 & 30) (Appendix A).

Atlantic Puffin—Atlantic Puffin breed in the Bay of Fundy and have fairly stable populations at the southwest end of the Bay; populations are highest in the Bay of Fundy in winter, made up of individuals from local populations as well as from northern migrants to the area. Puffin feed on small fish and will sometimes dive to considerable depths to capture prey. The species was moderately abundant during the November 13th survey and a single Atlantic Puffin was observed during the November 22 survey (0.9 and 0.1 individuals per observation period respectively) (Figures 25 & 30) Appendix A).

Common Murre—The Common Murre has only recently begun breeding in the Bay of Fundy and its occurrence is rare. Populations are highest in the winter, augmented by northern winter migrants. The species feeds on small fish and will sometimes dive to considerable depths to capture prey. Common Murre were observed only during November surveys and in low abundance and dominance (0.17 individuals per observation period in both surveys) (Figures 25 & 30) (Appendix A).

Thick-Billed Murre—This northern alcid visits the area from late Fall to early Spring, with stragglers (non-breeders) sometimes summering. Winter residents are present in modest numbers most years, with rare spikes in the population during very cold winters. Thick-Billed Murre often dive for fish in extremely deep waters. Only one was observed (November 22nd survey) throughout the course of the study (Figures 25 & 30) (Appendix A).

Black-Legged Kittiwake—Black-Legged Kittiwakes are regular Summer and Winter residents in the Bay of Fundy, as well as Fall and Spring transients. Modest numbers of mainly sub-adults summer here, while larger numbers overwinter. Occasionally thousands are blown in from the Gulf of Maine by southerly gales. The species was observed only in the last three surveys (October & November) in low to moderate abundances (0.08 - 3.7 individuals per observation period). Abundance and relative dominance (3.7 individuals per period and 6.4% of sightings respectively) peaked in early November when kittiwakes were the fourth most abundant species observed (Figures 25 & 30) (Appendix A).

4 CONCLUSIONS AND RECOMMENDATIONS

Overall

Conducting routine shore- and vessel-based surveys in Minas Passage and adjacent areas in 2010 has been useful as part of an overall environmental monitoring program for the tidal demonstration site. The present surveys, which were intended to provide additional coverage during bird migration periods, provided an overview of bird and marine mammal seasonal distributions, as well as information on timing and abundance of seabirds and waterfowl, both at the tidal power demonstration site and in the Inner Bay of Fundy including Minas Channel, Minas Passage, and Minas Basin. The surveys also provided information on occurrence and seasonal timing of Harbour Porpoise, the most-commonly-occurring marine mammal at the site and also a Species at Risk, with *threatened* status under the federal *Species at Risk Act.* Harbour Porpoise is a representative of one of the important animal groups—Cetaceans—potentially impacted by tidal power turbine installations, and their abundance and activities in the area may be a useful indicator of environmental change and the impacts of tidal turbines in Minas Passage.

Seabird densities in the study area measured in 2009 and 2010 are slightly lower than or comparable to densities for other Nova Scotia waters. Densities were lower than typical seabird densities in coastal and shelf areas in Nova Scotia waters (Fifield et al. unpublished manuscript) although peak densities can be comparable to those from adjacent areas of the Bay of Fundy (Lock et al. 1994) (Envirosphere Consultants 2010). The 2010 observations, combined with those of earlier baseline and monitoring studies carried out by FORCE, continue to suggest that the tidal demonstration site is not exceptionally important in terms of seabird and waterfowl abundance in the Inner Bay of Fundy.

Marine Mammals

Shore-based surveys for seabirds and waterfowl provided unexpected and significant information on the occurrence of Harbour Porpoise in the study area—showing that the species commonly occurred in most survey periods—as well as providing insight into movement and activity patterns. Only limited information was gathered on the behaviour of the species under different conditions of tide (most observations were made on ebbing tides from the end of slack water at high tide to the beginning of slack water at low tide). Future surveys could plan to collect more detailed information on the species when observed. No particular association of Harbour Porpoise was noted with the proposed location of tidal turbines, and, in addition, all individuals were swimming in the direction of the ebbing tide, and were thus near the surface. However the survey represents only a snapshot of daily activities of the species through the tidal cycle. Additional useful information on behaviour may be obtained by focusing observations on slack tide and flood tide conditions. In addition, the lack of summer to early-Fall observations at the study site, as well as observations in the late-March to early-May period, is a gap in assessing the overall pattern of abundance of Harbour Porpoise at the site. The daily movements of Harbour Porpoise are part of a larger pattern involving adjacent areas of Minas Basin and Minas Channel and also likely interactions with fish movements in the area, little of which can be determined from point observations at the study site. However the observations have provided information on local behaviour and distribution which may be valuable in assessing project impacts. Harbour Porpoise may therefore be an important indicator species at the site meriting additional observational effort in future.

Negligible sightings of marine mammals were made on vessel surveys in 2010 (only 5 Harbour Porpoise and no other species were observed in July and August combined) but similar surveys the previous year were more successful, in particular identifying various species of marine mammal including an unidentified whale and White-Sided Dolphin. Vessel-based surveys for seabirds provide useful additional information on marine mammals, in particular of other less common species of whales and dolphins, to aid in understanding their distributions and possible impacts of tidal device installations on them. Combining a limited number of vessel surveys with shore-based surveys may be an appropriate monitoring approach for both seabirds and marine mammals at the tidal installation site.

Seabirds and Waterfowl

The goal of the present project was to provide information on seabird and waterfowl species migrating through the study area in the Spring and Fall, and in particular to document the occurrence of diving birds such as loons, which are the most likely—because of their diving habits—to interact with sub-sea devices such as turbines. The shore-based component of the survey showed a Fall peak in migrants but a Spring peak, which was expected to occur, was not demonstrated, suggesting either that it occurred earlier in the year than the period covered by the survey or that it is not as pronounced at the site as in other areas. Many of the same species, including both the dominants and less common birds, were present throughout the May-November survey period, but highest number of species, representing the Fall migration, were only observed in October-November.

Loons were the principal family of water-associated birds targeted by Spring and Fall observations in the study, since they are known to migrate through the area and they feed by diving and consequently may interact with turbines. The Red-Throated Loon was the most abundant of the loon species observed (which also included Common Loon and Pacific Loon) and was particularly abundant in mid-November. In addition to the occurrence of loons in the Fall, however, another group of birds known for diving—the alcids (e.g. Common Murre, Thick-Billed Murre, Razorbill, and Atlantic Puffin)—appeared at the study site in mid- to late-November, and Razorbill occurred in the first May survey. These typically northern species, but which in the Bay of Fundy are a mix of winter migrants to Nova Scotia combined with some residents, are likely to be more common in the study area in winter. Because they are divers, and some (e.g. the Razorbill) are known to be deep divers, and because of their likely occurrence in the area in winter, they have the potential to be affected by interactions with turbines and their winter occurrence in the area is a potential data gap. Surveys extending earlier in the Spring to capture the spring migrants, as well as in mid-March and December, may be sufficient to document the winter occurrences of alcid species. Recommended surveys and rationale for 2011 are presented below:

Recommended Surveys for Seabirds and Marine Mammals,
Fundy Tidal Power Demonstration Site, 2011.

Type of Survey	Suggested Times	Number of Surveys	Critical Periods and Species Covered
Shore-Based Surveys	- mid-March	1	Late winter observations of over-wintering alcids and harbour porpoise.
	- early April - mid- April - early May	3	Early spring migration of loons and overwintering alcids; occurrence of harbour porpoise.
	- early December - mid-December	2	Winter observations of over-wintering alcids and harbour porpoise.
Vessel Surveys	- mid-July - mid-August	2	Summer, repeat earlier surveys of seabirds and marine mammals for continuity and monitoring purposes.

The vessel-based survey provided additional information on seabird abundance in mid-Summer, which allowed comparison to two surveys in July and August 2009, showing a core group of eight species: Herring, Great Black-Backed and Ring-Billed Gull; Common Loon, Common Eider, Black Guillemot, Double-Crested Cormorant and Northern Gannet which occurred with similar dominance relationships in terms of abundance in both years. Repetition of the July-August vessel surveys in future years, using abundance of the most abundant species as well as the combined abundance estimates of the core group, may provide an indicator of change in the communities in the site as part of a monitoring program (see table above). It would also increase the chances of sighting Harbour Porpoise and other marine mammals such as whales, which are important but poorly-studied components of the ecosystem in the Inner Bay of Fundy, and for which there is a lack of distribution and abundance information in the area.

Additional Ecosystem Components

The shore-based seabird and waterfowl survey also yielded information on the activity and catch of a fisherman using an anchored gill net at the site (although not reported here, herring and mackerel were commonly caught in May-June) and also observations of wildlife and environmental conditions on the shoreline and adjacent salt marsh areas. The shore-based surveys thus provide an opportunity to collect additional relevant environmental information at the site and this opportunity should be considered in deciding on future monitoring for the project.

5 REFERENCES

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APPENDIX A– Observational Data from Shore-Based Surveys, 2010

(Species names and associated codes are shown in Table 6.

Table A-1. Overall summary table for May 1, 2010 Survey.

Species	Date: May 1, 2010, 13:07 hrs to 18:37 hrs				Observer: Fulton Lavender							
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Overall.**											
	Number of Individuals Sighted per Observation Period											
	1	2	3	4	5	6	7	8	9	10	11		
RTLO	5			1				10	8	1			2.3
COLO	2		1		1	1							0.5
PALO		1					1	1					0.3
DCCO	6	3	1				1	3		2			1.5
GRCO	2		1	2	1	1	1	1	1	1			1.0
COEI	15			4	2	1	1	2	10		3		3.5
SUSC	3												0.3
RBME		1											0.1
GBBG	24	28	19	28	24	27	25	20	21	24	27		24.3
HEGU	9	7	8	7	9	9	9	10	8	16	20		10.2
BLGU	2	3			4	4	8	5	7	1	1		3.2
RAZO											6		0.5
												Total	47.7

Table A-2. Overall summary table for May 12, 2010 Survey.

Species	Date: May 13, 2010, 1130 hrs to 1730 hrs.				Observer: Fulton Lavender							
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Overall.**											
	Number of Individuals Sighted per Observation Period											
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO				3									0.3
DCCO			1	1			1			1			0.3
GRCO			1										0.1
NOGA	1					5		2	1	3	12	6	2.5
ABDU												2	0.2
COEI			4	2	1	2	1	3			3	1	1.4
WWSC											4		0.3
GBBG	26	30	23	31	23	18	22	16	20	20	19	22	22.5
HEGU	9	29	15	12	10	13	7	10	7	7	12	9	11.7
ICGU						1							0.1
LBBG									1				0.1
BLGU	5	5		3									1.1
												Total	40.5

Table A-3a. Overall summary table for May 27, 2010 Survey.													
Species	Date: May 27, 2010.						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Overall.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	5	2	2	5	6	2	2	1	2	3	3	1	2.8
PALO											1		0.1
COLO			2	3	5					3		1	1.2
DCCO	1	1			1	7		5		2	2	2	1.8
GRCO	1			1		1	1			1	1	1	0.6
NOGA								2		2	6		0.8
COEI	4	7					2	1	6	2	2	2	2.2
GBBG	27	32	35	23	26	30	21	21	21	15	18	17	23.8
HEGU	26	21	32	14	13	28	16	17	17	9	25	15	19.4
ICGU											1		0.1
LBBG											1		0.1
BLGU	2	5	3	7	6	6	5	4	2	1	4		3.8
												Total	57.0

Table A-3b. Inside Black Rock summary table for May 27, 2010 Survey.													
Species	Date: May 27, 2010.						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Inside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO									1	1			0.2
PALO													
COLO				3									0.3
DCCO										1		1	0.2
GRCO	1			1		1	1			1	1	1	0.6
NOGA													
COEI	4	7					2	1	6	2	2	2	2.2
GBBG	26	24	26	22	25	25	21	20	18	15	16	17	21.0
HEGU	19	13	17	11	11	12	13	13	14	8	17	15	14.0
ICGU													
LBBG													
BLGU	2	5	3	6	3	2	3	2	1	1	4		2.7
												Total	41.0

Table A-3c. Outside Black Rock summary table for May 27, 2010 Survey.													
Species	Date: May 27, 2010.						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Outside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	5	2	2	5	4	2	2		1	2	3	1	2.4
PALO											1		0.1
COLO					2							1	0.3
DCCO	1	1								1	1		0.3
GRCO													
NOGA								2		2	6		0.8
COEI													
GBBG	1	7	8			5		1	3		2		2.3
HEGU	7	8	12	2	2	15	3	2	2	1	4		4.8
ICGU													
LBBG											1		0.1
BLGU						1	2	2					0.4
												Total	12.0

Table A-3d. Turbine area summary table for May 27, 2010 Survey.													
Species	Date: May 27, 2010.						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Turbine area.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO					2			1					0.3
PALO													
COLO			2		3					3			0.7
DCCO					1	7		5			1	1	1.3
GRCO													
NOGA													
COEI													
GBBG		1	1	1	1								0.3
HEGU			3	1		1		2	1		4		1.0
ICGU											1		0.1
LBBG													
BLGU				1	3	3			1				0.7
												Total	4.3

Table A-4a. Overall summary table for June 12, 2010 Survey.													
Species	Date: June 12, 2010, 11:00 TO 16:30 hrs						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Overall.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO					1			1					0.2
PALO					1								0.1
COLO				1	1		1						0.3
DCCO	2	2	4	2	1	1	4	1	3	3	1	4	4.5
GRCO	1	1	2	1	1	1	1	1	1	1		1	1.1
NOGA	1	2		2		2		1	2	1	3	1	3.1
COEI	3	1	2	4	2	1	3	4	1	4	4	4	12.8
HADU	1									1			0.2
GBBG	3	6	3	2	2	4	5	2	2	2	3	7	22.3
HEGU	5	6	3	3	2	1	5	6	8	3	7	15	22.5
LAGU			1										0.1
BLGU	3	3	4	3	1	1	2	2	1	2	1	1	2.9
												Total	69.8

Table A-4b.Inside Black Rock summary table for June 12, 2010 Survey.													
Species	Date: June 12, 2010, 11:00 TO 16:30 hrs						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Inside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO													
PALO													
COLO				1	1								0.2
DCCO	2	6	6	8	6	2	3	5	3	4	1	5	4.3
GRCO	1	1	3	1	1	1	1	1	1	1		1	1.1
NOGA													
COEI	11	6	10	15	15	18	16	10	6	17	10	19	13.0
HADU	1									1			0.2
GBBG	25	21	27	28	24	21	23	21	14	15	14	13	21.0
HEGU	17	19	13	17	16	20	14	20	16	16	21	33	19.0
LAGU													
BLGU	6	4	6	4	1	1	4	4		1	1	2	2.8
												Total	60.2

Table A-4c. Outside Black Rock summary table for June 12, 2010 Survey.													
Species	Date: June 12, 2010, 11:00 TO 16:30 hrs						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Outside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO								1					0.1
PALO													
COLO							1						0.1
DCCO													
GRCO													
NOGA	3	1		2				1	13		5	1	2.2
COEI													
HADU													
GBBG		3				2			1			2	0.7
HEGU	8	3		1	2		3	3	7		1	2	2.5
LAGU													
BLGU													
												Total	5.5

Table A-4d. Turbine area summary table for June 12, 2010 Survey.													
Species	Date: June 12, 2010, 11:00 TO 16:30 hrs						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22,263N, 64 24.348W, **Turbine Area.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	Average
RTLO					1								0.1
PALO					1								0.1
COLO													
DCCO			1				2						0.3
GRCO													
NOGA		1				6				3	1		0.9
COEI													
HADU													
GBBG		1		1		3	1				1	6	1.1
HEGU			1				1				4	12	1.5
LAGU			1										0.1
BLGU										1			0.1
												Total	4.1

Table A-5a. Overall summary table for October 23, 2010 Survey.												
Species	Date: October 23, 2010						Observer: Fulton Lavender					
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Overall.**											
	Number of Individuals Sighted per Observation Period											
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO						3					3	1	0.6
COLO					1				1	2	1		0.4
DCCO									1	1	1	1	0.3
GRCO					1								0.1
ABDU					3		15						1.5
COEI	5	4	3	28	3	1	15	2	1			6	5.7
WWSC			1	2									0.3
SUSC		5											0.4
BLSC				1			10						0.9
RBME										1			0.1
COME						4							0.3
HADU			1										0.1
GBBG	6	2	3										0.9
HEGU	2	1	5	2		1	2	2	3		2	3	1.9
LBBG												1	0.1
BLGU												1	0.1
BLKI												1	0.1
RBGU	1		1	2		1	2	3	1	3		5	1.6
LTDU		2		1	2								0.4
RNGR			3										0.3
MALL							2						0.2
CAGO		1											0.1
												Total	16.3

Table A-5b. Inside Black Rock summary table for October 23, 2010 Survey.												
Species	Date: October 23, 2010						Observer: Fulton Lavender					
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Inside Black Rock.**											
	Number of Individuals Sighted per Observation Period											
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
DCCO									1	1	1	1	0.3
COLO										1	1		0.2
HEGU						1			2				0.3
BLGU												1	0.1
COEI	4	4	3	3	1	1	1	2	1			4	2.0
HADU			1										0.1
BLSC				1									0.1
ABDU					3								0.3
COME						4							0.3
												Total	3.6

Table A-5c. Outside Black Rock summary table for October 23, 2010 Survey.													
Species	Date: October 23, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Outside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
COLO					1				1				0.2
RTLO						1					3	1	0.4
RNGR			3										0.3
HEGU	2	1	4				2		1		2	2	1.2
RBGU	1			2		1	1	3	1	3		4	1.3
GBBG	6	2	3										0.9
LBBG												1	0.1
COEI				25	2		14					2	3.6
WWSC			1										0.1
RBME										1			0.1
												Total	8.08

Table A-5d. Turbine area summary table for October 23, 2010 Survey.													
Species	Date: October 23, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Turbine Area.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
GRCO					1								0.1
COLO										1			0.1
RTLO						2							0.2
HEGU			1	2				2				1	0.4
RBGU			1				1					1	0.3
BLKI												1	0.1
COEI	1												0.1
SUSC		5											0.4
BLSC							10						0.8
WWSC				2									0.2
LTDU		2		1	2								0.4
ABDU							15						1.3
MALL							2						0.2
CAGO		1											0.1
												Total	4.3

Table A-6a. Overall summary table for November 13, 2010 Survey.													
Species	Date: November 13, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Overall.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	7	11	13	8	6	11	13	40	93	129	40	12	32.0
PALO											1	1	0.2
RNGR						1							0.1
COLO		1				1			3		1	1	0.6
HOGR						2	1						0.3
DCCO		2		2	1							2	0.6
GRCO		1									1		0.2
NOGA							1				1		0.2
COEI	2				12		6		17	15	15		5.6
GBBG				1								1	0.2
BLKI	9							35					3.7
MEGU					1								0.1
RBGU	5		2	8	8		2						2.1
HEGU	12	5	8		6		10		20				5.1
RAZO		1		7	12			2	1				1.9
COMU		2											0.2
ATPU				1			4			2	3	1	0.9
ABDU						4						3	0.6
BLSC											1		0.1
SUSC	4												0.3
WWSC	1				2								0.3
LTDU		2											0.2
COME					3	2							0.4
RBME	3	3	4				1				3		1.2
BLGU					1		2	1	2	4			0.8
												Total	57.3

Table A-6b. Inside Black Rock summary table for November 13, 2010 Survey.													
Species	Date: November 13, 2010							Observer: Fulton Lavender					
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Inside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO							2	5					0.6
PALO													
RNGR													
COLO													
HOGR						2							0.2
DCCO					1							2	0.3
GRCO		1									1		0.2
NOGA													
COEI													
GBBG				1									0.1
BLKI	2												0.2
MEGU													
RBGU			1										0.1
HEGU	1	2	1		2								0.5
RAZO													
COMU													
ATPU													
ABDU						4						3	0.6
BLSC													
SUSC													
WWSC													
LTDU		2											0.2
COME					3	2							0.4
RBME	3	3	3								3		1.0
BLGU													
												Total	4.2

Table A-6c. Outside Black Rock summary table for November 13, 2010 Survey.

Species	Date: November 13, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Outside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	4	5	11	1	1	4	3	28	29	53	10	3	12.7
PALO													
RNGR						1							0.1
COLO						1			3				0.3
HOGR													
DCCO		2		2									0.3
GRCO													
NOGA							1				1		0.2
COEI	2				12					15	15		3.7
GBBG													
BLKI													
MEGU													
RBGU	1			2	4								0.6
HEGU	7		4		4		10		15				3.3
RAZO					11								0.9
COMU													
ATPU							3					1	0.3
ABDU													
BLSC													
SUSC													
WWSC					2								0.2
LTDU													
COME													
RBME													
BLGU								1					0.1
												Total	22.7

Table A-6d. Turbine Area summary table for November 13, 2010 Survey.

Species	Date: November 13, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Turbine Area.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	3	6	2	7	5	7	8	7	64	76	30	9	18.7
PALO											1	1	0.2
RNGR													
COLO		1									1	1	0.3
HOGR							1						0.1
DCCO													
GRCO													
NOGA													
COEI							6		17				1.9
GBBG												1	0.1
BLKI	7							35					3.5
MEGU					1								0.1
RBGU	4		1	6	4		2						1.4
HEGU	4	3	3						5				1.3
RAZO		1		7	1			2	1				1.0
COMU		2											0.2
ATPU				1			1			2	3		0.6
ABDU													
BLSC											1		0.1
SUSC	4												0.3
WWSC	1												0.1
LTDU													
COME													
RBME			1				1						0.2
BLGU					1		2		2	4			0.8
												Total	30.6

Table A-7a. Overall summary table for November 22, 2010 Survey.													
Species	Date: November 22, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Overall.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	2	2	4	6	3	12	12	21	9	1	1		6.3
COLO				1									0.1
HOGR											1		0.1
COEI	3												0.250
GBBG							1			1			0.2
BLKI									7	4			0.9
RBGU						2	5		3	2			1.0
HEGU	4	14	9	7	5	5			18	3			5.4
RAZO							1	20	3		15		3.3
COMU								2					0.2
ATPU										1			0.1
ABDU						1							0.1
WWSC										5			0.4
LTDU								1					0.1
RBME				1									0.1
BLGU			1			1	1						0.3
TBMU											1		0.1
												Total	18.7

Table A-7b. Inside Black Rock summary table for November 22, 2010 Survey.													
Species	Date: November 22, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Inside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	1	1	2	1		2	2	1	1				0.9
COLO													
HOGR													
COEI	3												0.3
GBBG													
BLKI													
RBGU													
HEGU													
RAZO													
COMU													
ATPU													
ABDU													
WWSC													
LTDU													
RBME				1									0.1
BLGU													
TBMU													
												Total	1.3

Table A-7c. Inside Black Rock summary table for November 22, 2010 Survey.													
Species	Date: November 22, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Outside Black Rock.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO	1			3	1	5	13	10	5	1			3.3
COLO				1									0.1
HOGR													
COEI													
GBBG							1						0.1
BLKI									7	1			0.7
RBGU						2	5		3	2			1.0
HEGU	4	14	6	6	4	5			18	2			4.9
RAZO								7	3		15		2.1
COMU													
ATPU										1			0.1
ABDU													
WWSC													
LTDU													
RBME													
BLGU						1	1						0.2
TBMU													
												Total	12.3

Table A-7d. Inside Black Rock summary table for November 22, 2010 Survey.													
Species	Date: November 22, 2010						Observer: Fulton Lavender						
	Location: Beach berm in front of Fundy Tidal Power shore facility, Black Rock 45 22.263N, 64 24.348W, **Turbine Area.**												
	Number of Individuals Sighted per Observation Period												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
RTLO		1	2	2	2	5	6	3	3		1		2.1
COLO													
HOGR											1		0.1
COEI													
GBBG										1			0.1
BLKI										3			0.3
RBGU													
HEGU			3	1	1					1			0.5
RAZO							1	13					1.2
COMU								2					0.2
ATPU													
ABDU						1							0.1
WWSC										5			0.4
LTDU								1					0.1
RBME													
BLGU			1										0.1
TBMU											1		0.1
												Total	5.1

Table A-8. Summary of sightings of water associated bird species at Black Rock Tidal Power demonstration Site, May 1 to November 22, 2010, from shore based observations.

	Individuals observed per 30 minute observation period						
Species	May 1	May 13	May 27	June 12	Oct 23	Nov 13	Nov 22
RTLO	2.27	0.25	2.83	0.17	0.58	31.92	6.25
COLO	0.45		1.17	0.25	0.42	0.58	0.08
PALO	0.27		0.08	0.08		0.17	
DCCO	1.45	0.33	1.75	4.50	0.33	0.58	
GRCO	1.00	0.08	0.58	1.08	0.08	0.17	
NOGA		2.50	0.83	3.08		0.17	
ABDU		0.17			1.50	0.58	0.08
COEI	3.45	1.42	2.17	12.75	5.67	5.58	0.25
WWSC		0.33			0.25	0.25	0.42
SUSC	0.27				0.42	0.33	
BLSC					0.92	0.08	
RBME	0.09				0.08	1.17	0.08
COME					0.33		
HADU				0.17	0.08		
GBBG	24.27	22.50	23.83	22.25	0.92	0.17	0.17
HEGU	10.18	11.67	19.42	22.50	1.92	5.08	5.42
ICGU		0.08	0.08				
LAGU				0.08			
LBBG		0.08	0.08		0.08		
BLGU	3.18	1.08	3.75	2.92	0.08	0.83	0.25
RAZO	0.55					2.08	3.25
HOGR						0.08	0.08
BLKI					0.08	3.67	0.92
RBGU					1.58	2.00	1.00
LTDU					0.42	0.17	0.08
COME						0.42	
RNGR					0.25	0.08	
ATPU						0.92	0.08
MALL					0.17		
CAGO					0.08		
COMU						0.17	0.17
TBMU							0.08
MEGU						0.08	
TOTAL	47.70	40.49	56.58	69.83	16.25	57.33	18.67

Table A-9. Distribution by area of sightings of water associated bird species at Black Rock Tidal Power demonstration Site, May 1 to November 22, 2010, from shore based observations.

	Individuals observed per 30 minute observation period						
Sub-Areas	May 1	May 13	May 27	June 12	Oct 23	Nov 13	Nov 22
Inside Black Rock	--[1]	--[1]	40.83	60.25	3.58	4.17	1.25
Outside Black Rock	--[1]	--[1]	11.50	5.50	8.08	22.67	12.33
Turbine Area	--[1]	--[1]	4.25	4.08	4.58	30.58	5.08
Total	47.7	40.49	56.58	69.83	16.25	57.33	18.67

[1] Observations not separated by sub-area.

Table A-10. Marine mammal sightings at Minas Passage study site, May – November 2010. Average number per 30-mnute observation period.							
	Abundance (Individuals per 30 minute observation period)						
	May 1	May 13	May 27	June 12	Oct 23	Nov 13	Nov 22
Grey Seal	0	0	0	0	0	0.25	0
Harbour Porpoise	0.91	0	0	0.67	0.17	1.17	0.82

Table A-11. Occurrence of water associated bird species at Black Rock Tidal Power demonstration Site, May 1 to November 22, 2010, from shore based observations.							
	Individuals observed per 30 minute observation period						
Species	May 1	May 13	May 27	June 12	Oct 23	Nov 13	Nov 22
RTLO	x	x	x	x	x	x	x
COLO	x		x	x	x	x	x
PALO	x		x	x		x	
DCCO	x	x	x	x	x	x	
GRCO	x	x	x	x	x	x	
NOGA		x	x	x		x	
ABDU		x			x	x	x
COEI	x	x	x	x	x	x	x
WWSC		x			x	x	x
SUSC	x				x	x	
BLSC					x	x	
RBME	x				x	x	x
COME					x		
HADU				x	x		
GBBG	x	x	x	x	x	x	x
HEGU	x	x	x	x	x	x	x
ICGU		x	x				
LAGU				x			
LBBG		x	x		x		
BLGU	x	x	x	x	x	x	x
RAZO	x					x	x
HOGR						x	x
BLKI					x	x	x
RBGU					x	x	x
LTDU					x	x	x
COME						x	
RNGR					x	x	
ATPU						x	x
MALL					x		
CAGO					x		
COMU						x	x
TBMU							x
MEGU						x	
TOTAL	12	12	12	12	23	25	17

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX D

Marine Mammal Detection Final Report

Detection of Marine Mammals and Effects Monitoring at the NSPI (OpenHydro) Turbine Site in the Minas Passage during 2010

FINAL REPORT

prepared by

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for

Fundy Ocean Research Centre for Energy (FORCE)

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Detection of Marine Mammals and Effects Monitoring at the NSPI (OpenHydro) Turbine Site in the Minas Passage during 2010

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1.0 EXECUTIVE SUMMARY

Information available on the near-field effects of tidal in-stream energy conversion (TISEC) devices on marine mammals is sparse. And data on diel activity patterns of marine mammals in the upper Bay of Fundy is lacking. The main questions addressed by this collaborative project between Acadia University and SMRU Ltd, in relation to TISEC device testing, are:

1. What are the activity levels of key cetaceans, specifically porpoises and dolphins, in the Minas Passage turbine demonstration area during late summer/fall?
2. How does porpoise and dolphin presence/activity near the deployed NSPI (OpenHydro) turbine compare with presence/activity at a control site?

The study involved a continuous ~3 month long passive acoustic marine mammal monitoring field study (10 August 2010 – 23 November 2010) while the NSPI (OpenHydro) tidal turbine device was deployed in the Minas Passage. Three C-POD hydrophones (autonomous cetacean echolocation click detectors, Chelonia Ltd) were deployed and recovered using custom-fitted bottom moorings with acoustic releases. Two devices were positioned in close proximity ~150m east and west of the turbine, while a third 'control' device was positioned ~700m west of the turbine site. Two C-PODs (east of the turbine and the control site) recorded click data continuously until the batteries expired (89 and 92 days post-deployment). The remaining C-POD only collected one day of data before stopping and its mooring sub-buoy was recovered damaged. Recommendations for deployment improvements, data loss prevention and future study design are made.

Overall, the key findings of the study were:
1) Confirmation of the ability to collect long-term high quality acoustic cetacean click train data from moored C-PODs in the Minas Passage;
2) No interference was caused by the concurrent use of Vemco acoustic transmitters and receivers (fish tracking study);
3) Only harbour porpoises were detected during the study period – no dolphin species were detected;
4) Harbour porpoise presence was detected on most days (93%), but usage of the site was typically low, averaging 5.2 minutes per day (SD=5.6, maximum=42) across typically 2-4

separate hours of the day, with detections present in only 11% of 4278 total hours monitored overall (resulting in a median porpoise Detection Positive Minutes per hour (IQR)=0 (0-0), maximum=23min);
5) Porpoise presence varied significantly with time of day, with daytime presence (9%) lower than nighttime (13%);
6) Porpoise presence varied by month (between 8-15%) with neap-tide related highs seen in mid-September (both C-PODs), as well as in mid-October at the control site;
7) No significant difference in porpoise presence was found when comparing the turbine (11%) and control (12%) site, but the control site exhibited greater variance in detection positive minutes (reflecting infrequent temporal spikes in detection activity), coupled with differences in click train parameters (believed to be related to behavior or activity state);
8) While site-specific current data was unavailable, weak peaks in periodicity were observed at scales of just over one day (reflecting the 24 hr 50 minute lunar cycle - the daily tidal rhythm), and at seven days for the control site alone.

In summary, C-PODs were found to be effective in monitoring cetacean presence. Harbour porpoises were detected regularly through late summer and autumn but did not (with a few exceptions during neap tides in September and October) appear to spend significant time periods around either the turbine or the control site (suggesting transit through Minas Passage or local foraging in areas out of detectable range). Presence was higher at night at both sites. We found no statistical evidence of the presence of the turbine attracting or repulsing porpoise, but when porpoises were present, behavior (based on click train parameters) appeared to differ between the two sites.

2.0 INTRODUCTION

Tidal energy is an untapped renewable energy source. Worldwide, only a small number of in-stream tidal turbines have been deployed. The Fundy Ocean Research Center for Energy (FORCE) is a Canadian non-profit institute that owns and operates a facility in the Bay of Fundy, Nova Scotia (Figure 2.1), where grid connected tidal energy turbines can be tested and demonstrated. It enables developers, regulators and scientists to study the performance and interaction of tidal energy turbines with the environment. The offshore test site is in the Minas Passage area of the Bay of Fundy near Cape Sharp, close to and west of Black Rock, roughly 10 km west of the town of Parrsboro (Figure 2.2).

Figure 2.1. Regional location of FORCE test site. Figure 2.2. Detailed location in Minas Passage.

There are four berths for testing tidal turbines in the deployment area. Nova Scotia Power Inc (NSPI) and its tidal technology partner OpenHydro deployed the first commercial scale tidal in-stream energy conversion (TISEC) turbine in the Bay of Fundy on November 12, 2009 and recovered the one megawatt device on December 16, 2010. Recovery was made ahead of schedule due to blade damage observed in late May 2010.

The Bay of Fundy Strategic Environment Assessment (SEA 2008) is one of many reports that highlight the scarcity of empirical data that is presently available on the near-field effects of TISEC devices on marine mammal or fish behavior. While the risk of direct collision remains a potential concern for marine mammals (Wilson et al. 2007), behavioral modifications or loss of foraging habitat due to anthropogenic noise disturbance (notably noise during turbine operation) and indirectly due to changes in prey populations (such as reef effects due to turbine presence) are considered two significant data-gaps that need assessment before any defensible build-out could occur.

The SEA (2008) also highlighted that the occurrence of marine mammals in the Upper Bay of Fundy was poorly understood and a long-term monitoring program was consequently advised. Minas Basin and Cobequid Bay are reported to be regularly visited by harbour porpoise (*Phocoena phocoena),* harbour seals (*Phoca vitulina*) and longfin pilot whales (*Globicephala melaena*). Occasionally white-sided dolphins (*Lagenorhynchus obliquidens*), humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*) and grey seals (*Halichoerus grypus*) are also seen in Minas Basin (SEA 2008). Overall, harbour porpoise (*Phocoena phocoena*) are the most commonly occurring species of cetacean in Minas Basin, seen year-round in small pods, while white-sided dolphins are believed to visit periodically in the summer (Bay of Fundy Ecosystem Partnership - http://www.bofep.org/minas1.htm; Envirosphere 2011). North Atlantic right whales (*Eubalaena glacialis*) congregate in the southern part of the Bay of Fundy to mate, nurse young, and feed; however, they typically do not migrate to the Upper Bay.

Since 2008, Envirosphere Consultants Limited have undertaken two dedicated boat surveys a year (July and August or October) in the vicinity (and waters ~10-15km east and west) of the FORCE demonstration area. No marine mammals were observed in 2008, but 19 harbour porpoise were seen in 2009 (plus also harbour seal, white-sided dolphin, and an unidentified whale) and only five harbour porpoise in the 2010 surveys (Envirosphere 2009, 2010, 2011). On each of 7 days in 2010 (May through November), shore-based marine mammal surveys (6 hr) were also completed in a position specifically overlooking the demonstration area (Envirosphere 2011). Small groups (typically 1-3, mode=1, max=7) of harbour porpoise were seen in the study area on five of these days, with one grey seal also observed on one occasion. Across the 84 30min scans undertaken, harbour porpoise were observed in the actual turbine site zone (the area seaward of Black Rock towards the Minas Channel and Cape Split) in 7 (8%) scan periods in total (May 1 (1), June 12 (1), November 13 (4) and November 22 (1)). There did not appear to be an association of the movements with time of day although most individuals were observed from mid- to late in the observation period (typically mid- to late afternoon or early evening) and reported as ‘nearly always swimming in the direction of the outgoing tide’ (Envirosphere 2011).

Passive acoustic monitoring (PAM) has become increasingly useful in studies of cetacean habitat use and behaviour, in particular when conditions are unsuitable for land-based observations or boat-based sighting surveys. Conventional sighting surveys for marine mammals are short duration, expensive and sighting efficiency can be severely affected by weather conditions; it rapidly decreases in rough seas, and is curtailed by factors such as fog, rain and of course darkness. For example, Palka (1996) showed that sighting rates of harbour porpoises dropped sharply in sea states above Beaufort 2. Alternatively, most whales and dolphins are generally highly vocally active and their vocalisations can be picked up using under water microphones (hydrophones) and importantly these PAM systems can operate 24 hours a day, 365 days a year, providing a power source is maintained. Furthermore, sounds produced by different animals frequently exhibit characteristics that in many cases, allow an identification of their species. For example, the lowest frequency sounds are blue whale moans, which are less than 10Hz and up to 25 seconds in duration. Some of the highest are the short narrow band echolocation clicks produced by porpoises which are typically around 0.1 milliseconds and between 100kHz and 150kHz in frequency (Au et al. 1999).

C-PODs (Chelonia Limited, see www.chelonia.co.uk) are considered a state-of-the-art passive acoustic monitoring technology and PODs are already in use across Europe and North America for on-going marine renewable impact assessments and site characterization studies (e.g., Cox et al. 2001; Culik et al. 2001; Teilmann et al. 2002; Carlström, 2005; Carstensen et al. 2006; Koschinski et al. 2006, Philpott et al. 2007, SMRU Ltd 2008, 2009, 2010a, Tollit et al. 2010). C-PODs incorporate a hydrophone, battery pack, memory and a hardware data-logger which detects and logs cetacean echolocation clicks. C-PODs can log data 24 hours a day and are therefore useful at providing continuous data on cetacean activity over extended periods. C-

PODs are relatively small, but are robust and deployed on bottom moorings for single periods of up to 5 months (duration dependent on battery life), after which they need to be recovered and the data downloaded, with subsequent redeployments being possible. C-POD hydrophones are focused on detecting click trains of porpoise, as well as other species of echolocating delphinids (for example white-sided dolphins). Species can be identified using the dominant frequency of the clicks and the spread of frequencies in the cluster of multipath replicates that are logged. Clicks can also provide basic information on behaviour, such as feeding, using the interval between clicks, which shortens as animals focus in on an object of interest, creating so called 'feeding buzzes'. C-PODs have been shown to record porpoise activity within a radius of up to ~300m, with 100% detection within a ~100m radius (Tougaard et al. 2006). It is noted that while useful in determining relative changes in frequency of occurrence or behaviour between sites or through time, they cannot provide a count of the number of animals recorded or be used for estimating absolute abundance (SMRU Ltd 2010b).

This collaborative project (Acadia University and SMRU Ltd) involved a continuous ~3 month long PAM field study (August 2010 – November 2010) while the NSPI (OpenHydro) device was deployed in the Minas Passage. The study originally aimed to collect data during turbine operation, as well as after removal of the device for inspection and repairs. This type of before and after data is considered important as it can be used to examine turbine effects. However, turbine removal was delayed until after the three C-PODs were removed and presently, it is also believed that the turbine was not operational during the entire C-POD deployment period, due to blade damage that occurred at some time before May 2010. Initially two blades were observed damaged, but on device removal all blades were missing and reported as broken off (Renewable Energy News, Issue 207, January 2011).

The main objectives of this study report were therefore revised (based on the assumption that the turbine was not operating during C-POD deployment) as follows;

1. Use continuous passive acoustic monitoring (C-PODs) to describe the presence and behaviour of key cetaceans within the FORCE demonstration area of the Minas Passage during August-November 2010.
2. Confirm the ability to collect long-term high quality click train acoustic data from moored C-PODs in the Minas Passage.
3. Detect whether the physical presence of the TISEC has any impact, based on analysis of data collected by C-PODs in close proximity to the turbine compared with a 'control' C-POD.
4. Provide preliminary data and recommendations that will assist the design of future effects monitoring projects in relation to marine mammals in the Minas Passage.

3.0 METHODS

3.1 C-POD deployments

The study was carried out in the Minas Passage area of the Bay of Fundy, Nova Scotia, Canada (see Figure 2.2). Three C-PODs were activated using a continuous scan and high pass filter of 80kHz and installed into custom-fitted bottom moorings with acoustic releases (provided by the Ocean Tracking Network) as follows. After removal of the C-POD mooring line and attachment ring (provided when purchased), the C-POD cylinder was attached to a Teledyne Benthos 875-T shallow water acoustic release (Figure 3.1). The C-POD was held against the fibreglass strong back of the release using two 316-stainless steel hose clamps. Pieces of neoprene rubber were placed against the fibreglass strong back and under the hose clamps as spacers to distribute pressure, prevent chafing, and reduce slippage. When attached the C-POD unit was longer than the strong back, with roughly 10-12cm of the C-POD extending beyond the buoy case on either end. This overhang was kept even on both sides in an attempt to equal out drag forces (Figure 3.1). The instrument package was then bolted into a modified SUB B3 streamlined instrument buoy (Open Seas Instrumentation, http://www.openseas.com/).

Deployments were carried out by ACER personnel on 10 August 2010. Units were deployed using a chartered commercial fishing vessel (Cape Rose) just before high tide in calm conditions. A 3/16” stainless steel drop shackle was connected to the release arm of the Teledyne Benthos 875-T acoustic release. The drop shackle was then connected to a ½” galvanized steel swivel which was connected to a 2m section of ½” galvanized steel riser chain using a ½” galvanized steel safety anchor shackle. The terminus of the riser chain was woven through a mass of 2” diameter steel chain links. The anchor links weighed approximately 200-220kg per mooring, Figure 3.2).

Figure 3.1. Attaching the C-POD to the acoustic release (left), and close up of the instrument package arrangement showing the top of the SUB buoy and C-POD hydrophone (centre), and the bottom of the SUB buoy showing the C-POD bottom and acoustic release point (right). Photos courtesy of Colin Buhariwalla.

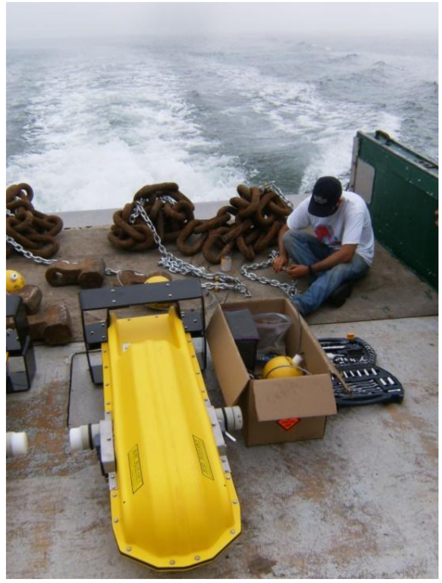

Figure 3.2. Rigging units for deployment of C-PODs. Mooring chain weights can be seen on the stern of the vessel. Photo courtesy of Colin Buhariwalla.

As the vessel approached station, the SUB buoy containing the C-POD and the length of riser chain were placed in the water off the stern. When precisely on station, the command was given and the mass of anchor chain was pushed over the stern. Coordinates provided in Table 3.1 are referenced to surface position of the vessel and not the exact final bottom position of the C-POD unit. Figure 3.3 therefore depicts the approximate locations of the three C-PODs relative to the location of the turbine. To doubly ensure data collection at the device site, E1-638 and W1-639 were both positioned in close proximity to the turbine (estimated to be 150m east and west), while W2-643 was deployed ~700m west of the turbine site. The location of site W2 represents a 'control', collecting independent echolocation clicks from (W1 and E1), and is outside the anticipated acoustic footprint of the turbine, but in similar water depths and bottom characteristics.

Table 3.1. Details of C-POD deployment on 10 August 2010.

C-POD ID (station)	**Deployed Lat**	**Deployed Long**	**Time (AST)**	**Water Depth (m)**	**Riser Length (m)**
E1 – 638 (Turbine east)	45.364347	-64.424548	13:13	40-50	2
W1 – 639 (Turbine west)	45.365555	-64.427995	13:22	40-50	2
W2 – 643 (Control)	45.367682	-64.434175	13:26	40-50	2

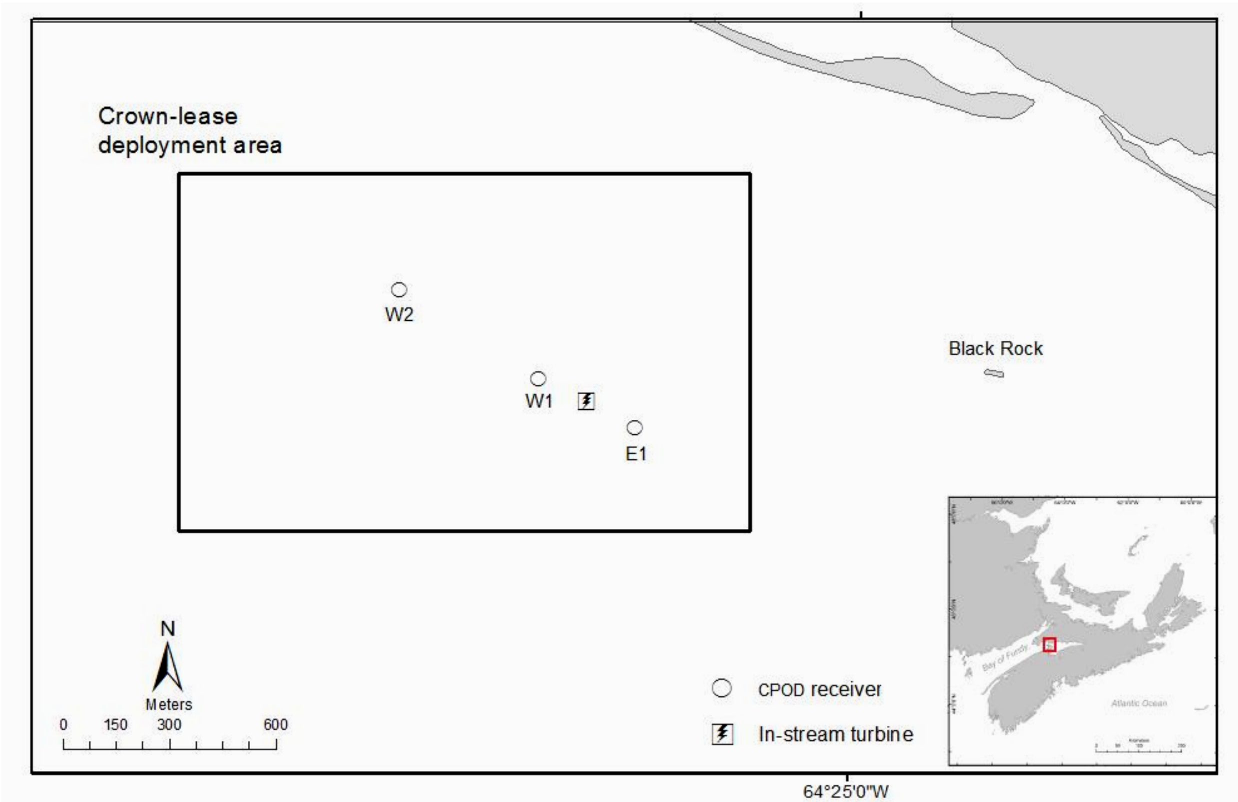

Figure 3.3. C-POD deployment station locations (circles) relative to the NSPI (OpenHydro) turbine and FORCE TISEC demonstration area (large rectangle). Distance between E1 and W1 was ~301m, and between W1 and W2 was ~538m.

3.2 C-POD retrieval

All three C-PODs (within SUB buoys) were successfully retrieved in calm conditions between 14:38 and 15:58 (AST) on 23 November 2010. The SUB buoys of C-PODs E1 (Turbine) and W2 (Control) were retrieved in good condition, however the W1 (Turbine) SUB buoy was found with significant damage, including a broken tail fin, and scrapes and abrasions on the nose of the casing (see Figure 3.4). All C-POD unit seals were intact and each unit was free of any signs of moisture or other internal damage. However, a thin layer of fine dust was observed inside each unit, presumably a result of wear from near constant vibration.

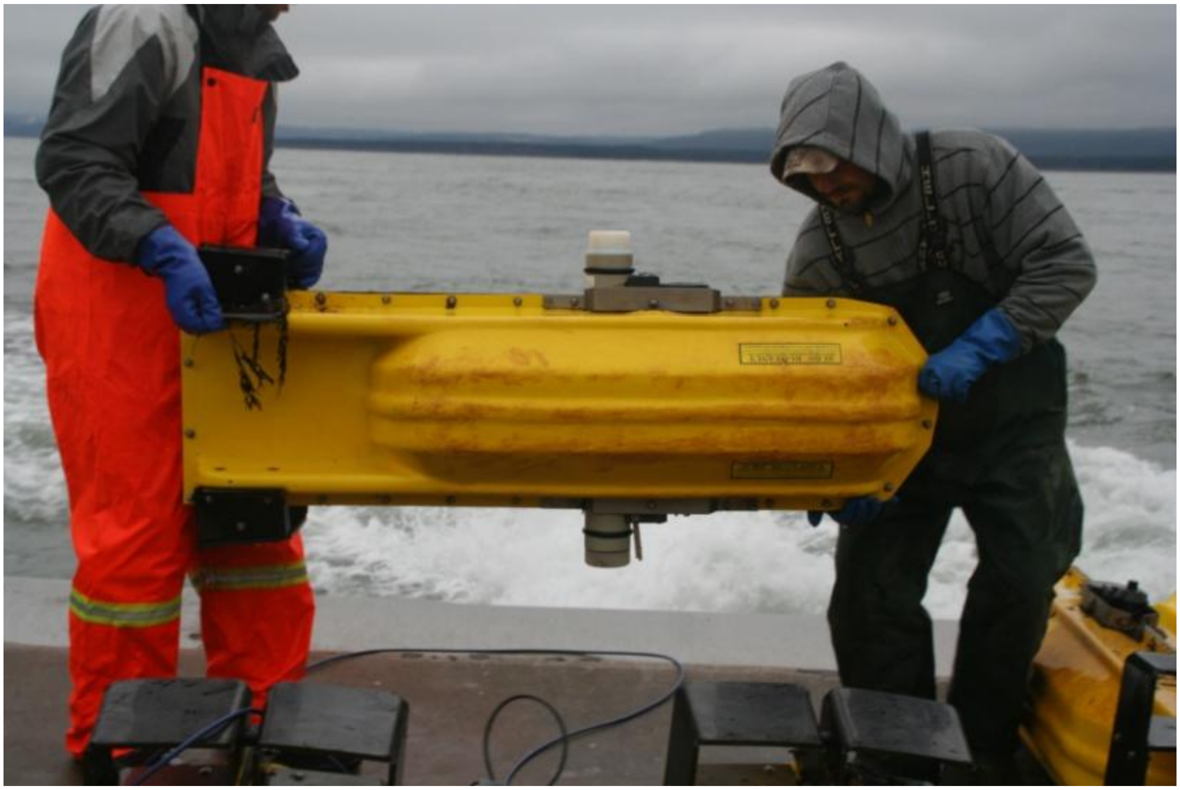

Figure 3.4. C-POD unit W1 immediately following retrieval. Note that part of the tail fin is missing. Photo courtesy of Colin Buhariwalla.

3.3 Instrument performance and data processing

The C-POD software version v1.054 was used for data download. All C-PODs collected cetacean presence data. E1 (Turbine) and W2 (Control) collected 89 and 92 days of continuous data before their batteries expired (Table 3.2). W1 recorded data for less than 1 day. In addition to logging centre frequency, frequency trend, duration, intensity (8 bit), bandwidth and envelope slope for each click, C-PODs record the angle-from-vertical of the unit and temperature every minute. In an attempt to ascertain the reason for the premature failure of W1 (Turbine), the angle-from-vertical for W1 was compared with E1 (Turbine) and W1 was found to have higher mean (4 degrees) and peak tilt levels, and once was found to reach a tilt of 86 degrees. Stoppage of the click recording occurred mid-minute which does not support the unit becoming tangled and inverted (leading to temporary shut-down), as shut down occurs at the end of the minute. Forces resulting in the external damage to the SUB buoy housing may have also caused a C-POD internal disconnection. The C-POD unit was tested after post recovery and appeared to be working during a short bench test. The exact cause of the stoppage is therefore unknown. It is recommended in subsequent C-POD deployments to maintain the angle of device cut-off at 250 degrees or to switch it permanently on prior to deployment.

Table 3.2. Summary of data collection success and instrument performance.

C-POD ID (station)	Data days	Damage	Battery power	Expiry date	CP1 Data File Size
E1 – 638 (Turbine east)	89	No	Expired	6/11/2010	822782 KB
W1 – 639 (Turbine west)	1	Yes	Viable	11/08/2010	31972 KB
W2 – 643 (Control)	92	No	Expired	9/112010	909701 KB

The C-POD mostly receives short segments of the trains of clicks produced by both dolphins and porpoises as they scan past it. Dedicated software algorithms identify these as click trains and assess the probability of such trains arising by chance from other broadband sources such as shrimp, rain, propellers, boat sonar, etc. The C-POD records the time and duration of each detected click and measures the inter click intervals (ICI) and determines a number of parameters (frequency, amplitude, duration, envelope and bandwidth). Dedicated C-POD software is then used in post processing to classify the raw click data using a set of two standard filters. The first determines the quality of the click train in the categories of high, moderate, low and questionable. The quality is based on several criteria that evaluate whether or not a series of consecutive clicks are indeed part of a click train, as opposed to clicks from different sources. The second standard filter then determines the likely species of these click trains. The filter uses the following categories; porpoise-like, dolphin, other train sources, unclassed, and boat sonar. This filter works by using various parameters such as the frequency (in kHz) of the click, ICI, duration of the click train, and slope of the amplitude envelope. Previous research has shown that the use of porpoise-like clicks of high and medium quality, as well as dolphin clicks of high quality, are highly correlated with the presence of these two groups of species. Further analysis described below uses these classification categories for porpoise and dolphin click trains.

Initially, raw C-POD data is assessed by a trained C-POD operator and analyst to determine data quality. These assessments include checking if significant interference from external sources has occurred and the degree to which the maximum click count per minute has been reached, as well as validating the identification of a sub-sample of porpoise and all dolphin click train detections. Following data confirmation, our main analyses to characterize site use and investigate typical temporal patterns used the metric Detection Positive Minutes (DPM - the total number of minutes in a day or alternately in an hour in which porpoise clicks were detected) and Detection Positive Hours per day (DPH – the number of hours in a day in which at least one detection of clicks was detected). DPM is the most universally used metric when carrying out POD analysis, especially when presenting the data for environmental analyses (e.g., Rayment et al. 2009).

Autocorrelation of DPM data was assessed to ensure appropriate resolution of time periods under analysis. The data used is the count of clicks in time bins that can be from 1 min to 6 hours in size and uses a formula derived by Chatfield (2004), as follows.

> Given N observations $x_1, \ldots, x_N$, on a time series, we can form $N-1$ pairs of observations, namely, $(x_1, x_2), (x_2, x_3), \ldots, (x_{N-1}, x_N)$, where each pair of observations is separated by one time interval. Regarding the first observation in each pair as one variable, and the second observation in each pair as a second variable, then, by analogy with Equation (2.2), we can measure the correlation coefficient between adjacent observations, x_t and x_{t+1}, using the formula
>
> $$r_1 = \frac{\sum_{t=1}^{N-1} (x_t - \bar{x}_{(1)})(x_{t+1} - \bar{x}_{(2)})}{\sqrt{\left[\sum_{t=1}^{N-1} (x_t - \bar{x}_{(1)})^2 \sum_{t=1}^{N-1} (x_{t+1} - \bar{x}_{(2)})^2\right]}} \qquad (2.3)$$
>
> where
>
> $$\bar{x}_{(1)} = \sum_{t=1}^{N-1} x_t/(N-1)$$
>
> is the mean of the first observation in each of the $(N-1)$ pairs and so is the mean of the first $N-1$ observations, while
>
> $$\bar{x}_{(2)} = \sum_{t=2}^{N} x_t/(N-1)$$

The formula, for *r1,* gives the correlation between each time unit and the next one and for *r2* the correlation between each time unit and the one two time units later. The number of values in the series of lag values *r1, r2,* etc., is limited to the lower of 1000 or 20% of the number of bins. The larger bin sizes smooth the output where data is sparse, but as it reduces the number of data points the length of the autocorrelation may fall to 80% of the length of the data file. The same length of autocorrelation is used for all lag values. *r1, r2* values are plotted in a correlogram and the horizontal limits (*2/SqRt(N))* represent approximate 5% p-values and points outside them are 95% likely to indicate a real temporal correlation between values separated by that time difference. In this study, the autocorrelation of the DPM per minute across successive hours was assessed for each site. Since the autocorrelation was estimated to be 4 minutes for the Turbine site and 22 minutes for the Control site (i.e., above these time intervals porpoise detections are independent), the shortest time period and most appropriate level for statistical analysis was using the metric DPM per hour.

Variables under consideration using DPM metrics were deployment site location (near Turbine E1 versus Control W2), as well as monthly and time of day (diurnal) and longer-term cyclical (tidal) patterns. DPM per hour data for porpoise were found to be highly skewed (due the high number of hours without detections, i.e., DPM/hr=0) and we have therefore reported median and inter-quartile ranges (Zar 1999). We applied a kernel smoother to raw DPM per hour data to allow visual assessment of trends. This statistical technique represents the set of irregular data points as a smooth line or surface. When detected, porpoise were generally logged for just one or two minutes within that one hour analytical period. The comparative statistical test therefore used a binomial (presence or DPM/hr >0 versus absence or DPM/hr =0) Generalized Linear Model (GLM) using the Log Link in R (version 2.9.2).

The interaction between tidal cycle and current speed is complex and can clearly influence the presence of porpoise (Tollit et al. 2010). Site-specific current speed data at short temporal resolution are required for a robust analysis. In the absence of detailed current data, we have confined our analysis to assessing the extent of longer-term cyclical patterns (one day and greater) by using power spectra to compare variance patterns in the kernel smoothed hourly DPM data across time frequencies. For a given signal across a time series, the power spectrum gives a plot of the portion of a signal's power (in this case variance in DPM) falling within given frequency bins. Thus, it provides a summary of the periodicity of the signal within the time series.

More detailed behavioural data can be generated by the interpretation of individual click trains. A Kruskal-Wallis test was used to assess if inter-click interval, click duration or the number of clicks per click train varied between the two deployment sites.

3.4 Study plan variance

As detailed above, we have assumed the turbine was not operational during the C-POD deployment period. C-POD-W1 collected <1 day of data and click train information from this device is not included in this report. We recommend in future that each C-POD is turned on permanently (i.e., not affected by tilt angle) just prior to deployment to avoid premature shut-down due to excessive device tilt. The sound scene of the Minas Passage was active (i.e., many non-cetacean clicks were recorded), especially during spring high tides (see section 4.1.1 in the results). During 8.7% of 256,638 minutes, the click maximum (4096) was reached, resulting in failure to log clicks in the last 6 seconds or more of each minute. While not considered to have impacted any of the conclusions in this report, future deployments should consider increasing the maximum number of clicks limit and maintaining a low band pass frequency at 80 kHz. The increase in the low band pass frequency will reduce the number of lower frequency clicks logged and may also result in increasing the battery life beyond the 92 day maximum recorded in this study.

4.0 RESULTS

4.1 Data summary

Upon successful retrieval of all the three C-PODs, it was determined that one of the SUB buoys had been damaged while moored. As the attached C-POD (W1 – 639) had only one day of data recorded, it is likely that the SUB buoy damage occurred soon after deployment. Only one porpoise Detection Positive Minute (DPM) was logged on C-POD-639 when it became non-functional and stopped recording on August 11, 2010, and there were no dolphin DPM.

Therefore data from that POD were not included in further analyses. Fortunately, that unit was one of two near-turbine site units. The other two C-POD units successfully recorded three months of data for a total of 181 data days and 4278 hours (Table 4.1).

Table 4.1. Start and end dates, and duration of recordings by C-POD.

C-POD ID (site)	Start Date	End Date	# of days recorded	# of hours recorded
E1- 638 (Turbine east)	10/8/2010	6/11/2010	89	2107
W1- 639 (Turbine west)	10/8/2010	11/8/2010	1	23
W2 - 643 (Control)	10/8/2010	9/11/2010	92	2171

During the deployment period the water temperature logged ranged from 5.39°C to 8.41°C, with an average of 7.34°C ± 0.86 (SD). From 1st September onwards, there was a generally decreasing trend (Figure 4.1).

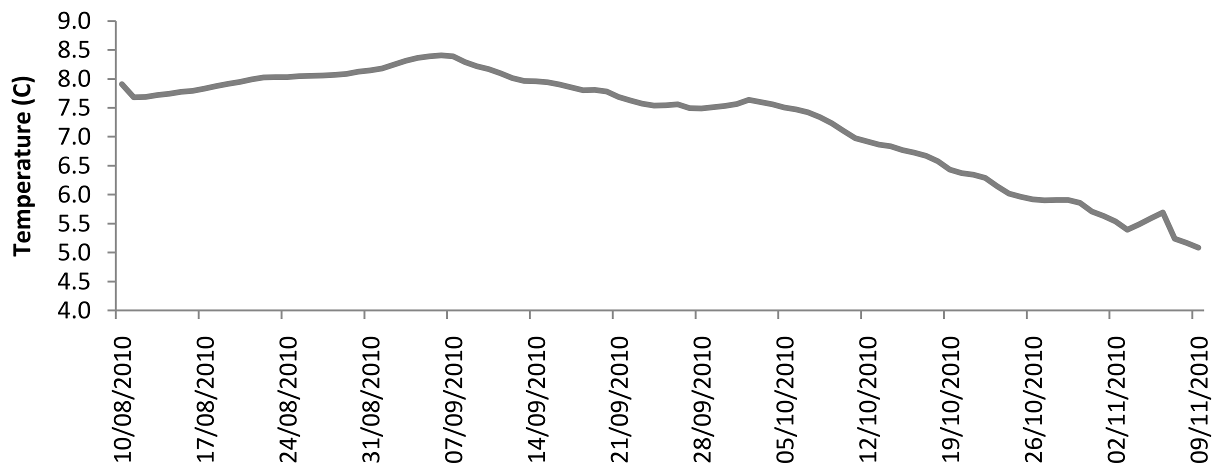

Figure 4.1. Daily temperature averaged across the two C-PODs from 10 Aug – Nov 2010.

Tilt angle was recorded for every minute of data collection on C-PODs 638 (Turbine) and 643 (Control). The average tilt angle per hour was then calculated so as to correspond with hourly reported tidal heights from the Canadian Hydrographic Services' Cape Sharp site in Minas Passage (http://www.waterlevels.gc.ca/). These were then plotted to identify trends (Figure 4.2) and to determine how similar conditions were between the two sites. Tilt angle is measured from vertical, such that a tilt angle of zero is a directly vertical C-POD unit.

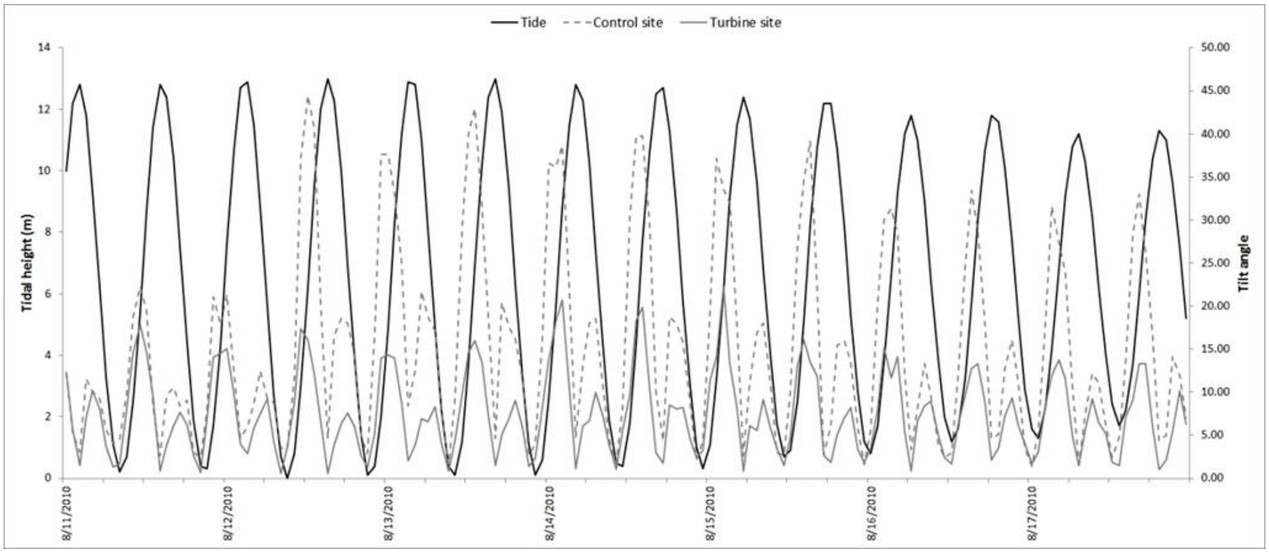

Figure 4.2. One week (Aug 11-17, 2010) plot of tidal height (left axis) in Minas Passage and tilt angle (right axis) from the Turbine and Control site C-PODs.

There are a number of trends evident in Figure 4.2. Peaks and troughs in tilt angle correspond well at the Turbine and Control sites, but the Control site has in general twice the range in tilt angle (most clearly during flood tides). Maximum tilt angles for the Control average close to 35-40 degrees at spring high tide, while averaging only 15-20 at the Turbine site. Differences are also reflected on data at minute resolution with the Control having higher tilt values (Median=12 [IQR=0-22, Maximum=180]) compared to the Turbine site (Median=0 [IQR=0-12, Maximum=116]). A tilt of <20 degrees was registered in 91% of minutes for the Turbine site and 72% of minutes for the Control site. Tilt angle maxima on a daily cycle clearly coincide with the time between low tide and high tide when the currents are at their strongest. Tilt angles are clearly also higher during a flood tide than an ebb tide, indicative that the bay of Fundy tidal bore (flood tide only) is clearly measurable at 40-50m depth.

4.1.1 Overall sound scene and unfiltered click detections

The FORCE tidal demonstration area has a tidal range exceeding 11 m and current speeds of up to 6 m/s. Because strong currents can impact the noise levels in a given area C-PODs may record additional data by detecting tonal sounds in background noise. This data is post-processed to determine which of the clicks is a likely porpoise or dolphin click. Tonal click-like sounds can be created from biotic, abiotic (e.g., sediment movement) and anthropogenic sources such as boat sonar. A review of the raw unfiltered sound scene highlighted a clear spring-neap signal in the unfiltered clicks logged by both C-PODs (the black line in Figure 4.3). Each bell-shaped peak represents a spring tide (in which many more clicks are recorded than during neap tides). Spring tides occur every 14-15 days during full and new moons, when the sun and moon are gravitationally aligned. Peak springs are seen to occur every month during the new moon. The oscillations on the shorter time-scale represent daily tidal cycles. Research results from other C-POD studies have found sediment particles like sand in high tidal flows can cause lower frequency clicks to be logged. We believe the sound scene signal seen here also represents a signal caused by tidally influenced sediment movement. It is interesting to note that approximately half way through all the spring cycles, there is a period of reduced variance clicking. It is unknown what has caused this consistent feature in the sound scene. Short periods with boat sonar are also notable. Subsequent post-processing removes the vast majority of these ‘clicks’, resulting in only high and medium probability porpoise click trains.

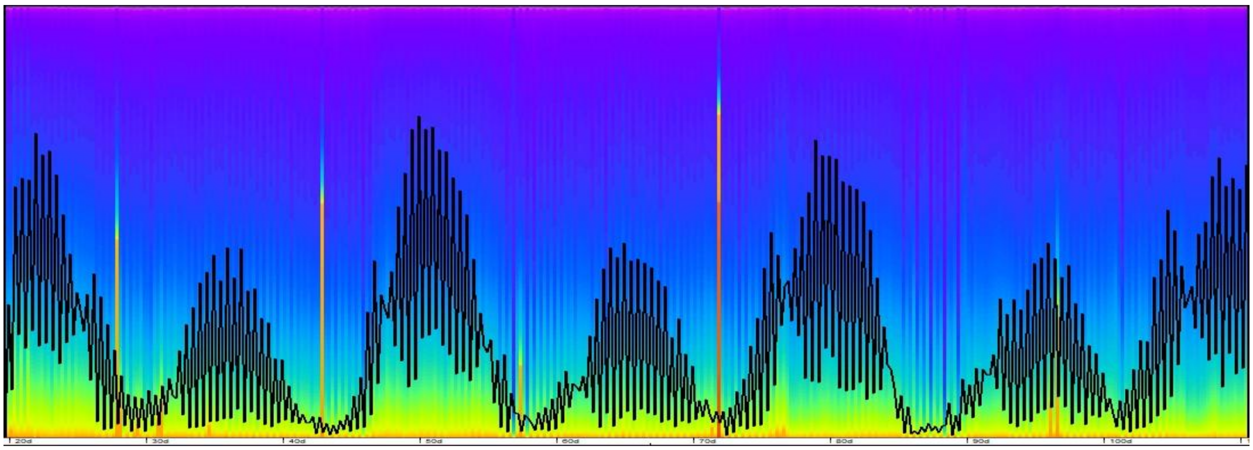

Figure 4.3. Click time series summary information from C-POD 643 (Control). The X-axis depicts the entire 92 days of recording. The Y-axis depicts the overall count of all recorded clicks in six hour bins before post-processing to filter only porpoise clicks. The black line depicts these total click counts, with a clear spring and neap tidal pattern evident in the sound series. Color depicts the frequency content of the clicks, ranging from orange at 50 kHz and purple at 125 kHz. The vertical orange lines were classified as boat sonar.

4.1.2 Assessment of interference by Vemco acoustic transmitters

As part of the larger environmental effects study in Minas Passage during 2010, Acadia University tagged various species of fish with implanted Vemco acoustic tags, which send an acoustic signal at 69 kHz on a regular basis. In addition to these tags, there were several Vemco acoustic transmitters and receiver units located in the demonstration area during the C-POD deployment period. Because the Vemco tags transmit sound within the detection capabilities of the C-PODs, we checked the data to ensure that if the Vemco signals were received, they were at least not detected as click trains. Our analysis of the data do show periods when the C-PODs detected the Vemco signals, indicating that a tagged fish or other Vemco tag was in the vicinity of the C-POD, however these Vemco signals were not erroneously detected as click trains. Figure 4.4 illustrates this well. The lower trace is the raw click data. Clearly visible are a series of eight pulses of signal from a Vemco tag at 69 kHz, however these signals do not show up in the upper trace which is where click trains are identified and depicted. Thus, we determined that the click train filtering process effectively excluded the Vemco signals from the C-POD data set.

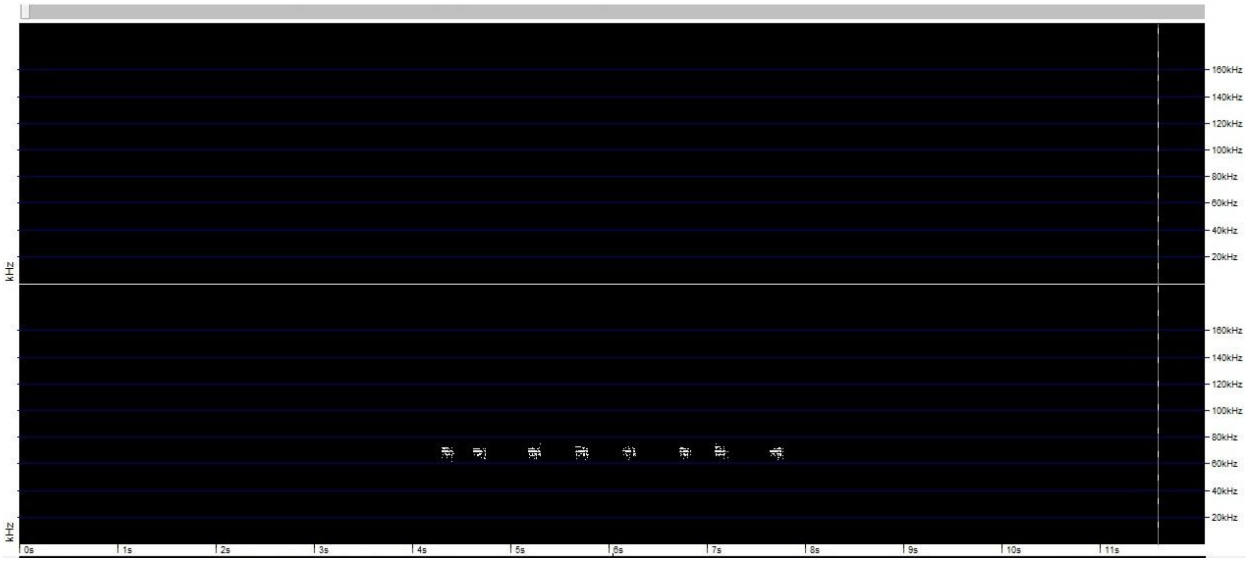

Figure 4.4. Display trace from the C-POD software. X-axis is time in seconds, Y-axis is frequency in kHz. The lower trace displays the raw click data, while the upper trace displays identified click trains. Cleary visible are eight 69 kHz signals from a Vemco tag in the lower trace. The click train filters were successful in rejecting this signal as a click train, as it does not show up in the upper trace.

4.1.3 Frequency of porpoise click detections per day

Porpoises were detected on the majority (93%) of days (Turbine: 83 out of 89 days, Control: 85 out of 92 days), averaging 5.2 ± 5.64 (SD) Detection Positive Minutes (DPM) per day overall (4.17 ± 3.00 DPM per day at the Turbine site and 6.20 ± 7.23 DPM per day at the Control site). The Turbine site had a median of 4 DPM per day (interquartile range: 2-6) while the Control site also had a median of 4 DPM per day (interquartile range: 2-7). Using the average DPM per day, porpoises were present during 0.3% and 0.4% of the day respectively at the Turbine and Control sites. This occurrence ranged from zero to 0.9% and zero to 2.9% of the day respectively at the Turbine and Control sites. Figure 4.5 shows the range of DPM per day for the two PODs across this deployment period. Peak periods occurred from ~3/09/2010 through ~23/09/2010 and again from ~13/10/2010 through 1/11/2010 at both sites, but especially at the Control site. Fourteen days with daily peaks in excess of 10 DPM were observed for the Control site compared to four at the Turbine site. These peaks appear mostly to correspond with the onset and period of the neap tide, but no clear-cut neap-related pattern emerged in further DPM per hour analyses (see section 4.2.3). Porpoise click trains were detected in a median of 2 different hours of the day (interquartile range: 2-4). Neither C-POD detected any confirmed dolphin clicks, at any time.

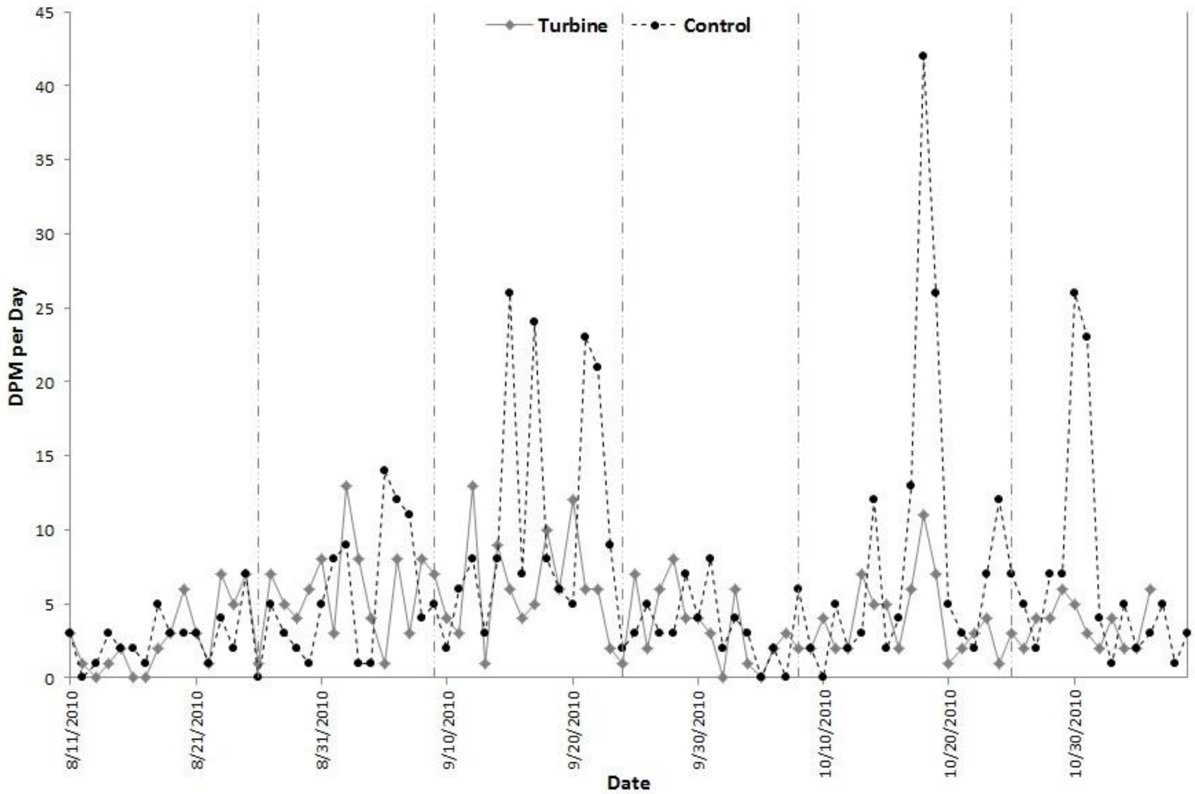

Figure 4.5. Porpoise Detection Positive Minutes (DPM) per day for C-POD 638 (Turbine, grey line and diamonds) and 643 (Control, dashed line and black circles) from August to November 2010. Vertical dashed lines denote time of peak spring tide.

4.2 Analysis of Detection Positive Minutes (DPM) per hour

Median DPM per hour of porpoises over the duration of these deployments was considered low (Table 4.2), with a median of zero, resulting in a frequency distribution with a strong right hand skew (Figure 4.6). No porpoise click trains were detected during 89% and 88% of the recorded hours at the Turbine and Control sites respectively (Turbine: 1878 of 2107 minutes, Control: 1919 of 2171 minutes, Figure 4.6). Just one single minute of detection was recorded in an additional 6.8% and 7.1% of total hours at each site respectively, a period of time likely indicative of transit travel. Maximum presence in a single hour was 7 and 23 minutes respectively, but with a large majority of ≤3 minutes presence per hour.

Table 4.2. Porpoise Detection Positive Minutes per hour at two sites during Aug-Nov 2010.

C-POD ID (Site)	Median	Interquartile range	Max	Hours, n
638 (Turbine)	0	0-0	7	2107
643 (Control)	0	0-0	23	2171

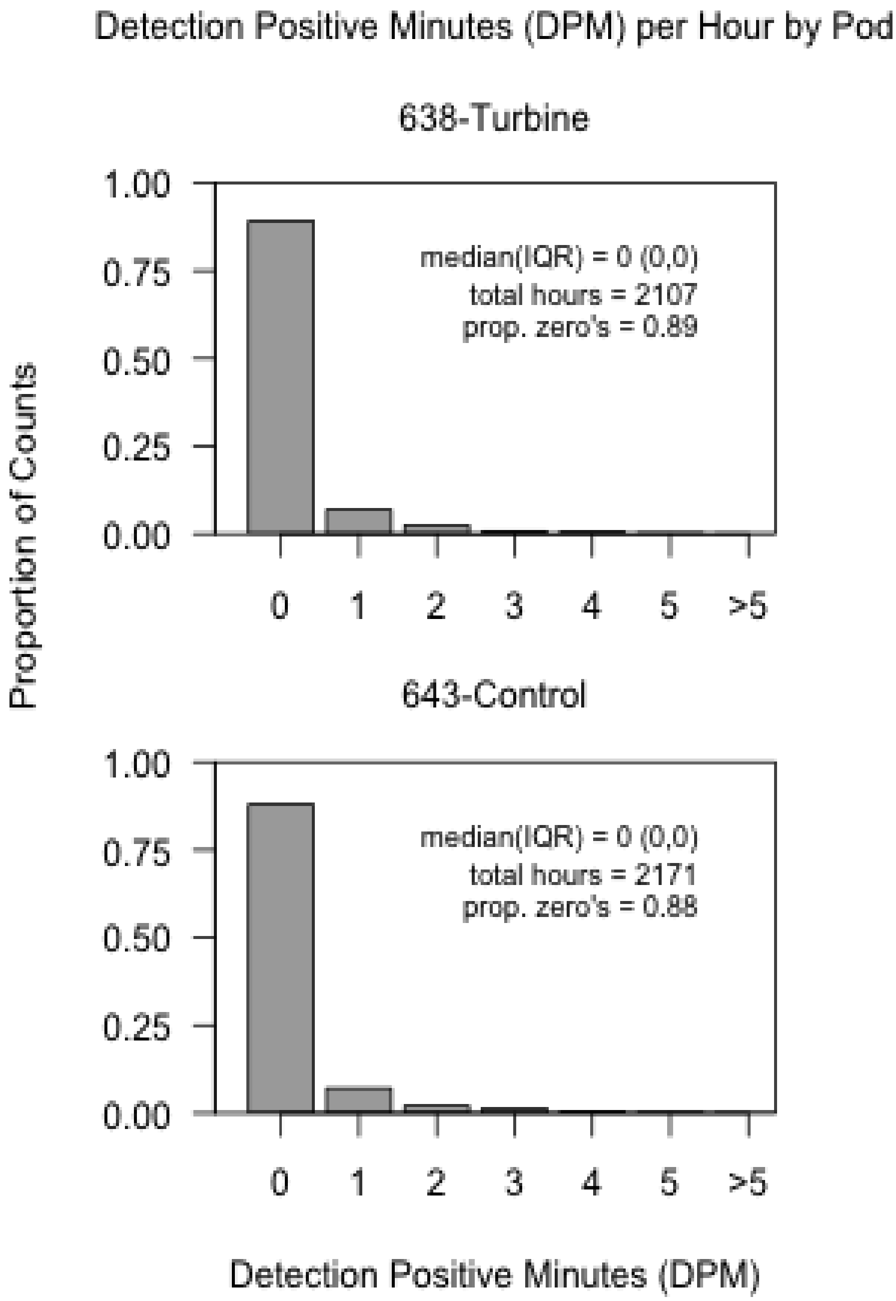

Figure 4.6. Frequency histogram of porpoise Detection Positive Minutes per hour for each POD (site) over the duration of this deployment. For each POD the median (Inter-quartile range or 1st quartile and 3rd quartile), as well as total hours of recording and proportion of time with zero DPM per hour are also reported.

4.2.1 Site and month effects on DPM per hour

Porpoise presence per hour did not vary significantly by deployment site (Binomial GLM; $\chi^2_{df=1}$ =1.52, P=0.218, Figure 4.7 & 4.8) and we therefore combined data from both sites to test for effect of month. Porpoise presence per hour did vary significantly by month (Binomial GLM; $\chi^2_{df=3}$ =23.52, P<0.001, Figure 4.8 & 4.9). Highest probability of porpoise presence was seen in September (seen in 15% of hours), followed by October (11%), August (9%) and November (8%) (Figure 4.9). We note that the two months with lowest probability porpoise presence were also months in which data from partial months was collected. Median, minimum and inter-quartile values for DPM per hour by month were all zero, with maximum values of 5 (Aug.), 13 (Sept.), 23 (Oct.), and 3 (Nov.) minutes per hour. No interaction between month and site was found, but site differences through the study period become apparent using data from nighttime (Figure 4.10). This figure depicts kernel smoothed DPM per hour at night for each site. DPM per hour increases through August at both sites, peaking in mid-September. DPM per hour then declines at both sites, followed by a second notable peak in the second half of October at the Control site only. The Control site clearly shows higher peaks and variability than the Turbine site (Figure 4.10).

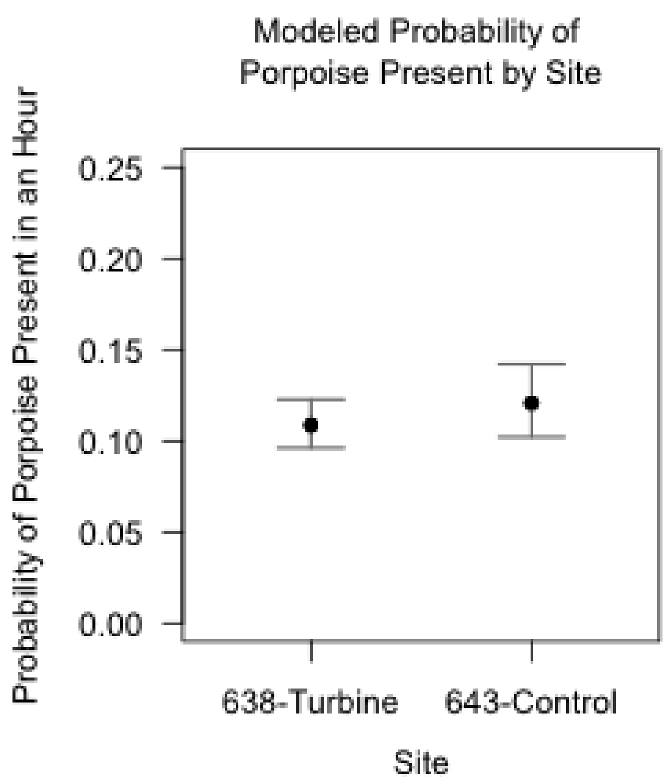

Figure 4.7. Probability of porpoise presence in an hour by site from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

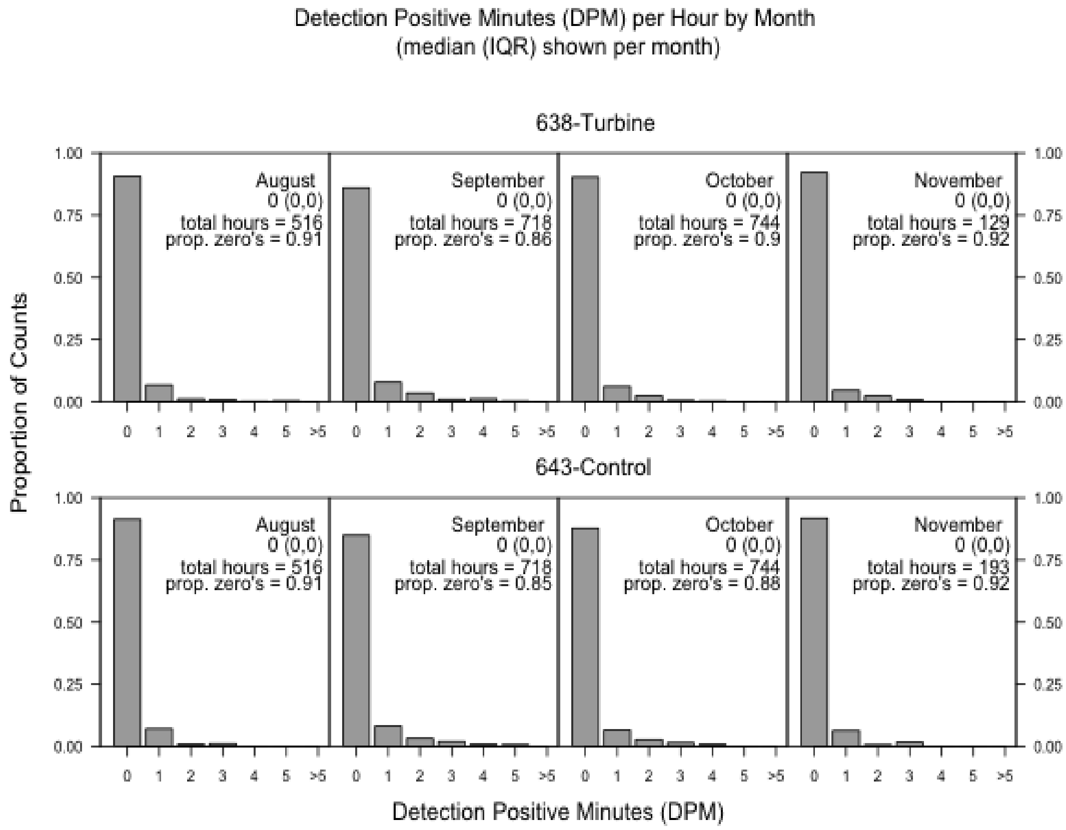

Figure 4.8. Frequency histograms of porpoise Detection Positive Minutes per hour by month and C-POD. For each C-POD the median (Inter-quartile range), as well as total hours of recording and proportion of time with zero DPM per hour are reported.

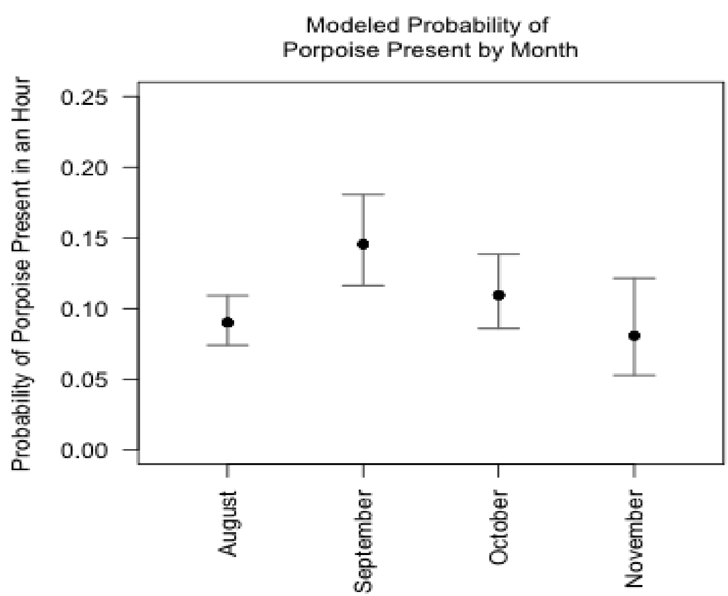

Figure 4.9. Probability of overall porpoise presence in an hour by month from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

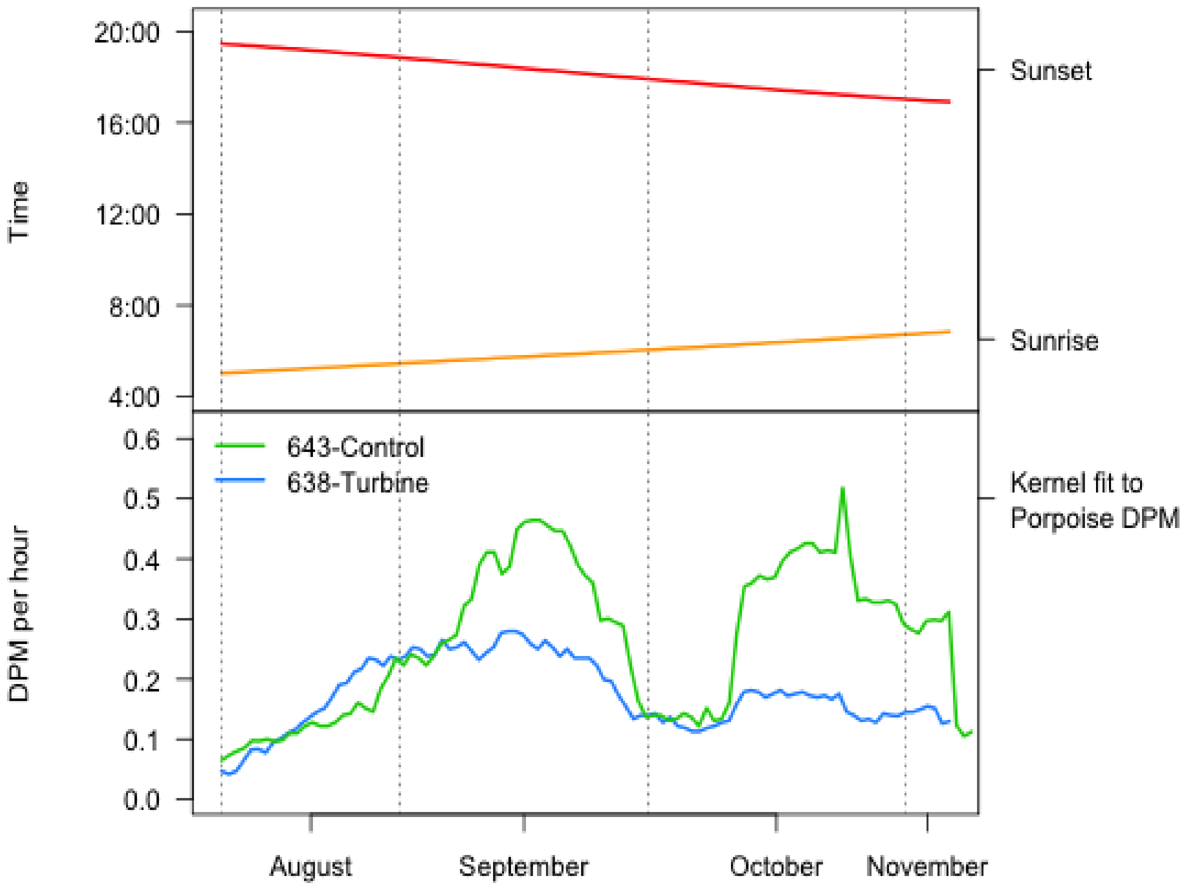

Figure 4.10. Study period variability in day length (top panel) and smoothed DPM per hour at night (bottom panel).

4.2.2 Time of day effects on DPM per hour

Porpoise presence per hour was significantly different in daytime versus nighttime (Binomial GLM; $\chi^2_{df=1}$ =16.93, P<0.001, Figure 4.11), with nighttime (13.5% presence) having a higher probability of porpoise presence than daytime (9%). The median, minimum, and interquartile ranges for porpoise DPM were all zero for day and night, while the maximums were 13 and 23 respectively. Figure 4.12 illustrates the change in DPM across hour of the day for each site. The Turbine site has a peak DPM at 2:00 in the morning with the lowest DPM at noon. The Control site has its highest DPM at midnight and its lowest DPM at 11:00 in the morning. This diel effect appears more consistent across months at the Turbine site (once again more variation in the Control site), however there was a significant interaction between time of day and month (Binomial GLM; $\chi^2_{df=3}$ =12.60, P=0.005, Figure 4.13). This indicates that the peaks and troughs in DPM vary across the hour of day depending on the month, at both sites. In September, both sites had high presence during the day, whereas in October, a clear peak is seen only at the control site during the night.

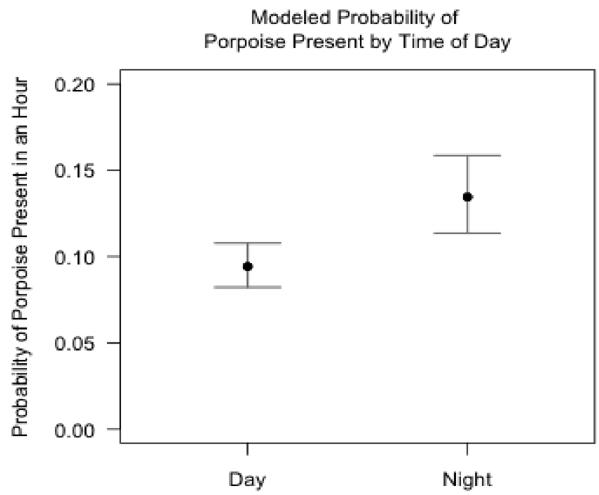

Figure 4.11. Probability of overall porpoise presence in an hour by time of day from the fit of a Generalized Linear Model (sites and days combined). Error bars represent 95% confidence intervals.

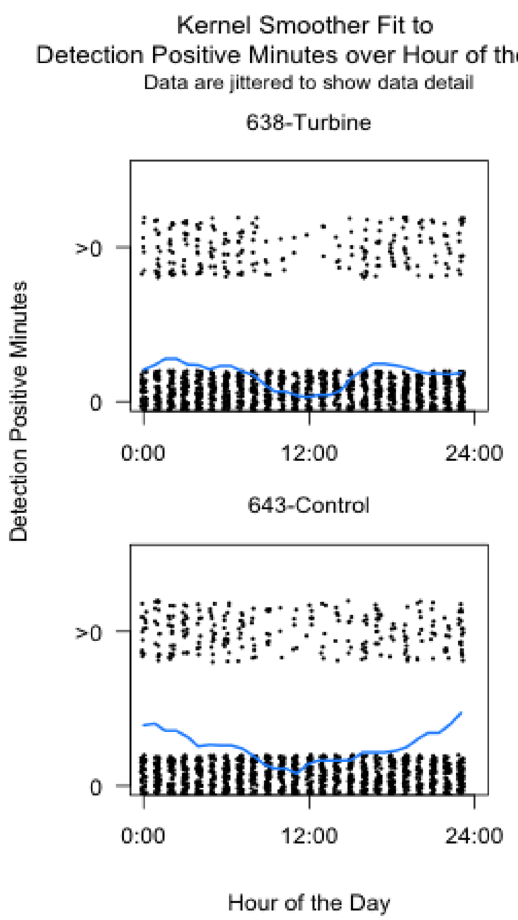

Figure 4.12. Detection Positive Minutes per hour by hour of the day for each C-POD with a kernel smoother (blue line) to depict trends (based on raw data).

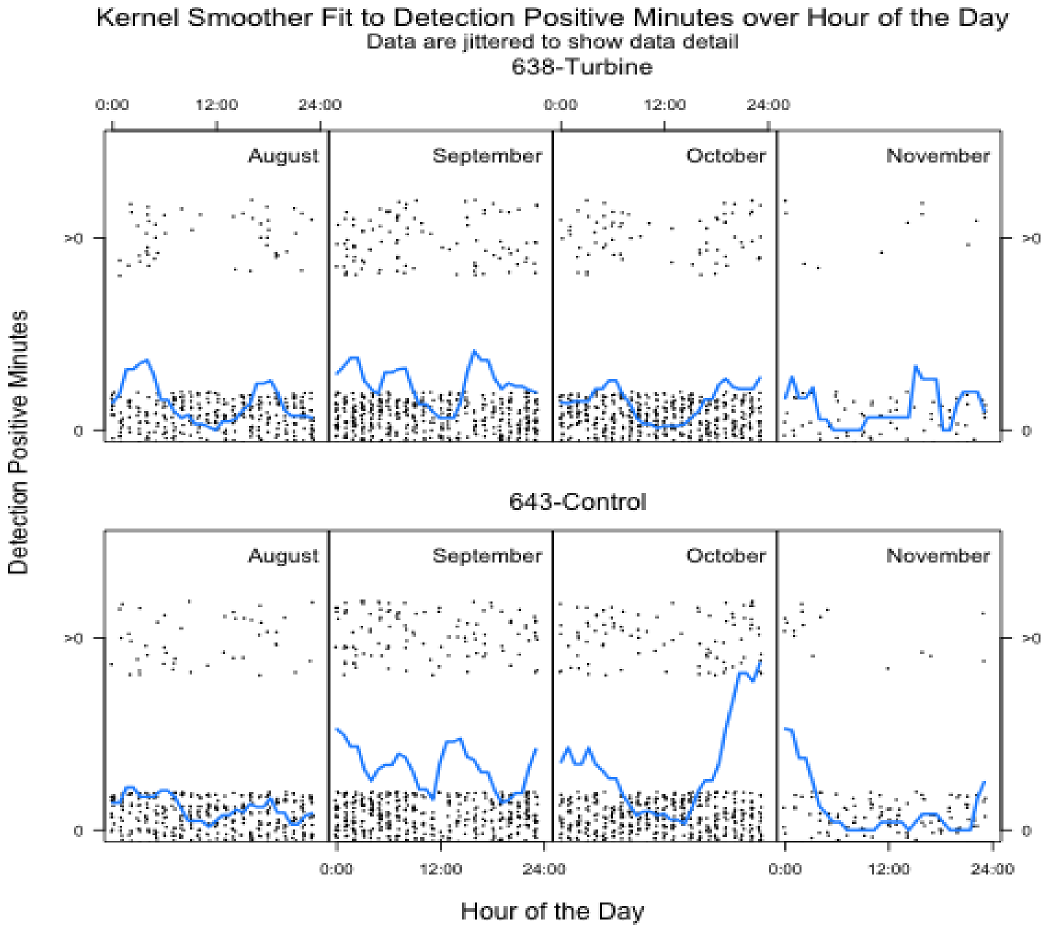

Figure 4.13. Trends in Detection Positive Minutes per hour across hour of the day and by month and site (blue line) to depict trends (based on raw data).

4.2.3 Tidal cycles and DPM per hour

ADCP data were not collected during the C-POD deployment sites so a direct comparison of DPM per hour with current velocity was not possible. However, tidal cycles do occur on a regular ~daily pattern with a ~15 day spring-neap tide cycle superimposed on top of the daily cycle (Figure 4.3). To investigate whether DPM per hour at the two sites followed a similar pattern we generated power spectra from the DPM per hour at midnight (the overall maximum DPM per hour period for both sites). Power spectra provide a summary of the periodicity of the signal variance within a time series. Both sites show a peak at ~26 hours which corresponds closely with the ~daily tidal cycle (25 hours 50 minutes). That is to say that there is a peak in porpoise detections on the same scale as tides are occurring. At this point it does not tell us if this is happening during tidal exchanges or at high or low tides. The Control site also shows a peak in its spectrum that corresponds to a ~7 day lag, a period often seen in ocean time series, thought to sometimes represent meteorological storm frequencies. No such periodicity was seen on the turbine site C-POD though. No clear peaks are seen at ~15 days, which would correspond to the spring-neap tidal cycle. This may indicate that porpoise use of these sites is driven more by the daily tidal cycle than the extreme spring-neap cycle. Signal variance is clearly higher at the Control site, reflecting the increased variability seen in DPM through the study (Figure 4.5).

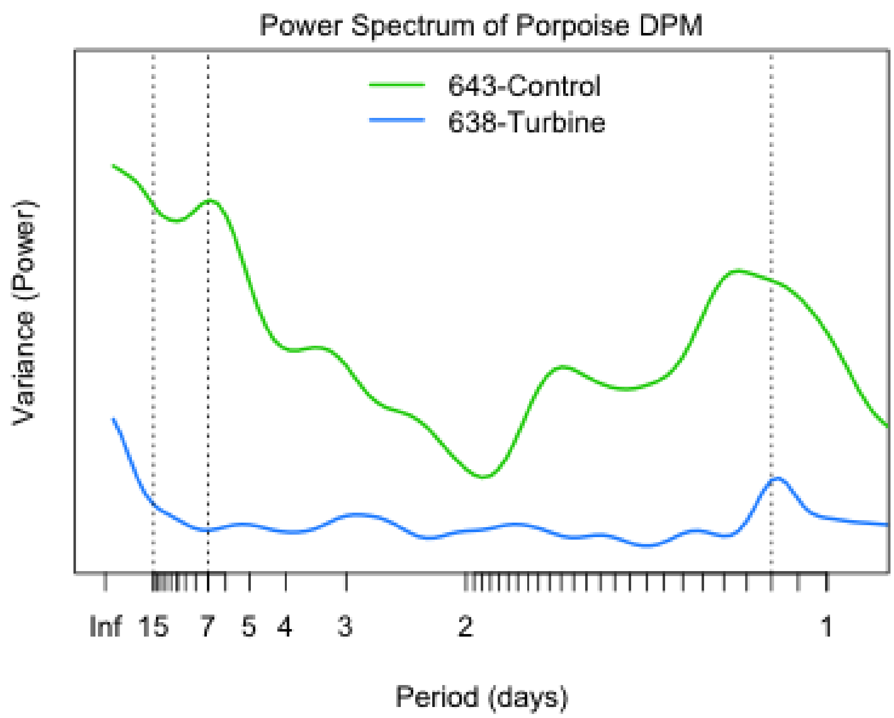

Figure 4.14. Power spectrum of DPM at the two sites at midnight. The x axis marks between 1 and 2 are in hours from 1 to 2 days (e.g. 1 day is 24 hours, the first mark to the left is 25 hours, etc.). The vertical dashed lines illustrate ~daily tidal cycles (~26 hours), a weak cycling at a frequency of ~7 days at the control site, and the ~15 day spring-neap tide cycle (where there is little evidence for a peak).

4.3 Analysis of click train measurements

Although porpoise occurrence (measured using DPM per hour) did not vary significantly by site, there is still the potential that the two sites are used differently by porpoises, especially as monthly trends in DPM per hour were not consistent across sites. To test possible behavioural or activity state differences, we calculated the following click train detail for each site; Inter Click Interval (ICI), click train duration, and number of clicks per click train. Kruskal-Wallis tests determined that all three variables were significantly lower ($P<0.001$) at the Control site than the Turbine site (Figure 4.15). The median (interquartile range) ICI was 35100 µs (20200-51280) at the Control site and 43060 µs (30260-58670) at the Turbine site. This translates into a median rate of 28 and 23 clicks per second at the Control and Turbine sites respectively. Median click train duration was 455800 µs (219800-801700) at the Control site and 720100 µs (379400-1293000) at the Turbine site while the median number of clicks per click train was 15 (11-20) and 16 (11-26) at those respective sites. So while click rates were higher at the control site (meaning lower ICI), there were fewer clicks per click train because the click trains were shorter.

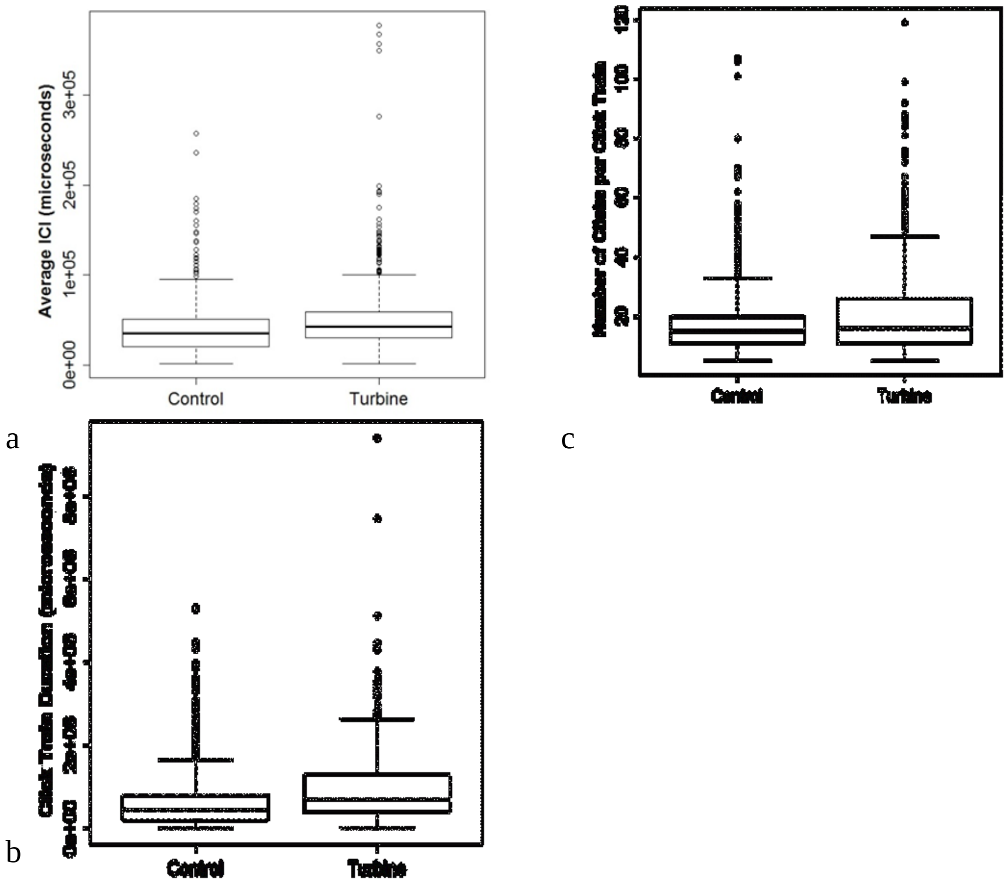

Figure 4.14. Boxplot of a) Average Inter Click Interval (μs), b) Click train duration (μs), and c) Number of clicks per click train (right panel) for each site.

5.0 DISCUSSION

Assessing the impact of single TISEC devices on the environment is clearly an important first step prior to any larger-scale development. The power of conclusions from any impact study is primarily influenced by relevant data quantity and quality. In pilot level TISEC device impact assessments that include whales, dolphins and porpoises, passive acoustic monitoring is considered a primary method in cost-effectively collecting long-term data (SMRU Ltd 2010b). Long-term data sets are required, especially for studies on marine mammals, mainly due to their wide movement patterns and flexible and variable life history patterns.

Dedicated boat and shore surveys of the Minas Passage area highlight that harbour porpoises clearly represent the most abundant marine mammal (Envirosphere 2011), thereby theoretically increasing the likelihood of potential interactions by porpoise with TISEC devices. Porpoises are highly vocal animals, and wild individuals in Danish waters have been shown to produce sonar-click trains on average every 12 seconds (Akamatsu et al. 1992, 2007).

C-PODs log continuously and are therefore useful for providing continuous data on porpoise activity within a radius of up to ~300m (Tougaard et al. 2006). However it is important to stress, they only record porpoises that are actively echolocating, and range is likely to vary depending on direction of travel and to what extent clicks are produced off-axis. Detection rates of 100% are believed to occur at ~100m. Despite these limitations, C-POD data is considered useful in comparing relative frequency of occurrence between sites, through time or after anthropogenic impact (e.g., construction periods, turbine presence, turbine operation).

This study represents ~181 days (4278 hours) of data successfully collected from two of three C-PODs moored in 50m water depth in Minas Passage between August 10th 2010 and November 23rd 2010. Only click trains from porpoises were recorded on the C-POD (i.e., no confirmed delphinid click trains were detected during scanning). Interference by Vemco acoustic transmitters deployed concurrently was not found to be a problem. Interference by non-biological sound sources caused low levels of data clipping and solutions to this issue have been highlighted in the recommendations section below. While the intention of the study was to collect data during turbine operation, it appears that the turbine was nonfunctioning during the C-POD deployment period.

Harbour porpoise presence was detected on most days (93%), but usage was typically low, averaging ~5 minutes per day and a maximum of 42 minutes. This represents daily usage levels of 0.3-0.4% of a day (max=2.9%). Typically, click trains were detected in 2-4 (maximum of 8) separate hours of each day, with detections present in just 11% of the total 4278 hours monitored overall. These values are similar to porpoise usage of TISEC deployment areas in Strangford Lough narrows (County Down, Northern Ireland, SMRU Ltd 2009), but some 25 fold lower than usage recorded in Admiralty Inlet (Washington State, USA, Tollit et al. 2010). Overall, our GLM analysis of deviance indicated porpoise presence varied between day and night (9% versus 13%), as well as across months (ranging between 8% and 15%), but that it did not vary between the Turbine and Control sites (with presence 11% and 12% respectively).

Land-based surveys of the demonstration site detected lower rates of porpoise (71% of seven observation days and 8% of 84 30 minute scan periods, Envirosphere 2011). Differences likely reflect data collected over 42 hours versus 2100+ hours, as well as the fact only one day (23/10/2010) of land-based surveys coincides with data collected using C-PODs. On this day, Envirosphere monitored from 10:30-16:30 and detected a single porpoise in the zone east of the turbine zone between 15:00-15:30 and 16:00-16:30 (with direction of movement unknown).

During the same 6hr survey period a single porpoise click train was detected by the near Turbine C-POD at 16:29. Clicks were also recorded 3 minutes later (16:32) by the Control C-POD 839m west of the near-turbine C-POD, suggesting rapid directed movement out of the Basin. During this time there was a strong ebb tide with a ~10 meter exchange from the high at 13:00 to the low at 20:00, suggesting the animal was moving with the tidal current. Both C-PODs also detected porpoise clicks on this date at three time periods, twice prior to the Envirosphere survey period and once after sunset. Land-based sightings recorded mainly small groups of 1-3 individuals. Though not in the scope of this report, the minute resolution level of C-POD data can clearly provide fine-scale individual animal information on site usage patterns.

The harbour porpoise are a small coastal temperate water species listed as a species of "special concern" and protected under the Canadian *Species at Risk Act* (SARA). Gaskin (1977) estimated the summer Bay of Fundy porpoise population to be 4000, with a more current abundance estimate of the Gulf of Maine/Bay of Fundy harbour porpoise stock at 89,700 animals (CV=0.22), based on the 1999 surveys by Palka (2000). During summer (July to September), harbour porpoises are concentrated in the northern Gulf of Maine and southern Bay of Fundy region, generally in waters less than 150 m deep (Gaskin 1977; Palka 1995), with a few sightings in the upper Bay of Fundy and on the northern edge of Georges Bank (Palka 2000). During fall (October-December) and spring (April-June), harbour porpoises are widely dispersed from New Jersey to Maine, with lower densities farther north and south. Palka (2000) reported high densities of porpoise in the Bay of Fundy region in water depths of 55-128m, somewhat deeper water than found at the C-POD deployment sites, but certainly corresponding to depths found in other locations within Minas Passage (which has a maximum depth of ~120m).

In the Bay of Fundy, harbour porpoises feed primarily on juvenile Atlantic herring *Clupea harengus harengus* (Gannon et al. 1998), although weaning calves consume euphausiids *Meganyctiphanes norvegica* (Smith & Read 1992). In both the summer and fall, Atlantic herring comprise the largest portion of the diet. In the fall, however, porpoises expand their diet to a wider range of prey, including juvenile gadids (such as hake) as they move south into the Gulf of Maine (Gannon et al. 1998). Because of their small size, harbour porpoises are unable to carry large energy stores, so their patterns of movement are likely to be strongly related to the distribution of their prey. Similar to that found in Europe (Calstrom 2005) and Admiralty Inlet, Washington (Tollit et al. 2010), this study highlighted a significant increase in porpoise presence in the night (13%) compared to the day (9%). This may reflect increased diel availability of their preferred prey, herring, at night, as they move into the water column, but we also note these patterns were not consistent across months. For example, September exhibited peaks in presence during the daytime and nighttime, while October exhibited a clear daytime low. Patterns may also be related to circadian rhythms, external cues (light cycles), periods of herring spawning (some of which occur locally in the fall) or to some combinations of all these factors. It is also important to recognise that porpoises have the ability to hunt visually in the photic zone.

Satellite tracking studies in the Bay of Fundy and Gulf of Maine indicate that porpoise movements occur on at least 2 spatial and temporal scales. Individuals inhabit relatively restricted areas for days to weeks (fine scales) and then make rapid movements over periods of hours to days across larger scales (meso-scales) to other restricted areas (Read & Westgate 1997). Harbour porpoises use restricted focal areas in the Bay of Fundy during the late summer, with the size of each monthly focal area ranging from 122-415 km^2 (Johnston et al. 2005). It is notable that harbour porpoises appear to favour foraging habitats with relatively high tidal flows (Goodwin 2008, Hall 2004, Tollit et al. 2010) or regions of enhanced relative vorticity, such as island and headland wakes (Johnston et al. 2005). Regional (Outer Bay of Fundy) density estimates vary from 1.5-9.6 porpoise per km^2, largely dependent on state of the tide (highest values found during the flood tide in tidally mixed locations, Johnston et al. 2005). Gaskin and Watson (1985) reported increased densities of porpoises during neap tides in New Brunswick, Canada. This study identified some tidally-related patterns (for example a power spectrum peak at ~25 hours due to the daily tidal cycle period, and peak usage coinciding with certain neap tides in September and October), however, given the overall low usage of the area, these observations need longer-term datasets (and site-specific current data from models or ADCP deployments) before conclusive tidal patterns can be described with any confidence. Power spectrum peaks were also seen at 7 days at just the control site, but the cause of this peak is uncertain. It should be remembered that <10 days of data were collected during November and thus presence data from this month should be treated with caution.

We have assumed the turbine was not operational during this study. Consequently, this study is only able to compare two similar sites - with and without the presence of the turbine and gravity base structures. We found similar patterns of overall daily usage, median DPM per day and hourly rates of porpoise presence with no statistical difference between the sites. This suggests that the porpoise are neither attracted to, nor repulsed by, the turbine infrastructure. However, fine-scale usage patterns were not considered identical, with lower DPM peaks and overall variability observed at the Turbine site. Furthermore, in a preliminary analysis of key click train parameters (thought to be proxies for changes in behaviour or activity type, see Todd et al. 2009) we did see significant differences between the sites. Click rates were higher at the control site (meaning lower ICI), and there were also fewer clicks per click train because the click trains were shorter in duration. In terms of how this translates to different behavior or site usage there are a few potential interpretations. Click trains may be shorter at the Control site because the animals are making faster sweeps with their click trains, and thus the C-POD detects a shorter click train as the animal is not focusing its echoes in one direction for a long time. This might be indicative of the porpoises more actively searching for prey at the control site. In addition, cetaceans normally produce clicks at a rate such that the ICI equals the two way travel time of a click plus a fairly constant (and small) lag time (Au & Hastings 2008). This allows the animal to produce a click, wait for its return after it has reflected off of the target, and then to process that information (thus the lag time) before producing another click. The difference in median ICI translates to (assuming a speed of sound at 1500 m/s) a maximum target distance of 26 meters at the Control site and 32 meters at the Turbine site. This may also be indicative of animals getting closer to potential prey items. However, these data are preliminary at this point and determining if these differences have biological significance will take more data and a closer look at these click train details during specific events to determine patterns and test specific hypotheses. We also note that the tilt data from the two sites varied considerably, suggesting some local site differences in current speed and/or eddies.

In summary, C-PODs were found to be effective in monitoring cetacean presence. Harbour porpoise were detected regularly through late summer and autumn but did not (with a few exceptions around neap tides in September and October) appear to spend significant time periods around either the turbine or the control site (suggesting mainly transit through Minas Passage or more preferred local foraging areas are out of detectable range). Presence was higher at night, but we found no statistical evidence of the presence of the turbine attracting or repulsing porpoise, but when present porpoise behavior (based on click train parameters) appeared to differ between the Turbine and Control sites.

6.0 FUTURE RECOMMENDATIONS

a) C-POD settings and equipment: We recommend increasing the maximum click count to a higher setting per minute and ensuring the C-POD cannot be turned off (due to tilt angle) during deployment.
b) C-POD moorings: We recommend increasing the robustness on the clamps used to connect the C-PODs with the strong backs and ensuring optimal conditions during deployments.
c) Deployment length: We recommend that batteries in C-PODs be replaced at 3 monthly intervals to prevent loss of data from battery expiry.
d) Future deployment study design: A longer overall period of C-POD deployment in 2011 is recommended, using a gradient sampling study design.
    i. A 6 month period covering April/May through November could be achieved with only one recovery and redeployment visit (i.e., three field site visits in total).
    ii. Future study designs should recognise the need for C-POD redundancy at key locations (suggest 2 C-PODs per site, if possible).
    iii. Given that the noise source levels of each TISEC device are uncertain, we recommend a gradient BACI design approach. This design would involve placing C-PODs in each of the 4 berth areas. A further 6 C-PODs in ‘control’ areas outside the leased area are recommended: four units located 500m north, east, south and west of the demonstration site, and two C-PODs 1000m east and west. Future designs should position the control sites to maximize data collection in the area of any likely build-out. The strategy of collecting control data in four directions aims to build in a level of redundancy.

iv. The location of control sites should be informed by advice from regional experts with knowledge of the tidal currents, eddies and bottom characteristics of the Minas Passage. Ideally, one C-POD site should also be positioned to monitor porpoise presence in the deeper waters of Minas Passage.

7.0 ACKNOWLEDGEMENTS

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FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX E

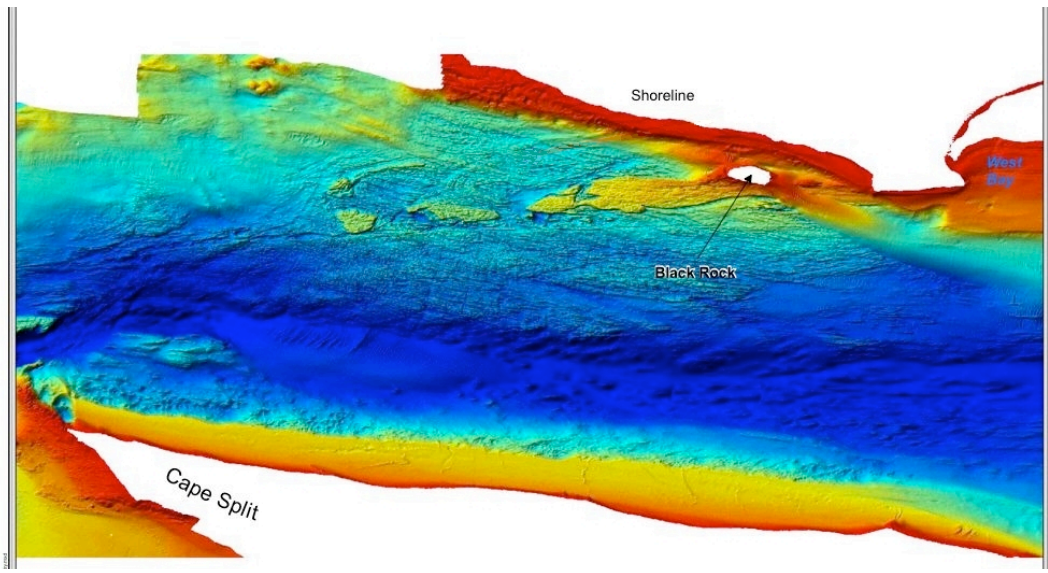
Lobster Summary Final Report

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT

LOBSTER CATCH MONITORING

Summary of Results from Three Surveys with Recommendations for a Revised Survey Design

FINAL REPORT



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EXECUTIVE SUMMARY

Commercial fishing for lobster is important in Minas Channel, as well as most of the Bay of Fundy. Lobster fishing is one of the few commercial fishing operations likely to occur near the deployment area and an environmental effects monitoring (EEM) program has been implemented to assess potential changes in fishing success as result of construction and operation of the tidal energy program. The program consists of setting commercial lobster traps within test and control areas. Three surveys, two in the fall of 2009 and one in the spring of 2010, have been conducted to date. This EEM program is planned to continue as turbines are installed to provide input to the environmental management of the tidal energy program.

This report summarizes the key results from the 2009 and 2010 surveys and demonstrates the ability of the EEM program to identify significant effects. It includes an independent statistical review of results from the three surveys. The statistical review is incorporated into the comments on the significance of results observed by the monitoring, as well as recommendations for design improvements.

The primary difference between the two fall surveys conducted in 2009 was that the first survey took place prior to the commercial lobster fishery and the second survey took place while the fishery was active. Comparison of catch rates in the two fall surveys indicated that the catch of market-sized lobster was significantly lower ($P<0.0001$) during the commercial fishery (Fall Survey 2) than before (Fall Survey 1), documenting an effect from the commercial fishery.

The relationship of lobster size is an important variable affecting distributions of lobster, with smaller lobster generally found closer to shore in shallower water. Large lobster, greater than 110 mm carapace length, were less abundant but widely distributed with no statistical correlation with depth. A related finding was that the test area appears to be moderately fished commercially in comparison to a higher level of exploitation around Black Rock. The deeper ridges and banks, particularly in the Western Control Area, do not appear to be significantly fished.

A turbine was installed on November 12, 2009, part way through Fall Survey 2. Statistical comparison of the mean catch from traps 200-300 m from the turbine deployment site were significantly lower ($p=0.0002$) after turbine deployment. This comparison should be not taken to indicate an effect from turbine deployment because there were a number of differences in conditions, including water depth variations from traps being shifted by currents and effects of the commercial fishery, which could explain the differences in catch rates. However, the comparison does indicate the level at which differences can be detected in the EEM program conducted and that the program warrants continuation.

The key recommendation involves combining the two design elements into a single Before – After Control-Impact (BACI) design that will improve the efficiency of the survey, while providing a similar ability to detect potential impacts, both nearfield and farfield. The recommendations also suggest that the existing samples can be used for comparison with future results. However, it would be advisable, since new sampling stations need to be randomly selected, that pre-deployment data be collected using the new design. A fall survey in 2011, prior to the start of the commercial fishing season, is the top priority, followed by a spring survey to better document movements in and out of the area.

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1 BACKGROUND

1.1 Program Rationale

A pilot tidal energy program is being established in Minas Channel west of Black Rock near Parrsboro, Nova Scotia. Development of the program is being coordinated by the Fundy Ocean Research Centre for Energy (FORCE), an independent body comprising private industry, government and academia. FORCE's Board of Directors consists of technology developers testing with FORCE, one representative from the Province of Nova Scotia, and an independent academic from a relevant discipline appointed by the Province of Nova Scotia.

Different designs of tidal power generators are to be installed within a 1.6 km^2 crown lease area[1] at mid-tide depths of approximately 60 m, with power and communication lines running to shore north of Black Rock. Nova Scotia Power Inc. (NSPI) installed the first prototype tidal generator on November 12, 2009, and additional units are planned for installation by other companies within the same lease area in 2012.

Commercial fishing for lobster is important in this area, as well as most of the Bay of Fundy. Lobster fishing is one of the few commercial fishing operations likely to occur near the deployment area and an environmental effects monitoring (EEM) program has been implemented to assess potential changes in fishing success as result of construction and operation of the tidal energy program. The program consists of setting commercial lobster traps within test and control areas. Three surveys, two in the fall of 2009 and one in the spring of 2010, have been conducted to date. This EEM program is planned to continue as turbines are installed to provide input to the environmental management of the tidal energy program.

1.2 EMAC Review and Input

An Environmental Monitoring Advisory Committee (EMAC) has been established to provide independent expert scientific and traditional ecological knowledge advice to the Fundy Ocean Research Centre for Energy (FORCE) on the adequacy of the environmental effects monitoring programs related to the Fundy Tidal Energy Demonstration Project. EMAC is tasked with:

- providing a forum for review of environmental monitoring program results;
- reviewing EEM programs and making recommendations for improvement; and
- communicating advice to FORCE on EEM programs.

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[1] The total crown lease area includes the test demonstration area of 1.6 km^2 plus a corridor area of 0.47 km^2 for cables to shore, for a total of 2.07 km^2.

One of the aims of EMAC is to encourage the EEM programs to be as cost-effective as possible while meeting their intended purpose. Direction and advice will be based on "adaptive management" principles, defined as: "an iterative process of planning and implementing an action, monitoring, evaluating and making adjustments as needed. Dr. Robert Miller, a member of EMAC, provided input to the statistical review appended to this report, but he remains independent of the main findings of this report, avoiding any conflict of interest.

This report is intended to provide EMAC with a summary of survey results and recommendations for improvement in survey design and implementation. This report summarizes previous reports focusing on key lessons learned. It also includes a review of the survey design with suggestions about how to make to make it more efficient, but also what kind of environmental change is likely detected by the program.

1.3 This Report

This report summarizes the key results from the 2009 and 2010 surveys and demonstrates the ability of the EEM program to identify significant effects. It includes an independent statistical review of results from the three surveys. The statistical review is incorporated into the comments on the significance of results observed by the monitoring, as well as recommendations for design improvements. A copy of the independent review is appended to this report. Readers are referred to previous data reports for more detailed portrayal of survey results. These surveys were carried out before and after deployment of the NSPI turbine in November of 2009, and thus provide some initial indication of potential effects from deployment and operation. When information is available prior to the potential impact, the design is often referred to as a Before – After Control-Impact (BACI) design (Smith 2002).

It is important to note that while approaches used in other similar EEM programs were utilized in the initial design of these surveys, the environment, especially the very strong bottom tidal currents, is unique and no similar study had been previously conducted in these conditions. Initial survey information collected has provided critical information necessary to evaluate the program design and to improve its efficiency through adaptive management.

2 PROGRAM DESIGN

2.1 Study Location

The crown lease development area and three initial proposed deployment sites are shown in Figure 2-1. The oval dark blue area on Figure 2-1 to the right of the crown lease deployment area contains Black Rock, a major feature of the coastal area. The town of Parrsboro is located approximately 15 km to the east of the study area. A fourth deployment berth has since been established.

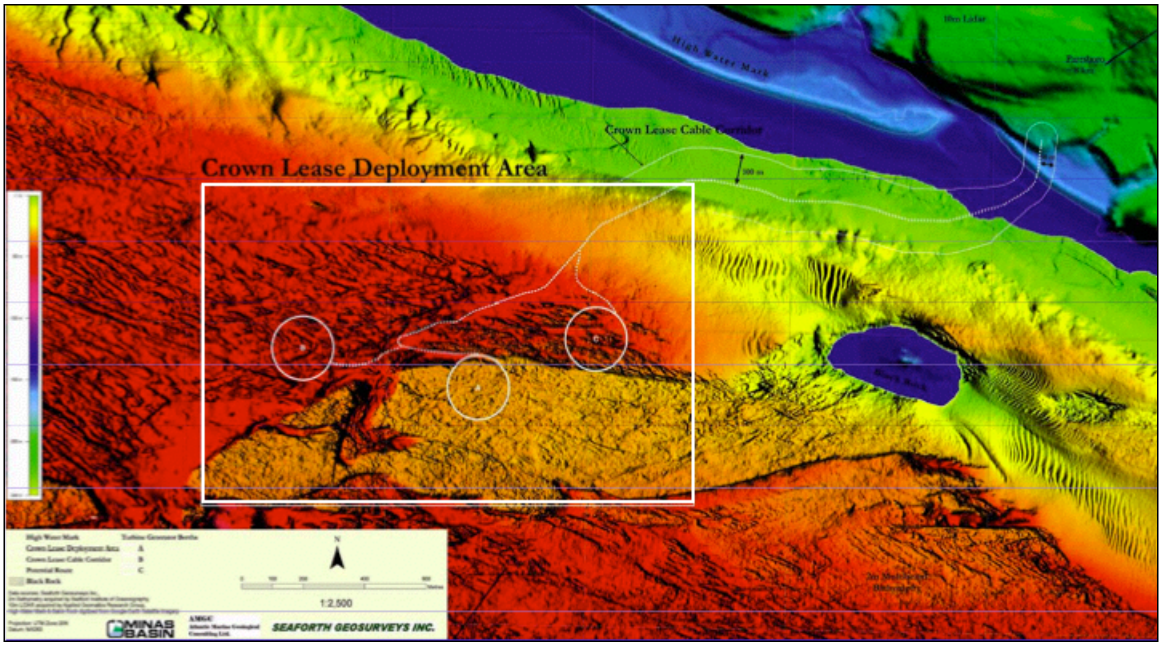

Figure 2-1: Crown Lease Development Area

In addition, a reference site for biological and physical monitoring has been established at 45° 21' 53" N, 64° 27' 32" W. Water depth at the site is 58 metres at mid tide.

2.2 Control and Test Comparisons

The design of the EEM program for lobster was based on measuring catchability within test and control areas. The crown lease deployment area was selected as the test area. Test Area refers to the area within which samples are considered affected by the treatment being monitored, i.e,. tidal power generator deployment and operation. Control areas were selected to the east and west of the test area. These area were selected because together they contained a range of lobster habitats similar to the test area, and they were assumed to be sufficiently far from the treatment that they would be unaffected by it.

The primary evaluation of effect was to be an Analysis of Variance comparing catchability within test and control area. Catchability was to be determined by deployment and retrieval of standard, baited, commercial lobster traps, similar to those used by local fishers. Test and control areas are illustrated in Figure 2-2.

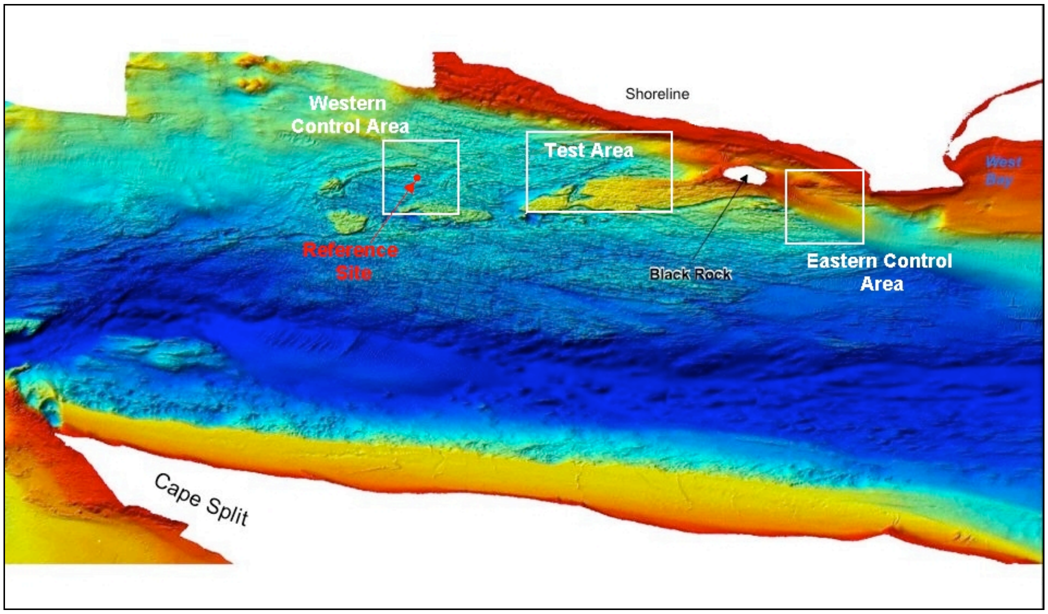

Figure 2-2: Location of Test and Control Areas

All stations were selected randomly and no stratification was used. Initially 25 stations were selected in the test area and 10 stations in each of the two control areas.

2.3 Nearfield Comparisons

NSPI requested specific nearfield monitoring around their turbine before and after deployment. A series of sampling stations were established in a circular grid at 200 m and 500 m from the proposed deployment site. Four stations were established at each distance in north, east, west and south directions from the deployment location. These stations were monitored along with the test and control stations.

2.4 Survey Equipment

Sixty standard commercial lobster traps and associated gear, including buoys, were purchased for use in this study. Traps were weighted with approximately 100 kg of concrete poured into the bottom of each trap. Traps were baited with shad and herring soaked in brine and escape vents were blocked to retain all sizes of lobster. All fishing was carried out at or near slack tide. Eight traps were equipped with thermometers to record bottom temperature.

Traps were set over slack and rising or falling tide whereas recovery of traps could only be done during slack high or low tide because it was only then that buoys were visible. During the first survey, two days were required to set all the traps. In subsequent surveys the number of traps was reduced allowing them to be set in one day.

All fishing was carried out by the fishing vessel Cape Rose (CFV 3089) from the Parrsboro wharf (Photo 2-1). Fishing was conducted under DFO Scientific Licence #324435 in 2009 and #324436 in 2010.

Photo 2-1: Fishing Vessel Cape Rose at the Passboro Wharf at Low Tide

3 RESULTS FALL 2009 AND SPRING 2010 SURVEYS

3.1 Comparison of Surveys

The conduct of the surveys changed over time, with a general reduction in the number of traps in an effort to provide more efficiency and consistency in sampling. The sampling effort and numbers of lobster caught for the three surveys are provided in Table 3-1.

Table 3-1: Number of Traps and Lobster Caught by Surveys, in 2009 and 2010

Survey	Date	Number of Traps Set	Number of Traps Recovered	Number of Trap Sets	Number of Lobster Caught
Fall One, 2009	September 25 - October 3	51	48	132	1387
Fall Two, 2009	November 5 - November 18	48	41	126	1135
Spring, 2010	May 10 - June 4	28	23	192	755

The primary difference between the two fall surveys conducted in 2009 was that the first survey took place prior to the commercial lobster fishery and the second survey took place while the fishery was active. In addition, during the second survey the number of stations was reduced and some traps fished in pairs separated by 60 m of line; buoys were also doubled with the second buoy attached as a trailer buoy to shorten the time required to find the traps. Between the first and second fall 2009 surveys, the number of stations was reduced from 33 to 18 in the test area, and from 20 to 9 in the control areas. As Table 3-1 indicates, these changes only amounted in a small change in the number of traps fished or the number of sets conducted because in many cases, two traps were fished at a single station.

The changes between the two fall surveys improved the efficiency of sampling to some degree, but the paired traps were not as successful as hoped. The movement of traps in areas of particularly high currents was still excessive, in one case being over one kilometer from set to retrieval. This magnitude of trap movement affects the interpretation of the data as well as affecting the time necessary to find and retrieve the traps. In addition, retrieval of the paired traps frequently resulted in safety concerns if the ropes became tangled or other problems arose during hauling. As a result of experience in the second fall survey, further modifications were made to the design of the spring survey.

In the spring of 2010 the number of stations and the number of traps fished in pairs were further reduced. This resulted in only 6 control stations being used and 14 test stations. The number of test stations was more than double the number of control stations because of the need to maintain both nearfield and farfield sampling within the test area. Note, however, as Table 3-1 indicates, that the number of trap sets actually increased because the sampling was more efficient. Generally speaking the objective was to enable recovery of all traps in a single day of fishing and this was accomplished most, but not all of the time.

3.2 Location of Stations

The locations of stations in the fall and spring surveys are illustrated in Figures 3-1 and 3-2 for the test area. Figure 3-2 also provides an indication of the movement of traps between set and retrieval. Note that the movement of traps in the spring survey was lower than in previous surveys largely because previous movement was used as a primary factor in selecting stations for use in the spring survey.

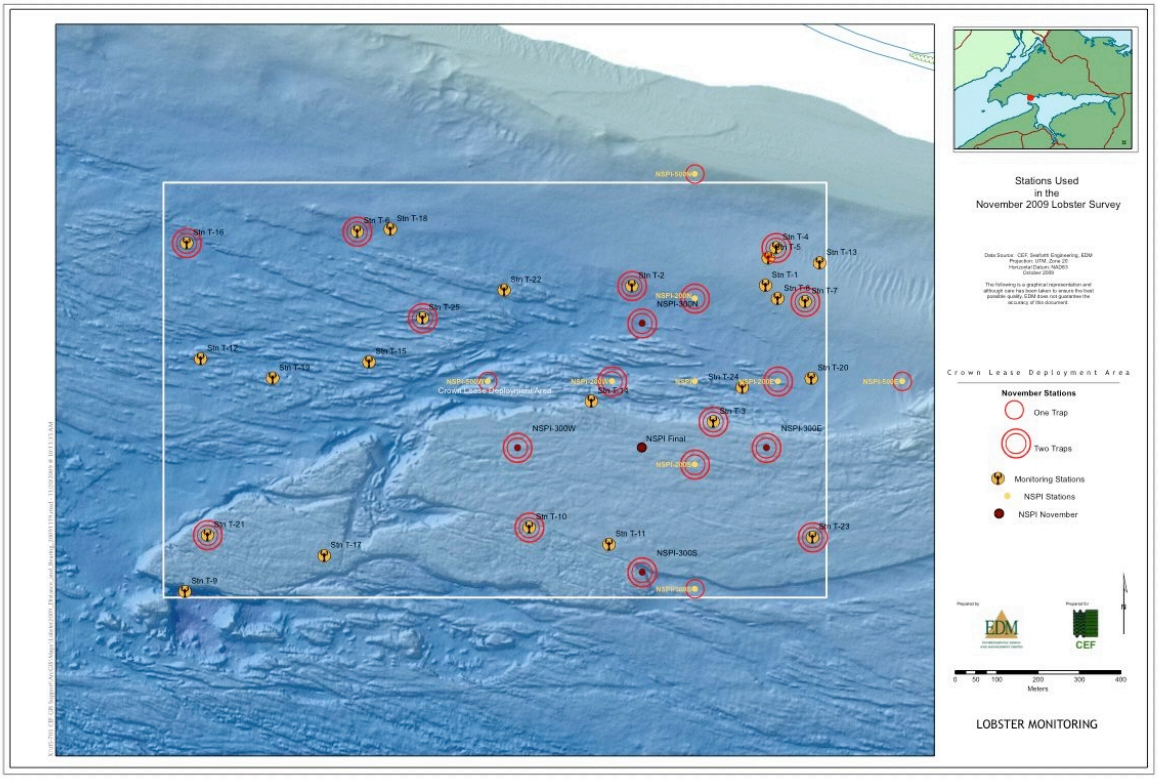

Figure 3-1: Sampling Stations within the Test Area in the Fall 2009 Surveys

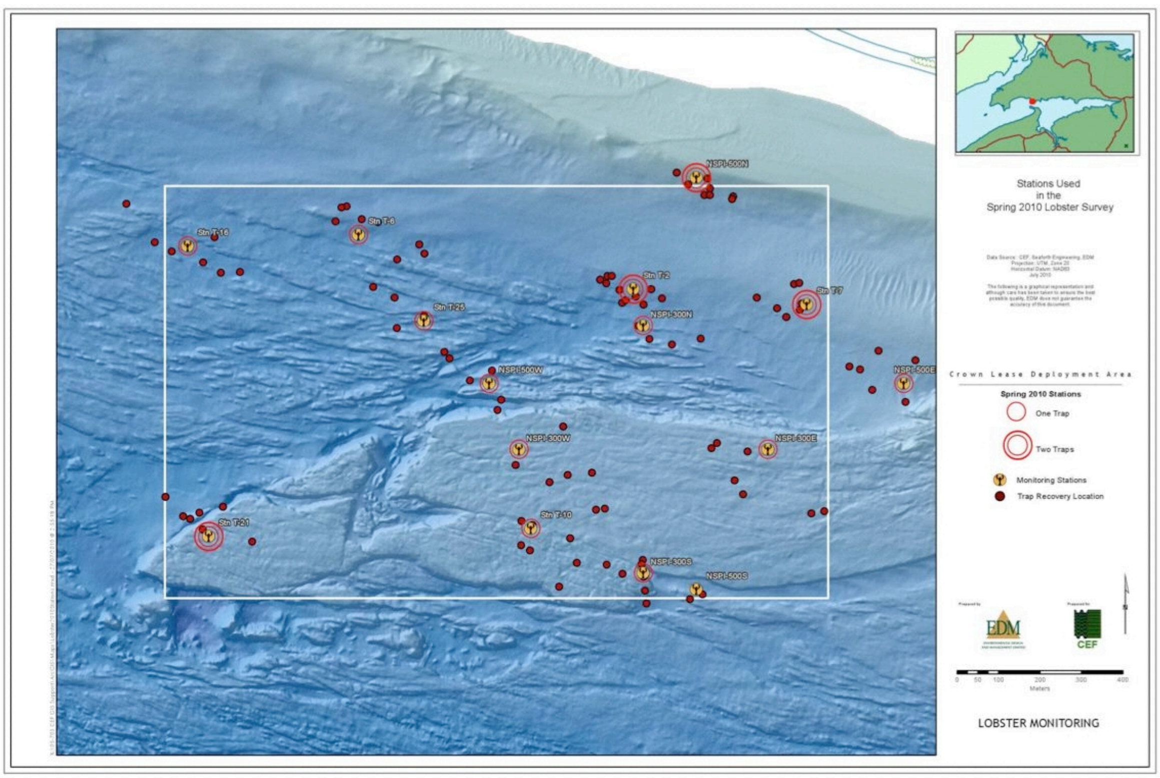

Figure 3-2: Sampling Stations within the Test Area in the Spring 2010 Survey

3.3 Differences between Spring and Fall Survey

Catch rates differed between the three surveys, with the largest difference between the spring and the two fall surveys (Table 3-2). Local fishers have said[2] lobster move out of the Upper Bay of Fundy in the fall and return in the early Spring. Fishing in the fall of 2009 was not carried on long enough to document a decline in catch rates because weather began to deteriorate in November. The survey in the spring of 2010 showed similar distributions of lobster by depth, but did not clearly identify increasing catch rates that would suggest an inmigration of lobster with time. Nonetheless, catch rates in the spring of 2010 were almost half of those in the fall of 2009.

Table 3-2: Catch Rates (Number of Lobster/Trap) in the Three Surveys

Survey	Catch Rate - Low Tide	Catch Rate - High Tide	Average Catch Rate
Fall One 2009	10.4	10.7	10.5
Fall Two 2009	11.2	7.1	9.0
Spring 2010	3.9	4.3	3.9

Lobster catch was divided into four size classes based on carapace length: < 66 mm; 66 to 82 mm; >82 to 110 mm; and > 110 mm. Lobster were considered market size above 82.5 mm carapace length. Statistical comparisons were done examining the relationship between catch rates, size class, water depth, and season using a generalized linear model (GLM). The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. In this case, a negative binomial model linking size class and catch rates was used. All interactions between depth and season were statistically significant ($p<0.05$). In addition, the relationship between size class, depth and catch rates remained similar regardless of season.

3.4 Major Variables Affecting Catch

The three most important factors affecting catch rates relevant to effects monitoring are:

- soak time;
- carapace length; and
- water depth.

The distribution of lobster by sex and whether females were berried or not was examined but did not appear to be variable spatially.

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[2] A project meeting was held with lobster fishermen early in design of the lobster monitoring program. In addition, local fishermen helped in implementation of the program and thus numerous conversations have taken place over the last two years.

3.4.1 Soak Time

Soak time refers to the length of time between setting and retrieval of a trap. Since the trap is baited and bait is usually consumed over a few days, soak time is a factor in trap efficiency. Soak time was considered to be an important potential factor in survey design, but the logistics involved in sampling were unknown. Trap movement from its set position, search time available, weather conditions, and number of traps fished all affected how long it takes between setting and retrieving a trap. Soak time was found to be a significant ($p<0.05$) variable in catch rates, with little interaction with other variables of interest (Bayley, 2010). The statistical review recommended that soak time be included in the analysis of potential project effects even though it would reduce the degrees of freedom in comparisons.

3.4.2 Carapace Length and Depth

Carapace length (CL) is the typical measurement for lobster size. Lobster size was found to be an important variable affecting distributions of lobster, with smaller lobster generally 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. Figure 3-3 illustrates the different relationships between size class and water depth for the fall and spring surveys. Large lobster, greater than 110 mm CL, were less abundant but widely distributed with no statistical correlation with depth. The relationships are similar for each size class but the density is lower in the spring for all size groups.

Figures 3-4 and 3-5 illustrate the generalized distribution of lobster by size class from trap results of the fall and spring surveys based on the generalized linear models illustrated in Figure 3-3.

If there is movement in and out of Minas Channel with season, this movement does not appear to substantially affect the size distribution. This is an important finding of the surveys to date. Further surveys to investigate inter-annual variation would be helpful.

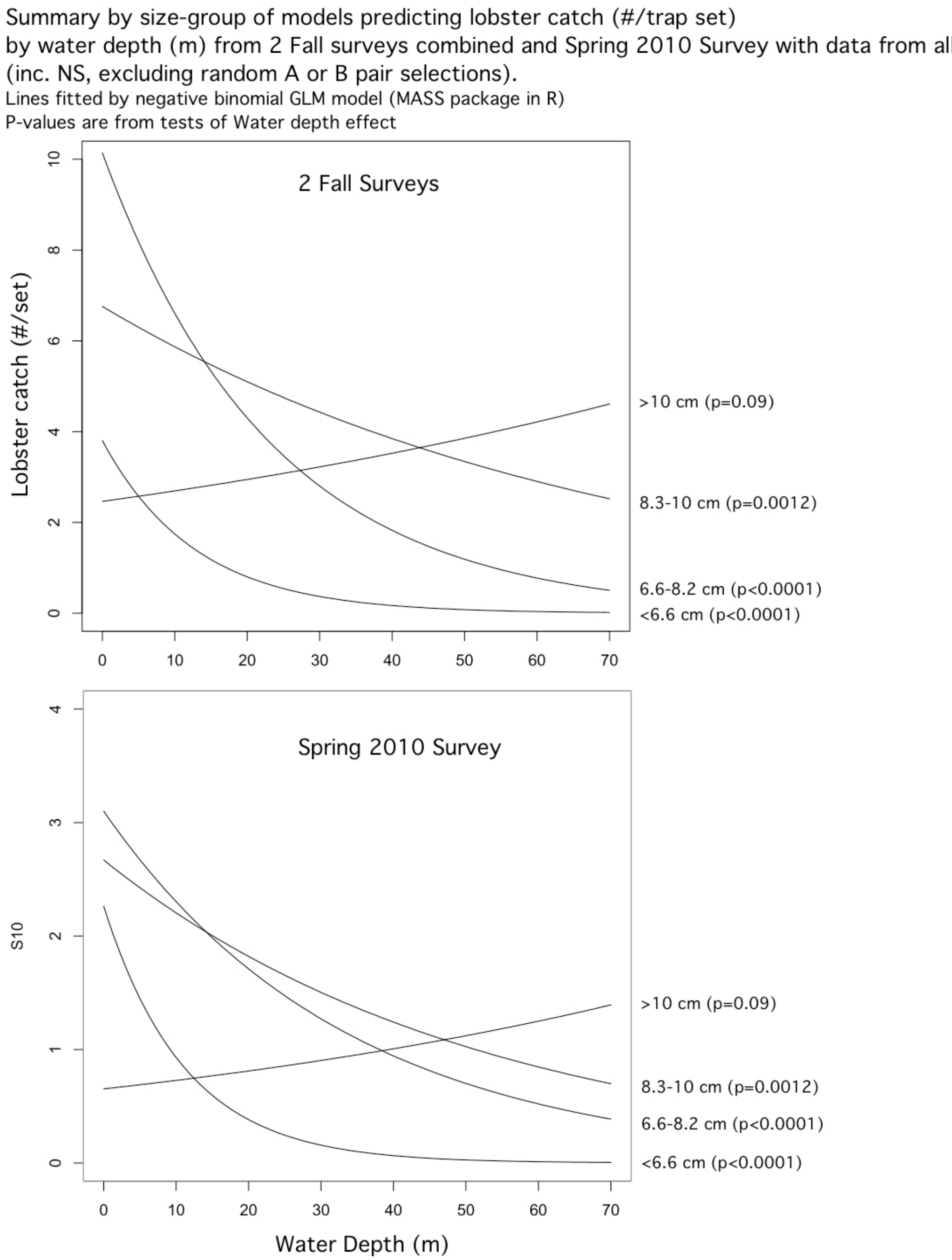

Figure 3-3: Relationships between Size Class and Water Depth by Survey

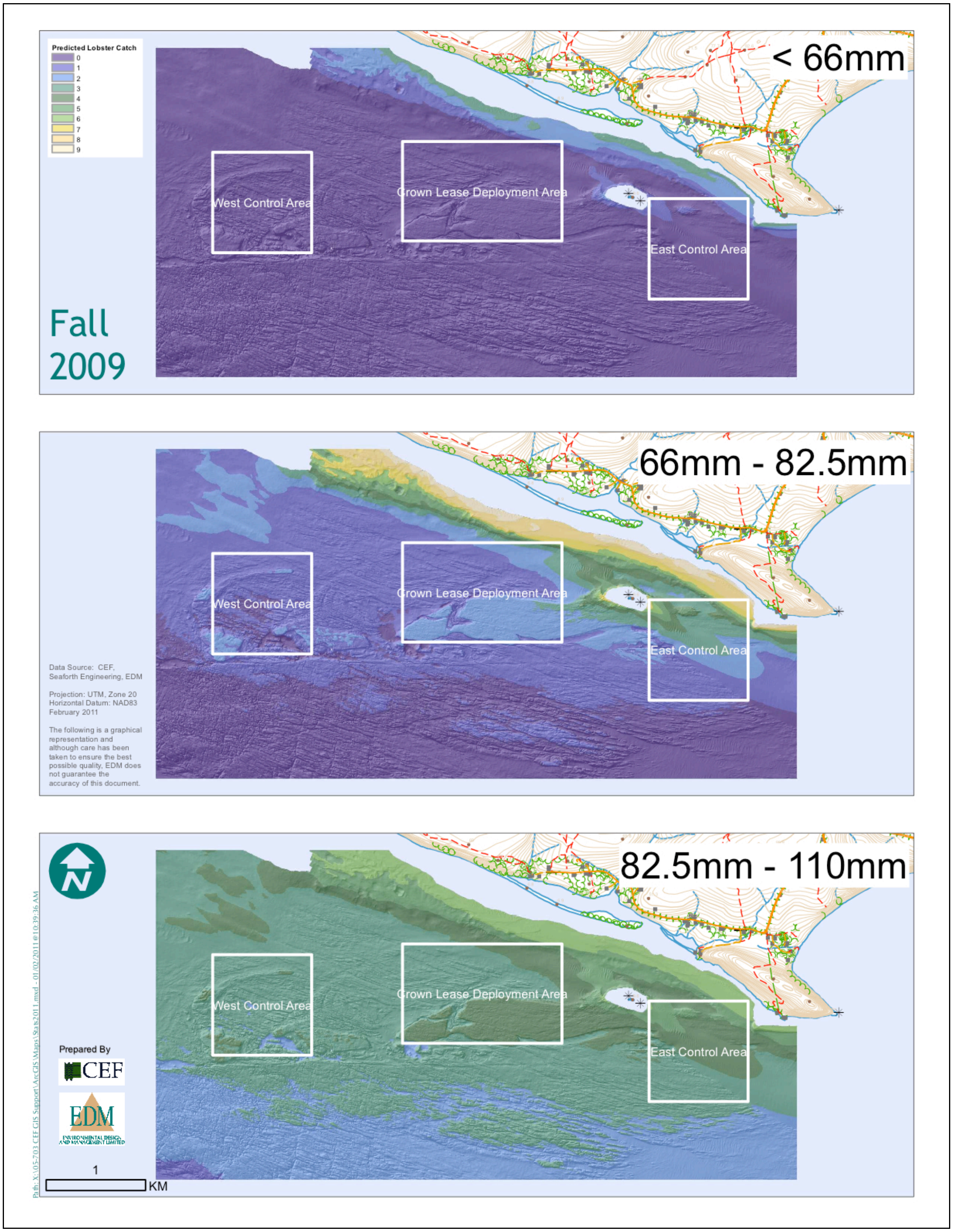

Figure 3-4: Generalized Density of Lobster Based on Fall 2009 Survey Results

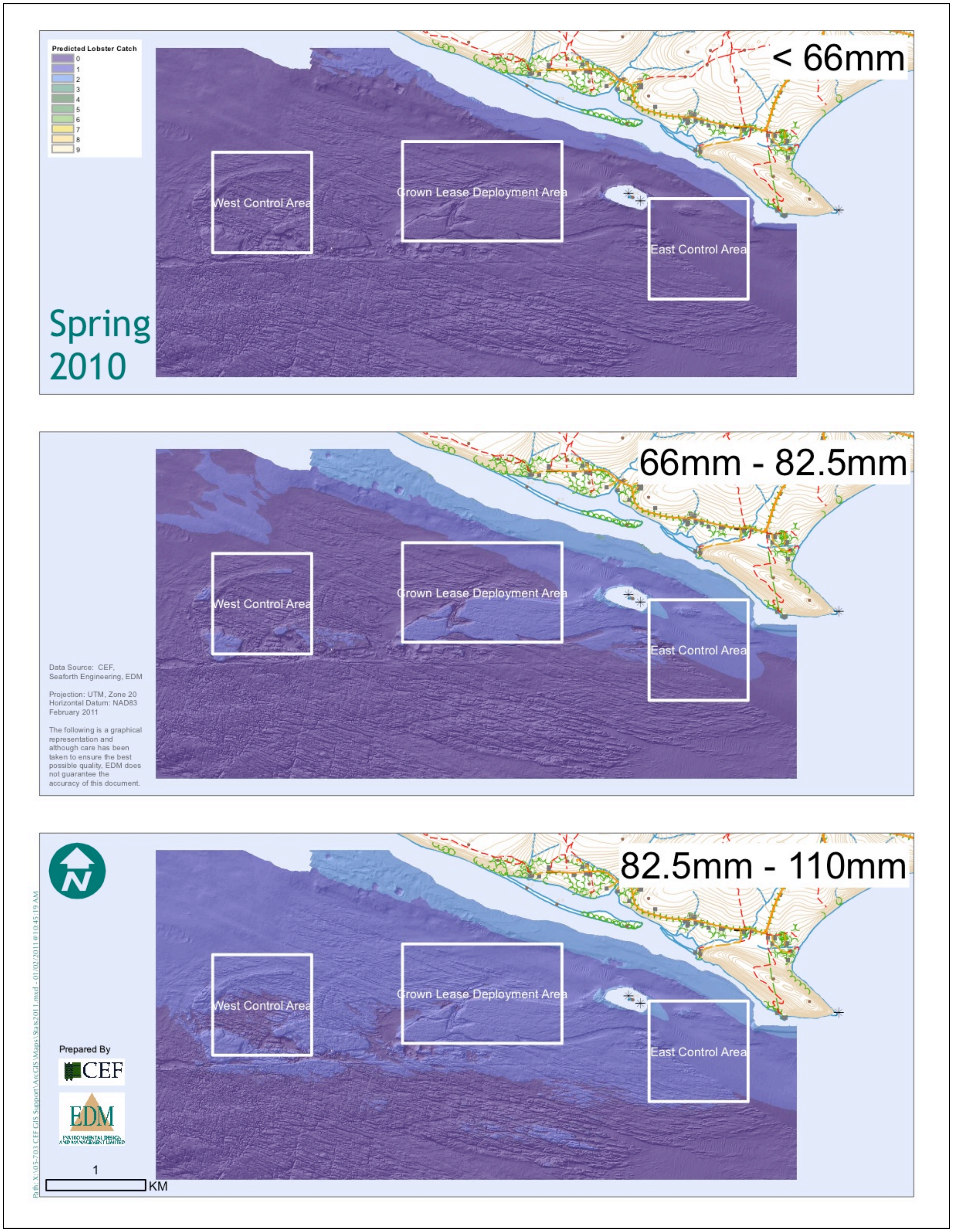

Figure 3-5: Generalized Density of Lobster Based on Spring 2010 Survey Results

3.5 Trap Movement

Information on trap movement was obtained because the recovery location of the trap was recorded by a portable GPS and the trap was always reset at the initial sample site. Movement of traps may provide useful information to current modelers as well as berth holders because it can provide indication of direction and strength of bottom currents.

Trap movement will continue to be an issue, but it appears to affect survey efficiency more than analytical confidence. The movement of traps between set and retrieval is largely a random process – traps do not move in a consistent manner from one day to the next.

In the first survey, traps were moved by high tidal currents an average of 116 m between hauls, with a maximum shift greater than one kilometer. Figure 3-6 representing trap hauls on September 28, 2009 provides an example of the type of movement observed between the setting and hauling of traps.

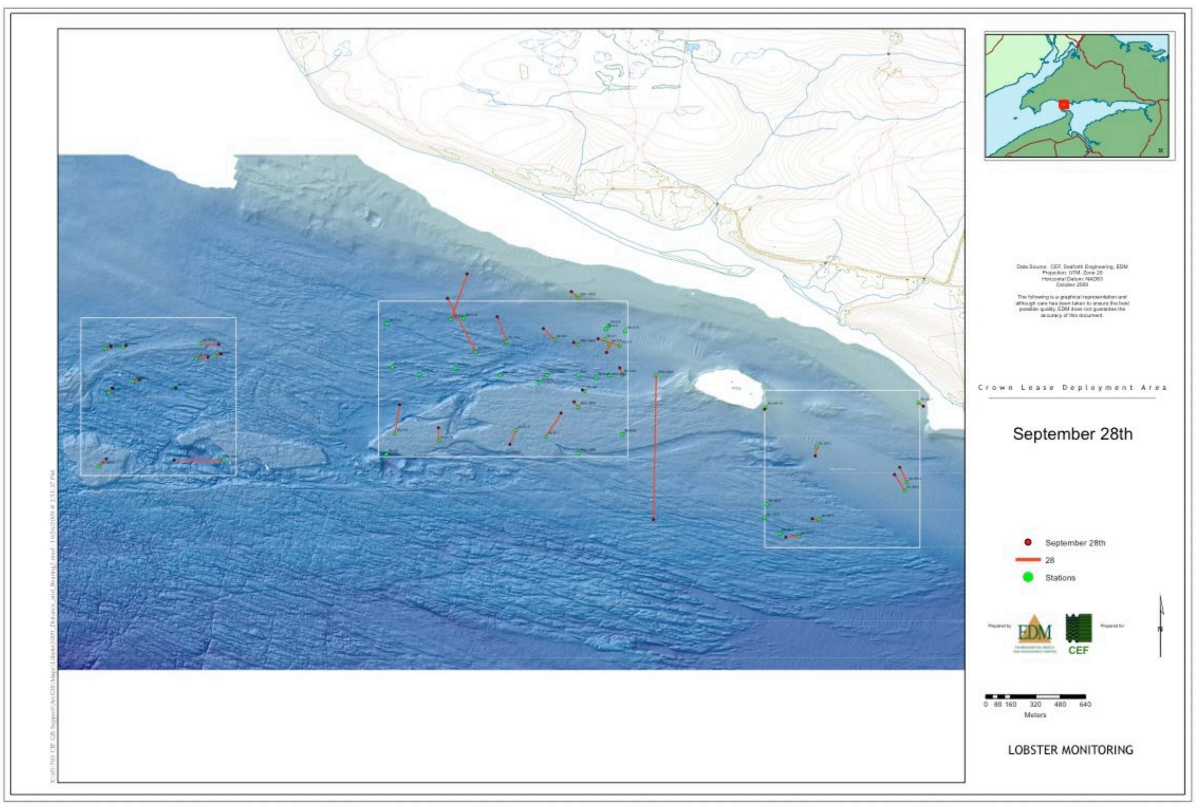

Figure 3-6: Location of Trap Haul Compared to Set Location for September 28, 2009

The pairing of traps in the second fall survey provided better replication in the sets and increased efficiency in the survey, but trap movement was similar with an average shift of 135 m between set and haul locations.

3.6 Effect of the Commercial Fishery

The two fall surveys took place before and during the commercial fishery. Analysis of the data was carried out to determine if the effect of the commercial fishery could be measured, and if so, was it the same in different areas. A generalized linear model using a negative binomial distribution was used to compare the catch rate of market-sized lobster in the Eastern Control Area between the two fall surveys. The comparison indicated that the catch of market-sized lobster was significantly lower ($P<0.0001$) during the commercial fishery (Fall Survey 2) than before (Fall Survey 1), documenting an effect from the commercial fishery in this area.

Similar comparisons were done with the proportion of market-sized lobster in the catch from the Test and Western Control Areas. Whereas the average catch of market-sized lobster dropped by 50% in Eastern Control Area, it only dropped by 29% in the Test Area and was roughly the same in both surveys in the Western Control Area. A comparison of areas indicated these differences were highly significant ($p<0.001$) with only a minor interaction between areas ($p=0.02$).

This comparison supported the general indications of fishing patterns by commercial fishermen in the area. The area around Black Rock (Eastern Control Area) was known to be a major fishing area and that was part of the reason for its selection as a control area. The Western Control Area was more difficult to fish and hence less frequently fished commercially. This comparison supports the value of the two control areas in the monitoring program, as a means to adjust results for the effect of the commercial fishery. It should be noted, however, that fishing patterns may change and continued monitoring will be required.

3.7 Effect of Turbine Deployment

A turbine was installed on November 12, 2009, part way through Fall Survey 2. The NS-samples, those in the grid around the turbine deployment site, provide samples from a before/after situation from close to (2-300 m) and further (about 500 m) from the turbine (Table 3-3).

Table 3-3: Catch Before and After Turbine Deployment from NSPI Stations

Distance from Turbine	200 - 300 m		500 m	
	Number of Samples	Average Catch/Trap	Number of Samples	Average Catch/Trap
Turbine absent	6	2.27	7	2.53
Turbine present	3	1.29	4	2.77

Statistical comparison of the mean catch from the 200-300 m traps was significantly lower ($p=0.0002$) after turbine deployment. In addition, average catch in three survey areas were not significantly different over the same time period (Bayley 2010).

This comparison should be not taken to indicate an effect from turbine deployment because there were a number of differences in conditions, including water depth variations from traps being shifted by currents, that could explain the differences in catch rates. In addtion, as noted in the detailed report on the two fall surveys, the largest drop in numbers was in market-sized lobster and this decrease occurred at the stations to the east, closest to the most intense commercial fishery (CEF 2010, page 32). However, the comparison does indicate the level at which differences can be detected in the EEM program conducted and that the program warrants continuation.

3.8 Survey Efficiency

Improvements were made in survey efficiency between each survey. Experience has indicated that approximately 15 stations can be sampled routinely in a day. More stations can be sampled at lower amplitude tides because search time is longer 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.

Consistency and balance in the design has been improving, but the following recommendations in design changes will lead to further improvements in efficiency and should provide a stable design for future surveys.

4 PROPOSED DESIGN CHANGES

The statistical review carried out by Dr. Peter Bayler (see appendix) has been important in two key areas:

- program design, and
- analytical methods.

4.1 Combining Nearfield and Farfield Designs

The largest change proposed in survey design involves the integration of the nearfield and farfield designs. Integration of the two designs has a number of advantages including:

- increased efficiency in sampling, i.e., obtaining the maximum amount of information for the least effort;
- all deployment areas are treated consistently; and
- there is a single approach to analysis using analysis of variance to separate factors.

Figure 4-1 illustrates the proposed design in the test area for allocation of stations where both the nearfield and farfield components are combined. Sample sites are to be selected randomly but stratified within distance zones established around all deployment sites as evenly as possible.

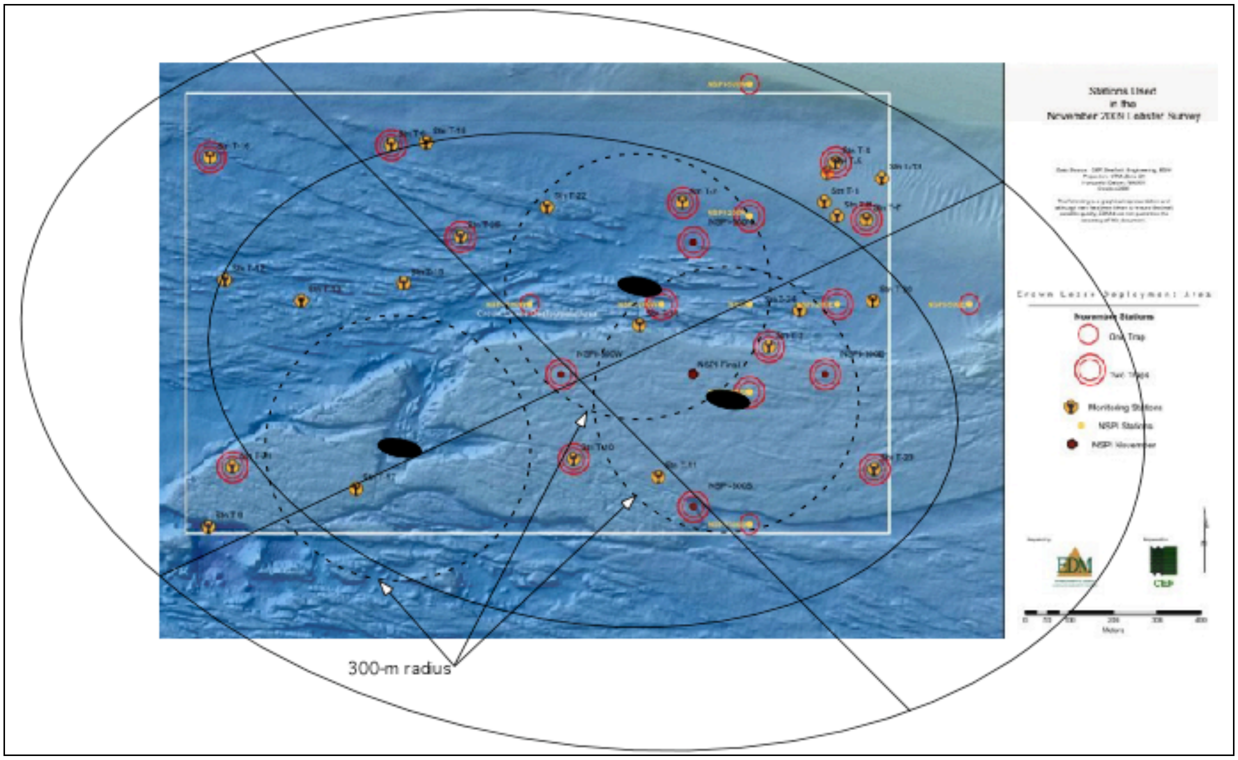

Figure 4-1: Proposed Sampling Design Combining Nearfield and Farfield Components

This proposed change in design requires new stations to be randomly selected. Since depth is known to be a significant variable, some stratification by depth can be introduced into the station selection to ensure that an adequate balance of depths are sampled. It is suggested that stations within the Test Area be selected first, and then stations within the two Control Areas be selected to provide a similar balance of depths within broad categories, such as shallow, intermediate and deep.

4.2 Statistical Comparisons

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. In this case a change in catch of 2 lobster per trap was considered appropriate. After accounting for soak time, approximately 30 samples per group in a simple analysis of variance would be needed to detect a change of 2 lobster/trap-set from a mean of 6 /trap, if Type 1 error is 0.1 and Power is 0.75 (Bayley 2010).

This would translate into a survey with 24 stations divided among eight quadrats for the Test area, and 24 stations divided between the two control areas. Each of these replicated 3 times would provide 72 samples, roughly equivalent to the suggested degree of prediction above.

Analytical methods were also reviewed. Although tests have been done with the standard log(count+1) transformation to produce approximately normal distributions for linear models, future definitive tests, including simple BACI, would be best conducted using generalized linear models with a negative binomial distribution.

5 Conclusions and Recommendations

5.1 Conclusions

The three surveys, two in the fall of 2009 and one in the spring of 2010, documented the size distribution of lobster and its seasonal change within the proposed tidal energy development area. The study also found a reduction in market size lobster in areas fished more heavily by the commercial lobster fishery, hence demonstrating the kind of effect that can be detected. A related finding was that the test area appears to be moderately fished commercially in comparison to a higher level of exploitation around Black Rock. The deeper ridges and banks, particularly in the Western Control Area, do not appear to be significantly fished.

The abundance of lobster was found to be different in the spring than the fall, although the size distribution in relation to depth and proximity to shore remained similar for all size classes. Lobster smaller than market size (<82.5 mm) were found in shallower water and closer to shore than market lobster. Larger lobster (>100 mm) were less sensitive to depth and they were found widely distributed regardless of depth or proximity to shore.

A significant reduction in catch was observed 200 to 300 m from the NSPI turbine deployment site. This should not be considered to necessarily indicate an effect from the turbine, but that the study was able to detect changes relevant to an EEM program.

5.2 Recommendations

The key recommendation involves combining the two design elements into a single BACI design that will improve the efficiency of the survey, while providing a similar ability to detect potential impacts, both nearfield and farfield. The recommendations also suggest that the existing samples can be used for comparison with future results. However, it would be advisable, since new sampling stations need to be randomly selected, that pre-deployment data be collected using the new design.

The three surveys conducted to date have established important pre-treatment conditions of the spatial distribution of lobster by size, with some indication of seasonal variations. What remains needed is a measure of inter-annual variability prior to deployment of turbines or associated equipment. It will be important to conduct surveys in 2011 to adequately establish baseline conditions for the revised stations, as well as provide a measure of variability between years. A fall survey, prior to the start of the commercial fishing season, is the top priority, followed by a spring survey to better document movements in and out of the area.

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Appendix A – Comments on the lobster monitoring component of the Fundy Tidal project

Peter B. Bayley revised December 23, 2010
Courtesy Faculty, Dept. Fisheries & Wildlife,
Oregon State University, Corvallis, OR 97331

Executive Summary

A. A simple BACI analysis based on limited samples at 2-300-m from the turbine indicated a significantly greater drop in mean catch following turbine installation compared to the control at ≈500 m. This result, and other considerations prompt the following questions:
1. Does the catch rate at ≈300 m continue at the observed depressed rate relative to ≈500 m during the extended presence of the turbine?
2. Will the catch rate change due to the disturbance of removal of the turbine?
3. If changed, did it recover after removal of the turbine?
4. Are there larger scale consequences of turbine presence?

A small scale, short term design restricted to within 500 m of the turbine addresses questions 1 and 2. A balanced design of 72 samples per survey accounts for distance and directional effects, with allowance for loss of samples and comparability with existing data. Questions 3 and 4 are addressed by larger scale seasonal survey that includes a continuation of the control and treatment strata of Design A sites, plus a similar number of random samples in Areas E and W. These designs are appropriate and with sufficient power for simple BACI tests.

B. Most existing samples are random or can be regarded as being approximately random, and can be used for future comparisons given comparable variances. An exception is the A-B paired samples that are strongly correlated, and produce a heterogeneous variance when combined with single samples. Paired samples should be discontinued, but random selections of one sample from each existing pair can be pooled with single samples for future analyses. The main weakness with existing data is the lack of balance among strata and replications at sites.

C. The soak-time (number of tides between setting and lifting traps) is an important component of fishing effort and significantly reduces bias and the mean square error, and thereby the efficiency of statistical tests. Further efforts to reduce soak-time variation are not recommended. The emphasis should be on maximizing balance by recovering as many traps as possible, even if there is delay.

D. After accounting for soak time, approximately 30 samples per group in a simple ANOVA (see Glossary) would be needed to detect a change of 2 lobster/trap-set from a mean of 6 /trap, if Type 1 error =0.1 and Power =0.75.

E. Although tests have been done with the standard log(count+1) transformation to produce approximately normal distributions for linear models, future definitive tests, including simple BACI, would be best conducted using generalized linear models with a negative binomial distribution.

Response variables

Counts of lobster per trap-set comprise positive integers that are not normally distributed. In addition the variance is not independent of the mean. The solution is either (a) to adopt an approximate normalizing transformation or (b) apply a generalized linear model with a response appropriate to count data, such as the negative binomial. I recommend (b) as the best approach to definitive analyses in the future. However, for the purpose of illustrating issues with the data collected so far using the simplest linear analyses (ANOVAs, etc.) and for approximate estimates of samples needed, I here adopt (a) by using a standard log-transformation of Ln(count+1) as the response (y). If not stated otherwise, 'count' is the total number of lobster caught per trap-set.

Sample unit considerations

Because of trap movements, recovery rates, and limited recovery time at slack periods due to tidal currents in Survey 1, a portion of stations in Surveys 2 and 3 were sampled with pairs of traps (A & B) connected by a 60-m rope. These samples indicated a high Pearson correlation between A & B of 0.712 (df=96 [=98 A,B pairs], P= 2.2e-16. Lag 1 autocorrelation of all A,B samples was 0.54 compared to 0.37 for other samples, when the order of samples was the original collected order. Finally, the overall variance of A,B response data was 0.701. The remaining single-sample data pooled from the same Surveys (2 & 3) had a variance of 0.949. The variance ratio test indicates that these estimates are significantly different (p = 0.015, 2-tailed).

Therefore there is an issue of a mixture of variances which could compromise the interpretation of analyses [For linear statistical analyses, samples should at least be independent and there should be a single common error variance]. To illustrate the extent of this, I compared ANOVAs (analyses of variance) among surveys (2,3) and Areas (T, NS, EC, WC) between two sets of data. The first set comprised only A and B samples, the second of all other samples plus one random selection from each A,B pair. Therefore, the second set comprises relatively independent samples because they did not include A and B together.

Each survey had one or more samples from predetermined sampling stations at different dates. Therefore data were blocked by station(location) nested within each Area (see Area/Loc in model below).
Here are 2-way ANOVAs for each Set from Surveys 2 and 3:

Analysis of Variance Table for 1st Set (A & B samples only)
Response: LnCnt (=Ln("total lobster count" + 1)
model: lm(LnCnt~survf*Area+ Area/Loc) (Loc = Location = Station)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
survf	1	13.246	13.25	36.061	1.14e-08 ***
Area	3	15.357	5.119	13.935	3.67e-08 ***
survf:Area	3	16.563	5.521	15.030	1.02e-08 ***
Area:Loc	19	29.428	1.549	4.2164	1.49e-07 ***
Residuals	169	62.079	0.367		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
survf:Area = interaction between Survey(surv) and Area
Area:Loc = interaction representing nesting of Loc(station) in Area.

Analysis of Variance Table for 2nd Set (single samples)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
survf	1	36.809	36.809	86.534	2.85e-15 ***
Area	3	11.510	3.837	9.020	2.36e-05 ***
survf:Area	2	1.159	0.580	1.363	0.26
Area:Loc	13	21.973	1.690	3.974	3.14e-05 ***
Residuals	102	43.389	0.425		

[All analyses were done using R: (R Development Core Team (2009).]
While the difference between the survf:Area interaction significances is striking, the important issue is the difference between the Residual (error) mean square which was 0.425 for the independent samples (2nd Set) and 0.367 for the A,B paired samples (1st set). This is not primarily a spatial issue because station(Loc) was nested in Area and in both cases their contribution to sum of squares was considerable and highly significant. The residual error is biased downwards with the A,B pairs because of correlated pairs taken at the same time. Use of these data could result in false positives (i.e., thinking there is a significant difference where none exists) when interpreting tests. One could combine A & B into a single sample, but the degrees of freedom would be

halved and one could still not mix the data with samples from single traps.

I recommend that the A,B pair sampling be discontinued. Apparently there have been problems retrieving the paired traps and there is still trap movement and difficulties with retrieval. For the purpose of using existing data in future analyses, randomly selecting one sample from each A,B pair and pooling those samples with the single samples is recommended. I draw from this independent set (352 samples from the 3 Surveys) in the example analyses below (my particular random selection has been saved and is available for others to check on my results).

Soak Time

Soak Time is the number of tides between setting and retrieving traps. As CEF (LobsterFall Survey R#1BD60D.pdf) noted, as soak time increased, catch tended to increase until some maximum was passed when it started to decrease due to attrition of the catch. While the defined fishing effort is the trap-set, the amount of time it was set comprises an additional 'nuisance variable' (see Glossary). Because it appeared to be non-linear, it does not appear wise to alter the response variable by redefining catch-per-effort as catch per trap-set x tides. Rather, I first explored the data by introducing effort as the nuisance variables, soaktime and soaktime-squared, to simulate a unimodal (parabolic) effect on the standard response (Ln(count+1)).

Again, we look at ANOVAs that are likely to be used in future analyses in which Surveys and Areas are blocked, and station data blocks nested within Areas. This time the covariates soaktime and soaktime-squared are added (available for Surveys 2 and 3), making it an analysis of covariance (and I excluded NS-samples that are reported separately below):

lm(LnCnt~survf*Area+ Area/Loc +survf:soaktime + Area:soaktime + soaktime + I(soaktime^2))

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
survf	1	19.621	19.621	64.407	7.72e-13 ***
Area	2	21.470	10.735	35.238	9.13e-13 ***
soaktime	1	9.406	9.406	30.875	1.69e-07 ***
I(soaktime^2)	1	2.924	2.924	9.598	0.00243 **
survf:Area	2	3.148	1.574	5.167	0.00704 **
Area:Loc	17	25.385	1.493	4.902	7.01e-08 ***
survf:soaktime	1	1.348	1.348	4.426	0.0375 *
Area:soaktime	2	0.321	0.161	0.527	0.59
Residuals	120	36.557	0.3046		

Both soaktime effects were significant. There is a barely significant survf:soaktime interaction. A simplified version omitting these:

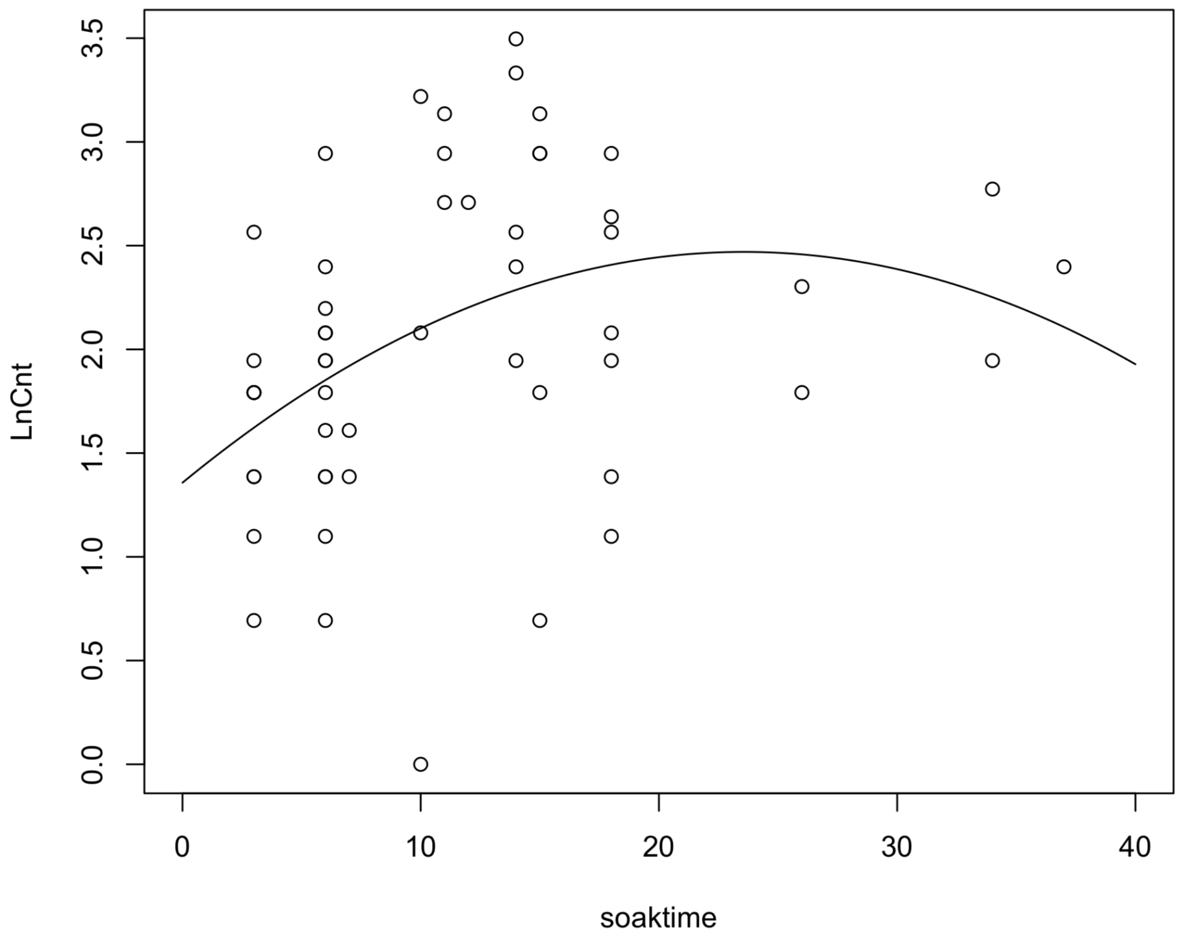
lm(LnCnt~survf*Area+ Area/Loc + soaktime + I(soaktime^2))

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
survf	1	19.621	19.621	63.133	1.05e-12 ***
Area	2	21.470	10.735	34.542	1.24e-12 ***
soaktime	1	9.406	9.406	30.264	2.09e-07 ***
I(soaktime^2)	1	2.924	2.924	9.408	0.00266 **
survf:Area	2	3.148	1.574	5.065	0.00770 **
Area:Loc	17	25.385	1.4932	4.805	9.44e-08 ***
Residuals	123	38.227	0.3108		

Soaktime and its square were highly significant, with signs (positive and negative, respectively) indicating a parabolic response. Apart from potential biases such as weather effects on soak time, the residual error (mean square) is reduced by 19% from 0.3822 without soaktime variables (analysis not shown) to 0.3108 shown above, reducing numbers of samples needed for a given power (see below).

A similar analysis was done with the 'non-random' NS samples only, in which there were no interactions with soaktime, and significant soaktime and soaktime^2 coefficients. In this case (analyses not shown) the residual error (mean square) was reduced by 21% from 0.4654 without soaktime variables to 0.3686.

An example is plotted below from Survey 2 Area data with the predicted parabola:



In future analyses soaktime and its square should be considered and included if their coefficients are significant. In the foregoing analyses it was worth the cost of 2 DF to account for soak time and its square. In trial analyses of some subsets I found that the coefficient for Soaktime^2 was not significant (but for soaktime was always significant and positive). Therefore, in future analyses tests for both variables may indicate inclusion of only soaktime at the cost of only 1 DF. Further reducing variation, or degrees of freedom lost, with this variable may be possible by avoiding long soak times, but in any case it is not recommended because spurious interactions may result when combining old data, such as from Survey 2, with new. The emphasis should be on maximizing balance by recovering as many traps as possible, even if there are some longer soak times due to delay.

Water Depth

Depth of sample is strongly related to Area, which is a major stratum in the design. Therefore, analyses that include Area and depth as main effects will be confounded. Mean depths for all samples are shown with corresponding mean Ln(Catch+1) (=LnCnt) by Area (including NS) and Survey are shown below:

	Survey 1		Survey 2		Survey 3	
Area/NS	Depth (n)	LnCnt	Depth (n)	LnCnt	Depth (n)	LnCnt
EC	-30.5(23)	2.82	-21.9(26)	2.19	-24.0(50)	1.87
NS	-36.1(24)	2.20	-34.6(29)	2.15	-31.1(61)	1.30
T	-37.9(57)	2.32	-39.6(56)	1.96	-40.0(71)	0.92
WC	-46.6(28)	1.85	-45.8(15)	1.75	-46.1(10)	0.54

(n = # of samples; Depths in Survey 2 were interpolated as means from samples of corresponding Stations in Survey 1 or 3)

A trend of decreasing mean catch with increasing depth is evident (and of similar significance as soaktime) in all Surveys, despite the occurrence of commercial fishing in Area EC during Survey 2 and varying soak times.

This relationship does not affect BACI-type relationships as long as control Areas along with a consistent sampling design are maintained for before/after comparisons. Because sampling can vary due to trap loss and tweaks in the design, consistency of mean depth in Areas should be checked, so that statistically blocking Areas accounts for depth differences.

Number of samples needed

The power of a test is the ability to detect a difference. It is the complement (1-beta) of the Type II error (beta), which is the probability of failing to detect a difference when one exists. Logically a Type I error (alpha) needs to be posited also, which is the probability of erroneously detecting a difference when none exists. In an ANOVA, the ability to detect a difference between means of groups (power = 1-beta), given alpha, depends on the residual error variance (= variance within groups) and the number of samples, n. Therefore, among the five entities that are interrelated any one can be predicted (albeit with some computing difficulty) from the other four.

Software was only available to predict n when comparing groups in a balanced 1-way ANOVA. In our case, I have presumed a more stringent error tolerance (alpha=0.05, beta = 0.20) and a less-stringent one (alpha=0.10, beta = 0.25). As a guide, an ANOVA is constructed in which a ‘control’ group (before turbine operation) provides a mean of 6 lobster/trap-set (≈equal to the mean from

Area T in Survey 2), while a 'treatment' group (during subsequent turbine operation) registers a mean loss of 2 lobster/trap-set. This 33% drop in raw figures translates to a 17% drop in terms of the transformed response, Ln(count+1). Several approximate predictions are shown here in which the residual mean squares are presumed from the foregoing, more complex ANOVAs:

Using Residual Mean Square of 0.3108 (from previous analysis including soaktime):
For alpha = 0.05 and power = 0.8 (beta = 0.2), n = 44 for each group
For alpha = 0.10 and power = 0.75 (beta = 0.25), n = 30 for each group

or, using Residual Mean Square of 0.3822 (ignoring soaktime):
For alpha = 0.05 and power = 0.8 (beta = 0.2), n = 54 for each group
For alpha = 0.10 and power = 0.75 (beta = 0.25), n = 37 for each group .

As an example in which error variance is about 0.31, if we accept a 1 in 20 chance of a false positive (alpha=0.05) and a 1 in 5 chance of failing to detect a difference (beta=0.2), we would need about 44 samples from a control and 44 from a treatment to detect a mean change of 2 lobsters /trap-set from a control of 6/trap-set.
The effect of a model with soaktime variables decreases the number of samples required by19% (44/54) for alpha=0.05 and beta=0.2.

An example of a turbine-effect test
A turbine was installed on November 12, 2009, part way through Survey 2. There is a before/after situation estimated by NS-samples close to (2-300 m) and further (about 500 m) from the turbine. The means(Ln(count+1)) and sample sizes (in parentheses) were as follows:

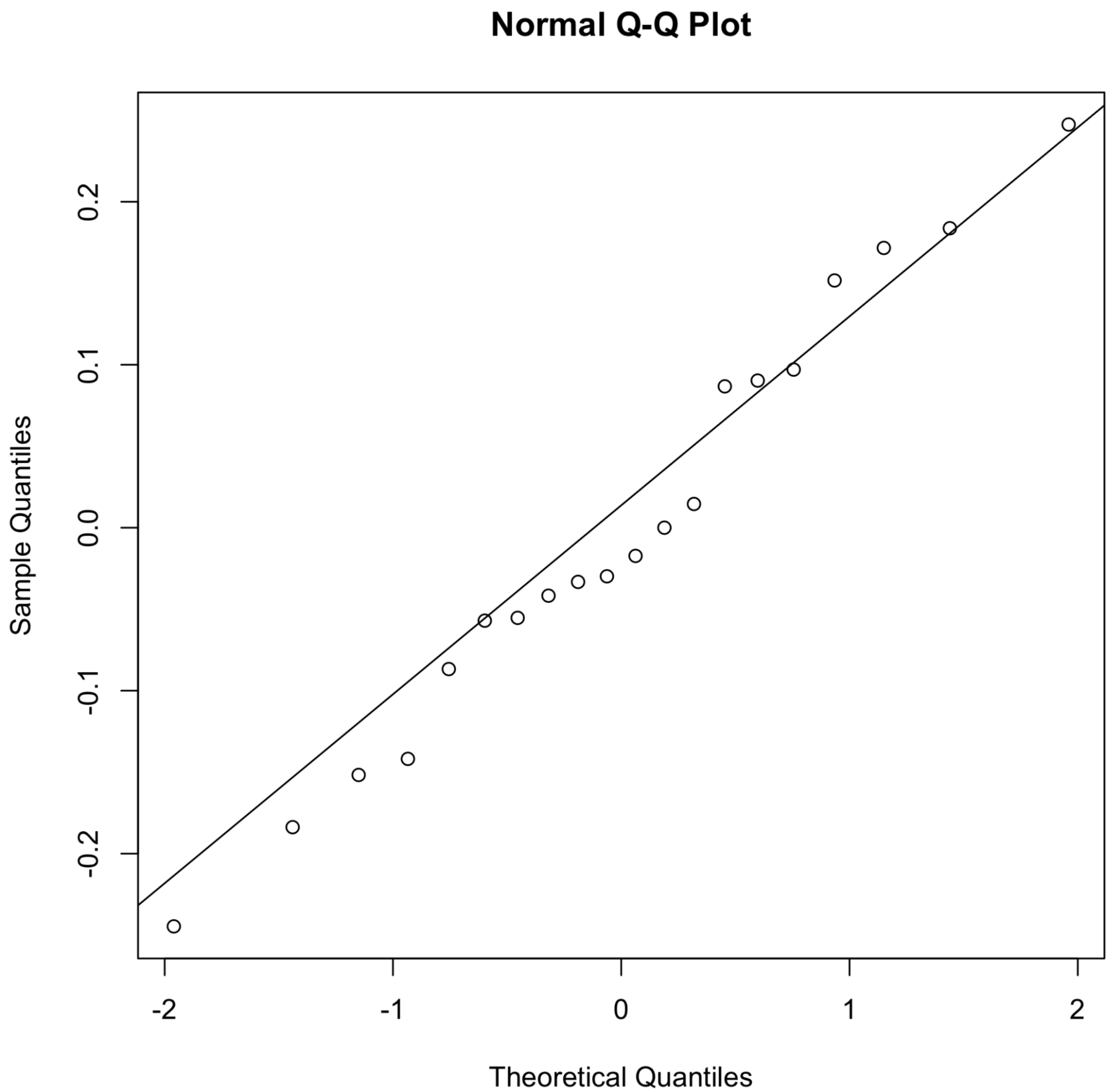
2/300m or 500m (NS23_5):	2/300m	500m
before Turbine (BT):	2.27(6)	2.53(7)
during Turbine (AT):	1.29(3)	2.77(4)

The analysis of covariance is as follows (there were no interactions with soaktime):

lm(LnCnt ~ NS23_5*BT_AT +NS23_5f/Loc + soaktime+ I(soaktime^2))

	Df	SumSq	Mean Sq	F value	Pr(>F)
NS23_5	1	2.2613	2.2613	55.26	7.4e-05 ***
BT_AT	1	0.3972	0.3972	9.71	0.014 *
soaktime	1	1.9774	1.9774	48.32	0.00012 ***
I(soaktime^2)	1	1.4045	1.4045	34.32	0.00038 ***
NS23_5:BT_AT	1	1.7079	1.7079	41.73	0.00020 ***
NS23_5:Loc	6	3.0316	0.5053	12.35	0.00115 **
Residuals	8	0.3274	0.0409		

The important observation here is the interaction (NS23_5:BT_AT, P=0.0002) between the two main effects, before/during turbine (BT_AT) and proximity (NS23_5) to turbine. This interaction indicated that the reduction during turbine presence was greater than any that might have occurred at the 500m distance. The following Normal Q-Q plot of residuals indicates limited departure from normality



The tendency for lower residuals than predicted at the lower left is partly a function of the arbitrary constant, 1, in the Ln(Count+1) transformation, because the deviation is reduced when 0.1 is used.

Given that this result was surprising to some, I have explored four avenues that may support or contradict its validity:

1. Recall that with each paired A/B sample one was randomly selected. With such small samples sizes in this analysis it is possible that the random selection resulted in markedly different estimates. The 2/300-m samples were paired (the 500-m not). The following shows the means for the A/B samples not

selected:

2/300m or 500m (NS23_5):	2/300m	
before Turbine (BT):	2.33(6)	
during Turbine (AT):	0.73(3)	

An analysis of covariance according to the foregoing model again indicated a significant interaction (NS23_5:BT_AT, P=0.0027) between the two main effects, before/during turbine (BT_AT) and proximity (NS23_5) to turbine.

2. Another potential source of bias may be due to the varying distances due to the turbine being placed 200 m SW of the original planned position. The following shows the mean distances of the samples from the actual location (followed by sample size and range):

2/300m or 500m (NS23_5):	2/300m	500m
before Turbine (BT):	260(6, 131-379)	537(7, 362-669)
during Turbine (AT):	223(3, 131-361)	586(4, 362-669)

An ANOVA based on these four means showed that there was no difference in turbine distance between before and after turbine (BT_AT) at either distance group (NS23_5, P=0.87) and no interaction (NS23_5:BT_AT, P=0.52).

3. As mentioned previously (Water Depth), mean water depth might have varied as a result of incomplete replication of all sites:

2/300m or 500m (NS23_5):	2/300m	500m
before Turbine (BT):	-36.9(6)	32.1(7)
during Turbine (AT):	-37.8(3)	27.3(4)

An ANOVA based on these four means showed that there was no difference in water depth between before and after turbine (BT_AT) at either distance group (P=0.58) and no interaction (NS23_5:BT_AT, P=0.50). Even the mean depth between distance groups (NS23_5) was not significant (P=0.10) even though the North 500-m sites were in shallower water.

4. Finally, the three Areas also did not indicate a reduction in mean catch during turbine presence:

Area:	T	EC	WC
before Turbine (BT)	1.92(17)	2.31(10)	1.69(5)
during Turbine (AT)	2.05(11)	2.30(7)	2.03(3)

In conclusion, this analysis indicates a significant (P<0.001) reduction of lobster catch rate at a distance of around 223-m from the turbine. The average magnitude of this drop was 43% in terms of Ln(catch+1) or 70% in terms of the catch (number of lobster per trap-set). It should be stressed that ‘after turbine’ (AT) data were recorded within a 6-day period (Nov. 12-17) following turbine installation on Nov. 12. Moreover, it is reported that the turbine was not functioning. Therefore, it is possible that this localized effect was due to the disturbance associated with installation.

This analysis also illustrates how a simple BACI-type analysis (Green (1979); http://www.web-e.stat.vt.edu/vining/smith/B001-_o.pdf) might be applied in the future. It also raises questions leading to one of the proposed designs described below.

Design Considerations

The non-NS Stations were randomly positioned in the 3 Areas T, EC and WC, and varying portions of those locations were resampled and retained in subsequent Surveys. The following shows the numbers of samples (excluding one of each A,B pair) by Survey and Station:

Station (Loc)

Surv	EC1	EC10	EC3	EC4	EC5	EC6	EC7	EC8	EC9
1	3	3	3	2	3	2	3	2	2
2	4	4	5	0	0	0	3	0	1
3	8	8	8	0	0	0	8	0	5

Station (Loc)

Surv	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T2	T20	T21	T22	T23	T24	T25	T3	T4	T6	T7	T8
1	3	3	1	3	1	1	3	3	3	3	3	3	3	3	2	3	3	3	1	3	3	3
2	3	0	0	0	0	0	3	0	0	0	2	0	1	0	3	0	2	2	4	3	4	1
3	7	0	0	0	0	0	7	0	0	0	7	0	8	0	0	0	6	0	0	8	8	0

Station (Loc)

Surv	WC1	WC10	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9
1	3	3	2	3	2	3	3	3	3	3
2	0	0	1	0	0	0	0	3	2	2
3	0	0	0	0	0	0	0	7	0	0

One statistical approach is to pair treatment and control samples by date at fixed locations, allowing differences to be compared by site “before and after” as in a paired BACI scheme (Stewart-Oaten et al. 1986). However, this requires consistent sampling by specific locations and dates, which, as demonstrated by this table, is difficult given the trap losses, trap fishing limitations, and design changes. Conversely a simple BACI approach is easier to balance. However, while it is possible to account for the considerable variance among Stations, as I have done by nesting them in Areas in the forgoing analyses, there is clearly poor balance to the point of producing singularities that restrict the statistical options available. The designs described below attempt to minimize this problem.

Traps in the NS 'fixed' Stations moved because of the tides as did their non-NS counterparts, and their positions relative to the turbine changed when the latter was changed. Effectively, they could be regarded as approximately randomly located within larger areal boundaries centered at about 2-300 m and 500 m from the turbine. This permitted the simple BACI outlined in the previous section. In both sampling approaches there is also an element of randomness in the movement of the lobsters themselves. It is noteworthy how similar the results of analyses were between spatially random data from the 3 areas in which many Stations were not revisited, and the relatively fixed NS data (see Soak Time section). In both cases the change in residual mean square was similar with and without soak time variables. The levels of significance were also similar. This similarity, however, cannot be guaranteed, and better designs are recommended below.

Proposed Designs

The proposed changes are with the benefit of hindsight. None of the foregoing design issues could have been avoided without foreseeing the huge effects of tidal forces on trap movement and loss, and on the ability to fish the traps consistently, even when the weather is kind. The following outlines two connected designs at different scales that attempt to maximize balance and the utility of existing data, given trap movement and the risks of trap loss.

To date, we have a suggested, short-term indication of a turbine effect at a local scale, and no indication at a larger scale. Five questions come to mind (with hints of sampling required):

1. Does the catch rate at ≈300 m continue at the observed depressed rate relative to ≈500 m during the extended presence of the turbine? (sample while the turbine is still there);
2. Will the catch rate change due to the disturbance of removal of the turbine? (sample during and immediately after turbine removal);
3. If changed, did it recover after removal of the turbine? (sample at least one season after turbine removal);
4. Are there larger scale consequences of turbine presence? (sample at larger spatial scale consecutive fall and/or spring seasons).
5. How does one approach a multiple turbine scenario?

Relevant to all these questions is the status of the turbine when in place, information which is not available to date. Obviously it is important to know if the turbine is turning and if it is generating. NS Power should devise a method of monitoring the turbine while in situ.

Two related designs, one at a local scale (Design A) to address questions 1 and 2, and a large scale, Design B, to address 3 and 4 are outlined below. Both can incorporate existing data with the constraints outlined in this report. If Design A results are non-significant with sufficient power, funding for Design B may be considered unnecessary.

Design A

To answer questions 1 and 2, a local scale, short-term design should be limited to the turbine area. One approach would be to assign samples to two annuli (strata) around the turbine, at 300-350m (treatment) and 450-500m (control). Sample sites for temporal replication should be assigned randomly in each of four directional substrata (-45-45°; 45-135°; 135-225°; 225-315°) relative to the direction of the turbine (0°) in each stratum (see Figure). These substrata are to account for possible directional effects due to water currents and noise from the turbine. Some traps will undoubtedly drift outside their annulus, hence the 100-m separation between the primary strata. The separation also assures some contrast between strata and comparability with existing NS data.

Regarding numbers of samples, it is important to have back-ups to ensure as balanced a design as possible. Analyses will include nesting of site replications within substrata, and nesting of sites from the latter in the two strata (300-350m, 450-500m). Balance is important at all levels. A suggested design is 12 randomized stations in each stratum, (3 in each substratum -45-45, 45-135°, etc.) each repeated 3 times. Replicating 3 times at each location, and having 3 locations in each substratum would provide good insurance for single losses in locations or site replications, and still retain temporal and spatial replication at the substratum level. If all samples could be completed, the total samples per survey (either 'before' or 'after') would be 72 (=3x3x4x2), meaning 36 for each stratum, which provides good power for the main treatment/control effect. For comparison, the first 3 surveys, excluding half of the A/B pairs, achieved 132, 73, and 147 completed samples respectively. While mean traveling time would be reduced, total time available may be more limiting to answer questions 1, and 2. Whatever variant of this scheme is chosen, it is strongly recommended to not have less than 3 samples in each cell, because if one is not completed there would still the minimum of 2 required to provide random error estimates within cells.

A minimum distance between sites may be desirable to avoid physical interference and spatial correlation (see next Figure). In this case, re-randomizing locations for proposed sites to maintain this minimum would be acceptable. I believe that one spatial randomization procedure is acceptable to define sites for future surveys. The design cannot account for lobster possibly being attracted to the turbine as a protective structure, because of the 300-m safety zone for trap placement.

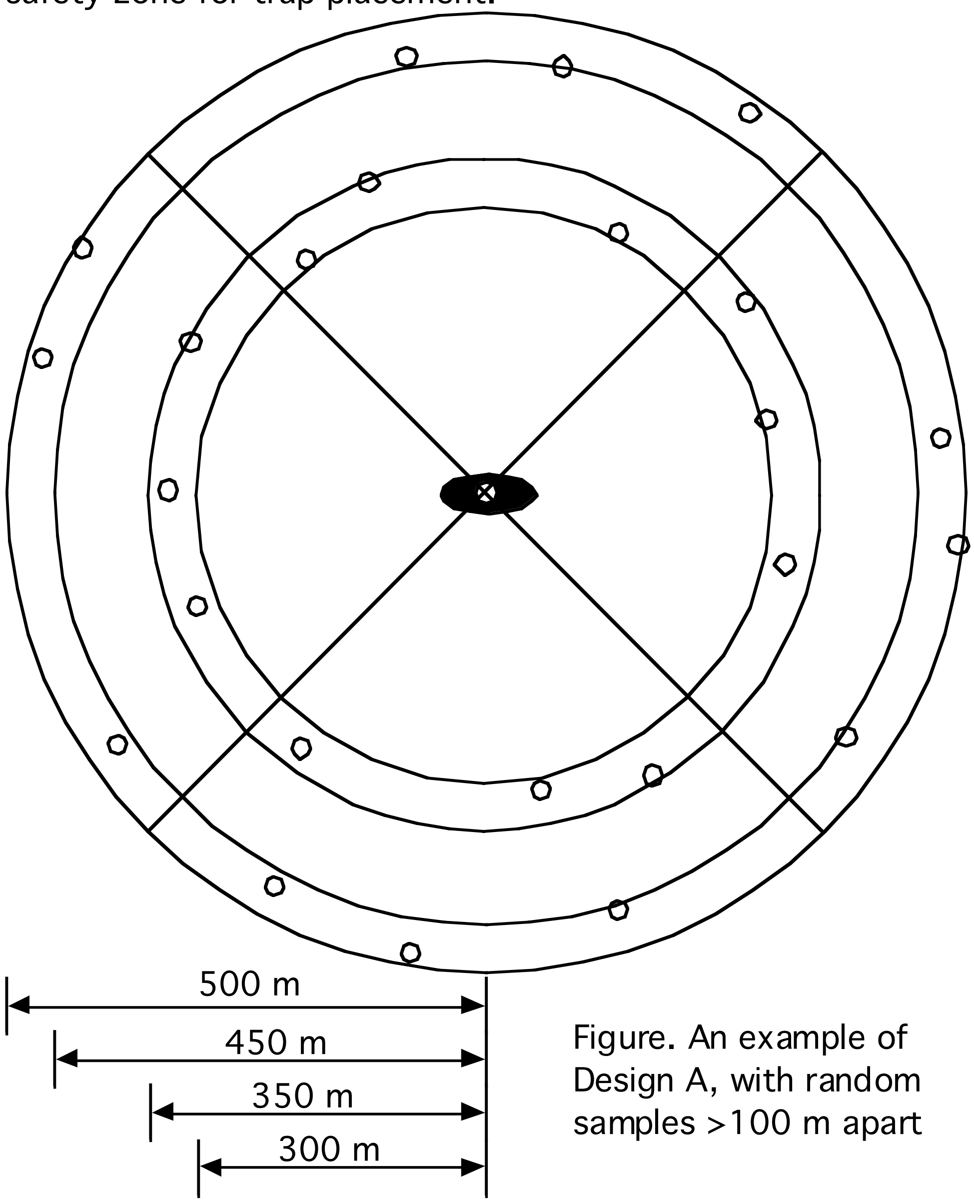
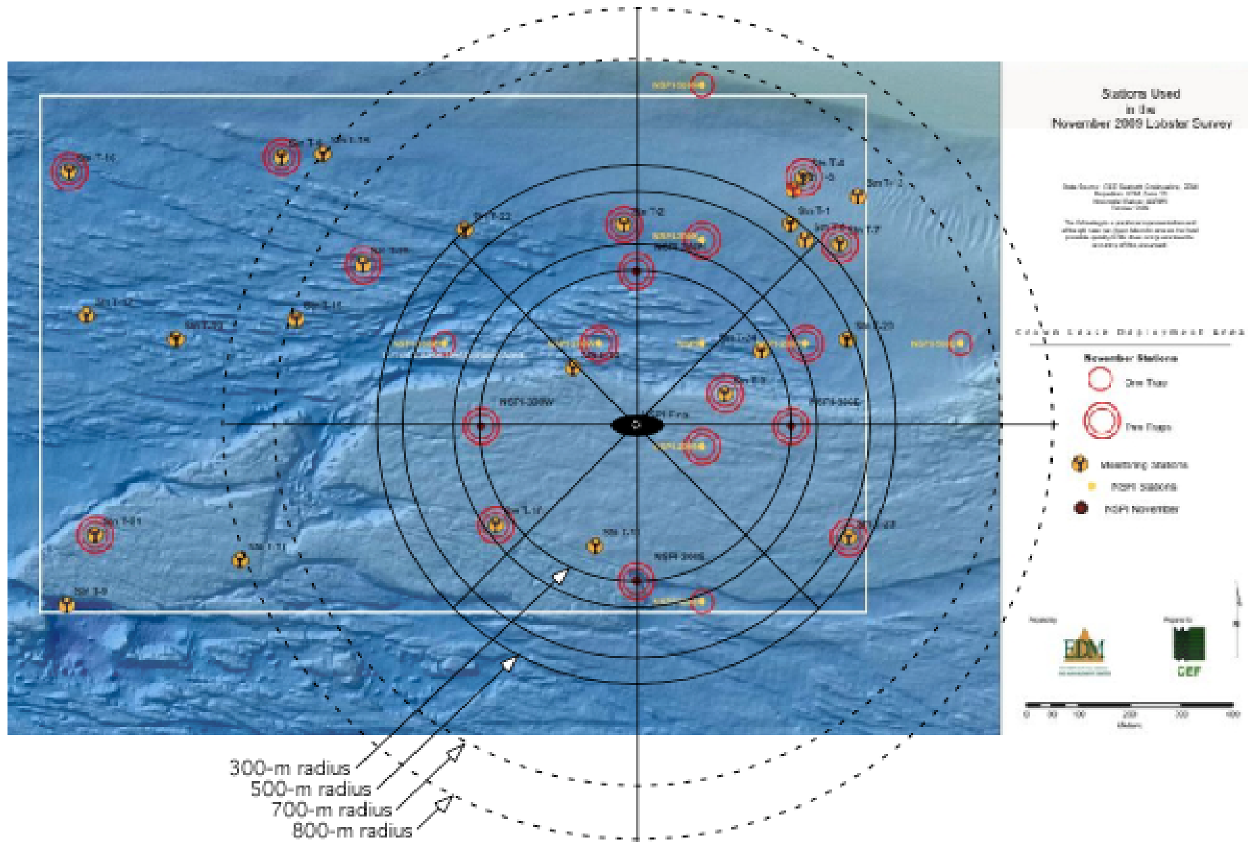


Figure. An example of Design A, with random samples >100 m apart

The following figure shows the placement of this design around the current turbine location in Area T.



I have shown the quadrats oriented as NSEW. It would make more sense to rotate the axis so that mid-points of two opposing quadrats were aligned with the mean tidal current direction. In this way, directional effects of the turbine in action could be tested and compared with the two lateral quadrats.

It has been suggested that wider annuli be added and sampled from and used instead of a continuation of Area T samples. I have drawn annuli of 700-m and 800-m radii merely to facilitate consideration. There may need to be censoring of projected samples in extremely shallow water. However, the data indicate that down to the minimum depth of 5.1–m sampled, there is no indicated change in direction of the increase in catch with decreasing depth as reported above under Water Depth. While tidal current will be slower, it is possible that turbine noise will amplify or be sustained in the water column or via the substrate as depth decreases. The ‘before’ control data will establish any differences that can be accounted for.
I should also add that for every mean distance chosen, the randomization design could occur along the perimeter of each circle rather than in an annulus. In either case, we are setting up a null hypothesis that there is no catch difference between certain mean distances and directions. Within that hypothesis I have

randomized positions as much as possible.

Design B

Questions 3 and 4 and the desirability of continued monitoring will need to be reassessed if results of Design A are non-significant and/or of small effect magnitude. Otherwise, a longer term (question 3) and larger spatial scale (question 4) design needs to be considered. Such a strategy should include a continuation of turbine area sampling as described in Design A, and a continuation of Area E and W samples. Given the desirability of continuation of Design A sites, albeit at a lower intensity, and the inclusion of a significant part of Area T by those samples, I don't believe a continuation of Area T randomized sites is necessary unless it is known that more turbines are planned in that area.

Given the above recommendations for Design A, a similar sampling effort to each annulus in Design A, in terms of number of samples, could be applied to Areas E and W resulting in 36 samples each (total 72) per survey. Therefore, a total sampling effort of 144 samples per survey would include 36 each for Areas E and W. Replicating 3 times for each site, would require 12 randomized sites for Areas E and W. Existing sites can be used or randomly selected from. To summarize, each survey (each fall and/or spring) would dedicate 12 randomized sites (stations) to each of 4 strata: Turbine-300m, Turbine-500m, Area E, and Area W. Each site would be replicated three times. This would provide balance, sufficient power, and insurance for losses (with the option to 'rebalance' by selecting from completed samples for analysis). I cannot comment on the relative merits of fall and spring surveys, but a fall survey should be completed before the start of the fishing season in order to avoid any effect of that factor on experimental catches, especially in Area E.

Several Turbines

Regarding question 5, Design A could only be utilized if the turbines are considerable distances apart. Based on our current limited information "considerable distance" may be 500 to 1000-m. If they are too close to be considered to have independent effects on samples, many randomized locations would need to be censored without necessarily guaranteeing independence. An alternative would be to broaden the question by assessing the joint effect of a cluster of turbines. Instead of distinguishing distance from turbine on a categorical basis (treatment/control), as implied by the strata in Design A, one can take a continuous approach by expressing samples from each site in terms of their distance from one or more turbines (D_i for turbine i). One would not, however, expect D_i itself to best express the drop in intensity of noise or current from a turbine. For example, the decay of, say noise, from a point source over a two-dimensional surface (e.g., the sea bottom), should be approximately proportional to $1/ D_i$. A joint effect of n similar turbines would therefore be proportional to $\Sigma(1/ D_i)$ (i=1,n), which could be incorporated as a covariate in a simple BACI, in which its interaction with the before/after variable would be tested.

It should be added that considerable cooperation with the NS Power engineers would be required. Installing individual turbines over several seasons would result in a "moving target" and would not leave enough time for the joint impact to be monitored, and would extend the lapse of time between the before and after samples, thereby weakening the assumptions in the BACI analysis. .

Analysis comments

The total lobster catch, either here transformed as Ln(Catch/trap-set+1) or better still untransformed in a negative binomial model, is the most robust response statistically. However, it may be desirable for biological reasons to deal with subsets, such as market-size lobster. A related size grouping of interest would be 70-82 mm under legal size; 82-100 mm legal but immature, and >100 mm mature. Changes in such groups may occur independently of the total catch. Each group could be analyzed separately, but there will be higher CV and lower power. Alternatively, relative changes could be assessed by simultaneously analyzing catch rates of the three size groups using a multinomial response as an extension of the negative binomial, at the cost of 2 DF but with the benefit of using all data. This would test whether proportions of size classes responded differently to the treatment.

Conclusions

In summary, these recommendations are more in line with sampling reality and with feasible statistical analyses. Spatial randomization for each survey among all strata is statistically more appropriate (and was already done in the 3 Areas), yet given the pseudo-random implications ascribed to the variable locations of the current NS data it is not unreasonable to use most of the existing data (after allowing for the A,B separation as recommended above) in future comparisons, if variances are consistent. A further advantage of spatial randomizing within strata and attempting to conduct even sampling among Stations is that the design will remain robust in the face of inevitable trap losses and movement. Simple BACIs that depend on testing for a different change closer to the turbine compared to further afield, as demonstrated in the previous section, would be the most appropriate approach.

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Appendix: Terms of Reference.
Address the following questions:

1. What is the appropriate statistical design for the base test and control study (BACI)?

2. What is the appropriate statistical design for the NSPI grid stations?

3. What transformations of the data are most appropriate for comparisons?

4. How much of the existing data can be used in future analysis?

5. How has station selection/reduction biased the analysis - is it acceptable?

Glossary

ANOVA = Analysis of variance, linear statistical approach that tests differences in means of groups defined by one or more categorical variables

Anacova = Analysis of covariance, linear statistical approach that tests differences in means of groups defined by one or more categorical variables, including effects of one or more continuous variables.

P or **Pr** = probability (between 0 and 1) that the result (e.g., an estimate of a coefficient) would be different from zero (null hypothesis not disproved) from repeated random sampling.

DF = Degrees of Freedom, which in statistical linear models is the number of samples less the number of fitted coefficients, being a measure of the robustness of the estimated model.

Location(Loc in analyses) is synonymous with Station, meaning a fixed sampling location determined randomly in the design. Of course this 'location' often moves by the time the trap is lifted.

Nuisance variable : is a variable that is not of interest in itself, but influences the results that may be confounded if the nuisance variable(s) were omitted.

Interaction (first order) in statistics is the effect of a change in one explanatory variable on the effect of a second explanatory variable on the response (Y). It is the same when the two explanatory variables are interchanged. It is denoted by ':' between the explanatory variables in the analysis results.

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APPENDIX F

Fish Migration Literature Review, 2010

OCCURRENCE AND MIGRATION OF FISHES IN MINAS PASSAGE AND THEIR POTENTIAL FOR TIDAL TURBINE INTERACTION

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June 30, 2010.

INTRODUCTION

The objective of this review was to identify the movement and migration of fishes in Minas Passage by species and seasonal occurrence based on the available published and unpublished literature. An annotated list was compiled from sources available since the 1800's as well as personnel observations based on fisheries research in Minas Basin since 1980. There are numerous good publications on the marine fishes of Atlantic Canada and for different regions of the Bay of Fundy and its tributaries as well as research works on individual species many of which are Honors, Masters and Ph. D. Theses completed at Acadia and Dalhousie Universities and the University of New Brunswick.

SOURCES OF DATA

Leim and Scott (1966) compiled approximately 60 years of observations on marine fishes of Atlantic Canada resulting from the fisheries work at the Biological Station, St. Andrews, NB. Their book includes considerable specific references to the populations of fishes found in the Bay of Fundy and Minas Basin and is often more complete than Scott and Scott (1988), which although excellent, has lost some of the local detail available in the earlier work. Scott and Scott (1988) is excellent with respect to the up-to-date taxonomy of Atlantic fishes, their biology and North Atlantic distribution. The systematic arrangement in this annotated work is based on Moyle and Cech (1996).

Perley (1852) was the first to describe the fish and fisheries of the inner Bay of Fundy (iBoF). His observations form the baseline to which later works can be compared. Huntsman (1922) was the first modern work on the fishes of the inner Bay of Fundy. Bousfield and Liem (1959) provided more information on the fishes of the iBoF and their work was followed with studies by Bleakney and McAllister (1973), Dadswell and co-workers (1984a) and Dadswell and Rulifson 1994. Bleakney and McAllister (1973) described the fishes that were stranded by extreme low tides at Kingsport in Minas Basin. Dadswell and co-workers (1984) and Dadswell and Rulifson (1994) detailed seven years of study on the iBoF including Cumberland Basin and Minas Basin and sampling using drift gill nets (6cm – 14cm stretched mesh), drags (small mesh, 5cm stretched) and mid water trawls (5cm stretched mesh), shore seines and intertidal weirs. Wehrell (2005) surveyed fishes captured by a rock hopper drag (a specialized "Yankee 35" drag, 12.7 stretched mesh) from June to September in the southern Bight of Minas Basin and Scots Bay. Dyer and co-workers (2005) detailed the fisheries for the region from Minas Channel to Minas Basin.

Fisheries and Oceans Canada (DFO) conducts yearly, routine stock assessments cruises and ichthyoplankton surveys in the Bay of Fundy (Scott 1987; Scott 1988; Simon and Comeau 1994). These surveys are conducted using a standard Yankee '35' drag, 12.7cm stretched mesh with a smaller mesh, cod-end liner and with 330um 'bongo' plankton nets. There are approximately 22 stations occupied in the Bay of Fundy from Scots Bay to the Lurcher Shoal region. Unfortunately the stations go only as far as Minas Channel and there are no stations in Minas Passage or Minas Basin. All fishes are identified, enumerated and measured and physical oceanographic variables measured (temperature, salinity and substrate).

Based on the number of studies and the similarity of resulting fish captures, the fish occurring in the Bay of Fundy and Minas Basin are well known. Unfortunately there have been very few directed fish studies within Minas Passage except for surveys of herring larvae (Bradford and Iles 1993).

THE ENVIRONMENT

Minas Basin is a warm water, marine habitat of the inner Bay of Fundy (Bousfield and Liem 1959). Annual temperature ranges from a peak of 16-20^{o}C in summer (Aug-Sept) to 0-1^{o}C in winter (February). Winter is characterized by drifting blocks of ice which in some years cover most of Minas Basin from January to March and severely scour the substrate of the intertidal zone (Bleakney and McAllister 1973). Salinities range from 24ppm at the inner end of Cobequid Bay to 30ppm in Minas Passage (Bousfield and Liem 1959). Much of the subtidal, benthic substrate is sand and gravel with extensive intertidal zones (1-3km wide) of sand, silt and mud (Bleakney and McAllister 1973). Minas Passage and Minas Basin have low to high turbidity depending on tidal amplitude and time of year (Amos 1984). Turbidity is lowest during neap tides and in summer, highest during spring tides and in winter. Turbidity is highest in Cobequid Bay at the inner end of the Basin and least in Minas Passage. The fishes of Minas Basin and Minas Passage reflect these characteristics, consisting of marine and diadromous species with a high proportion of coastal migrant, warm water stocks from as far south as Florida (Dadswell et al. 1984a) and stocks from the Scotian Shelf (MacDonald et al. 1984) and the Gulf of Saint Lawrence (Saunders 1969).

Minas Passage is the body of water connecting the inner Bay of Fundy and Minas Channel to Minas Basin. Minas Passage has temperatures of 14-16^{o}C from June to October (Bradford 1987) and because of powerful currents the water column is isothermal from bottom to surface (Tee 1975; AECOM 2009). It is a region of complex and powerful currents caused by the extreme tides of the inner Bay of Fundy where the intertidal range is up to 17m at the inner end of Minas Basin during large spring tides (Garrett 1972). Tidal velocities up to 3-6m/s occur in Minas Passage during falling and rising tides and four large gyres have been identified around Cape Split and Cape Blomidon (Tee 1975; Greenberg 1984). Residual currents were calculated with speeds up to 0.75m/s (Tee 1975). The strong tidal velocities have scoured most of the substrate of Minas Passage to bedrock (AECOM 2009). Minas Passage is about 12 km long and the currents and gyres would be expected to hinder the progress of smaller species and life stages through the Passage but may help to speed the progress of larger species and life stages. In general, fishes make about 2 body lengths/s (bl/s) at cruising speed (Moyle and Cech 1996) and fishes smaller than about 50cm in length could be held up in Minas Passage for longer periods than their average migration rates especially if caught up in the gyres.

RESULTS AND DISCUSSION

Details are provided on a total of 77 fish species that have either been recorded in Minas Basin, Minas Channel and/or Minas Passage or can reasonably be expected to occur. Where information is available seasonal migratory timing, water column distribution and known or expected abundance are provided. It is very likely that more fish species occur in Minas Passage than are listed and their abundance could be greater than anticipated. These details will be determined as fish studies progress in the Passage.

The fishes are listed in two ways. A taxonomic listing is provided as a narrative for easy access to the species information and scientific references. The fishes are also compiled in a list which categorizes them with regard to their potential risk of interaction with the proposed turbines and incidental harm, and provides suggested capture gear for sampling, periodicity of occurrence in Minas Passage and abundance (Table 1).
The red category includes fishes that have a high probability of interaction with the turbines and/or potential for significant harm to their population. The orange category is fishes with a moderate probability of interaction with the turbine and a low to moderate risk of harm and the green, fishes with a low probability of interaction or harm. Degree of potential harm was determined by fish size and susceptibility to turbine passage impact (strike, pressure effects, shear and cavitation; Dadswell and Rulifson 1994), their habitat (pelagic or benthic), their importance to fisheries and the health of their population (endangered, threatened; etc.) The taxonomic listing is similarly color coded for cross reference to the categorized listing (Table 1). A total of 10 fishes are listed in the red category, 11 in the orange category and 57 in the green category.

Four species of fish which are known to occur in Minas Passage have been declared ‘endangered’ or ‘threatened’ by the Committee on Endangered Wildlife in Canada (COSEWIC) and/or are listed in the Canadian Species at Risk Act (SARA). Inner Bay of Fundy Atlantic salmon (SARA, endangered, Schedule 1), porbeagle shark (SARA, endangered, no schedule), striped bass (SARA, threatened, no schedule) are protected to one degree or another and may need an ‘assessment of harm’ for any potential environmental impact. Barndoor skate are listed by COSEWIC as ‘endangered’ but have not been listed by SARA. Atlantic sturgeon is listed as a ‘species of concern’ by COSEWIC but has not been given a status.

Compilation of Fishes

Class Agnatha **'Jawless fishes'**

Order: Myxiniformes **"hagfish"**

1. *Myxine glutinosa*- Atlantic hagfish. Marine, benthic. Hagfish are abundant in the outer Bay of Fundy over mud bottoms (Scott and Scott 1988). They are benthic scavengers that usually burrow into the substrate during daytime. Hagfish attack dead and dying fishes and will predate on shrimp. Sampling with baited traps can capture up to 500 hagfish during a 12 hour set in Passamaquoddy Bay (Scott and Scott 1988). Hagfish have never been observed in the inner Bay of Fundy but they possibly occur inside Minas Basin where there are subtidal mud substrates.

Order: Petromyzontiformes **"lampreys"**

2. *Petromyzon marinus* – sea lamprey. Anadromous, pelagic. Larvae are benthic in fresh water where they burrow into mud and silt of stream banks. Adults are pelagic in marine situations and are blood predators of fishes (Scott and Scott 1988). Lampreys are common in all Bay of Fundy tributaries with marine access. Sea lampreys are semelparous and spawn in freshwater streams during April-July after which the adults die. After hatching larvae remain burrowed into sand-silt bottoms of streams for up to seven years before they metamorphose into juveniles and then migrate to sea. They begin preying on fishes for blood during estuarine emigration. Maritime populations migrate to sea and live offshore on the Scotian Shelf preying on fish blood for an indeterminate period (Halliday 1991). Adults return to fresh water when mature (Scott and Scott 1988). They are known from the Shubenacadie, Gaspereau and Kennetcook Rivers in Minas Basin (Scott and Scott 1988). They probably also occur in all other Minas Basin streams with anadromous fish populations.

Juveniles migrating offshore should be common within Minas Passage during spring (April-June) attached to adult and juvenile gaspereau, shad and salmon. Abundance should be in the 10's of thousands. Adults migrating inshore to spawn should be found in Minas Passage during April-June. Lampreys are difficult to capture when in mid-water, marine situations because of their eel like form which allows them to escape from most sampling gear (Halliday 1991). Adult abundance during inward migration through Minas Passage would probably be in the range of 1000-10,000/yr. Adult sea lampreys will be susceptible to turbine strike because of their body size, pelagic habitat and attachment to other fishes.

Class Chondrichthyes **'Cartilaginous fishes'**

Order: Squaliformes **"sharks"**

Many of the sharks have large body size (1-10m) which increases their chance of blade strike during turbine passage. Although most are never common or abundant in Minas Passage they are mostly predators and scavengers, which means there is a good probability they will be attracted to the turbine sites if there are dead or wounded fish present (Moyle and Cech 1996).. Such behavior will further increase their chances of turbine impact.

3. *Odantaspis taurus* – sand tiger shark. Marine, benthic. Sand tigers are a rare species in Canada. Two specimens have been observed in the outer Bay of Fundy (Scott and Scott 1988) and two were captured during summer (August) inside Minas Basin (Dadswell and Rulifson 1994). They may be more common in Minas Basin than observations suggest since the sandy bottom habitat preferred by sand tigers is widely available inside Minas Basin and summer water temperatures are warm (Bousfield and Liem 1959).

Records indicate this species would be rare in Minas Passage and would only be encountered incidentally during summer. Abundance expected in Minas Passage would probably be in the range of 1-10/year.

4. *Alopias vulpinus* – thresher shark. Marine, pelagic. Thresher shark have been captured in the Bay of Fundy (Scott and Scott 1988) and may occur annually in the inner Bay. Perley (1852) described three captured in drift gill net catches in Shepody Bay and fishers have described them from weir catches in Minas Basin (Leim and Scott 1966). Other authors have questioned these records (Templeman 1963) but the physical characteristics of threshers are very particular (the extremely long upper tail lobe) and records by fishers are probably valid. A very good description of a 'thresher' tail a meter in length taken from a shark caught in Minas Basin is given in Perley (1852). Specimens captured in the outer Bay of Fundy were large (3-5 m; Scott and Scott 1988) and large individuals have been taken off Yarmouth in shark derbies during recent years (Dadswell, pers. obs.). Large sharks that were tagged have been documented to travel long distances rapidly (up to 5000 km; Casey and Kohler 1990) and virtually any species of large shark could be expected in the inner Bay of Fundy during summer.

Threshers feed on herring, alsoids and squid all of which are abundant forage items in Minas Basin during summer (Dadswell et al. 1984a; Bradford and Iles 1992). Threshers should be expected in Minas Passage during June to September but only in small numbers (1-10/yr?). They would be attracted to turbine sites because of vibrations from wounded fishes.

5. *Carcharodon carharias* – great white shark. Marine, pelagic. Piers (1934), Templeman (1963) and Scott and Scott (1988) have documented nine white sharks from the Bay of Fundy which were caught in the outer Bay from July to November. Case (1968) documented a 5.2 meter specimen caught in a drift gill net off Noel Head

in Minas Basin on August 15, 1966. A photograph of this specimen is in his publication. There is also an unconfirmed report of a great white taken from a weir off Advocate in Minas Channel during the summer of 1977 (Dadswell et al. 1984a).

Large great white sharks captured in the Bay of Fundy had fed on harbour porpoise and harbour seals. Great white stomachs are also often filled with whale blubber (thought to be from dead whales; Carey et al. 1982) but they are also known to attack living whales in packs. Since porpoises, seal and whales are abundant in all parts of the Bay of Fundy during summer great whites should be expected in Minas Passage especially during August. Abundance will be very low, probably not more than 1-5/yr and possibily not every year.

6. *Cetorhinus maximus* – basking shark. Marine, pelagic. Basking sharks are common in the Bay of Fundy during summer. Perley (1852); Templeman (1963) and Scott and Scott (1988) report 12 documented occurrences from the outer Bay. Specimens often wash ashore off Saint John Harbour on either side of the Bay after being struck by ships. One, living, basking shark was observed by a wind surfer inside Minas Basin off Evangeline Beach during September 1987 and a dead specimen was found off Alma in Chignecto Bay during early October 2008 (Dadswell, pers. comm.).

Basking sharks are one of the largest fishes in the ocean and attain lengths of over 10m (Scott and Scott 1988). They filter feed on planktonic organisms, especially shrimp and they are known to dive to depths of 300m at night to feed (Tobey 1977). These sharks then rise to the surface during daylight to 'bask' on the surface where they are struck and often killed by ships. They should be expected at depth or at the surface in Minas Passage during July to October. They will probably occur annually in the Passage but numbers will be low (1-5/yr).

7. *Isurus oxyrinchus* – shortfin mako shark. Marine, pelagic. Apparently common in the outer Bay of Fundy during summer but has never been reported in the inner Bay (Scott and Scott 1988). Numerous specimens have been captured recently during shark fishing derbies and landed in Yarmouth (Dadswell, pers. obs.). Mature specimens are 2-3m in length. Probably may not occur in Minas Passage

8. *Lamna nasus* – Porbeagle shark. Marine, pelagic. Porbeagle is the most common shark species in the inner and outer Bay of Fundy other than dogfish shark. Until recently there was a commercial fishery for porbeagle in the outer Bay during summer. Catches averaged about 10MT/yr (Campana et al. 2002). Recently, however, porbeagle was declared endangered (CSAS 2005; Campana 2007) and the fishery was closed.

Porbeagle sharks are common in Chignecto Bay and Minas Basin during summer. Dadswell et al. (1984a) reported two captured at night with drift gill nets off Grindstone Point in Chignecto Bay on August 5 and September 3, 1980. One was captured at night with drift gill nets in Minas Passage off Blomidon during July, 1984 (Dadswell pers. obs.). These three specimens were all females from 2.1-2.2m in length (Dadswell et al. 1984a). Another, 318kg female was captured in a herring net off Halls Harbour in Minas Channel on July 15, 1986 (Anon 1986).

Porbeagle is a fast swimming, epipelagic shark that feeds on salmon, herring. alosids and squid (Scott and Scott 1988; Joyce et al. 2002). Porbeagles probably follow the abundant herring and alosid runs that occur in the inner Bay during summer (Dadswell et al. 1984a). They can be expected in Minas Passage from July to September. Estimated annual abundance is probably in the range of 10-100 individuals. They will occur near the surface at night and in deeper water during day.

9. *Mustelus canis* – smooth dogfish. Marine, pelagic. Smooth dogfish are uncommon in the Bay of Fundy (Scott and Scott 1988) and has been reported only in the outer Bay during summer. They could occur in Minas Passage during summer mixed with spiny dogfish.

10. *Somniosus microcephalus* – Greenland shark. Marine, pelagic and benthic. Greenland sharks are extremely rare south of the Gulf of St. Lawrence. A few specimens have been taken in the outer Bay of Fundy during winter (Templeman 1963).

Greenland shark are large but sluggish. They feed on fishes especially salmon, as well as seals and carrion. They are common in the arctic and could be more common than known during winter in the Bay of Fundy (Scott and Scott 1988). There is a lack of fish studies in the Bay of Fundy during winter and this fish may be present. Greenland shark could be found in Minas Passage during winter but probably never more than sporadically.

11. *Squalus acanthias* – spiny dogfish shark. Marine, pelagic and benthic. Dogfish shark are extremely abundant in the inner Bay of Fundy during summer and occur in the outer Bay all year (Scott 1988; Wehrell 2005; Campana et al. 2008). Commercial catches of 600-700 MT, which would be approximately 30,000-50,000 adults, are landed from Minas Basin annually (Dyer et al. 2005). Dogfish are taken by drags, hand line (Dyer et al. 2005) and drift gill net (Dadswell et al. 1984a).

The dogfish sharks found in Minas Basin during summer are mostly female (95%) and mean size averages about 85cm (Moore 1996; Wehrell 2005). Dogfish feed on wide variety of marine organisms from jellyfish to other fishes, each other and carrion. They can be expected to occur at all depths in the inner Bay, mainly on bottom during day and at the surface at night but they usually rise to the surface at slack tide regardless of time of day (Dadswell, pers. obs.). They are one of the most common larger fishes in Minas Basin, Minas Passage and Minas Channel during May to October (Dadswell et al. 1984a; Scott 1988; Wehrell 2005).

The dogfish that occur in Minas Basin during summer are probably representatives of a number of stocks. Dogfish tagged inside Minas Basin during June to August were recaptured within a few months as far south as Rhode Island, USA and offshore as far as the edge of the Scotian Shelf (Moore 1996).

Dogfish will be migrating through Minas Passage during April to October in large numbers. Inward movement will occur during April-July and outward movement from July to October. Based on an estimated fisheries mortality for the Bay of Fundy (Campana et al. 2008) and the annual landings in Minas Basin (Dyer et al. 2005) approximately 1-2 million dogfish occupy the Basin each summer and must move in and out through Minas Passage. Dogfish are often scavengers and would be attracted to turbine sites by the presence of dead fish.

Order: Rajiformes ‘skates and **rays”**

All ‘skates and rays’, except the Atlantic torpedo, are strictly benthic fishes to the point where they commonly bury themselves in the substrate during day and emerge at night (Scott and Scott 1988). They are almost always found over sand, silt and mud bottoms. All species feed on benthic invertebrates except the Atlantic torpedo which is a fish predator. Most of the species listed below can be expected in Minas Passage during spring to fall but probably pass through rapidly because of the absence of their preferred substrate (AECOM 2009). The skate population in Minas Basin is unknown but based on trawl catches it must be quite large (Wehrell 2005).

12. *Torpedo nobiliana* – Atlantic torpedo. Marine pelagic and benthic. Torpedo rays are a rare species on the Canadian Atlantic coast and are known only from the outer Bay of Fundy during summer (Scott and Scott 1988; Dadswell, pers. obs.). It attacks fish prey and stuns them with electricity pulses. It may possibly occur in Minas Passage during mid-summer.

13. *Raja erinacea* – little skate. Marine, benthic. The little skate is known from the entire Bay of Fundy and occurs from the lower intertidal zone to offshore. This species is very common in Minas Basin during summer (Wehrell 2005) and will be found in Minas Passage.

14. *Raja senta* – smooth skate. Marine, benthic. The smooth skate occurs in deepwater (30-60m) off the outer Bay of Fundy all year (MacDonald et al. 1984). Deepwater habitat is absent in Minas Basin except in Minas Passage where the substrate would provide little habitat for this species. It may occur in Minas Channel, perhaps during winter.

15. *Raja radiata* – thorny skate. Marine, benthic. The thorny skate is common in the entire Bay off Fundy year around (Scott 1988). It is common in Minas Basin during summer (Wehrell 2005). It will occur over hard bottom (Scott and Scott 1988) and may be more common in Minas Passage than the other skates. Scott (1988) recorded it from Minas Channel.

16. *Raja ocellata* – winter skate. Marine, benthic. Winter skates are very common in the entire Bay of Fundy all year and are found from the lower intertidal zone to offshore (Scott 1988). This skate is the most common in Minas Basin during summer and is probably also present during winter (Bousfield and Leim 1959; Wehrell 2005). Winter skate should be expected in Minas Passage but residency is probably short term.

17. *Raja laevis* – barndoor skate. Marine, benthic. Barndoor skates occur year round in the Bay of Fundy (Liem and Scott 1966). It occurs in Minas Basin during most of the year (Bleakney and McAllister 1973) but is not abundant. The barndoor is a large skate and besides invertebrates also preys on fishes (Scott and Scott 1988). Probably occurs in Minas Passage during movements to and from the Bay of Fundy.

The barndoor skate has been declared endangered by COSEWIC but at this date is not listed for protection by SARA.

Class: Osteichthyes **'Bony fishes'**

Order: Acipenseriformes **"sturgeons"**

18. *Acipenser oxyrinchus* - Atlantic sturgeon. Anadromous, benthic. The Atlantic sturgeon is the fifth most common fish captured by trawls in Minas Basin during summer (Wehrell 2005). The aggregation in Minas Basin during summer numbers about 10,000 individuals/yr and consists of mainly juveniles of 1-2m in length (Wehrell et al. 2008; Wehrell, pers. comm.). Adult Atlantic sturgeons are known to reach 4.6m in length (Scott and Scott 1988). Tag returns from sturgeon marked inside and outside Minas Basin and preliminary DNA analysis (Wirgin pers. comm.) indicate the sturgeons are from numerous stocks along the Atlantic coast.

Atlantic sturgeons first appear along the north shore of Minas Basin during April/May and migrate through the Basin to the Southern Bight during July/August then exit by Minas Passage during September (Wehrell et al. 2008). An unknown portion of this aggregation as well as young juveniles and adults may over winter in freshwater tributaries of Minas Basin (Dadswell pers. obs.). At present the commercial fishery for Atlantic sturgeon in the Bay of Fundy is closed except in the Saint John River. Formerly in Minas Basin weir catches were harvested.

Atlantic sturgeons spawn in the Saint John, Annapolis, Saint Croix, Stewiacke/Shubenacadie rivers and formerly in the Avon River in the Bay of Fundy and Minas Basin drainages (Huntsman 1922; Dadswell 2006; Dadswell pers. obs.). Juveniles remain in estuaries for 3-5 yr. After movement to sea large juveniles and adults feed and migrate along east coast of North America from Chesapeake Bay to Labrador. Atlantic sturgeons tagged inside Minas Basin have been recaptured as far south as Cape Cod, Massachusetts and as far north as the Gaspe, Quebec. Atlantic sturgeons that were tagged outside of Minas Basin and recovered inside Minas Basin by commercial fishers or during research were from the Hudson, Connecticut and Merrimack Rivers (Wehrell, pers. comm.).

Similar to sharks, sturgeons have large body size which increases their chances of turbine blade strike. Dead sturgeons have been found each year below the tidal turbine at Annapolis Royal.

Atlantic sturgeon feed on benthic invertebrates and small fishes (sand lance; Scott and Scott 1988) in the subtidal and over the Minas Basin tide flats at high tide (Armitage and Gingras 2003). They appear to congregate in discrete 'sturgeon holes' at low tide that are well known and usually avoided by trawl fishers (Dadswell pers. obs.). Sturgeon are primarily benthic fish but for unknown reasons they rise to the surface and make spectacular jumps during high tide (Dadswell pers. obs.)

Atlantic sturgeon will be common to abundant in Minas Passage moving inward during May-June and outward during August-September and will occur throughout the water column. Up to 10,000 individuals can be expected to pass through Minas Passage twice a year and the abundance will increase in the near future as sturgeon conservation efforts in Canada and the USA take effect (Dadswell 2006).

19. *Acipenser brevirostrum* – shortnose sturgeon. Anadromous, benthic. The shortnose sturgeon is only found in the Saint John River estuary region of the Bay of Fundy (Scott and Scott 1988). The shortnose is a small species of sturgeon that only reaches a maximum length of 1.4m (Dadswell 1979). It feeds primarily on various species of molluscs in fresh water and low salinity regions of warm estuaries.

During 30 years of fisheries work in Minas Basin using virtually every means of fish capture gear available a shortnose sturgeon has never been seen (Dadswell pers. obs.). Shortnose sturgeons are not expected to occur in Minas Passage.

Order: Anguilliformes **"eels"**

20. *Anguilla rostrata* – American eel. Catadromous, benthic. American eel are common to abundant in all tributaries of the Bay of Fundy, in estuaries and along marine shorelines. Larvae arrive in Bay of Fundy after drifting north in the Gulf Stream from spawning grounds in the Sargasso Sea (Scott and Scott 1988). Mainly females migrate upstream in rivers while males live in estuaries and along the sea shore (Jessop 1996). Eels are predatory, feeding on all invertebrates and fishes they can ingest. Females return to the sea after 7-10 years of growth to maturity and with the mature males migrate to the Sargasso Sea to spawn. After spawning the adults die.

American eel support commercial fisheries at all life stages (as glass eels entering freshwater, as yellow eels during growth in freshwater and as silver eels while migrating back to the sea; Jessop 1996)). Eel are an important, local fishery in the Minas Basin tributaries (Dyer et al. 2005). Eel populations around the North Atlantic are in severe decline and are being considered for listing (SARA/COSEWIC)

Glass eels (6-10cm long) will be abundant in Minas Passage during April and May. Silver eels (80-100cm long) will migrate offshore through Minas Passage during August to October. The abundance of glass eels occurring in Minas Passage annually will probably be in the millions (Jessop 1996). Silver eels migrating seaward will probably number in the range of 10,000-20,000. Eels are scavengers and would be attracted to a turbine site by dead fish.

Order: Clupeiformes **"herrings"**

The clupeids lack a lateral line and instead have evolved a highly specialized gas bladder that functions to enhance sound reception (Hoss and Blaxter 1979). The system includes two, thin-walled, forward projecting tubes from the gas bladder that interface with the otic bulla of the hind brain. Rapid hydrostatic pressure flux during turbine passage causes expansion in the gas bladder and tubes leading to hemorrhaging of the hind brain and often death. All clupeids are susceptible to high turbine passage impact (Stokesbury and Dadswell1991; Dadswell and Rulifson 1994).

Clupeids also school into dense ‘bait balls’ when under attack by pelagic fishes or cetaceans as a predator defense mechanism (porpoise; Moyle and Cech 1996). If a school of herring or alosids during the ’bait ball’ condition made turbine passage many would be struck because of the dense packing of the school.

21. *Alosa aestivalus* - blueback herring. Anadromous, pelagic, planktivorous. The blueback herring, ‘gaspereau’ or ‘river herring’ are common to abundant in every tributary of the Bay of Fundy with spawning habitat (rapids) and access (no water fall at head of tide; Dadswell 1985). They spawn in fresh water in spring (May-June) after which adults return to the sea (Scott and Scott 1988). Juveniles migrate to sea during August to October at an average length of 10cm (Stokesbury and Dadswell 1989). Growth to maturity requires 4-5 years at sea where the North American Atlantic stocks migrate north and south annually.

Blueback herring are extremely abundant in the pelagic zone of Minas Basin during summer. Mid-water trawl catches up to 345/hr of ‘gaspereau’ were made off Economy Point during late June 1983 (Bradford 1987). Stone (1985) found adult blueback herring were most abundant in Minas Basin gill net catches during July and in weirs during August and September. The summer aggregation in Minas Basin is derived from east coast stocks from as far south as Virginia (Rulifson et al. 1987; Dadswell and Rulifson 1994).

Blueback herring and alewifes (gaspereau) support a fishery in the Gaspereau and Shubenacadie Rivers (Dyer et al 2005) and in the intertidal weirs of Minas Basin (Dadswell et al. 1984a). Adults and juveniles are taken in the intertidal weirs from April to December but the major movement through Minas Passage is probably into Minas Basin from March to July and exiting the Basin from July to November. The timing, spatial distribution and intensity of this movement require research but the abundance of this population will be in the 10’s of millions.

22. *Alosa pseudoharengus* – alewife. Anadromous, pelagic, planktivorous. Like blueback herring, alewife (together known as ‘gaspereau’ in the Maritimes) are common to abundant in every tributary of the Bay of Fundy with spawning habitat (lakes and slow riverine areas) and access (no water fall at tide head). They spawn in fresh water in spring after which the adults return to sea (Scott and Scott 1988). Juveniles migrate to sea during August to October at an average length of 10 cm (Stokesbury and Dadswell 1989). Growth to maturity takes 4-5 years at sea where stocks migrate north and south along the Atlantic coast annually (Neves 1981).

Alewife are extremely abundant in the pelagic zone of Minas Basin during summer where mid-water trawl catches of ‘gaspereau were up to 345/hr (Bradford 1987) and drift gillnet catches are up to 55/100m/30min (Dadswell et al. 1984a; Stone 1985). Like blueback herring the summer aggregation in Minas Basin is derived from many Atlantic coast stocks (Rulifson et al. 1987; Dadswell and Rulifson 1994).

Alewife support commercial fisheries in the Gaspereau and Shubenacadie Rivers (Dyer et al. 2005) and from intertidal weirs of Minas Basin (Dadswell et al. 1984). The commercial catch in the Gaspereau ranged from 64-200MT/yr and the Shubenacadie, 50-

363MT/yr during the period 1965-2000. The spawning population of alewife in the Gaspereau River ranges from 200,000-1 million adults annually (Gibson and Myers 2003). Alewife is captured in rivers from April to June and in intertidal weirs from April to December.

The majority of alewife movement through Minas Passage is probably inward during March to July and outward from August to November. Like blueback herring the timing, spatial distribution and intensity of this movement requires research but again the abundance will be in the 10's of millions of individuals from 0+ to 6+yrs.

23. *Alosa sapidissima* – American shad. Anadromous, pelagic, planktivorous. American shad are common to abundant in all Bay of Fundy tributaries with spawning habitat (deep, rapid flow riverine sections) and access from the sea (no head of tide waterfall; Liem and Scott 1966). They spawn in rivers in spring (May-June) after which adults return to sea. Juveniles depart fresh water after 3-4 months of growth (Aug – Oct). Adults and juveniles migrate along the Atlantic coast from Florida in winter to the Bay of Fundy, the Gulf of St. Lawrence and Labrador in summer. During a 5 year study in Minas Basin and during which 8000 external tags were applied to shad, there were approximately 400 tag returns from as far south as Florida and as far north as Labrador (Dadswell et al. 1987)

Large commercial fisheries exist in the Saint John, Shubenacadie and formerly the Petitcodiac and Avon Rivers in the Bay of Fundy (Leim and Scott 1966; Dadswell et al. 1984a). The shad fishery in the Shubenacadie varied from 10-60MT between 1991 and 2001 (Dyer 2005). The population in the Annapolis River is closed to commercial fishing but has 100,000 – 150,000 spawning adults annually (Melvin et al. 1985). After spawning these fish are captured in the inner Bay of Fundy (Melvin et al. 1986). Shad are taken by drift gill net and intertidal weirs in Minas Basin during May-August (Dadswell et al. 1984b).

Shad of all ages are extremely abundant in the inner Bay of Fundy during summer (May- October: Dadswell et al. 1983) where the population consists of migrating stocks from all rivers on the Atlantic seaboard from Labrador to Florida (Dadswell et al. 1987). The coastal migratory population enters the Bay of Fundy along the Nova Scotia shore and follows the residual current pattern through the Bay departing on the New Brunswick shore. Shad become increasing dense as they move into the embayments (Minas Basin, Cumberland Basin) at the inner end of the Bay of Fundy where the run effectively doubles back on itself. Population estimates for American shad in Minas Basin during 1982 indicated approximately 3 million adults were in the Basin during the 12 week period from June 1 to August 30 (Dadswell et al. 1984b).

Shad migrate inward through Minas Passage to Minas Basin from April-July and outward to the Bay of Fundy during July-October. The total population (0+ juveniles to adults) migrating through Minas Passage annually is probably in the range of 10 million fish. Migration speed of feeding shad in the Bay of Fundy was estimated at 3.0-3.5 km/d (Dadswell et al. 1987). Shad of 40-50cm in length should make the crossing through Minas Passage in about 4-5 days. Smaller shad will probably take longer.

24. *Brevoortia tyrannus* – Atlantic menhaden. Amphidromous, pelagic. The menhaden feeds on phytoplankton and detritus. Juvenile menhaden are found in large

Bay of Fundy estuaries (Annapolis and Saint John Rivers; Stokesbury and Stokesbury 1993). Adults spawn in Minas Basin near Economy Point (Dadswell, unpub. data) and some over winter in Kennebecasis Bay in the Saint John River estuary (Scott and Scott 1988). The population that spawns in Minas Basin is possibly the only spawning occurrence in Canada. Occasionally, southern stocks from Chesapeake Bay penetrate into the Bay of Fundy during warm summers.

The stock that occurs in Minas Basin is small and seldom more than 10-20 individuals are found in intertidal weirs during late summer (August; Dadswell, pers. obs.). This species is not fished commercially in Canada.

Adults would traverse Minas Passage inward to spawn in Minas Basin during May-June. Adults and juveniles would depart Minas Basin via Minas Passage in late summer. Population size moving through Minas Passsage probably consists of a few hundred adults and 10 thousand+ juveniles.

25. *Clupea harengus* – Atlantic herring. Marine, pelagic, plantivorous. Herring are common to extremely abundant in all parts of the Bay of Fundy. Adults are marine, benthic spawners and stocks congregate on Lurcher Shoal off Yarmouth during October, in Scots Bay during August, and in Minas Basin during May to spawn (Bradford and Iles 1993). Larvae and juveniles (brit) form dense schools in the inner Bay of Fundy. Bradford and Iles (1993) found larval densities were highest inside Minas Basin (5-35/10m^2). Abundance of herring larvae in Minas Passage during July were about 50% of the catches inside Minas Basin (Bradford 1987). One-half hour midwater trawl tows in Minas Channel caught 1000-10,000 brit during August and brit were abundant in other parts of the inner Bay of Fundy surveyed during February (Koeller 1979). Larger juveniles aggregate in Minas Basin during early summer ('June herring'; Perley 1852; Dadswell et al. 1984a; Bradford 1987). Adult herring schools occur at all depths in the water column but mainly near bottom during day and near surface at night. They form dense 'bait balls' when attacked by harbour porpoise pods (Dadswell pers. obs.).

Herring in Minas Basin, Minas Passage and Minas Channel are caught using intertidal weirs, intertidal gill nets and by purse seining (Bradford 1987). The spawning stock biomass of the spring spawning group in Minas Basin is estimated to be 500MT and yields annual catches of about 50MT (Bradford and Iles 1993). The spawning stock biomass of the summer spawning group in Scots Bay-Minas Channel is estimated at approximately 75,000 MT with an annual yield of about 15,000MT (Dyer et al. 2005). Atlantic herring support the largest fishery by biomass in the Bay of Fundy (CSAS 2007). The annual TAC is set at 20% of the estimated total adult biomass of 500,000MT.

Herring of most life stages (larvae, juveniles and adults) are common to extremely abundant in Minas Passage during the entire year (Koeller 1879; Bradford and Iles 1993). Larvae are abundant during spring, summer and fall and brit are common during winter. Large juveniles and adults are abundant moving inward and outward through Minas Passage during March – June (Minas stock adult spawners, 'June' herring juveniles). Adult spawners from the Scots Bay spawning stock are abundant in Minas Channel during July-September and large schools probably penetrate Minas Passage during this period. Abundance of all stages of herring in Minas Passage could be in the range of 10-100's of millions during periods of passive (larvae) and active (juvenile, adult) movement. Larvae and juveniles are capable of maintaining themselves in discrete areas near their spawning sites where productivity is high (Iles and Sinclair 1982). Based on observed abundances of larvae and juveniles three of these regions are inside Minas Basin near Economy Point, in Minas Passage and in Minas Channel (Koeller 1979; Bradford and Iles 1993)

Order: **Salmoniformes "salmon, trout and smelt"**

26. *Salvelinus fontinalis* – brook trout. Anadromous, benthic. Populations of brook trout occur in virtually every tributary of the Bay of Fundy from small brooks to large rivers (Scott and Scott 1988). Juveniles remain in fresh water but adults enter marine waters from April to September then return to over winter in freshwater. Brook trout support the most popular recreational fishery in Nova Scotia (McMillan ; pers.comm.).

Although brook trout are common to all tributaries of Minas Basin, Minas Passage and Minas Channel they are very seldom found during sampling in Minas Basin (Dadswell et al. 1984a, Dadswell pers. obs.). During weir surveys in Minas Basin since 1982, brook trout have never been encountered even when the weirs are situated within a kilometer or two of known brook trout streams (Walton River; Harrington River). Likewise, brook trout are never encountered during gill net sampling or angling in marine waters (Broome, pers.comm.). Brook trout probably occur only in the mouths of fresh water tributaries of Minas Passage and are probably in estuarine waters only from April to August.

27. *Salmo salar* – Atlantic salmon. Anadromous, pelagic. There were approximately 59 Bay of Fundy tributaries which had stocks of Atlantic salmon but at least 7 of these now extinct because of dams or causeways (Amiro 2003). Inner Bay of Fundy stocks were declared endangered by COSEWIC in 2003 and are now listed under Schedule l by SARA (no allowable take; CSAS 2004). Minas Basin had salmon runs in most tributaries including the Shubenacadie-Stewiacke, Salmon, Gaspereau, Cornwallis and Avon and all tributaries along the north shore from Truro to Parrsboro. Many of these streams now lack populations because of causeways (Avon) or because of the inner Bay of Fundy wide collapse of stocks (Gibson et al. 2003b).

Atlantic salmon spawn in fall in fresh water streams and most adults from iBoF rivers return to sea by December (Amiro et al. 2003). Juveniles (parr) remain in fresh water for 1-3 years then migrate to sea during May-June as smolts. Adults remain at sea for 1-2 years migrating in the North Atlantic in regions with water temperatures of 4-10C (Scott and Scott 1988). Adults home to natal iBoF rivers from July to November. Salmon runs in most Minas Basin rivers consisted of 1SW adults (50-60cm in length) and returning kelts (multiple spawners; Huntsman 1954; Amiro et al. 2003).

Formerly Minas Basin had both commercial and recreational salmon fisheries. The commercial fishery was closed in 1982 (Dadswell et al 1984a) and the sports fishery in 1992 (Amiro et al. 2003). Salmon were taken by the commercial fishery in Minas Basin by drift gill nets and intertidal weirs (Huntsman 1958). Catches from 1900-1982 varied between 1-4MT/yr (Dadswell et al. 1984a). The angling fishery occurred in most Basin tributaries. Formerly, angling catches in the Shubenacadie-Stewiacke River basin were from 500-1000/yr (Morantz 1978) but catches in other tributaries seldom exceeded

100/yr (Amiro et al. 2003). The estimated population of returning adults to Minas Basin tributaries was around 40,000 as recently as 1989 but only 250 were counted in 1999 (Amiro 1999). Similarly, parr densities have declined in all tributaries (Gibson et al. 2003b). The smolt run size in the Gaspereau River during 2009 was estimated to be about 5600 but only 1100 were wild smolt, the rest were hatchery stocked fish (Quinn 2010).

Atlantic salmon smolts can be expected migrating seaward through Minas Passage during May to July. Atlantic salmon adults will occur in Minas Passage from June to December. Although most adults will be from Minas Basin tributaries some are migrants from other Bay of Fundy stocks, the USA (Connecticut and Penobscot Rivers) and the Gulf of Saint Lawrence (Miramichi River; Saunders 1969: Meister 1984). Pre-spawning adults will be migrating inward during June to November. Kelts (post-spawning salmon) will be moving seaward during Nov.-Dec.

Smolt migration speeds at sea average 6-26km/d (Lacroix and McCurdy 1996) and most smolts would be expected to clear Minas Passage in one to two days unless countered by gyre currents (Lacroix 2008). Adult salmon make from 20-50 km/day when migrating at sea (Meister 1984; Hansen et al. 1993) and movement through Minas Passage should be rapid.

Numbers of migrating smolts will probably be in the range of 10,000 to 20,000 annually (wild and hatchery fish) unless the iBoF salmon stocks rebound. Numbers of migrating adults at present population levels will probably be less than 500 individuals inward and perhaps half of this outward as kelts. If, however, iBoF salmon stocks rebound in the future 20,000 to 40,000 adults could make the passage each year and the number of smolts could increase up to a million annually.

28. *Salmo trutta* – brown trout. Anadromous, benthic-pelagic. Brown trout were introduced from Europe during the late 1800's and early 1900's and have become well established in Minas Basin rivers especially the Cornwallis and Shubenacadie (Leim and Scott 1966). Their life history is similar to Atlantic salmon except brown trout remain at sea only from May to September and do not move far from their natal river. Brown trout are seen more often in intertidal weirs in Minas Basin than brook trout and are sometimes captured in drift gill nets (Dadswell et al. 1984a).

There are few rivers with brown trout near Minas Passage and this species should only occur sporadically offshore in the Passage. If present it would be from May to September.

29. *Oncorhynchus kisutch* – coho salmon. Anadromous, pelagic. Coho salmon were introduced to Maritime Rivers from western Canada during the early 1900's but most populations have since died out (Scott and Scott 1988). Coho were common in the Bay of Fundy during the 1980's when large numbers were being stocked in New Hampshire, USA and adults migrated north to the Bay of Fundy (Martin and Dadswell 1983). The New Hampshire stocking was terminated in the 1990's. There was a spawning population in the Cornwallis River which resulted from these New Hampshire introductions or other hatchery escapee's (Martin and Dadswell 1983).

Coho life history is somewhat similar to Atlantic salmon except they migrate to sea at a younger age and smaller size (after one year in the river). No adults have been recorded in Minas Basin since the late 1980's and the population in the Cornwallis River may be extirpated. They will probably not be encountered in Minas Passage.

30. *Oncorhynchus gairdneri* – rainbow trout. Anadromous, pelagic. Rainbow trout were introduced to the Maritimes from western Canada in the late 1800's and introductions continue into the present since rainbow trout in aquaculture operations often escape (Scott and Scott 1988). Their life history is similar to brown trout. Rainbows migrate into the sea in spring, feed in salt water during summer and return to fresh water during fall for over wintering.. The species is not common in iBoF tributaries but occurs in some. A few should be expected sporadically in Minas Channel.

31. *Osmerus mordax* – rainbow smelt. Anadromous, pelagic. Rainbow smelt are extremely abundant and ubiquitous in all regions of the inner Bay of Fundy (Dadswell et al 1984a). Spawning stocks occur in all rivers and brooks with access from the sea and spring arrivals are close to the same time each year. Two examples are: spawning smelt appear in the Gaspereau River on the south side of Minas Basin during late April and in the Portapique River on the north side during the second week of May (Dadswell pers. obs.). Spring arrival of spawning populations is exploited by recreational fishers but there is no directed commercial fishery in Minas Basin. After the eggs hatch in fresh water the larvae drift into the sea and there are dense concentrations of pelagic larvae in the Minas Basin from May to August (Roberts 1987; Bradford 1987). Adults occur pelagically in the water column and along shorelines (Dadswell et al. 1984a). Smelt are voracious feeders and eat virtually anything smaller than them (Scott and Scott 1988).

Surveys for smelt have never been carried out in Minas Passage but they should be expected to be abundant especially near shore. They are expected to occur in Minas Passage all year but may be more abundant during winter when the cold water in Minas Basin may cause them to migrate seaward.

32. *Mallotus villosus* – capelin. Marine, pelagic, planktivorous. Capelins spawn in the sand of beaches at the high tide level during May-June (Scott and Scott 1988). They have only been captured occasionally in the Bay of Fundy (Tibbo and Humpreys 1966) but there may be one stock that spawns on beaches of the Fundy National Park (Perley 1852). Capelin probably rarely occurs in Minas Passage but schools of this subarctic fish may be present during winter.

Order: Lophiiforhes "goosefishes, anglers"

33. *Lophius americanus* – monkfish. Marine, benthic. Monkfish are common but not abundant throughout the Bay of Fundy and in Minas Basin (Bleakney and McAllister 1973; Scott 1988). Monkfish feed largely on fishes especially flounders and tend to follow the flounder migration to the inner Bay of Fundy in summer. It can grow up to 1m in length. This fish is a benthic, lay-in-wait predator that moves into iuntertidal at high tide and is often stranded in Minas Basin by the rapid fall of the tide (Bleakney and

McAllister 1973; Dadswell, pers. obs.). It is taken in small numbers as by-catch in the groundfish and scallop drag fisheries and in intertidal weirs in Minas Basin and Scots Bay (Simon and Comeau 1994). The population in the Bay of Fundy is stable and landings from 1990 to 2000 averaged 700MT/yr (Beanlands et al. 2000).

Monkfish will be passing into and out of Minas Basin via Minas Passage from April to October. They will be present in small numbers and will probably remain on or near the bottom.

Order: Gadiformes "codfishes'

34. *Enchelyopus cimbrius* – fourbeard rockling. Marine, benthic. Rockling are a small, cod-like fish that are common over mud and gravel bottom in the outer Bay of Fundy (MacDonald et al. 1984). They are rare inside Minas Basin and have only been observed once (Bleakney and McAllister 1973). They prefer cooler water (Scott and Scott 1988) and may be more common in Scots Bay and Minas Channel. Daborn (1984) reported their larvae were abundant in neuston samples from Minas Channel. Adults are small and seldom exceed 30cm in length.

Rockling adults should be rare in Minas Passage since the bottom consists primarily of scoured rock (EA 2009). Rockling larvae could be abundant near the surface from May-August during some years.

35. *Gadus morhua* – Atlantic cod. Marine, benthic-pelagic. Cod were once very common in the entire Bay of Fundy but stocks are now depleted (CSAS 2006). Since 1990 landings in the Bay of Fundy have fallen from 24,000MT to 3800MT in 2006. Overfishing is probably the root cause but some are suggesting an oceanographic regime change has occurred (Bundy and Fanning 2005).

Cod are found in Minas Basin and Minas Channel only during the seasonal coldwater period when temperatures are from 3-8°C (November to June; Scott 1987). Cod feed on all types of invertebrates and fishes and will follow alosid spawning runs into the low salinity water of estuaries (Dadswell, pers. obs.). Cod were formerly caught commercially in Minas Basin by long lines set in the intertidal zone (Dadswell et al. 1984a) but the fishery is now closed. It is taken in intertidal weirs occasionally (Dadswell et al. 1984a) and as by catch in the flounder trawl fishery during June (Wehrell 2005).

Cod can be expected in Minas Passage from November to July but are probably most common during March-May. It will occur on bottom and in mid water. Until the stock rebounds numbers will be low and probably fewer than a thousand will pass in and out of Minas Basin during a year

36. *Melanogrammus aeglefinus* – haddock. Marine, benthic. Haddock were once very common in Bay of Fundy during summer from Scots Bay to Lurcher Shoal while on feeding migrations from Brown's Bank and the Gulf of Maine (Perley 1852; Scott 1988). After 1965, however, haddock have become rare in the inner Bay of Fundy because of over fishing and poor recruitment (Scott 1987; Frank 1992). Before the decline of the haddock stock in 1965 landings in the inner Bay of Fundy were high but all landings in

the Bay of Fundy continue to remain low and were only 5-8MT from 1990-2005 (Dyer 2005).

Haddock only occur in the Bay of Fundy during summer where they feed over mud bottoms on small invertebrates. In winter they are offshore on the Scotian Shelf (MacDonald et al. 1984; Scott 1988). Haddock have never been recorded from Minas Basin (Huntsman 1922; Dadswell et al. 1984a) even though they were once abundant in Scots Bay (Scott 1987). Their absence from Minas Basin could be explained because of a lack of proper substrate and because they select temperatures of 4-8^{o}C (Scott and Scott 1988). Haddock are not expected to occur in Minas Passage because of higher summer temperatures and a lack of feeding substrate (AECOM 2009). .

37. *Merluccius bilinearis* – silver hake. Marine, benthic and pelagic. Silver hake are common in the Bay of Fundy during summer from outer Minas Basin to Lurcher Shoal (Simon and Comeau 1994). Silver hake are commonly caught in intertidal weirs in Scots Bay and Minas Basin but never in large numbers. During the summer of 1979 they were abundant in gill net catches in Cumberland Basin (Dadswell et al. 1984a). No directed fishery for them is exists in the Bay of Fundy because of low abundance and lack of markets in North America (Simon and Comeau 1994).

Silver hake can be expected in Minas Passage during July to September but numbers will be low, probably only a few thousand fish. They will migrate predominately in the water column.

38. *Urophycis chuss* – red hake. Marine, benthic. Red Hake is common in all regions of Bay, especially so in the outer Bay of Fundy where juveniles (0+) are commensal with sea scallops during the first fall of their life (Garmen 1983). Juveniles (1+) are common to abundant in Minas Basin intertidal weir catches during July after leaving their scallop hosts and while on migration to the lower Bay of Fundy and the Scotian Shelf (Dadswell pers.obs.). Adult red hake have never been recorded inside Minas Basin.

Juvenile red hake (20-30cm) will be abundant in Minas Passage during June-August as they migrate from their scallop hosts and pass through the inner Bay of Fundy. Movement inward to Minas Basin will be during June, outward movement, during August. There will be large numbers of juveniles migrating, probably 10's of thousands, but since they are benthic fish they will remain near bottom.

39. *Urophycis tenuis* – white hake. Marine, benthic. White hake are common throughout the Bay of Fundy especially over mud bottom of the outer bay (Scott 1987; Simon and Comeau 1994). They are taken in drags in Minas Channel (Scott 1988) White hake are tolerant of reduced salinity and there are populations in Kennebecasis Bay of the Saint John River (Scott and Scott 1988) and Minas and Cumberland Basin (Dadswell et al. 1984a).

In Minas Basin they are commonly captured in small numbers by intertidal weirs and as by catch in flounder drags (Dadswell et al 1984a; Wehrell 2005) but there is no directed fishery. Individuals observed in the inner Bay of Fundy were all juveniles.

White hake probably occur in Minas Passage from April to October during movement into and out of Minas Passage. Numbers will be few.

40. *Pollachius virens* – pollock. Marine, pelagic. Pollock are common to abundant in the outer Bay of Fundy (Scott 1988), but rare in the inner Bay except in Minas Channel where there has been a fishery since the early 1800's (Perley 1852; Dyer 2005). Juveniles from spawning in the Gulf of Maine (Trippel and Brown 1993) form large schools inshore around the Bay of Fundy over gravel and pebble beaches in spring then aggregate around wharfs in summer-fall ('harbor pollock'; Rangely and Kramer 1995). Pollack are a pelagic predator that feed almost extensively on euphasids. Their abundance and growth rates have been declining in recent years probably because of competition with resurgent baleen whale populations (Trippel and Brown 1993).

Pollack are taken commercially and recreationally using drags, long lines, gill nets and hand lines. Aggregations of adults occur in regions of dynamic flow and upwelling, around reefs and in channels (Scott 1987). The commercial fishery in the Bay of Fundy was landing 40,000MT/yr during the 1980's (Trippel and Brown 1993) but these landings had declined to 4500MT by 2004 (Dyer et al. 2005). Pollack have never been recorded inside Minas Basin but are common and were formerly abundant in Minas Channel and Minas Passage (Perley 1852; Dyer et al. 2005).

Pollack are taken by hand line in Minas Channel and Minas Passage from April to October (Barkhouse, pers. comm.). They probably move into and out of Minas Passage with the tides. Abundance is low at present (Simon and Comeau 1994) but could increase if the stock rebounds. Current numbers are probably in the thousands to 10's of thousands.

41. *Microgadus tomcod* – Atlantic tomcod. Anadromous, benthic. Tomcod are extremely abundant in turbid regions of inner Bay of Fundy, especially Cumberland Basin and Cobequid Bay (Dadswell et al. 1984a). They are also abundant along beaches in remainder of the Bay of Fundy especially during winter. They are a small fish seldom exceeding 24cm in length and 4 yrs old.

Tomcod spawn in fresh water close to tide head in December and January (hence the common name 'frost fish'; Scott and Scott 1988). There is a huge run of spawning tomcod into the Shubenacadie estuary during December that attracts large numbers of baldhead eagle to the area (Reid 1982). Pelagic larvae occur in dense concentrations in Cobequid Bay and Minas Basin during summer (Bradford 1987).

There is no fishery for tomcod in the Bay of Fundy but they are an important forage species for fish and birds (Scott and Scott 1988). They are captured in intertidal weirs in Minas Basin (Dadswell et al. 1984a) and are commonly found marooned in the intertidal zone (Bleakney and McAllister 1973).

Adult tomcod will occur along the shoreline of Minas Passage, especially in winter and pelagic juveniles will be abundant offshore in Minas Passage during January to August after which they settle and move inshore. Numbers of pelagic juveniles during this period will probably number in the 10's of millions.

42. *Macrozoarces americanus* – ocean pout. Marine, benthic. Ocean pout are common to abundant in deep water of outer Bay of Fundy and rare to common in the inner Bay (MacDonald et al. 1984; Scott 1987). Scott (1988) reported them from trawl catches in Minas Channel and Wehrell (2005) in trawl catches in Minas Basin. Bleakney and

McAllister (1973) report them stranded in the intertidal zone in Minas Basin. There is no commercial fishery for ocean pout (Scott and Scott 1988).

Ocean pout will occur in Minas Channel during summer but in low numbers. They are strictly benthic in habit.

Order: Atheriniformes

43. *Menidia menidia* – Atlantic silversides. Marine, pelagic. Atlantic silversides are extremely abundant in estuaries and shore regions of inner Bay of Fundy and common along beaches in the outer Bay. Silversides form large schools over gravel and sand beaches (Gilmurray and Daborn 1981). They are a small species living only two years and growing to 20cm in length.

There is no commercial fishery for silversides in the Bay of Fundy but they are an important forage fish for larger predators such as striped bass. Silversides occurs along the beaches of Minas Passage (Dadswell et al. 1984a) but will probably never be encountered offshore.

Order: Cyprinidontiformes

44. *Fundulus heteroclitus* – mummichog. Marine, benthic, Mummichog occur along shorelines of Minas Basin but are most abundant in tide pools (Dadswell et al. 1984a)). They arrive in the tide pools during June and leave in October (Brown 1983). Mummichogs are another, small, prey species that are forage for larger predators especially blue herons. They seldom exceed 10cm in length and 4 years of age (Brown 1983).

Mummichog should be expected in salt marsh tide pools along the shores of Minas Passage but are unlikely to be encountered in open water except along the shore. In tide pools they can be abundant ($28/m^2$; Bleakney and Bailey-Meyer 1979).

Order: Gasterosteiformes "sticklebacks"

All sticklebacks are small fishes occurring in salt marsh or shoreline habitats (Scott and Scott 1988). They are common to abundant in beach seine hauls (Dadswell et al. 1984a) and tide pools in Minas Basin (Bleakney and Bailey-Meyer 1979). None are fished commercially. All are prey for larger fishes. Usually one of the species exceeds 20cm in length.

45. *Apeltes quadracus* – fourspine stickleback. Marine and estuarine, benthic. Fourspine stickleback are common throughout the Bay of Fundy along shorelines. They are abundant in lower salinities like the inner portions of Minas Bay (Dadswell et al. 1984a). If encountered in Minas Channel they will only occur along the shoreline or in tide pools.

46*. Gasterosteus aculeatus* – threespine stickleback. Marine and estauarine, benthic, pelagic. Threespine stickleback are the most common stickleback in most regions of the Bay of Fundy and are especially abundant along high salinity shorelines and among eel grass (Dadswell et al. 1984a). Unlike the other sticklebacks they often have completely pelagic populations that are found at the surface over deepwater (Dadswell pers. obs.).

Threespine sticklebacks will occur along the shoreline of Minas Passage and there may be a small population pelagic over the deepest part of the Passage. The pelagic group may be present all year.

47. *Gasterosteus wheatlandi* – blackspotted stickleback. Marine, benthic. Blackspotted stickleback co-occurs with threespine stickleback along high salinity shorelines (Scott and Scott 1988). It is not pelagic. It will probably be found along the shore line of Minas Passage during most of the year.

48*. Pungitius pungitius* - ninespine stickleback. Marine, benthic. Nine spine stickleback co-occurs with threespine and blackspotted sticklebacks in lagoons along high salinity shores. It is also abundant in lower salinity tidal 'lakes' (Scott and Scott 1988). It should be found along the shoreline of Minas Passage all year but will be rare.

Order: Sy**ngnathiformes "pipefishes and sea horses"**

49. *Syngnathus fuscus* – northern pipefish. Marine, pelagic. Pipefish are a warm water species found in lower salinity tidal 'lakes' around Bay of Fundy (Scott And Scott 1988). It is especially abundant in localities with eelgrass. During the late summer juveniles will drift in the water column for dispersal (Dadswell pers. obs.). It is a small species, seldom exceeding 30cm. There is no fishery.

Probably uncommon in Minas Passage except along the shore line in lagoons. Juveniles may be common in the drift of Minas Passage during August to October.

Order: Perciformes "basses, snappers, etc**"**

50. *Morone americana* – white perch. Estuarine and andromous, benthic and pelagic. White perch are especially abundant in lower salinity regions of estuaries particularly those with tidal barrages maintaining a lake-like situation (Annapolis, Peticodiac, Avon, Tantramar, Saint John; Scott and Scott 1988). It is rarely observed in open marine waters in Canada.

White perch will probably not be encountered in Minas Passage.

51. *Morone saxatilus* – striped bass. Andromous, pelagic along shorelines. Striped Bass are abundant in the inner Bay of Fundy, especially Minas Basin (Rulifson et al. 2008). There is a summer migration around the Bay of Fundy which consists of Canadian and USA stocks (Rulifson and Dadswell 1995). A large spawning stock occurs in the Shubenacadie River. The species is listed as threatened by SARA but has no schedule (Douglas et al. 2003). The commercial fishery is closed except as a permitted

by catch (one legal-sized bass/day) but angling is still permitted. Striped bass are captured in intertidal weirs and drift gill nets in Minas Basin and used to be taken by set gill nets around the shoreline.

Striped bass are anadromous and spawn at the head of tide during May-June. Juveniles move into estuarine waters during their first summer (Scott and Scott 1988). American and Canadian stocks are migratory along the Atlantic coast of Canada and the USA. Bass tagged in Minas Basin during summer-fall have been captured as far south as Virginia (Rulifson et al. 2008). Striped bass tagged in the USA have been recaptured at numerous localities in the Bay of Fundy (Rulifson and Dadswell 1995). If they do not migrate south, Canadian populations over winter in low salinity or freshwater localities such as Shubenacadie Lake.

Striped bass will be common in Minas Passage along the shoreline and in mid water. There will be an inward migration though Minas Passage during April to July and an outward migration during July to September. Adult abundance of the Shubenacadie population is 10,000-20,000 adults (Bradford pers. comm.) and an unknown number of USA fish enter Minas Basin each summer.

52. *Pomatomus saltatrix* – bluefish. Marine, pelagic. Bluefish are a summer visitor to the inner Bay of Fundy during periods of warm summer weather (Dadswell et al. 1984a). It can be abundant for short periods during July-August in some years and then will not be seen for 5-10 years (Scott and Scott 1988). It is taken by anglers when schools appear.

Abundance of bluefish will be low to nonexistence in most years then common to abundant for a short period during July-August in Minas Passage. It is a pelagic species and will be found offshore in the Passage.

53. *Cynoscion regalis* – weakfish. Marine, benthic. Weakfish are a very rare occasional summer visitor to the inner Bay of Fundy (Dadswell and Rulifson 1994). Few will be encountered in Minas Passage on rare occasions.

54. *Pogonias cromis* – black drum. Marine, benthic. Black drum are rare, occasional summer visitor to the inner Bay of Fundy (Scott and Scott 1988). It will be a rare visitor to Minas Passage.

55. *Ulvaria subbifurcata* – radiated shanny. Marine, benthic. Radiated shanny are common in the outer Bay of Fundy and probably in Minas Channel (MacDonald et al. 1984). It is especially abundant under rocks along cliff-like shores (Dadswell pers. obs.) and may be common in Minas Passage along the shoreline. It is a small species and seldom exceeds 20cm (Scott and Scott 1988). It will rarely be captured in any numbers except by directed sampling.

56. *Pholis gunnellus* – rock gunnel. Marine, benthic and intertidal. Rock gunnels are a ubiquitous and abundant fish throughout the Bay of Fundy (Scott and Scott 1988). It will

remain in the intertidal zone during low tide hiding under rocks and seaweed. Gunnels are a small fish rarely exceeding 20cm. It will be common in Minas Passage but will be strongly associated with the shoreline and benthic habitats.

57. *Anarhichas lupus* – wolffish. Marine, benthic. Wolffish were common in deep, coldwater regions of the Bay of Fundy (Scott 1987). They are usually found in areas with boulders and rough bottom with available den sites (Scott and Scott 1988). It has never been observed inside Minas Basin (Bleakney and McAllister 1973; Dadswell et al. 1984a). Wolffish feed on scallops and lobsters. Wolffish can grow to a large size (2m) but most caught recently are under 1m.

The wolffish fishery in the Bay of Fundy has never been large and there is no TAC set by DFO. Most landings are from by catch in the scallop fishery. Landings averaged 61MT from 1998-2001 (Anon 2002).

Wolfish may be found in Minas Passage since there are scallop beds but will be confined to the bottom. They will likely be present year round but will probably be most common in winter.

58. *Ammodytes americanus* – sand lance. Marine, benthic and pelagic. Sand lance is abundant along sand and gravel beaches of the Bay of Fundy and over deep water, sand bottoms. The species forms dense schools over intertidal zones at high tide and then penetrates the substrate to remain in the intertidal zone during low water (Scott and Scott 1988). They are a small species seldom exceeding 20cm and a forage fish for many larger predators especially Atlantic sturgeon which vacuum sand lance from under the sand.

Sand lance will probably not be common in Minas Passage because of a lack of sandy, benthic habitat but they could be locally abundant over sandy beaches.

59. *Scomber scombrus* – American mackerel. Marine, pelagic. Atlantic mackerel are common to abundant in the pelagic zone of the entire Bay of Fundy except in turbid regions (Dadswell et al. 1984a). Large weir catches are often made in Scots Bay but are rare inside Minas Basin. Mackerel are highly migratory. They winter off Long Island then move north to the Bay of Fundy and the Gulf of St. Lawrence for the summer (Scott and Scott 1988). Mackerel appear in Minas Basin during May to August. They are caught in intertidal weirs and drift gill nets. Because of low market demand the annual mackerel catch in the Bay of Fundy is not large even though mackerel are abundant. The TAC has been set at 75,000MT for a number of years but catches seldom exceed 20% of this value (CSAS 2005).

Mackerel will occur in Minas Passage during May to September and in some years may be abundant. They will be pelagic in the water column and in schools. Abundance could be in the 10's of thousands.

60. *Peprilus triacanthus* – butterfish. Marine, pelagic. Large schools of butterfish are common in the inner Bay of Fundy during summer, especially Minas Basin (Dadswell et al. 1984a). Butterfish are small (max 30cm), forage species. In most regions of the Atlantic coast there is a limited fishery for them (Scott and Scott 1988). There is no fishery in Canada.

Butterfish occur in Minas Basin from June to September (Dadswell et al 1984a). They will be common to abundant in Minas Passage and will occupy the pelagic region of the Passage. Abundance could be in the millions but is unknown.

Order: Cottiformes "sculpins"

61. *Hemitripterus americanus* – sea raven. Marine, benthic. Sea ravens are a common member of benthic fish community throughout the Bay of Fundy (MacDonald et al. 1984; Scott 1988). They are common but seldom abundant in Minas Basin during summer (Dadswell et al. 1984a). There is no fishery for this species.

Sea ravens will probably be found in Minas Passage during most of the year. They will be benthic and abundance will be low.

62. *Myoxocephalus aeneus* – grubby. Marine, benthic. Grubby are a very common, small, inshore species along hard substarte shorelines of the Bay of Fundy (Dadswell et al. 1984a). They are usually found in association with seaweed. They are benthic and a common member of the inshore community. Grubby seldom grow larger then 20cm.

Grubby will be found along the shores of Minas Passage and could be common over hard substrates in deeper water. They are strictly benthic in habit (Scott and Scott 1988).

63. *Myoxocephalus octodecemspinosus* – longhorn sculpin. Marine, benthic. Longhorn sculpin are abundant in most parts of the Bay of Fundy (Scott 1988). They are a 'large' species of sculpin reaching about 35-45cm (Scott and Scott 1988). They are commonly captured off wharf's by recreational anglers. There is no commercial fishery.

Longhorn sculpin will be common in Minas Passage but seldom abundant. They are strictly benthic in habit. They should be found year round.

64. *Myoxocephalus scorpius* – shorthorn sculpin. Marine, benthic. Shorthorn sculpin are common in most of the Bay of Fundy. This sculpin occurs onshore during winter and is mostly found over hard substrates (Scott and Scott 1988). They are not common inside Minas Basin (Dadswell et al. 1984a).

Shorthorn sculpin should be common over the hard substrate bottom of Minas Passage. They will be present all year. This species was observed in the video record taken around the turbine sites during October 2009 (Dadswell pers. obs.).

Order: Labriformes 'wrasses'

65. *Tautoga onitis* – tautog. Marine, pelagic. Tautog are a very rare summer visitor to the inner Bay of Fundy (Dadswell and Rulifson 1994). Tautog are seldom expected to occur in Minas Passage and only 1-2 individuals will be encountered if and when they do.

66. *Tautogolabrus adsperus* – cunner. Marine, pelagic. The cunner is a common resident of the outer Bay of Fundy and is especially common around wharfs (Scott and

Scott 1988). It is rarely observed in the inner Bay of Fundy and has never been recorded inside Minas Basin (Bleakney and McAllister 1973; Dadswell et al. 1984a). It should be, however, expected in Minas Passage. The Passage has considerable hard bottom substrate and probably numerous underwater cavities. Cunner use cavities during winter for hibernation (Scott and Scott 1988) and it may be common along the shores during this period.

Order: Cyclopteriformes 'lumpfishes'

67. *Cyclopterus lumpus* – lumpfish. Marine, benthic and pelagic. Lumpfish are found throughout the Bay of Fundy Bay except in the turbid inner reaches and it is known from Minas Basin (Bleakney and McAllister 1973; Wehrell 2005). It is most abundant along rocky shores and over hard, rocky bottom and could be common in Minas Passage. All Cyclopteriformes have a ventral 'sucker' that allows them to attach to the substrate or seaweeds in order to maintain position in strong currents (Scott and Scott 1988). Lumpfish caviar is the basis for a commercial fishery in Newfoundland but there is no fishery in the Bay of Fundy (Dadswell et al. 1984a)

Juveniles are pelagic among floating seaweed during summer then move inshore to seaweed beds during fall. Juvenile lumpfish are very abundant in the surface floating masses of seaweed drifting in the Bay of Fundy and have been taken from this habitat in Minas Channel (Daborn and Gregory 1983). Adult, spawning males turn red in spring and remain to guard the egg mass attached to rocks after spawning. The habitat along the shores of Minas Passage is excellent for lumpfish spawning (Scott and Scott 1988; AECOM 2009).

Lumpfish larvae and juveniles will be common in drifting masses of seaweed on the surface in Minas Passage during June to September. Abundance in some years could be high depending on survival of larvae (Daborn and Gregory 1983). Adult lumpfish may be abundant along the rocky shores of Minas Passage especially when spawning in spring since they are caught in Minas Channel and in Minas Basin (Scott 1988; Wehrell 2005).

68. *Liparus atlanticus* – Atlantic snailfish. Marine, benthic. Atlantic snailfish are common in the Bay of Fundy in localities with kelp beds to which they attach with their ventral sucker (Scott and Scott 1988). They have been caught in Minas Passage in drags that brought up kelp fronds (Dadswell pers. obs.) Snailfish are small fish and rarely exceed 10cm in length.

Atlantic snailfish will be common among kelp beds in Minas Passage year round. Their distribution will be concentrated along the shore and probably in depths less than 10m which is about the deepest the kelp distribution reaches.

69. *Liparus inquilinus* – inquiline snailfish. Marine, benthic. This small snailfish is usually found in association with sea scallops with whom they live commensally for their entire life (Able and Musick 1976). They are common wherever scallop beds occur such as around Blomidon on the south side of Minas Passage.

Inquiline snailfish will be common year round in Minas Passage wherever there are sea scallops. Snailfish larvae will probably be common near the surface in Minas Passage during late winter and spring.

Order: Pleuronectiformes "flounders"

70. *Paralichthyes oblongus* – fourspot flounder. Marine, benthic. Fourspot flounder is a southern species that is an occasional summer visitor to the Bay of Fundy but is never abundant (Scott and Scott 1988). It has been captured in Cumberland Basin but not Minas Basin (Dadswell and Rulifson 1994). It will probably occur rarely in Minas Passage and in small numbers. It is a benthic species and is likely to remain on the bottom at all times.

71. *Scophthalmus aquosus* – windowpane. Marine, benthic. Windowpane is common throughout the Bay of Fundy especially over sandy substrate (Scott 1987). They are very abundant in Minas Basin and often the most abundant fish in intertidal weir catches (Liem and Bousfield 1959). They are seldom taken commercially in Canada (Scott and Scott 1988).

Windowpane will probably not be common in Minas Passage because of the low incidence of sandy substrate (AECOM 2009). It could, however, be locally abundant along shore where there are sandy beaches since it is common in Minas Channel (Scott 1988) and abundant in Minas Basin (Wehrell 2005). It will be most abundant in summer but will probably occur all year.

72*. Glyptocephalus cynoglossus* – witch flounder. Marine, benthic. Witch flounder is a common resident of deep water, mud bottom locations in the Bay of Fundy (MacDonald et al 1984; Scott 1987). It is an important commercial flounder and is marketed in Canada as sole.

Witch have never been captured in Minas Basin and are rarein the inner Bay of Fundy (Scott 1988). They may occur in Minas Channel but will probably not occur in Minas Passage.

73. *Hippoglossus hippoglossus* – American halibut. Marine, benthic. Halibut are found throughout Bay of Fundy (Scott 1988) but only juveniles penetrate into Minas Basin during spring (Wehrell 2005). Large adults are common around the Advocate region of the inner Bay of Fundy and support a small commercial fishery (Simon and Comeau 1994). Juveniles and adults are taken by angling and commercially using bottom set long lines. Annual landings in the inner Bay of Fundy are about 10MT (Dyer et al. 2005).

Halibut are a predatory flatfish that pursue herring schools (Scott and Scott 1988) and large and small individuals should be expected in Minas Passage during spring. They should be expected to occur throughout the water column during bouts of foraging. Individuals probably follow herring schools into Minas Basin (Minas adult stock, 'June' herring) from March to July before warm water temperatures restrict halibut occurrence inside Minas Basin (Wehrell 2005). Abundance is probably in the range of a few hundred to a few thousand individuals.

74. *Liopsetta putnami* – smooth flounder. Estaurine, benthic. Smooth flounder are found in inshore, warm water habitats throughout the Bay of Fundy (Scott and Scott 1988). They are most abundant in the inner Bay (Minas and Cumberland Basins) but also common in Passamaquoddy and St. Mary's Bay. In Minas and Cumberland Basins smooth flounder feed over mud flats at high tide (Scully 1983; Dadswell et al. 1984a). They are not utilized as a commercial species in Canada since their total abundance is low (Scott and Scott 1988).

Smooth flounder will be found in Minas Passage but only in localized, inshore mud habitats. In these sites a few thousand individuals are likely to occur (Scully 1983).

75. *Pseudopleuronectes americanus* – winter flounder. Marine, benthic. Winter flounder are the most abundant and ubiquitous flounder in the Bay of Fundy. They are a dominant resident of most benthic fish communities in both the inner and outer Bay of Fundy (MacDonald et al. 1984; Scott 1987). Winter flounder spawn inshore in May. Juveniles are common along shorelines in fall. Growth is rapid and they reach maturity at 3 years of age (Scott and Scott 1988).

Winter flounder support important commercial and recreational fisheries in the Bay of Fundy (Simon and Comeau 1994). They are captured commercially by drags and intertidal weirs in Minas Basin. They are also taken in large amounts by drags in Scots Bay and Minas Channel (Wehrell 2005). Flounder landings in the region peaked at 200MT in 1992-93 but declined to 100MT by 2006 (Dyer et al. 2005). They are also an important angling species.

Winter flounder migrate in and out of the Bay of Fundy between summer and winter (MacDonald et al. 1984). Their abundance peaks in Minas Basin during July then declines during summer both from the effects of migration and the intense fishery (Wehrell 2005). Minas Basin represents one of the most valuable nursery areas for winter flounder in the Bay of Fundy (Scott and Scott 1988)

Winter flounder will be migrating inward through Minas Passage from April to June and outward from July to October. There has never been a population estimate of the stock in Minas Basin during summer; but since the annual landings at present are about 100MT (Dyer et al. 2005), the average size of flounder in the catch is about 500gm (Wehrell 2005) and annual fishing mortality is probably in the order of 50%, the minimum adult stock size can be estimated at about 400,000 fish. All these adult flounder as well as juveniles must pass through Minas Passage twice annually.

76. *Limanda ferruginea* – yellowtail flounder. Marine, benthic. Yellowtail flounder are taken consistently in the outer and inner Bay of Fundy in association with winter flounder but they are never abundant (MacDonald et al. 1984; Scott 1987). Wehrell (2005) observed three yellowtails taken in Minas Basin during a summer-long trawl survey when thousands of winter flounder were taken daily. Yellowtail flounder are landed as 'flounder' in the Canadian catch statistics and cannot be separated from the landings of other flounders.

A few yellowtail flounder will probably occur in Minas Passage during each summer. Numbers will be low.

Order: Tetradontiformes **"filefishes"**

77. Mola mola – ocean sunfish. Marine, pelagic. Ocean sunfish are a common but never abundant summer visitor to the Bay of Fundy (Scott and Scott 1988). Large specimens are captured in weirs of the outer and inner Bay during summer. Parasites from an individual caught in a weir in Scots Bay are stored in the Acadia University Museum. Ocean sunfish have a habit of 'basking' on surface lying on their side. They feed on jellyfish and attain a large size 2-4m. There is no fishery for ocean sunfish.

Ocean sunfish could occur in Minas Passage during most summers but abundance will rarely exceed 1-2 individuals. They have never been observed inside Minas Basin.

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TABLE 1 A list of fishes known to occur or could reasonably be expected in Minas Passage.
Fishes are catagorized by potential risk of interaction with proposed turbines.
Red Category: High probability of interaction with turbine and/or potential for significant incidental harm
Orange Category: moderate probability of interaction and low to moderate risk of incidental harm
Green Category: low probability of interaction and/or incidental harm

FISH SPECIES	GEAR TYPE FOR SURVEY	SEASONALITY
RED CATAGORY		
Sea lamprey	midwater trawl, off collected fishes	juveniles: May-July adults: April - June
dogfish shark	bottom trawl, bottom long line drift gill net	April to October
porbeagle shark	drift gillnet (night)	June - September
basking shark	drift gill net, observation	June - October
Atlantic sturgeon	bottom trawl, drift gillnet	April - October
blueback herring	midwater trawl, drift gill net	juveniles - all year adults March-Sept
alewife	midwater trawl, drift gillnet	juveniles - all year adults March-Sept
Atlantic herring	plankton net, midwater trawl drift gillnet	juveniles - all year adults March-Oct
Atlantic salmon	drift gillnet	juveniles May - July kelts Dec-May spawners May-Nov
pollock	midwater trawl, drift gill net angling, hand line	April - October
ORANGE CATEGORY		
barndoor skate	bottom drag	all year
American eel	plankton net, midwater trawl	glass eel, April - May

		siver eel, A Aug-Oct
Atlantic menhaden	midwater trawl, drift gill net plankton net	adults - May - June juveniles la summer
rainbow smelt	midwater trawl, drift gill net plankton net	all year
Atlantic cod	bottom drag, bottom long line shore set gill net handline	November - July
striped bass	drift gill net, angling shore set gill net	April - September
wolffish	bottom drag, bottom long line scallop drag	all year, winter?
American mackerel	midwater trawl, drift gill net angling	May - September
lumpfish	drift gill net, bottom drag plankton net	all year spring spawning
American halibut	bottom drag, bottom set long line hand line	April - July
winter flounder	bottom drag, shore seine, angling	April - October
GREEN CATEGORY Atlantic hagfish	baited traps	all year
sand tiger shark	drift gill net	July - September
thresher shark	drift gill net	June - September
great white shark	drift gill net	June - September
shortfin mako shark	drift gill net	June - September
smooth dogfish	drift gill net, bottom drag	summer

Greenland shark	drift gill net, bottom drag	December-March
Atlantic torpedo	drift gill net, bottom drag	July - September
little skate	bottom drag	all year
smooth skate	bottom drag	winter
thorny skate	bottom drag	all year
winter skate	bottom drag, shore seine	all year
shortnose sturgeon	bottom drag	probably never
brook trout	shore seine, angling	April - August
brown trout	shore seine, angling	April - August
coho salmon	drift gill net	April to September
rainbow trout	shore seine, drift gill net	April - September
monkfish	bottom drag	April - October
fourbeard rockling	bottom drag, plankton net	all year, juv May-Aug
haddock	botton drag, handline	June - September
siver hake	midwater trawl, drift gill net	June - September
red hake	bottom drag, scallop drag	June- August
white hake	bottom drag	April - October
Atlantic tomcod	bottom drag, plankton net	all year
ocean pout	bottom drag	April - October
Atlantic silversides	plankton net, shore seine	all year
mummichog	scoop net, shore seine	all year
fourspine stickleback	scoop net, shore seine	all year
threespine stickleback	scoop net, shore seine	all year

blackspotted stickleback	scoop net, shore seine	all year
ninespine stickleback	scoop net, shore seine	all year
northern pipefish	scoop net, shore seine	all year
white perch	drift gill net, midwater trawl	all year
bluefish	drift gill net, angling	July - August
weakfish	bottom, drag, drift gill net	July - August
black drum	bottom drag, drift gill net	July - August
radiated shanny	bottom drag	all year
rock gunnel	scoop net, shore seine	all year
sand lance	plankton net, midwater trawl	all year
butterfish	midwater trawl, drift gill net	June - September
sea raven	bottom drag, shore seine	all year
grubby	bottom drag, shore seine	all year
longhorn sculpin	bottom drag, shore seine	all year
shorthorn sculpin	bottom drag	all year
tautog	drift gill net, bottom drag	July-August
cunner	bottom drag, shore seine	all year
Atlantic snailfish	bottom drag, scoop net	all year
inquiline snailfish	scallop drag	all year
fourspot flounder	bottom drag	July- September?
windowpane	bottom drag, shore seine	all year
witch flounder	bottom drag	March - Novenber?
smooth flounder	bottom drag, shore seine	all year

yellowtail flounder	bottom drag	June-September
ocean sunfish	observation	July-August

FISH SPECIES	ABUNDANCE	REASONS FOR CATEGORY ASSIGNED
Sea Lamprey	common common, 100-1000/yr	pelagic in water column, large body size
dogfish shark	very abundant, millions mostly female	pelagic, large body size, commercial species risk of blade strike
porbeagle shark	rare, 10 -100/yr	pelagic, large body size, SARA listed high risk of blade strike
basking shark	very rare, 1-5/yr	pelagic, very large body size high risk blade strike
Atlantic sturgeon	abundant, 10,000+/yr	sometimes pelagic, large body size high risk of blade strike
blueback herring	extremely abundant millions -10's millions	pelagic, commercial fishery high risk of turbine pressure effect
alewife	extremely abundant millions - 10's millions	pelagic, commercial high risk of turbine pressure effect
Atlantic herring	extremely anundant 100's of millions	pelagic, large commercial fishery high risk of turbine pressure effect
Atlantic salmon	common, 10,000/yr rare, 100/ year rare- common 100-1000/yr	pelagic, SARA schedule 1 iBoF population endangered
pollock	common, 1000 -10,000	pelgic. medium body size, commercial selects high energy habitats
barndoor skate	rare	benthic, listed COSEWIC large body size
American eel	abundant, millions	pelagic. Commercial large body size

	common, 10,000 - 20,000/yr	population declining, may be listed
Atlantic menhaden	rare, 100 - 1000 common, thousands	pelagic, effected by pressure may be only Canadian population
rainbow smelt	extremely abundant millions	resident all year, pelagic larvae, recreational fishery
Atlantic cod	common, 1000 -10,000	commercial fishery, semi-pelagic population low abundance
striped bass	common, 10,000 - 20,000 adults	semi-pelagic, mostly along shoreline listed by SARA, no schedule listed threatened
wolffish	rare, hundreds/yr	commercial, being studied for listing COSEWIC
American mackerel	common 10's thousands	commercial but low demand pelagic, low abundance most years
lumpfish	juveniles abundant in surface drift seaweed, adults 100 - 1000	pelagic juveniles, potential commercial fishery for roe
American halibut	rare, 100 - 1000	very valuable commercial fishery large body size
winter flounder	abundant, ~400,000 adults	commercial fishery
Atlantic hagfish	unknown??, may not be present	no commercial fishery, benthic
sand tiger shark	very rare, 1-10/yr	southern occasional
thesher shark	very rare, seldom	southern, occasional
great white shark	very rare 1-5/ yr	southern occasional
shortfin mako shark	very rare, may not occur	southern occasional
smooth dogfish	may not occur	southern occasional

Greenland shark	may not occur	arctic - sub arctic
Atlantic torpedo	may not occur	southern occasional pelagic
little skate	common	benthic
smooth skate	very rare	benthic, not recorded inner Bay
thorny skate	common	benthic
winter skate	very common	benthic
shortnose sturgeon	never observed	benthic restricted to Saint John R. estuary
brook trout	rare in marine water	estuarine
brown trout	rare in marine water of Basin	estuarine
coho salmon	rare, probably extripated	introduced, population extripated
rainbow trout	rare, never observed	introduced, estuarine
monkfish	common 10-100/yr	benthic, often in intertidal commercial
fourbeard rockling	adults rare, larvae abundant	bentic as adults, small size
haddock	once common Scots Bay	benthic, select soft substrate select cold temperatures
silver hake	common, 1000's	mostly juveniles, no commercial fishery
red hake	common, 10's thousands	all juveniles, benthic commensal with scallops
white hake	common, 100's -1000's	juveniles, benthic
Atlantic tomcod	extremely abundant	small adult size, large population planktonic juveniles
ocean pout	very rare	strictly benthic, no fishery
Atlantic silversides	extremely abundant	inshore on beaches
mummichog	extremely abundant	inshore in tide pools along shore in winter
fourspine stickleback	common	inshore, beaches, estuarine, small adults
threespine	abundant	inshore on beaches, small adults

stickleback		
blackspotted stickleback	common	inshore on beaches, small adults
ninespine stickleback	rare	inshore, estuarine, small adults
northern pipefish	rare	inshore lagoons, small adults
white perch	rare	estuarine, small adults
bluefish	rare, 10-100/yr	southern occasional
weakfish	very rare	southern occasional
black drum	very rare 1/yr	southern occasional
radiated shanny	possibly abundant onshore	benthic, small adults
rock gunnel	abundant in intertidal	benthic, small adults
sand lance	rare	benthic, selects sand bottom habitat
butterfish	abundant? Millions	small adult size, no fishery
sea raven	common	benthic, no fishery
grubby	common	benthic, small adults, no fishery
longhorn sculpin	common	benthic, small adults, no fishery
shorthorn sculpin	common	benthic, no fishery
tautog	very rare, 1-10/yr	southern occasional
cunner	common	small adults, no fishery
Atlantic snailfish	rare? Common?	snall adults, around kelp
inquiline snailfish	common in scallop beds	small adults, commesal in scallops
fourspot flounder	rare, 1-10/yr	benthic, southern occasional
windowpane	abundant	benthic, no fishery
witch flounder	very rare	benthic, selects mud substrates
smooth flounder	common inshore	benthic, inshore only, mud sustrates

yellowtail flounder	rare, , 10-100/yr	benthic
ocean sunfish	rare, 1-5/yr	pelagic at surface, no fishery

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APPENDIX G

Drift Net Report – July 2010

Results of a Study to Evaluate the Feasibility of Using a Drifted Gill Net to Survey Fish Species Present in the Minas Passage, Bay of Fundy

Prepared for

Fundy Ocean Research Centre for Energy

By

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Results of a Study to Evaluate the Feasibility of Using a Drifted Gill Net to Survey Fish Species Present in the Minas Passage, Bay of Fundy

1. Background/Objective

Evaluation of the potential impact of tidal power turbines on fishes within the Minas Passage requires knowledge of the abundance and species composition of fish present during various times of the year. At present, estimates of fish biomass are underway using Femto echo-sounding technology in combination with trawl netting to identify species composition. An additional potential approach to collection and identification of fish species composition is by using drifted gill nets. Although some investigators have raised doubts about the feasibility of this approach in the highly turbulent environment of the Minas Passage, others having considerable experience in the use of drifted gill nets in other turbulent areas of the Minas Basin feel that this should not be a serious problem, and that it will in fact be more effective in capturing fish, and especially larger fish, than trawls considering that the latter are not usually effective in catching larger fish in midwater unless towing speed is very high or a very large net is used. The objective of this study was to evaluate the feasibility of using drifted gill nets to capture fish within the area of the Minas Passage being surveyed with the Femto echo-sounding technology.

2. Methodology

The basic approach was to use the same drift net techniques successfully employed by commercial shad fisherman working within the Minas Basin. This involved using gill nets deployed from a deep-sided skiff and periodically tended to ensure that the net did not fold in upon itself. The gill net employed in this study consisted of three 100 m long by 6 m deep sections, each with a different mesh size, tethered together to form one net 300 meters in length. The mesh sizes used were 7.6, 10.1 and 12.7 cm which were considered appropriate for fish species ranging in size from gaspereau to sturgeon and dogfish. The boat employed was a 7 metre Carolina Skiff powered by a 50 HP outboard motor.

3. Results

The study was carried out during a flood tide on 14 July 2010, one day after the first scheduled Femto survey.[1] The bi-weekly tidal cycle during this period was at the spring tide level.

[1] It was originally intended to arrange for this study to be carried out at the same time as one of the Femto surveys being carried out in the same area by others. However, the schedule for the Femto surveys was only made available to us on 12 July which, because of other commitments on our part, was on too short a notice to allow for this.

The boat departed from the Kingsport wharf at 12:25 and arrived within the Minas Passage at 12:50. Two drifts were carried out. The track covered by each drift is illustrated in Figure. 1.

Figure. 1. Area covered by each drift.

Track 1 began at 13:30 and traveled a distance of 5.4 km over a period of about 45 min. Track II began at 14:45 and traveled a distance of 8.8 km over a period of 58 min. Despite poor weather conditions caused by heavy fog and, at times, heavy rains, both drifts were carried out successfully. On both occasions the net required tending only once to ensure that it did not drift in upon itself. Of particular note is that no problems in controlling the drift net were encountered due to the strong currents or turbulent conditions within the passage.

Despite the successful drifts, no fish were captured. This, however, was not completely unexpected as this technique is typically most successful under conditions of neap tides and low visibility within the water column resulting from either high turbidity or night time conditions, none of which occurred at the time of this survey.

Although an attempt was made to produce a video record of the drift net survey procedure, the required visibility was too limited due to the heavy fog and rains.

4. Conclusions

Based on this preliminary study there is little reason to believe that the high current velocities and turbulence within the Minas Passage preclude the use of drift net surveys to provide, along with other survey techniques, the much needed information on the times and areas of occurrences of fish species present within the Minas Passage.

5. Recommendations for Further Drift Net Surveys

Successful capture of fish using drift net procedures requires knowledge of where and when fish are present within a specified area, both within the specific geographic region of interest as well as the depths at which they occur within the water column. In addition, knowledge of the current patterns within the Minas Passage is necessary to establish the location of the most favourable areas to employ drift nets and this information can only be acquired with experience. At present, there is little information of this type available for the Minas Passage. However, this information should become available after the results of the planned Femto surveys and fish tracking studies using acoustic technologies are completed, and this would increase the success of drift net surveys.

It is also highly likely that drift net surveys carried out at night time and/or at low water and the neap tidal cycle would be considerably more successful than day time, spring tide, or high water surveys. The main fish species present within Minas Passage during summer are typically clupeids (Atlantic herring, shad and gaspereau) and sharks (dogfish and mackerel sharks) (Dadswell 2010). All these species are day-night vertical migratory species. They remain near bottom during day time and rise into the water column surface after sunset or when water turbidity is high.

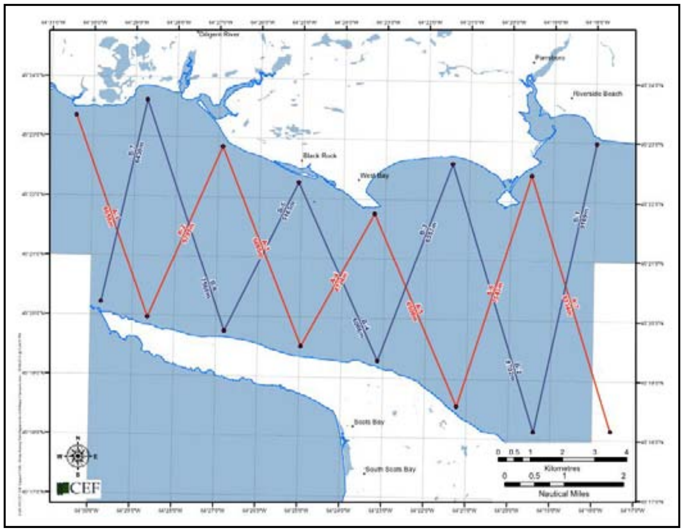
6. References

Dadswell, M.J. 2010. Occurrence and migration of fishes in Minas Passage and their potential for tidal turbine interaction. Report prepared for FORCE. 34p.

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX H

Fish Surveys 2010 – Final Report



Fish Surveys in Minas Channel

Final Report on 2010 Surveys

Submitted to:
FORCE and NSPI

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June, 2011

EXECUTIVE SUMMARY

Fish surveys were conducted from June to October of 2010 in Minas Channel using an 18.6 m stern trawler outfitted with a mid-water trawl and a hydroacoustic fish monitoring system. Surveys sampled acoustic backscatter from throughout the water column, which after editing was converted to fish density, and collected species and fish size from discrete depth intervals. The collection of fish and acoustics is common practice in the herring seining industry within the Bay of Fundy, but previous hydroacoustic surveys associated with assessment of tidal power generation had not caught fish within Minas Channel.

Fishing in the high tidal currents of Minas Channel is challenging, requiring appropriate gear and sufficient vessel horsepower. Apart from one or two small shore-based weirs, commercial fishing for finfish in Minas Channel is almost entirely restricted to herring seining when currents permit. Most herring seining occurs in and around Scotts Bay with a few excursions by seiners following schools into the channel. Commercial fishing for any species other than lobster is infrequent within the tidal power lease area.

The fish survey was intended to identify seasonal changes in fish distribution both spatially and vertically in the water column. The primary data collection method was hydroacoustics, which provided information on fish biomass seasonally and spatially, coupled with fishing to identify specific species and sizes of fish likely forming the acoustic targets. Initial survey trials to develop protocols were carried out in June with approximately bi-weekly surveys conforming to a consistent methodology conducted from July to October. The NSPI/OH turbine was in place within the tidal power lease area during these surveys. This report focuses on the joint interpretation of July to October acoustic and tow results, but also incorporates information from earlier 2010 surveys.

Permits were required to carry out net sampling with a midwater trawl in Minas Channel. Two permits were obtained from Fisheries & Oceans Canada for these studies: Permit #326039 was a Scientific Licence; and, Permit #326040 was a Species at Risk Act (SARA) Licence. No species listed under SARA were caught during any survey work in 2010.

Herring dominated the catch, especially in June and early July. The patchiness and dominance of herring in the data reduced the correlation between hydroacoustic data and biomass of non-herring species because they increased the probability that the beam of the sonar and the net sampled different densities of fish. Nonetheless, the quality of the data was considered good and there was reasonable consistency between catch data and the acoustic record for the water interval sampled by the net.

Herring, dollar fish, mackerel, gaspereau, smelt, and lump fish were the most consistent species caught. At times predominately bottom species, such as sea raven, summer flounder,

and winter skate were caught well above the bottom[1]. Gadoid (cod-like) fishes, including tom cod, silver hake, red hake, and pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm FL). Around 10 krill were also caught frequently in tows. The main seasonal change noted in catch was the decline in numbers of herring in July[2] and the catch of large striped bass and dogfish in September and October.

The midwater trawl and survey vessel worked well under difficult fishing conditions. The net was able to catch what appears to be a representative sample of species and size ranges regardless of tidal stage and current speed. The low number of large fish caught may have been due in part to the short duration of the tow. The high currents largely controlled the direction of tow, sometimes in hard to predict ways.

Key findings:

- Surveys found that fish were relatively evenly distributed throughout Minas Channel between July and October.
- Spatial differences were noted in gaspereau and dollar fish distributions, whereas mackerel showed distinct differences between day and night concentrations.
- The tidal power lease area had biomass densities similar to other parts of Minas Channel and was not found to be a specific migration or passage route for any species.
- Correlation between estimated acoustic biomass and catch biomass by tow was significant ($p<0.05$), but was clearly reduced by a few exceptional values.
- Major differences between tow and acoustic estimates of biomass were most probably a result of differences in catch and acoustic detection of herring and the patchiness of schools.
- The major components of finfish biomass in Minas Channel appear to be adult herring moving into the channel in June, followed by young herring in later July and August, gaspereau in September, and a broader mix of species leaving the upper Bay of Fundy in October.
- Both acoustic and tow data indicated a relatively even distribution of biomass throughout Minas Channel, with little spatial differences or concentration by species.
- Depth preferences were observed for some species but trends were not statistically significant or were heavily weighted by results from a single tow.

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[1] Juveniles of many bottom-associated species may be found higher in the water column at early life stages, but many of the individuals caught were not juveniles. For example, 3 of 7 sea raven and 2 of 14 summer flounder were greater than 30 cm in length.

[2] The abundance of adult herring has been reported to reach a maximum in July and early August in the inner Bay of Fundy (Melvin, G. pers. comm.)

- Tidal conditions were not a significant predictor of biomass, but the strong tidally-induced currents may have increased the variation and range in spatial and vertical fish distributions.
- Fish were acoustically observed moving upwards in the water column at night, but catches were higher during the day, suggesting visual cues increased catch efficiency.
- Mackerel catch was significantly different between day and night, as was acoustic biomass in the near bottom layer.

Further analysis of acoustic data, especially the data collected concurrently with tows, could be examined to evaluate target strength estimates for key species. Individual acoustic targets could be isolated and examined in more detail in an effort to associate acoustic targets with specific components of the catch.

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1 BACKGROUND

1.1 Purpose

The Upper Bay of Fundy is an important rearing, feeding and reproduction area for many fish species. Commercial species of importance include herring, dogfish, and flounder. Recreational species include striped bass, shad and in very limited numbers salmon. Most of these fish move in and out of the bay seasonally and would potentially pass through the tidal power lease/demonstration area in Minas Channel. Fish passing through this lease area could possibly interact with the underwater turbine units, referred to as Tidal In-Stream Energy Conversion (TISEC) devices. Thus, it is important to understand the relative numbers of fish passing through different areas and their distribution within the water column.

Fishing in the high tidal currents of Minas Channel is challenging, requiring appropriate gear and sufficient vessel horsepower. Apart from one or two small shore-based weirs, commercial fishing for finfish in Minas Channel is almost entirely restricted to herring seining when currents permit. Most herring seining occurs in and around Scotts Bay with a few excursions by seiners following schools into the channel. Commercial fishing for any species other than lobster is infrequent within the tidal power lease area.

Fish distribution studies conducted in 2010 were carried out to provide information on the relative density of fish moving in the bay through Minas Channel seasonally. Relative biomass and target depth in the water column were determined by hydroacoustic survey methods, while species and size was determined by fishing using midwater trawl.

1.2 Objective

The fish surveys were carried out to identify seasonal changes in fish distribution in three dimensions, between areas and vertically in the water column. Information collected could also shed light on migration paths, including depth intervals, used by major species migrating in and out of the Bay of Fundy through Minas Channel. The study aimed to identify relative densities of fish within Minas Channel and changes in abundance with respect to tides and season. The primary data collection method was hydroacoustics, but correlation with acoustic signals of fish species through sampling of fish was also an important part of this study.

These surveys are part of the Fundy Ocean Research Center for Energy's (FORCE) ongoing environmental effects monitoring program as part of the Environmental Assessment approval for the Fundy Tidal Energy Demonstration Project. It is part of longer term fish studies related to tidal power research to collect acoustic data, to test fish capture gear in strong current areas, and to monitor the environmental effects of tidal power generation within the Minas Basin. The high currents and tides present unique challenges and in many ways this work incorporates scientific research that will inform future EEM work.

1.3 This Report

This report includes detailed analysis of acoustic transect data and catch data from all 2010 fish surveys funded by the Fundy Ocean Research Centre for Energy (FORCE). Acoustic data collected along transects across Minas Channel are compared to catch from midwater tows and additional acoustic data collected over sections of the water column corresponding to that strained by the net. The NSPI/OH turbine was in place within the tidal power lease area during these surveys.

This report follows a preliminary report of findings based primarily on catch data. It briefly summarizes previous studies conducted in relation to tidal power in Minas Channel, but focuses on the 11 surveys completed between July and October, 2010. A database of all survey data, including survey logs, fish catch records, and trawl operating parameters for 92 separate tows has been assembled and will be made available through FORCE.

Generally speaking the midwater trawl used performed very well and caught a wide range of specimens, including very small (3 cm) to relatively large (70 cm) fish. Information presented focuses on the five species caught most consistently, but all species caught are described. Acoustic data from the eleven 14-transect surveys, as well as acoustic data collected concurrent with fishing, are also presented and analyzed.

1.4 Previous Surveys

Previous acoustic surveys of Minas Channel were conducted in August 2009 by the *MV Secord #1* and in April and May of 2010 by the herring seiner *Canada 100*. The zigzag transects were similar to those used in the current trial series but did not extend as close into shore.

The two acoustic surveys completed in April and May of 2010 along similar transects found lower biomass densities than trial surveys in June. All survey work in April and May was carried out during falling tide. Both surveys began in the dark and continued into daylight. In April, 3 of 10 surveys were run at night and in May, 5 of 10. April densities along transects ranged from 0.021 to 0.125 g/m^2 and in May they ranged from 0.003 to 0.473 g/m^2. Differences in the vertical distribution of biomass were noted, but no consistent difference was observed between night and daytime fish densities.

2 METHODS

2.1 Survey Components

2.1.1 Survey Design

Transects used in the surveys from June 2010 onward were closer spaced than earlier surveys and extended as close to shore as possible to detect nearshore migration of fish (Figure 2-1).

Earlier studies reported in Section 1.4 had a total of 10 transect lines and the trial survey had 14 over a similar area.

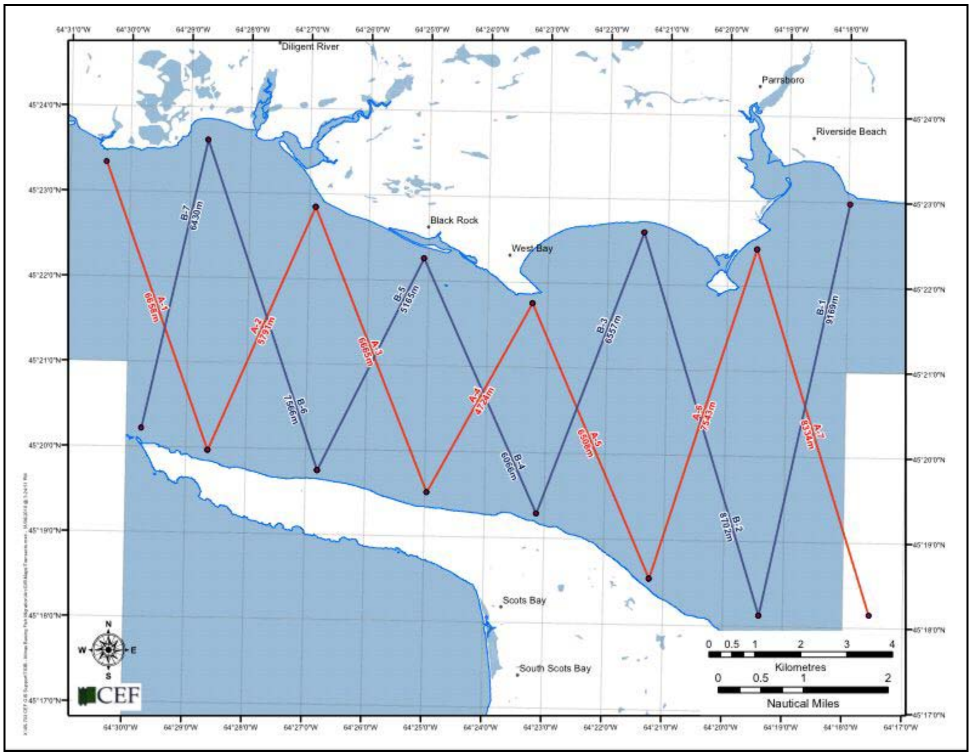

Figure 2-1: Transect Layout for 2010 Surveys

In relation to fish migration, many species are known to favour near shoreline areas for major migration paths (Jacques Whitford 2008; Parker et al. 2007; Jacobson et al. 2004). In early surveys more fish (in numbers caught) appeared to be found in the central deep water portion of Minas Channel (Figure 2-2). To determine if shoreline or central deep water channels were preferred by some species and not others, tows were generally made either near shore or in central deep water areas. However, the strong currents of the area tended to dictate the track of the tow regardless of its start location, thus positioning of the tow was only possible to a limited degree.

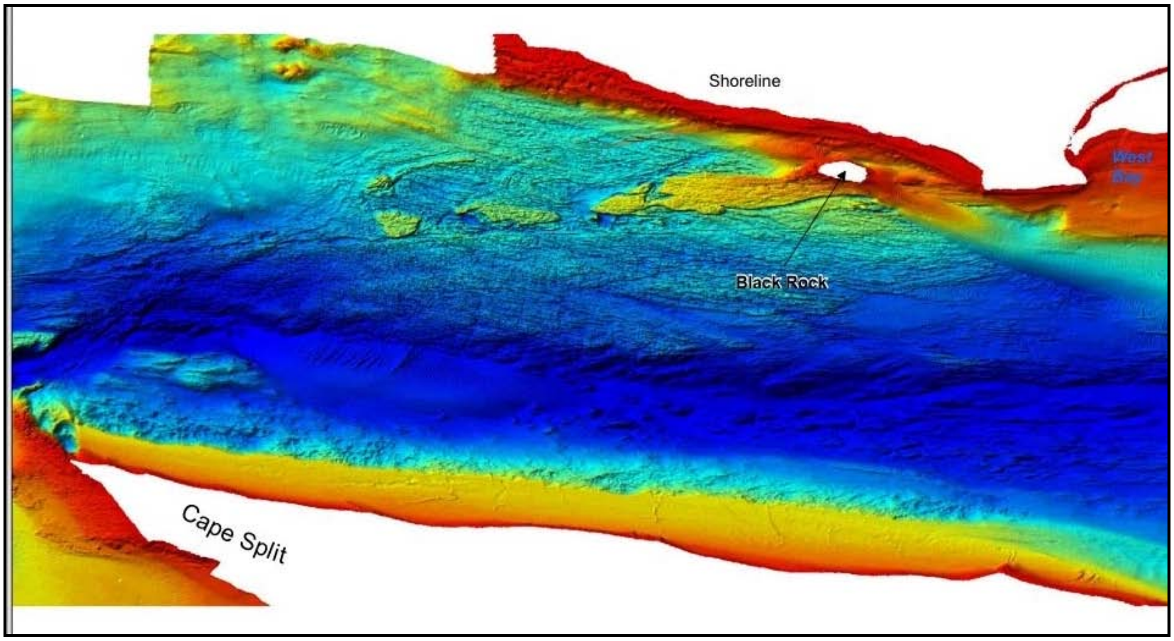

Figure 2-2: Bathymetry of Minas Channel

2.1.2 Analytical Methods

Guillard and Verges (2007) compared differences in biomass estimates in a small lake using different survey designs and statistical analyses. Sampling protocols, including zigzag, parallel and longitudinal transects, all produced comparable results; but autocorrelation between the data collected at the extremities of the zigzag transects could lead to difficulties in statistical analysis. Differences in acoustic biomass between day and night and in vertical distribution in the water column were statistically significant in the small lake studied. Similar comparisons seemed appropriate to the study in Minas Basin, with the addition of examining the potential effect of tidal conditions.

To reduce autocorrelation concerns and to reduce the volume of data analyzed, most statistical analyses of transect data were carried out on a randomly drawn 10% sample (by distance along a transect) of biomass from each of eleven surveys carried out from July to October.

2.1.3 Survey Equipment

The Carmelle #2 (Photo 2-1) was the survey vessel carrying out both the acoustics surveys and the midwater trawling. The Carmelle #2 is a 18.6 m LOA stern trawler of 63.8 tons and 442 HP with a 3.3 m draft. The vessel can sleep 5, has a hull speed of 10 knots, and is equipped with 2 hydraulic winches with a capacity of 500 fathoms (~ 915 m) of 1.4 cm wire rope on each drum. The vessel owner, Scotia Harvest Seafoods, owns the midwater trawl and has trawl monitoring equipment from CMC Electronics.

Photo 2-1: The MV Carmelle #2

The acoustic equipment used for these surveys was a Femto DE9320 Digital Echosounder. The data was logged to the computer hard-drive for post processing using the Femto Hydroacoustic Data Processing System (HDPS). The sounder was combined with a Furuno CA50B12, 50 kHz 12-degree transducer. The system output a 1.0mSec constant wave pulse at 60 ppm with a nominal output power of 1Kw. An acoustic ball calibration using a standard 38.1mm TG calibration sphere was performed by Femto Electronics on 17 June 2010 in Metaghan, Nova Scotia. Because profiling equipment was not available for sampling during surveys, estimated water column values for water temperature, mean depth, salinity and PH were fixed at 5 degrees, 40 meters, 32 ppt, and 8 respectively. Placement on the hull of the Carmelle 2 resulted in a 1.9 m offset plus an additional 3 m for 'ringdown' – thus data collection began approximately 5 m below the water surface. Similar equipment was used in the previous surveys aboard the fishing vessels *Secord* and *Canada 100*.

A midwater trawl equipped with gear monitoring sensors was used to sample fish identified by acoustic sampling. The midwater trawl had large mesh in the front of the trawl reducing progressively to 4 cm mesh, with 1.4 cm mesh in the codend. The net appeared to effectively catch fish in the 5 to 8 cm range and caught fish as small as 3 cm. All fish caught were identified to species, counted and fork length (FL) measured. In initial trial surveys large numbers of herring were enumerated by estimating total weight.

In June and July, most tows were conducted by interrupting an acoustic transect when a large group of targets was identified – a trawl was conducted at the appropriate depth interval to catch the fish associated with the acoustic targets. As the surveys progressed, fishing began to be carried out separately from the acoustic transects, with fishing carried out most often after one complete set of acoustic transects had been run (seven transects cover the channel and are considered a set, see Figure 2-1). In these latter cases a search was made for acoustic targets in areas near shore and in the deep central trough to identify appropriate tow locations.

The trawl used had a 15 m x 15 m mouth opening, which appeared appropriate for this work. When 45.7 m of warp were used, door spread indicated by the monitoring sensors was 30 to 35 m; fishing area is generally considered to extend from door to door. The doors for the midwater trawl are shown in Photo 2-2 and the net monitoring system display in Photo 2-3.

Logs were completed for both tows and acoustic transect surveys. All times were recorded in Atlantic Daylight Time. Transect logs recorded date, transect number, time every ten minutes, tide stage, ground speed, RPM and comments on relevant conditions such as weather or turbulence. Tow logs recorded date, time every 5 minutes, door spread, headline depth, warp out, ground speed, RPM, water depth, and comments.

Photo 2-2: Trawl Door for the Midwater Trawl used on the Carmelle #2

Photo 2-3: Marport Trawl Sensor Monitoring Display

2.1.4 Permitting

Permits were required to carry out net sampling with a midwater trawl in Minas Channel. Two permits were obtained from Fisheries & Oceans Canada for these studies: Permit #326039 was a Scientific Licence; and, Permit #326040 was a Species at Risk Act (SARA) Licence.

The Scientific Licence was issued pursuant to Section 52 of the Fishery General Regulations. It allowed CEF Consultants to determine the species and size of fish migrating in and out of the Minas Basin. The licence set out the vessel and type of gear, mesh size and established a maximum tow duration of 20 minutes. A report of species, number caught and size was required to be submitted immediately following each weekly survey.

The SARA licence considered the potential catch of at risk Inner Bay of Fundy Atlantic Salmon and set out provisions to minimize this risk. Requirements to minimize the potential capture of salmon included fishing at depths below 15 m and towing for no more than 20 minutes. Any mortality of an Atlantic salmon was required to be reported immediately – fortunately no salmon were captured. A comprehensive report was to be filed within 30 days of completion of the surveys.

2.2 Species Catchability

Since it is known that some species of fish are more easily caught by some fishing gear than others, the scientific literature on catchability of different species was reviewed. The primary reason for adjusting catch in most cases is to obtain more reliable population estimates by accounting for the differences in fishing efficiency for various species. The Minas Basin surveys are not intended to estimate populations but rather to identify relative seasonal movements of different species through the channel and differences in their vertical migrations. Nonetheless, catch and acoustic data were all converted to biomass for comparison. Thus, it is important to understand the magnitude of differences in catchability that might exist between different species, especially when comparing catch to acoustic data.

Table 2-1 provides coefficients from a review by Harley et al. (2001) to adjust catch for differences in relative catch success between trawls conducted in daylight and at night, and for differences in the relative catchability between species. These adjustments reflect differences between the biomass of the catch and the biomass of fish present in the area, and are based on vulnerability to the gear. Therefore, IYFS catchabilities combine the effect of probability of capture of fish in the path of the trawl with their vulnerability.

For example, the coefficient from the International Young Fish Survey (IYFS) is based on the use of midwater trawls and most bottom dwelling species like flounder are rarely present in the water fished by the trawl. Thus, the coefficient for this gear is extremely low because it largely reflects the small proportion of flounder that are in the trawl path. In the case of the Minas Channel surveys, however, we are not trying to estimate the population of fish over an extended area, but rather the biomass (or local abundance) within a column of water based on samples at a particular depth interval. Factors affecting the local probability of capture are different than those affecting the vulnerability to the gear, and include things like swimming speed and reaction to visual cues and/or noise.

Table 2-1: Coefficients to Adjust Catch Between Night and Day and Between Species

Species	Diel c_n	IYFS Catchability	Relative Catchability to Herring
Alewife	1.00	0.257	1.00
American plaice	1.22	0.0438	0.171
Atlantic cod	1.00	0.561	2.183
Atlantic herring	1.00	0.257	1.00
Sea raven	0.57	0.561	2.183
Silver hake	1.00	0.13	0.506
Spiny dogfish	1.00	0.561	2.183
Thorny skate	0.38	0.0438	0.171
Witch flounder	.90	0.0438	0.171

Source: Adapted from Harley et al. (2001)

The catchability coefficients indexed to herring are included in Table 2-1 because herring are the dominant species in overall catch in the Minas Channel surveys. As indicated, the adjustments for the various species of concern range from 0.171 to 2.183. The magnitude of the smaller coefficients almost certainly more influenced by the relative location of the fish and the gear (vulnerability) than the probability of capture for fish in the trawl path.

The diel coefficients in Table 2-1 come from Edwards (1968) and are proposed to convert biomass from trawls conducted at night to the equivalence of those carried out in daylight. The adjustments for day and night for the most abundant of our species are negligible. To obtain least-biased estimates of absolute (real) biomass, the caught biomass is divided by the IYFS catchability coefficient, and for night catches is further multiplied by the Diel (C_n) coefficient.

Mackerel are a potentially important species in Minas Channel but were not included in coefficients provided by Harvey et al. (2001). However, Deroba (2009) reviewed the catchability of mackerel in relation to US data from National Marine Fisheries bottom trawl surveys. Mackerel were assumed to have behaviour similar to herring in relation to door and net configurations. The behaviour of mackerel was also suggested to be similar to that of walleye pollock where catchability was greater during daylight when the fish were schooling, than during nighttime when the fish spread out to forage.

The coefficients for catchability reviewed here do not apply directly to the gear used in these surveys, but provide an indication of the likely magnitude of potential adjustments. As Benoit and Swain (2003) reported, small pelagic fishes, namely herring, alewife (gaspeareau), rainbow smelt, and mackerel, were all much more catchable during the day. The majority of flatfishes, all of the skates, and most of the sculpins had higher relative catchability during the night. Benoit and Swain (2003) also report length dependency in relative diel catchability in about half the species considered. Catchability for most species declines as fish length increases.

Overall, review of the literature did not identify variations in catchability for the various species caught in Minas Channel large enough to warrant adjustment in the catch, nor was it felt that the coefficients available were appropriate. For example, the low coefficient for flounder in Table 2-1 would not fully reflect the larger observed proportion of fish up in the water column due to high currents and upwelling found in Minas Channel. The available estimates, however, provide guidance in comparison of the results for the various species involved.

2.3 Comparing Acoustic and Catch Data

2.3.1 Net Monitoring Equipment

Many variables associated with fishing gear and vessel, including gear type, net opening, door spread, vessel, tow depth, and duration of tow, affect the quantity and quality of the catch. Some factors, such as gear, vessel and tow length, are key factors used to standardize effort between tows. Other variables may change between tows, such as effective fishing area of the net and the volume of water strained by the net, which can vary based on speed, warp length and currents. Of these, the effective net area likely has the largest effect, followed by the flow rate through the net, which determines the total volume strained.

The midwater trawl was equipped with a Marport system that reported trawl door, headline and bottomline performance. At times turbulence interfered with reception from the headline transmitter; in those cases the Vemco depth sensor provided headline depth data. The biggest advantage of the Marpot system when it operates well is that it allows the headline to be positioned at a particular depth layer to better sample targets being displayed on the hydroacoustic system.

The headline transducer did not provide reliable information on headline depth or net opening and a bottomline unit was not available during initial cruises. In July only trawl door operating parameters – depth, pitch and roll – were available. In early August two Vemco depth recorders were borrowed from DFO at Bedford Institute of Oceanography to record headline and bottomline performance for comparison with the door data. This comparison indicated the net opening remained generally consistent between 9 and 12 m, indicating good trawl performance, under all tow conditions.

The comparison of headline and bottomline depths helped establish the relationship between warp length and headline depth. In almost all tows a choice was made between three lengths of warp: 18.3, 45.7 or 91.5 m. While the door depth could be controlled by vessel speed, this comparison indicated that the headline of the net was only loosely correlated with door depth (Table 2-2). The primary factor affecting headline depth appeared to be warp length, with door depth only somewhat modifying the depth of the headline. In surveys following this comparison, warp length was used as the primary parameter determining desired fishing depth. While engine horsepower affected the depth of the doors to some degree, horsepower and rudder were primarily used to maintain a proper fishing configuration of the net.

Table 2-2: Range of Headline Depths at Different Warp Lengths, August 10 and 11

Warp Length (m)	Range of Door Depth (m)	Range of Headline Depth (m)
18.3	0.9 – 2.7	0.9 – 7.0 (average)
45.7	5.1 – 17.4	10 .1 – 13.3 (average)
91.5	23.8 – 31.0	20 – 31 (range)

Note: Range of headline depth was based on averages within a tow, except for deeper tows where average values were not available.

Since the Vemco depth sensor had proven useful, the same type of sensor was purchased for use in the survey and used on most subsequent surveys. The disadvantage of this sensor is that it does not provide real time information; information can only be downloaded after the survey and analyzed. As a result, attempts continued to get the Marpot system to provide reliable information on headline and bottomline depth.

On September 1, a new Marport headline sensor provided a more consistent and reliable reading for the headline depth but did not appear to provide a reasonable figure for net opening based on the bottomline sensor. Comparison with the Vemco sensor on the bottomline again indicated that the net opening (in this case, the distance between the headline and bottomline) remained relatively consistent with door spread relative to the length of warp out. On September 16, further improvements were made to the Marport system and the system provided generally consistent and reliable readings for the headline depth and net opening for subsequent surveys.

The relative similarity of the catch between tows supports that fishing effort was quite consistent – duration of tow usually has the most influence on effort providing the net is in a proper fishing configuration. A flow meter was installed during the last survey to measure flow through the net to provide additional information on volume strained, but results were unreliable because the propeller did not appear always free to rotate. Further research to determine better installation methods for a flow meter should be undertaken in future surveys.

2.3.2 Determining Water Depth Fished

Determining the depth distribution of different fish species was an important aim of the study. Thus, an estimate of the depth interval sampled by the net was needed for all tows, particularly for comparison to the acoustic targets observed over the time of the tow by the sonar system. Warp length and door depth were the two parameters most often available for all tows, while headline depth was the next most frequently available and bottomline depth the next. Surveys conducted earlier in 2010 tended to have only warp length and door depth operating parameters available, while later surveys tended to have direct measurement of headline and bottomline depths in addition to other parameters. Linear regression was used to determine how well door depth and warp length could predict headline and bottomline depth.

Including tows carried out during trial surveys in June, 2010, a total of 96 tows had both door depth and headline depth while 116 tows had headline depth and warp length. Since the headline and door depths varied throughout a tow, the most consistent values over the two parts of the tow of longest duration were usually used for analysis. Warp length was fixed over a tow and known for all tows. Both door depth and warp length were statistically significant ($p<0.0001$) predictors of headline depth, but door depth explained 78.7% (R^2) of the variation in the data whereas warp length explained 65.7%. The relationship between door depth (m) and headline depth (m) is shown in Figure 2-3.

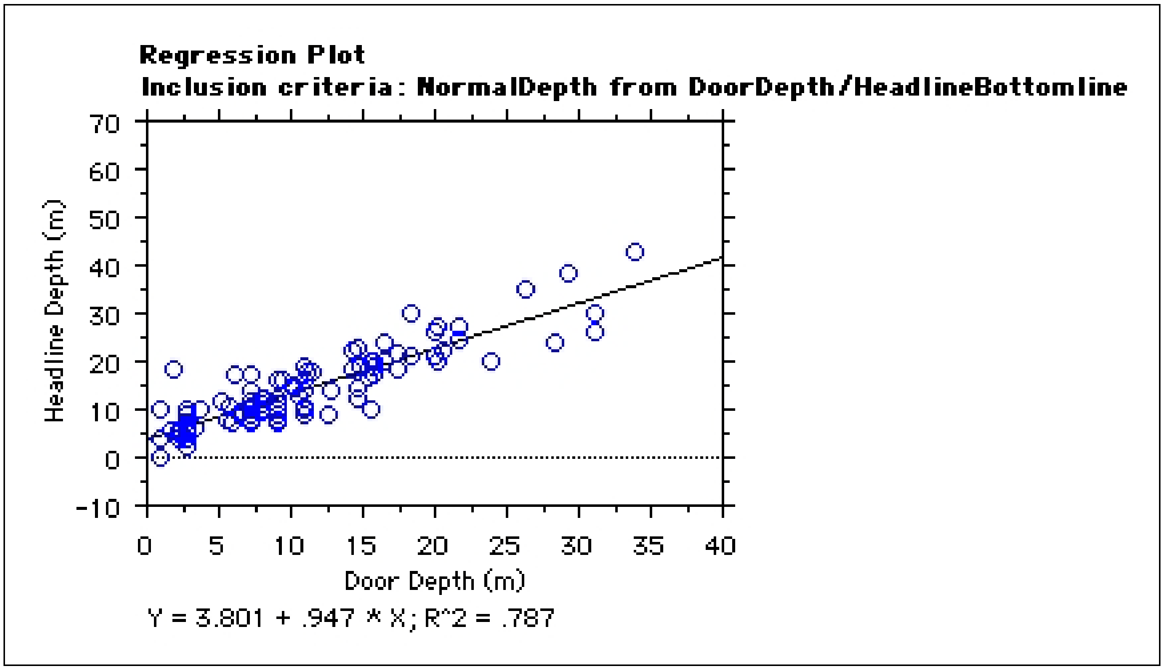

Figure 2-3: Linear Relationship Between Headline Depth and Door Depth

As Figure 2-3 illustrates, the fit of the data to the line was consistent over the range of depths. When both door depth and warp length were used to predict headline depth, R^2 increased to 0.892 and both variables were significant ($p<0.05$).

Headline and bottomline depth, or net opening, were directly related to warp length. As warp length increased, door spread increased resulting in a decrease in net opening (Figure 2-4). The linear equation predicting bottomline depth using both headline depth and warp length was significant (<0.05) and explained 89.2% (R^2) of the variation in the data. Note Figure 2-4 is shown to illustrate the effect of warp length on net opening, but the relationship by itself is not significant unless combined with door depth.

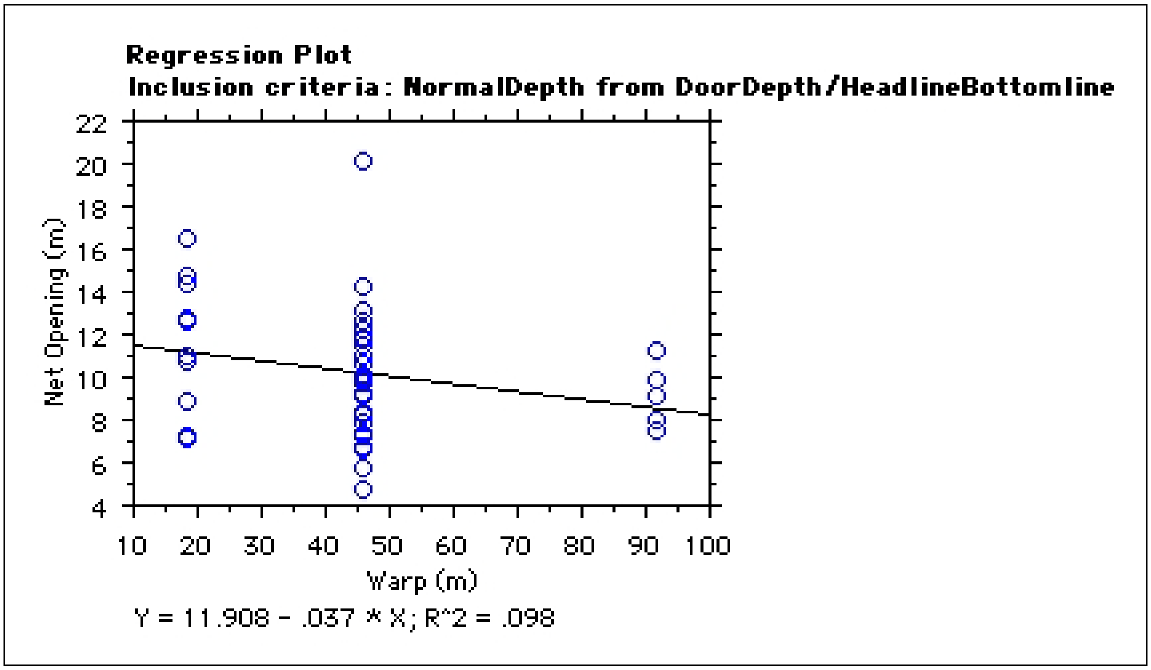

Figure 2-4: Relationship Between Warp Length and Net Opening

As indicated in Figure 2-4, net opening was more predictable when warp length was long; a short warp length was necessary to raise the net in the water and fish close to the surface but a short warp length also made the doors and net less stable.

Door depth and warp length were used to predict headline and bottomline depths where necessary to determine the appropriate depth interval for extraction of acoustic data collected during tows. Additional tow parameters that were used to determine the time interval between when a target appearing on the sonar record would be expected to enter the net were:

- vessel speed (6480 m/hr)
- length of warp (18 - 90 m)
- length of bridles (73 m)
- door spread (20 - 60 m)

The start of tow was considered to be the closest minute to when the desired length of warp had been released and the warp drums were locked in position. Considering these factors, a time delay of two minutes was used to match datasets between the noted start of the tow and the start of the acoustic data record.

2.3.3 Estimating Target Strength

The swim bladder is responsible for approximately 90-97% of acoustic energy reflected from a typical fish (Foote, 1980). The orientation of the fish within the sonar beam and changes in swim bladder volume with depth cause variations in target strength (TS). Thus target strengths of fish vary somewhat from study environment to study environment. In addition, the echo amplitude arising from a target of a given acoustic target strength will depend on the target's position with respect to the center of the acoustic beam, which in this case is 12 degrees.

Boswell et al. (2009) simulated the effects of fish orientation and length on acoustic biomass estimates based on data for Gulf menhaden. Target strength was based on:

$$TS = a \log_{10}(L) + b, \text{ where } a = 26.1,\ b = -65.6, \text{ and } L = \text{length in cm}$$

Other values for *b* in the above formula include -71.9 for herring and -84.9 for mackerel with the value of *a* remaining the same. The lack of a swim bladder in mackerel results in a lower target strength than for gadoids or herring.

Combined acoustic and trawl surveys have been conducted in the Barents Sea by Russia since 1982 (Shevelev et al. 1998). In 1995, echo intensities of cod, haddock and redfish were isolated into three length groups and relationships between length-weight and target strength developed. Mean echosounder target strength values *in situ* for cod and haddock of 16 and 40 cm length were determined to be about -46 and -38 dB, respectively.

Surveys found that the vertical distribution of fish by size class between the bottom and pelagic layers was due primarily to behaviour of fish at different sizes. Determining these types of vertical segregation of species or size classes of fish is important to allow interpretation of acoustic information.

To arrive at a calculated biomass for catch for comparison to the acoustic biomass measured during tows, the target strength for most species of fish was estimated using a value of 16.5 for *a*, and -65.6 for *b* to match the TS of -46 and -38 dB from Shevelev for cod and haddock. A value of 26.1 for *a* was used for herring and a value of -84.9 for *b* for mackerel.

In the Boswell et al. (2010) study, target strengths in dB were converted to equivalent backscattering cross section by:

$$\text{Sigma} = 10^{TS/10}$$

The backscattering cross section is a linear function and can be summed to provide a total number for a tow that should be proportion to the acoustic biomass, assuming the mix of fish is consistent. This formula was used to calculate what is referred to in this report as the calculated (from catch) and/or acoustic biomass expressed in g/m^2.

2.3.4 Processing Sonar Data

Echo targets recorded by the acoustic system were reported as Sa in dB. Sa was determined by summing the (linear) Volume Scattering Coefficients (Sv) and converting them to Sa for each ping by multiplying by the sample interval in meters and then converting to dB. Following this calculation for each ping, the (linear) average was calculated over a number of pings based on "good" navigation fixes, with generally 10 fixes per interval. This averaging was done to remove navigation jitter due to GPS resolution and precision.

A distance weighted mean of all (linear) interval Sas was calculated to get a single distance weighted Sa in dB for a particular transect, tow, etc., depending on the particular analyses to be conducted. This algorithm was selected because it was the most efficient and least affected by navigation inaccuracies.

A value of -199.9 was selected to represent the equivalent of zero targets as a minimum Sv level. If an interval has a value -90 dB and all the remaining have no targets and are thus represented by -199.9, the linear mean distance weighted Sa converted to dB will be between -90 and -199.9 depending on how many intervals are in the transect.

Volume backscattering strength in decibels was converted to volume backscattering cross section, which is a linear measure. Once the backscatter is in a linear form it should be proportional to biomass provided the fish mixture remains the same. A proportionality factor, i.e., so many g of biomass per unit backscattering cross section, can be used to adjust backscatter based on a mix of fish consistent in species and size over transect lines. No proportionality factor was used because an appropriate methodology has not yet been developed. Part of the study was intended to examine whether adjustments for species mix would significantly affect interpretation of results.

2.3.5 Estimating Biomass

Obtaining biomass estimates from the acoustic data over the duration of the tow was straightforward. The start and end time of the acoustic data section comparable to the section of water actively fished by the net was determined from the tow log. A lag time of two minutes was used to account for the distance between the acoustic beam and the front of the net (headline). The depth interval from which targets were extracted was determined from the best estimate of headline and bottomline depth. The resulting vertically integrated backscatter was determined over the net sampling depth, then averaged over the length of the tow and subsequently converted to decibel form by Femto. This backscatter value was converted to biomass using the Sigma equation in the previous section.

Converting trawl catch to a biomass estimate equivalent to the acoustic estimate required consideration of different target strengths between species and size of the fish (length). Appropriate target strength (TS) versus length relations for each biological component were needed to compute an overall estimate of acoustic backscattering cross section per unit of biomass. Major differences in target strength between some species are known, for example, mackerel and dogfish are known to have lower target strengths than other species that possess a swim bladder. For this study, target strengths were estimated by the TS equation in the previous section for three major groups of fish caught, namely:

- herring (using a = 26.1 and b = -65.6)
- cod, haddock and most other species (using a = 16.5 and b = -65.6)
- mackerel (using a = 26.1 and b = -84.9)

Using the above formula, estimates of target strength were calculated for each size class of fish at 2 to 4 cm length intervals. Once a target strength was obtained, it was converted to a biomass estimate using the Sigma formula in the previous section and multiplied by the number of fish in that size class. All biomass numbers for all species and size classes were summed to provide an estimated total biomass for the tow.

These TS estimates were general approximations based on literature values. Special consideration was made for dogfish based on review of the literature. Using the mackerel equation for TS for dogfish would have produced a value of -37 dB, but a TS value of -30 dB was used based on a report by O'Driscoll (2004). Cochrane (pers. comm.) suggested a value of -49 dB would be more appropriate for the size of the fish (66-69 cm) based on other literature. Consideration of how these different values of TS for dogfish effect estimates of overall biomass helps clarify the influence of individual fish on summed tow biomass. Only three dogfish were caught during the survey program and all three were caught in a single tow on October 25. Reduction in the target strength for dogfish would have reduced the biomass estimate for that tow from 0.00419 to 0.00123 g/m^2. Overall, total biomass values in any one tow ranged from 1.65 to 0.000005 g/m^2 and the effect of the different target strength values was relatively small in comparison to this range.

More analyses of acoustic targets collected concurrent to trawling could be used to investigate the suitability of these target strength estimates and possible variation between species, but this work was not carried out. The emphasis was to develop estimates of biomass that were comparable in magnitude to that collected during acoustic transects, but were not intended to estimate population biomass.

Biomass estimates were reported in square metres rather than adjusting them to reflect a specific volume of water. This suggests that the biomass is evenly distributed over a column of water from the surface to the bottom regardless of the particular depth interval selected. Corrections for volume would be required if estimates of population biomass were desired.

Additional adjustments to biomass numbers were not made for species catchability, trawl parameters or species mix. Adjustments for net performance were not made because monitoring equipment had indicated that net opening was relatively consistent and no clear relationship could be determined between trawl parameters and size of catch or size of fish caught. Adjustments for catchability were not made because coefficients for catchability by species and size were not appropriate for the conditions encountered in Minas Channel. Adjustments to acoustic backscatter estimates based on species mix were not made because consistent relationships between survey factors, such as light, water depth or tide, and species mix were not established in the analyses conducted. Adjustment for either catchability or trawl parameters was considered unlikely to result in changes to magnitude of biomass estimates sufficiently large to affect the results from analyses conducted.

3 INITIAL TRIAL SURVEYS

Two trial surveys were conducted in June of 2010 to determine parameters for a longer-term survey. An initial requirement was to determine if the midwater trawl available to the Carmelle #2 could adequately catch fish in the strong and variable currents of Minas Channel.

3.1 First Survey

The first trial survey took place on June 19. The emphasis in this first survey was to determine if the midwater trawl could be fished effectively and if the hydroacoustic system would provide data relatively free of turbulence. At Parrsboro, high tide was at 06:46 (all times are in ADT) and low tide at 12:59. An initial tow was carried out at 08:30 during a strong ebb tide to test the net and net monitoring equipment. The tow was conducted on the eastern side of the survey area in 90 m of water with the headline at depths of 30 to 50 m and door spread of 30 to 55 m.

The tow was conducted into the tidal current and the vessel had a negative ground speed during the tow. The tow was continued for about 35 minutes as the effects of changes in warp length and ship speed on the net were evaluated. Catch in the initial tow is provided in Table 3-1.

Table 3-1: Catch in Initial Tow of First Survey, June 19

Quantity	Species	Length (cm)
1	Dollar fish	10
2	Silver hake	18
1	Sea raven	30
1	Herring	22
1	Mackerel	20
3	Tomcod	8, 10, 25
1	Gaspereau	30
3	Summer flounder	25
2	Winter skate	35

Note: A single length indicates all fish were the same size.

After the initial tow, acoustic transects were run between 09:50 and 16:15. A second tow was carried out at 10:50 as the vessel was part way along Transect A3 to investigate surface to bottom blue 'haze' on the echo sounder similar to that shown in Figure 3-1. The source of the haze was not determined but it did not recur often and did not appear to have an important effect on data analysis. System gain was not changed nor was a signal threshold increased to remove the "haze". For reference, water depth in Figure 3-1 ranged from about 10 m to 120 m. The blank data space at the top of the record represents the transducer offset of 1.9 m below the water surface plus approximately 3 m for 'ringdown' where reliable data cannot be obtained..

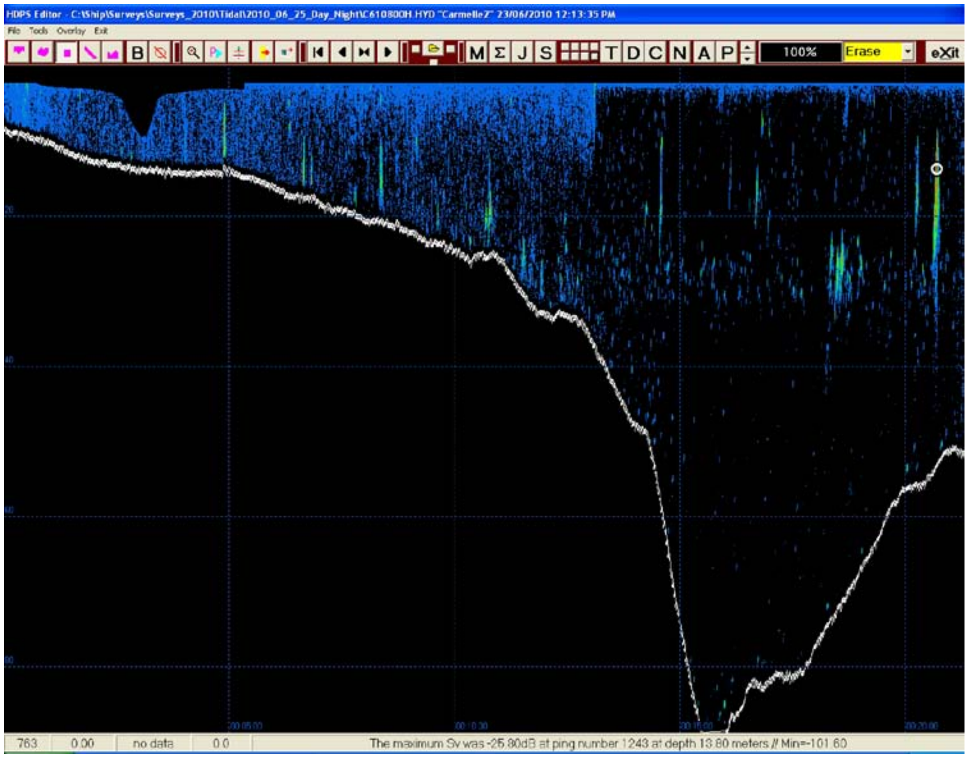

Figure 3-1: An Echogram Showing Blue Haze (left) and Typical Targets (right)

The second tow was carried out in 85 m of water with an initial depth of doors at 35 m. Approximately 10 minutes into the tow the doors dropped to 50 m in 65 m of water and the net touched bottom, indicated by a small tug on the vessel. The net was immediately retrieved but it had a large rip in the bottom. Catch consisted of one small sea raven and one dogfish. Further fishing was not possible but acoustic transects were continued beginning near Cape Split (B7) until tide was high enough to allow docking at the wharf at the end of the next rising tide. The net was taken to Dartmouth for repair.

Even though the net was damaged, the first survey had met the survey objective – it was demonstrated that the midwater trawl could effectively catch a wide range of species under the difficult conditions found in Minas Channel. In addition, fishing techniques were identified that would avoid future net damage. The hydroacoustic system was also shown to provide relatively clean imaging, free from interference of turbulence.

3.2 Second Survey

The second survey took place between 12:00 June 24 and 21:00 June 25, 2010. The net was repaired and in good working order for these trials. However, tides were high and the weather was poor with winds from the southwest resulting in heavy turbulence for much of the survey. The turbulence made conditions poor for collection of acoustic data. Turbulence[3] was visible on the echo sounder extending 5 to 15 m below the transducer over a large proportion of the transect lines run in the outer portion of the survey area (near Cape Split). For this reason, most analysis was focused on the inner portion of the survey area (between Parrsboro and Cape Blomidon) where turbulence was generally less.

It should be noted that the vessel was not a major source of turbulence. Observation suggested that waves would entrain air bubbles and the strong current eddies would carry these air bubbles downward throughout the surface layer of water. Vessel speed or direction had little, if any, influence on the appearance of the turbulence on the echo sounder.

A total of 32 transect lines were run and 9 tows conducted. The midwater trawl was fished with variations in net floatation, weight and warp length. Typically three spherical floats were attached to each edge of the headline and heavy steel weights to the edge of the bottom line. Initially the headline transducer indicated the net was deeper than the doors. The additional floats were removed and bottomline weight reduced to allow the net to fish more in line with the depth of the doors for the third tow. Combinations of floatation and weights were tested but the headline transducer did not provide consistently useful information concerning the configuration of the net. Door sensors reliably transmitted depth, spread and orientation.

3.3 Differences in Acoustic Backscatter Between Night and Day

During the second survey, transects were run during different tides and during day and night. Unfortunately the wind came up the evening of June 24 and considerable turbulence impaired data quality between 20:00 June 24 and 11:00 June 25. Acoustic biomass along transects surveyed in the day and in the night were compared in the eastern portion of the survey area (Figure 3-2) to minimize the impact of the turbulence. Data from eight transects run in the daytime and three night transects were available for comparison. Acoustic biomass density was 0.016 kg/m^2 in day transects and 0.012 kg/m^2 in night transects (Clay 2010e).

[3] Turbulence, as used in this report, is a distinctly different phenomenon from the "blue haze" illustrated in Figure 3-1. Turbulence is characterized by higher signal strengths resulting in display colours ranging from primarily yellow (moderate strength) to spots of red (high strength) and it emanates from the surface in a series of coherent downward spikes. It is likely generated by small air bubbles entrained in the water by wave and current action.

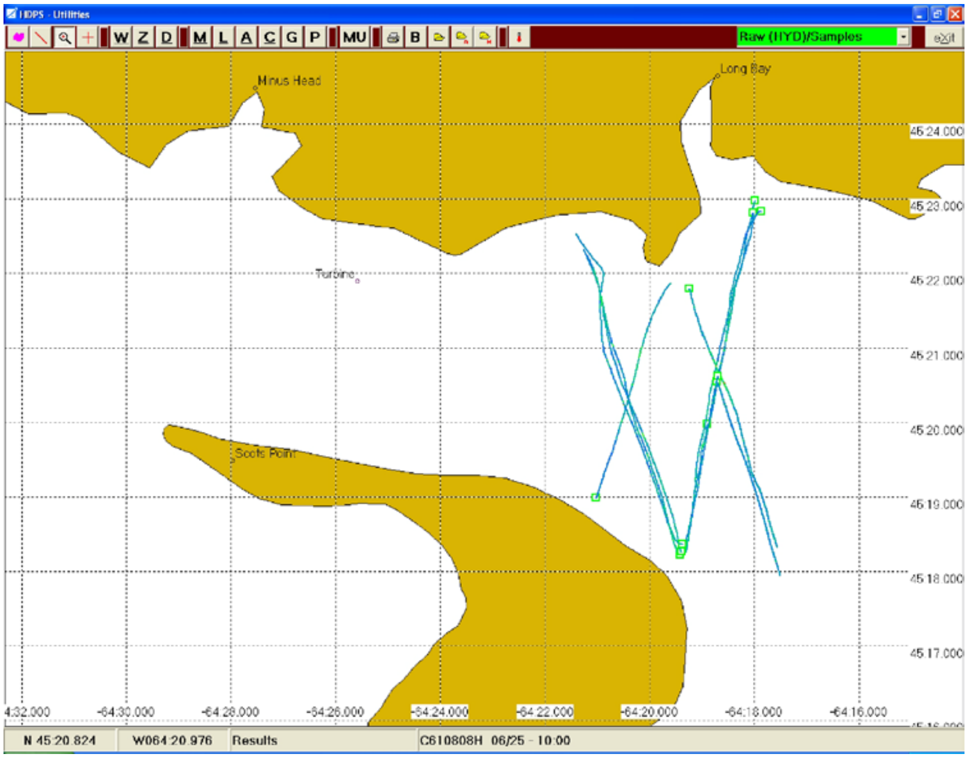

Figure 3-2: Day and Night Transects in the Eastern Survey Area

While the density of acoustic targets was not significantly different (ANOVA, p=0.34), there was more difference due to location of targets in the water column. Figures 3-3 and 3-4 illustrate the overall depth of targets from the transducer in night and day transects, respectively. Note the red line indicates the change in target density (kg/m^3) from the surface down while the green line indicates target density from the bottom up.

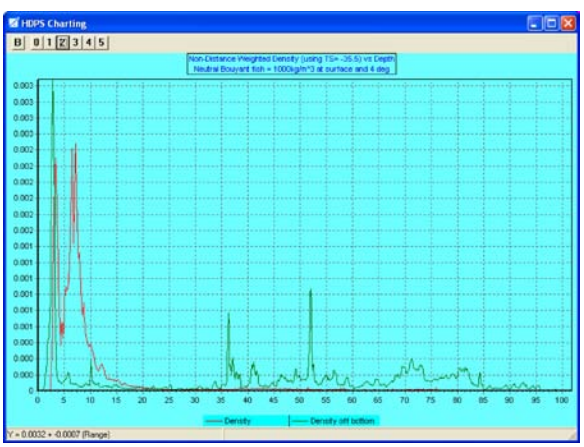

Figure 3-3: Night Time Depth of Targets

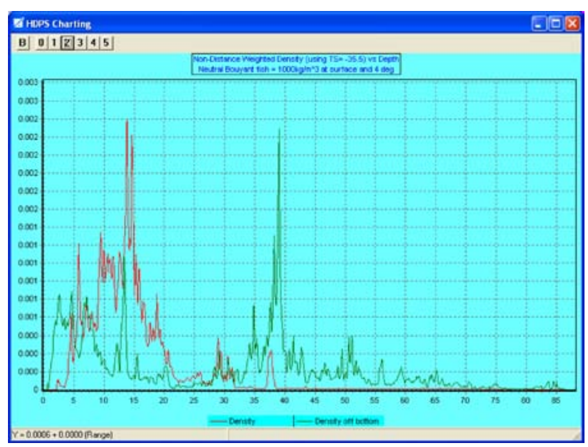

Figure 3-4: Day Time Depth of Targets

Figures 3-3 and 3-4 illustrate the general upward shift in acoustic target density at night (vertical scale), especially near the surface in the upper 20 m of the water column (horizontal scale). Depth to the center of mass[4] of daytime transects was 14.8 meters and for nighttime 10.1 meters. In the daytime, targets were more widely dispersed in the water column and there were more targets observed near bottom. This observation would be consistent with a general trend in fish behaviour of fish moving up off the bottom at night.

3.4 Comparison of Catch and Acoustics Data

Midwater trawls were carried out throughout the survey area (Figure 3-5). Generally a tow was made when a group of targets considered to represent fish were observed during a transect. The final tow, Tow #9, was carried out in an area where few but distinct low amplitude targets were observed, which were presumed not to be fish, for comparison to other tow results. Efforts were also made to carry out tows in different parts of the survey area under different tide and wind conditions.

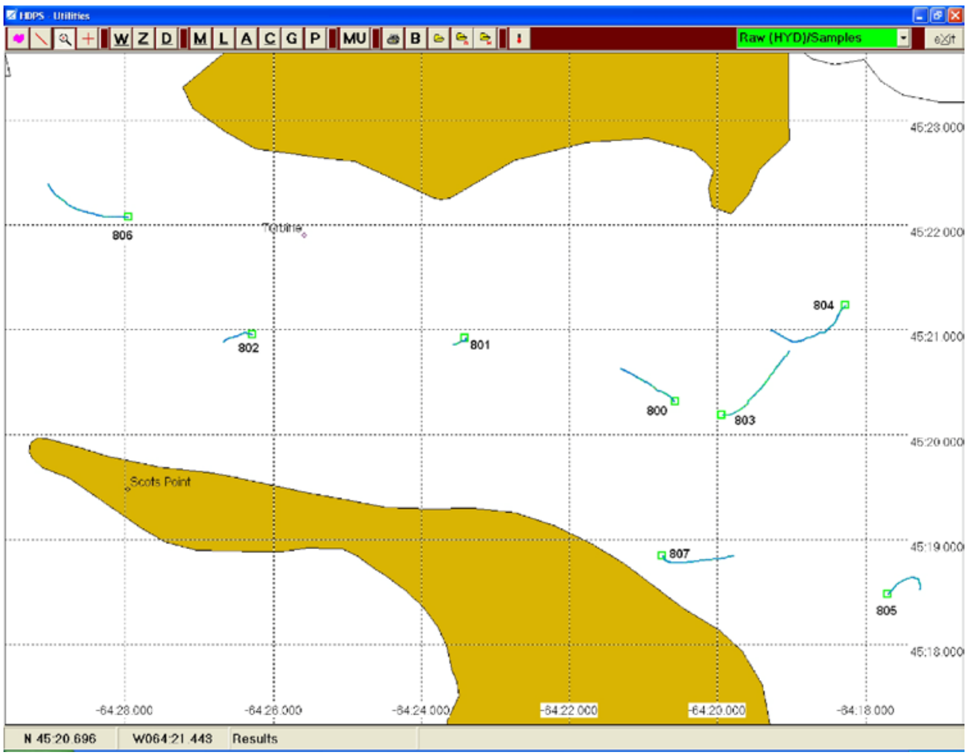

Figure 3-5: Location of Tows, June 24 and 25

Generally the acoustic biomass density during tows was higher than that found on a typical transect (Table 3-2), indicating that the vessel was successful at carrying out tows in locations of higher acoustic biomass density. The acoustic biomass in Table 3-2 was determined for the entire water column because in these early surveys a reliable estimate of

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[4] Depth to the centre of mass is calculated by multiplying the linear volume scattering coefficient at each sample by the depth of that sample; then dividing the result by the sum of all the linear volume scattering coefficients.

the depth interval sampled by the net was not yet available. However, the tow was made at the depth interval where most targets were observed. . It should be noted that the low biomass density of Tow 9 was intentional for comparison to other tow results.

Table 3-2: Catch and Acoustic Biomass by Tow, June 24 and 25

Date	Tow #	Transect #	Acoustic Biomass (kg/m^2)	Total Catch (kg)
June 24	Tow 1	800	0.127351	.2
	Tow 2	801	0.572319	100
	Tow 3	802	0.114551	50
	Tow 4 - bad deployment			
June 25	Tow 5	803	0.124851	15
	Tow 6	804	0.003507	15
	Tow 7	805	0.065824	12
	Tow 8	806	0.138374	75
	Tow 9	807	0.000741	.05

The catch was significantly correlated with the acoustic biomass density ($p=0.02$, $r^2=0.63$). The catch in Tow 1 may have been low due to net malfuction; if data from Tow 1 is excluded from the analysis, r^2 increases to 0.70.

Variations in net flotation, weight and warp length and poor reception of headline information likely reduced the correlation between acoustic biomass and catch, as well as reduced the ability to target a specific portion of the water column. Nonetheless, data quality was adequate and can be improved upon in future surveys.

The catch was almost exclusively herring in weight and numbers, but a number of other species were also caught (Table 3-3).

Table 3-3: Catch in Tows During Survey 2, June 24 and 25

Date	Tow No.	Time	Catch
June 24	1	1355 to 1415	22 herring
	2	1710 to 1732	90 kg of herring, 5 mackerel
	3	1900 to 1920	45 kg of herring
	4		No catch, bad deployment
June 25	5	1104 to 1125	15 kg of herring, 1 mackerel, 1 smelt
	6	1245 to 1306	15 kg of herring, 2 mackerel
	7	1402 to 1425	10 kg of herring, 1 mackerel, 1 lump fish, 1 dollar fish
	8	1902 to 1923	70 kg of herring, 2 smelt
	9	2028 to 2050	2 silver hake, 1 smelt

The small catch in the first tow likely resulted from a tangle in the bottom line as the net was being deployed. Sensors indicated the net was not fishing properly and when the net was retrieved a small hole in the second belly was found and repaired. No further net damage was experienced but the doors would not assume an appropriate position during Tow #4 and no catch was obtained.

Herring were consistently caught regardless of the variations in net configuration or locations and timing of tows. Other species, such as mackerel, are likely more difficult to catch so the proportion of species in the catch is not likely a direct ratio of what is in the water column[5]. Duration of tow also affects the selectivity of the gear with shorter tows lessening the catch of faster and larger fish. The trawl doors act as initial herding cues and thus the alignment of the net behind the doors can also affect the selectivity of the gear.

3.5 Components of a Typical Survey

Based on results from the trial surveys conducted in June, a series of surveys were planned and conducted at regular intervals from July to October. Surveys were generally spaced by between 6 and 14 days. All surveys, except one that was carried out from Halls Harbour, were conducted from the Minas Basin Pulp & Power wharf in Hantsport. As in the trial surveys, all routine surveys were performed by the trawler Carmelle #2 using a midwater trawl, with acoustic data collected by the Femto DE9320 echosounder system. Based on the results of trial surveys conducted in June of 2010 and earlier acoustic surveys, combined trawling and acoustic transect surveys incorporated:

- both day and night transects; and,

[5] Catchability coefficients are commonly used to adjust catch in trawls by species, but appropriate coefficients for the mid-water trawl used in this survey are unknown. No adjustment for catchability differences among species was done in this report.

- day and night fishing of selected target groups.

Available information suggested that efforts should be made to survey the outer portion of the survey area near Cape Split at slack tide to minimize the potential problems of turbulence in this area. This was facilitated by running transect lines from east to west on the falling tide and from west to east on the rising tide.

A typical survey required 21 hours from wharf to wharf to allow sufficient time to travel between Hantsport and the survey area and to complete a full survey under different tides as well as fishing within day and night periods. The balance of effort between night and day work was influenced by the timing of high tides for departure and arrival at the wharf. The trip from Hantsport to and from the survey area required about 1.5 hours with the appropriate tide.

4 SURVEY RESULTS

Following the trial surveys, hydroacoustic data were collected and uploaded to the Femto ftp site but not processed until late in 2010. Thus preliminary reports on the routine surveys conducted between July and October were focused almost entirely on fish catch and trawl performance. Table 4-1 outlines the number of surveys and tows carried out from July to October.

Table 4-1: Numbers and Surveys and Tows by Month in 2010

Month	Survey Dates	Number of Surveys	Number of Tows
July	July 12	1	5
	July 21-22	1	9
	July 26-27	1	8
August	August 10-11	1	7
	August 19-20	1	10
	August 24-25	1	9
September	September 1-2	1	10
	September 16-17	1	9
	September 30-	1	2
October	October 1		8
	October 5-6	1	8
	October 25-26	1	7
Totals		11	92

The trial surveys carried out in June were undertaken at a time when herring were abundant in the Minas Channel and were discussed fully in Section 3. Estimates of acoustic biomass indicate that herring biomass was substantially higher in June than earlier or later in the season. Emphasis in this section is on the main surveys carried out July to October, 2010 and focuses on a wider range of species.

The acoustic data quality is affected by turbulence, which at times obscured the acoustic record from surface to bottom. Heavy turbulence was associated with either wind and waves or high tidal currents. It appeared that deep eddies, when tidal currents were particularly strong, could induce heavy turbulence similar to that produced by wind and waves. As a result, turbulence was hard to predict and did not always occur in similar areas. Turbulence has been removed from the acoustic data by visual inspection of the echogram. The resulting information is considered to be relatively free of the effects of turbulence.

4.1 Seasonal Trends in Acoustic Transects

All acoustic transect data was divided into three depth intervals: 1-14.9 m; 15- 29.9 m and 30-44.9 m, as well as a layer 15 m off bottom and an integrated total depth interval. Table 4-2 provides the mean backscatter (Sa in dB) averaged from each survey transect for the three upper depth intervals.

Table 4-2: Relative Backscatter (Sa) at Depth Intervals by Survey

	Backscatter (Sa in dB)		
Survey	**Depth 1-14.9 m**	**Depth 15-29.9 m**	**Depth 30-44.9 m**
July 12	-98.037	-109.177	-147.269
July 21	-76.328	-80.870	-80.266
July 26	-79.434	-77.826	-91.326
August 10	-71.705	-78.227	-92.190
August 19	-68.831	-75.7999	-91.359
August 24	-81.611	-81.098	-95.510
September 1	-80.897	-75.195	-92.186
September 16	-72.550	-73.236	-86.825
September 30	-83.364	-74.792	-88.811
October 5	-70.509	-69.834	-98.103
October 25	-83.380	-79.036	-96.333

In Table 4-2 the higher backscatter levels are indicated in red and yellow, with red the highest. The higher backscatter levels shift from the surface 15 m to the intermediate 15 to 30 m depths as the season progresses, moving deeper after the end of August. The potential affect of tide and light conditions are described later in this section. Backscatter levels during the August 24 survey were lower than surveys earlier or later in the summer, indicating a mid-summer trough in fish biomass.

Figure 4-1 illustrates the seasonal change in surveys by depth interval when backscatter is converted to an equivalent acoustic biomass (g/m^2). The term equivalent biomass is used to indicate that the conversions used attempt to make acoustic and catch numbers equivalent and comparable to each other but may not reflect true biomass because of the mix of species observed and limited background information on target strength. A seasonal shift in biomass is observed from the surface layer (0-14.9 m) to the intermediate layer (15-29.9 m) and possibly deeper as well.

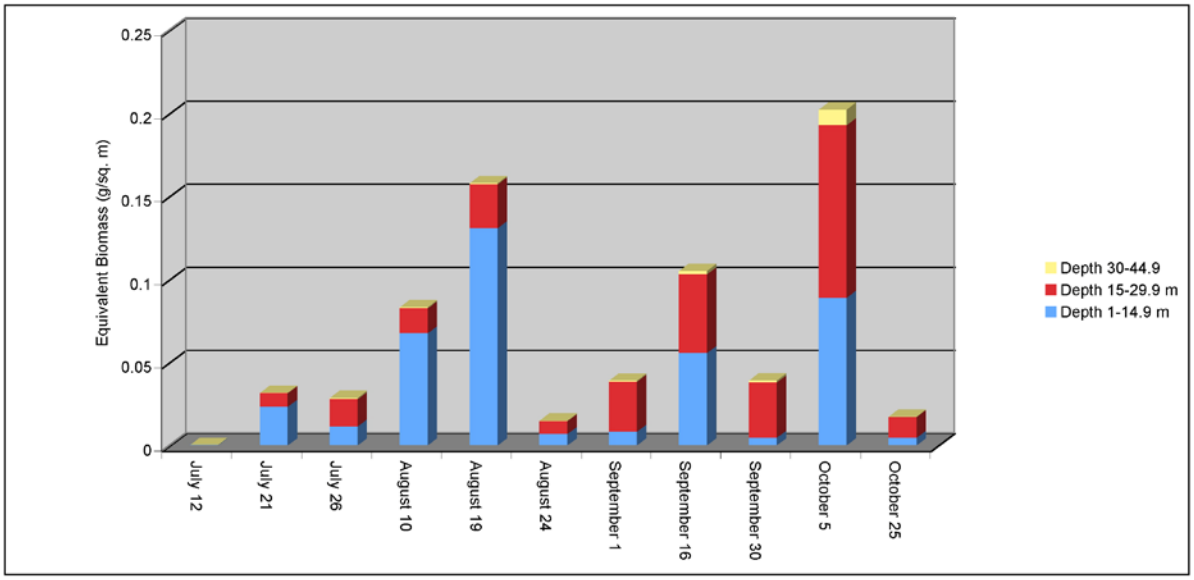

Figure 4-1: Comparison of Acoustic Biomass by Depth Interval Between Surveys

4.2 Species Composition

Herring, dollar fish, mackerel, gaspereau, smelt and lump fish were the most consistent species caught. At times predominately bottom species, such as sea raven, summer flounder, and winter skate were caught well above the bottom. Gadoid (cod-like) fishes, including tom cod, silver hake, red hake, and pollock, were caught in low numbers, inconsistently, and were generally small (<10 cm FL). Around 10 krill[6] were also caught frequently in tows.

The relative abundance of different species of fish changed seasonally. Total catch in all tows by month is provided in Table 4-3 for the most common species caught. Herring, by far, outnumbers all other species caught in the spring, with herring catch beginning to drop in July. In October, when most herring are thought to leave Minas Basin, herring still make up the largest single component in most tows, but have dropped to about 7% of their June average.

[6] Krill were not likely identified as targets by the 38 kHz echosounder unless tightly aggregated.

Table 4-3: Monthly Total Catch in Tows by Selected Species

	Species (number of fish)					
Month	**Herring**	**Dollar fish**	**Mackerel**	**Gaspereau**	**Smelt**	**Lump fish**
June	8096	1	9	0	4	1
July	5749	151	20	17	31	0
August	1047	431	167	100	173	5
September	1335	36	55	24	12	6
October	582	13	42	8	3	7

The average catch per tow shows a greater dominance of herring in June than in other months (Figure 4-2).

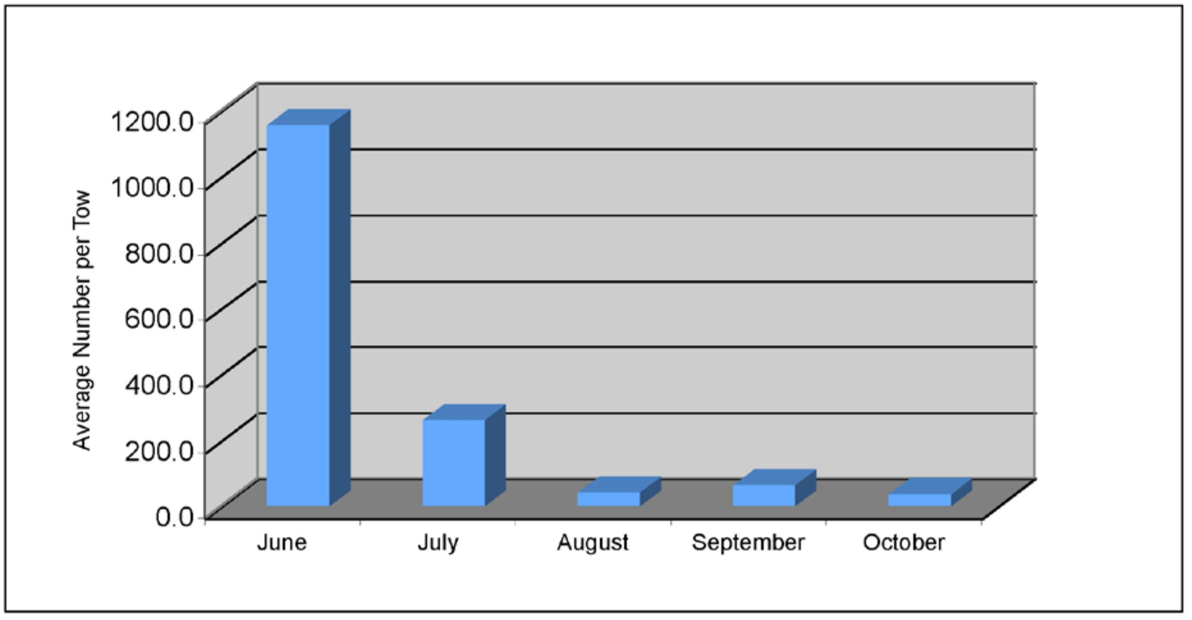

Figure 4-2: Average Number of Herring Caught per Tow by Month

The seasonal distribution for other species is generally different than that of herring – other species tend to be most abundant in August (Figure 4-3). Dollar fish tended to dominate the catch in July and August. No gaspereau were caught in June and no lump fish were caught in July, but other species listed in Figure 4-3 were caught in some numbers throughout the season.

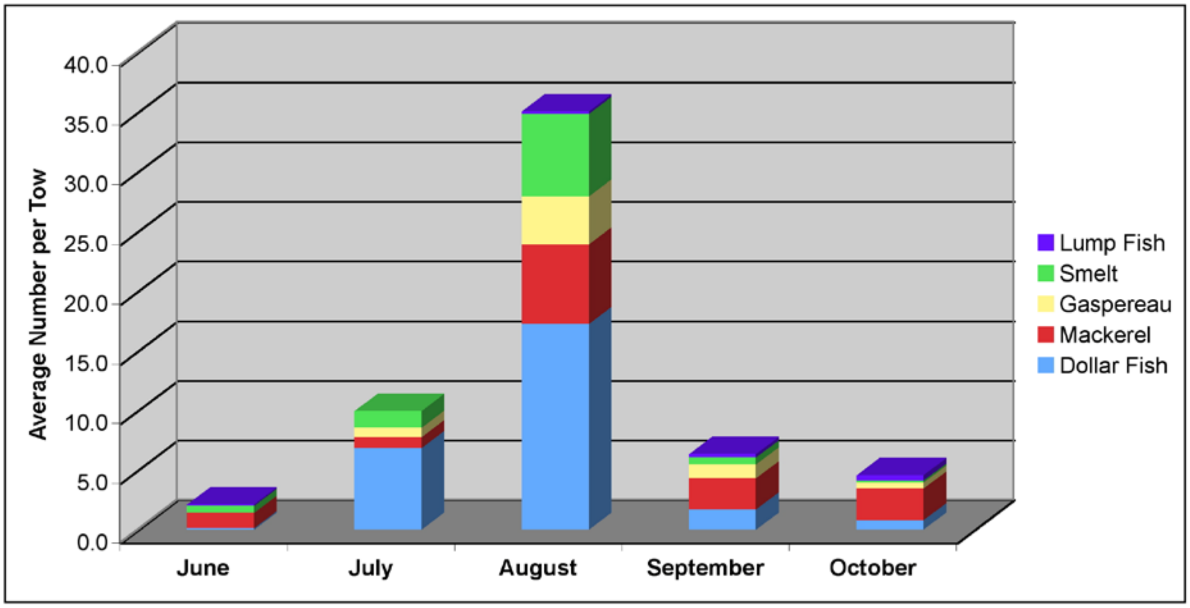

Figure 4-3: Average Number Caught by Species (except herring) per Tow by Month

Figure 4-4 illustrates the same catch data converted to equivalent biomass[7] by survey without correcting for catchability. Note that the large herring catch on July 12 is shown truncated to improve clarity in the relative catch in other surveys and of other species. Mackerel abundance showed the largest difference in the catch composition, largely because of the low target strength of mackerel. Dollar fish form a high proportion of the biomass in August, with a gradual shift to gaspereau in late August and September.

[7] The biomass units are reported in g/m^2 because corrections were not made for sampling volume, however, sampling volume of the net appeared sufficiently consistent that comparison of catch between tows was realistic.

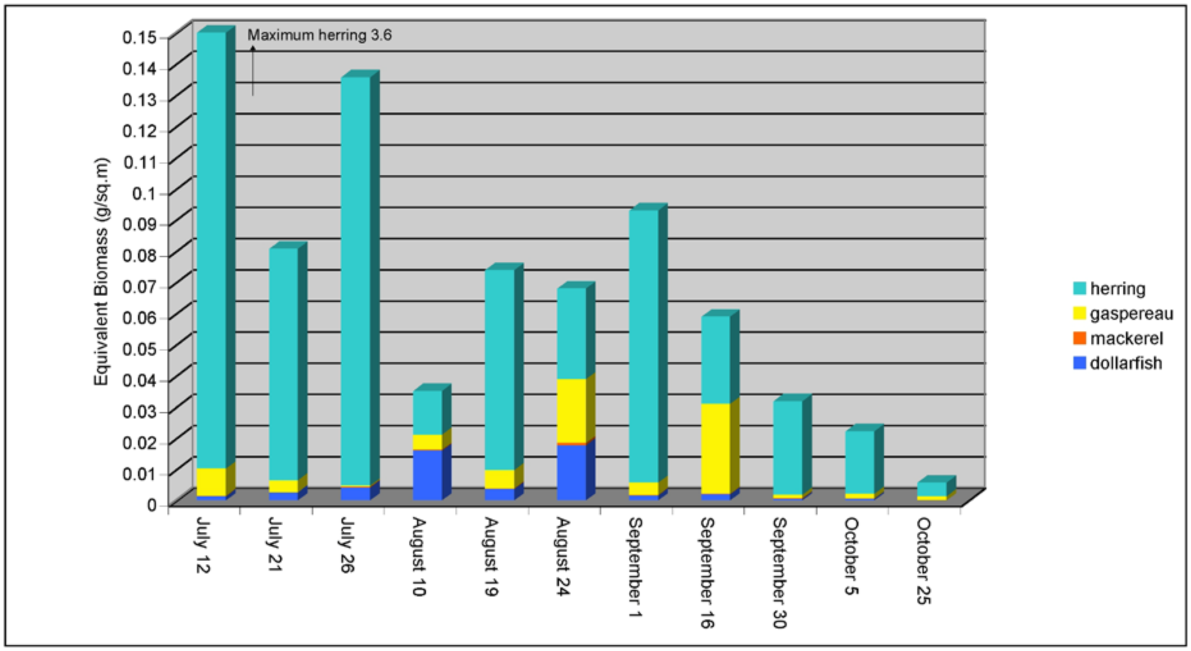

Figure 4-4: Calculated Biomass of Catch by Major Species and Survey

Surveys likely missed spring migrations into Minas Basin. Shad, striped bass and larger gaspereau known to move through Minas Channel early in the season were not sampled.

4.2.1 Length Frequency

Some of the species passing through the Minas Channel spawn in the area and length frequencies in the catch tend to be bimodal, representing older spawning fish and younger juveniles or young-of-the-year. Herring and gaspereau are examples of small pelagic species that spawn in the area and showed bimodal length frequencies. Almost all the large herring greater than 17 cm in length (Figure 4-5) were caught in the July 12 survey; herring in the catch from July 21 onwards were primarily in the 8-15 cm length.

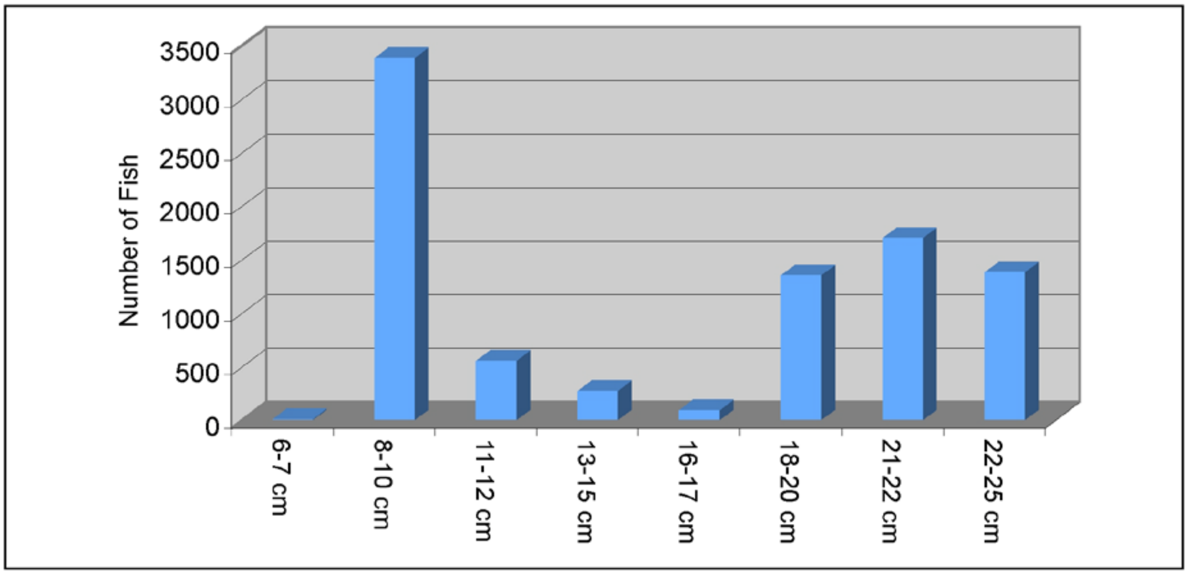

Figure 4-5: Length Frequency of Herring in Survey Tows

Most of the large gaspereau (23-25 cm) were caught in the September 16 survey, with 3 caught during the Jul 12 survey. The few gaspereau larger than 25 cm (Figure 4-6) occurred sporadically through the survey period. The largest number of mid-sized gaspereau (13-17 cm) was caught during the August 24 survey. The smaller size class (8-10 cm) of fish was caught primarily on October 25 and may represent young-of-the-year fish beginning to leave the upper Bay of Fundy.

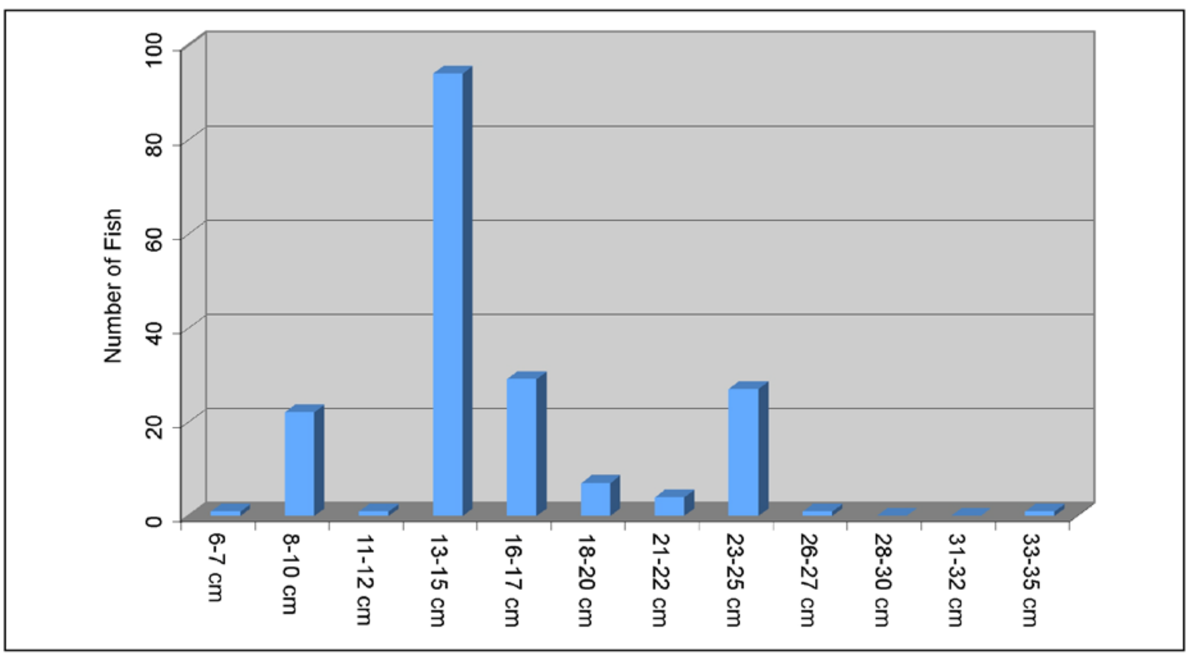

Figure 4-6: Length Frequency of Gaspereau in Survey Tows

Most gadoids caught were small (<16 cm in length) juvenile fish, but 1 pollock and 2 silver hake between 26-30 cm were caught.

Small (2-4 cm FL) 3-spine stickleback were the smallest fish caught. The largest fish caught were striped bass (67-77 cm FL) and dogfish (69 cm FL). The striped bass and dogfish were caught in later surveys on September 17 and October 26, although a dogfish was also caught in the initial June survey when the net was damaged fishing too close to bottom.

4.3 Location Preference

Figure 4-7 illustrates the distribution of acoustic backscatter (Sa in dB) over all transects carried out on July 12. Maps of acoustic backscatter for all transects are provided in Appendix A. Review of these maps shows a relatively even, broad distribution of acoustic backscatter, but as noted previously, a gradual shift in maximum biomass from the surface depth layer to the intermediate layer is observed most clearly in late in August. At the same time, spatially, fish appear evenly distributed throughout the channel with no apparent concentrations in specific areas.

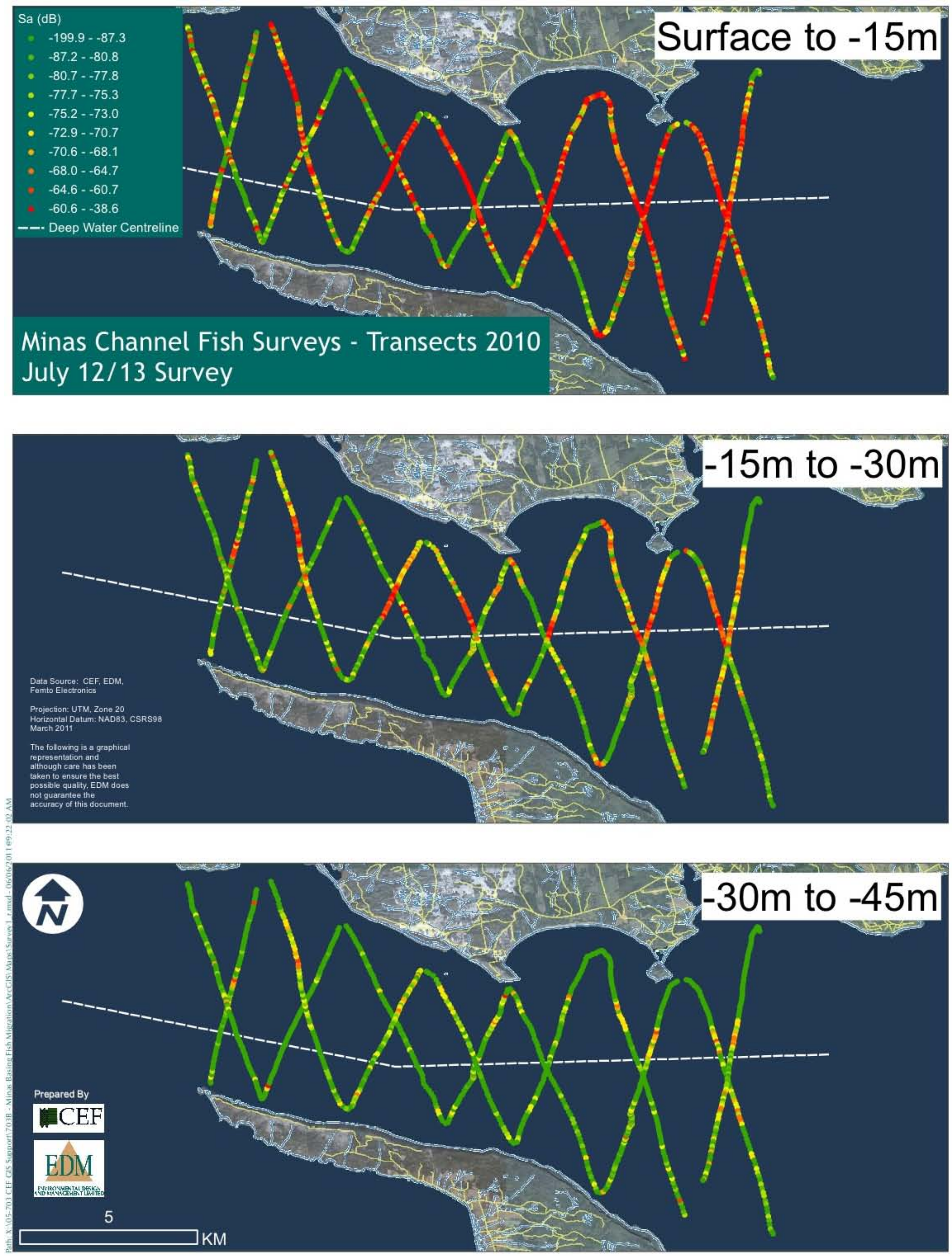

Figure 4-7: Distribution of Backscatter (Sa in dB) in July 12-13 Transects at Three Depth Intervals

Behaviour of some fishes, such as salmon, would suggest that migrating fish would have a preference to move near shore. Fish are caught commercially in a few shore-based weirs along the north shore of Minas Channel supporting that some fish move near shore[8]. However, prior to these surveys in Minas Channel no information was available to indicate the relative proportion of most fish moving through different parts of the Channel. When selecting locations to tow based on visual interpretation of the sounder record, locations tended to divide into central deep-water channel areas and shallower areas closer to shore.

An equal distribution of tows to the north and south were desired, but the commercial lobster fishery complicated selection of tow sites because it was important to avoid tangling the net and lines with buoy ropes from lobster traps. Many areas near shore, particularly on the north side of the channel, could not be fished because lobster traps were located in the area. The commercial lobster season normally extends from March 1 to July 31 and October 15 to December 31.

Table 4-4 indicates the number of tows carried out in the north, central and southern portions of Minas Channel. These areas were demarked generally by the start position of the tow. A large proportion of tows (68.1%) were initiated in the central, deep-water trough of the channel, but strong tidal currents caused tows to proceed in various directions.

Table 4-4: Number of Tows Across the Minas Channel

Location	Number of Tows
North	10
Central - Deep	62
South	19

When GPS positions for tow tracks became available, it was possible to define tow tracks in proximity to the central, deep-water trough. Table 4-5 compares the catch from tows where the track was within 750 m of the mid-line (see Figure 4-10) to tows from other areas. Similar numbers of most species were caught in the deep, central trough area, with percentages ranging between 45 and 55%. Exceptions were dollar fish, which were more concentrated (61.3%) outside the deep, central area, and gaspereau, which were more concentrated (69.5%) within the deep, central area.

[8] A shore-based weir is located near the tidal power lease area but catches from this weir have not been monitored. Catch of SARA species, such as Atlantic salmon, are not reported to be a concern at this weir.

Table 4-5: Number of Fish Caught by Location

Species/Size	Central Deep Area	Other Areas	Percent Deep
Herring, young[9]	2153	2161	49.91%
Herring, adult	2511	2019	55.43%
All Herring	4664	4180	52.74%
Dollar fish	244	387	38.67%
Mackerel	133	145	47.84%
Gaspereau	130	57	69.52%
Lump fish	10	8	55.56%

When the mean calculated biomass from tows was compared between tows within 750 m of the centerline and others, none of the means were statistically significant. Even though only one of 28 gaspereau larger than 23 cm in length was captured outside the central, deep area, the mean difference in biomass was not significant (p=0.143, n=47, 45). Similarly, the mean difference in calculated biomass for dollarfish was not significantly different (p=0.591, n=47, 45) between areas.

4.4 Comparison of Acoustic and Tow Biomass

Figure 4-8 illustrates the overall distribution of acoustic backscatter (Sa expressed in dB) recorded during tows carried out during the eleven surveys between July and October. The tows are relatively evenly spread through Minas Channel and no apparent pattern in fish density is obvious. Maps of fish catch by species are provided in Appendix B.

[9] Herring were divided into young and adult based on the length frequency shown in Figure 4-5, with fish less than 18 cm in length referred to as young, and larger fish as adults.

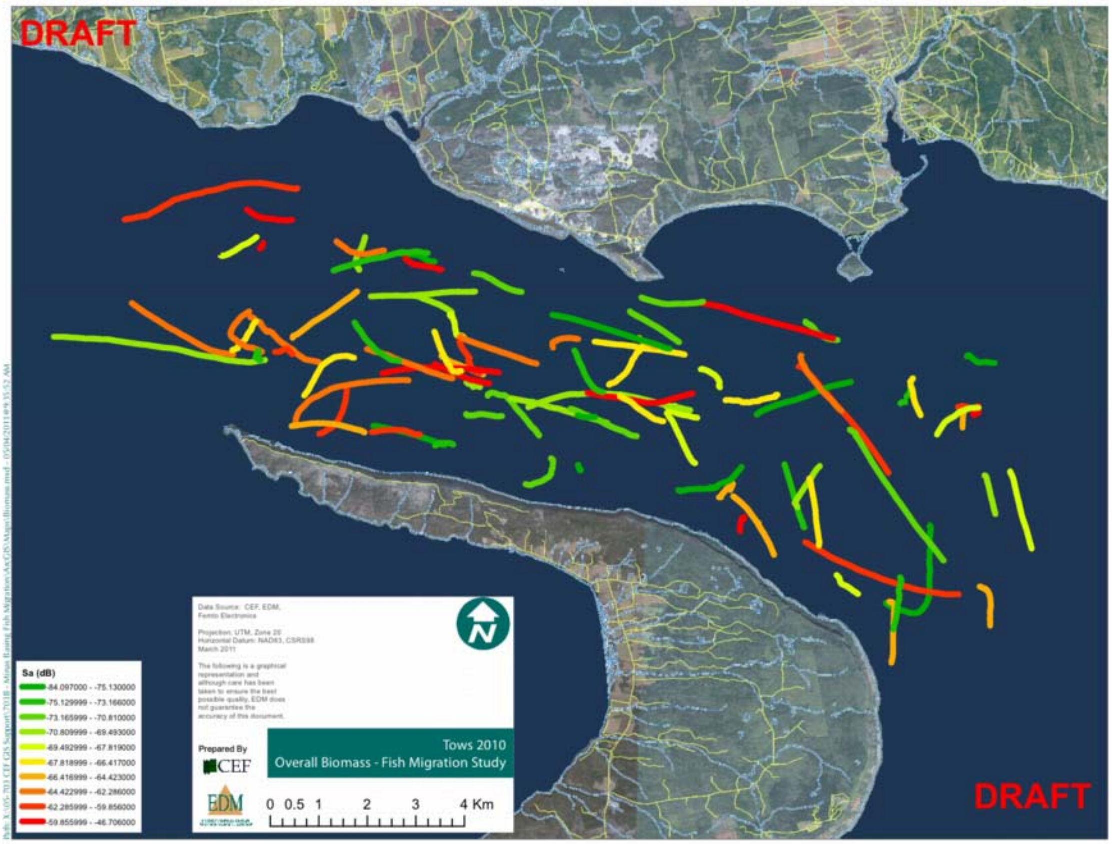

Figure 4-8: Composite Backscatter (Sa in dB) Collected During All Tows

The correlation between catch-based and acoustic backscatter converted to biomass was determined by simple linear regression. One tow did not have an acoustic biomass because of equipment failure and three tows did not obtain a catch. These points were dropped from the analysis leaving a total of 87 data points for comparison.

An initial linear regression did not indicate a significant (p=0.97, n=87) correlation between the catch and acoustic estimates of biomass. Figure 4-9 illustrates that eight data points substantially diverge from the general cluster of data points.

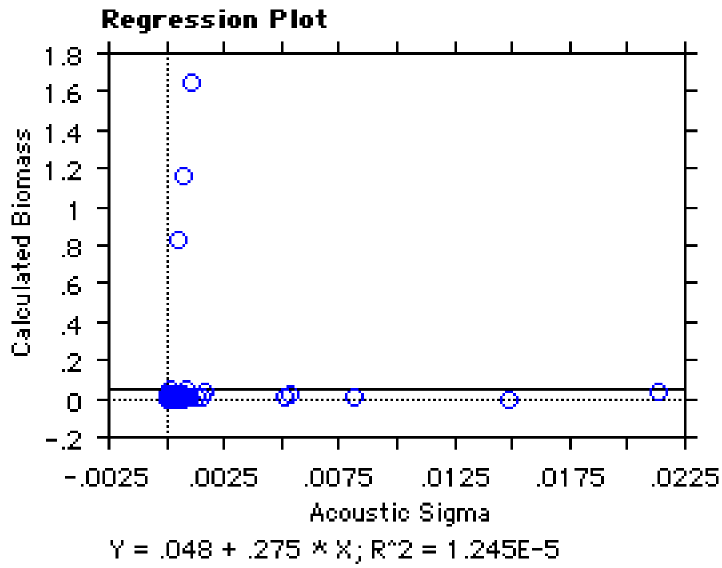

Figure 4-9: Regression Plot of Catch Biomass to Acoustic Biomass

The three high values in calculated biomass represent large catches of herring, which may be related to the schooling nature of the fish and the random chance of the net passing through a small school. The high values of acoustic sigma (backscatter converted to equivalent biomass) could similarly be a result of the net not following directly in the path of the sonar beam or insufficient time for the net to herd the fish observed on the sonar into the net. The regression was calculated a second time with these eight outliers removed (Figure 4-10), and a significant correlation ($p=0.0002$, $n=79$) was obtained. R^2 was 0.159, indicating that the correlation explained almost 16% of the variation in the data.

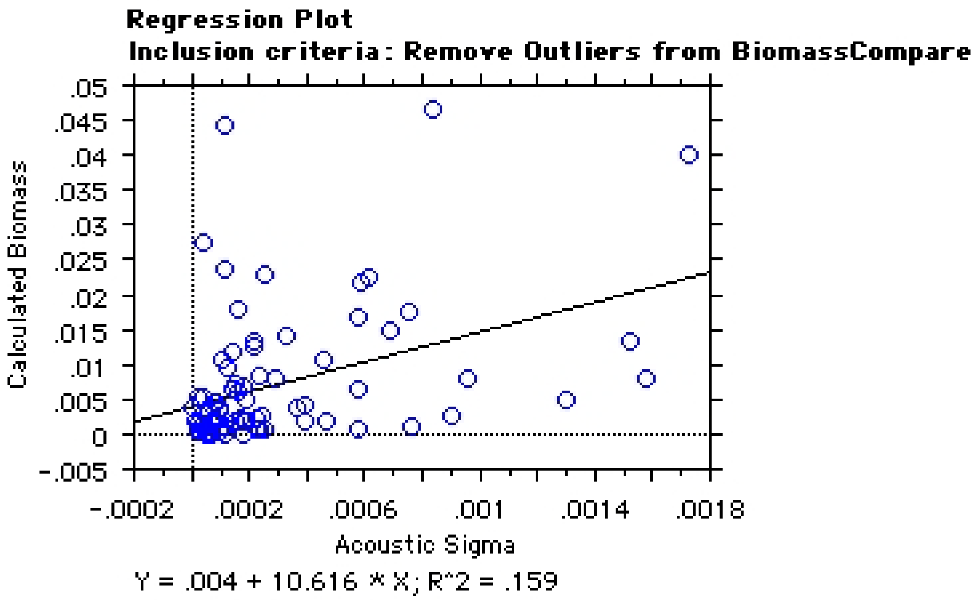

Figure 4-10: Regression Plot of Catch Biomass to Acoustic Biomass with Outliers Removed

Correlation of calculated and acoustic biomass for herring alone was investigated to see if a better fit was obtained. The correlation of herring only catch and acoustic biomass was higher than for catch of all species combined. A regression of herring catch and acoustic biomass with the eight outliers removed was significant ($p<0.0001$, $n=90$) and R^2 increased to 0.222. Correlations with catch of other species caught frequently were poor, supporting that herring have a dominant influence on the acoustic biomass overall.

The strong influence of herring on the correlation between catch and acoustic biomass and the low correlation for other species suggests that adjusting the biomass catch calculations by estimates of catchability for other species would not likely increase the significance of the correlation.

4.5 Depth Preference

An initial review of the depth distribution of fish in the catch divided tows into near surface, intermediate, and deep categories. These initial categories were defined based on door depth (Table 4-6). As more data from the trawl monitoring equipment was collected and analyzed, the relationship between door depth, warp length, and headline depth became clearer. Once headline and bottomline depth estimates were available for all tows, a mid-tow depth was calculated based on the average of headline and bottomline depths over the tow. This more accurate depth estimate was then used to define depth intervals that better reflected the depth interval fished. In some tows the headline depth was considerably deeper than the door depth, and as a result some tows changed depth category. Overall, net opening generally ranged between 8 and 12 m, and a single deep tow was made at a maximum headline depth of 65.9 m.

Table 4-6: Number of Tows by Depth Interval Based on Door Depth or Mid-Tow Depth

	Based on Door Depth		Based on Mid-Tow Depth[1]	
Depth Interval	Range (m)	Number of Tows	Range (m)	Number of Tows
Surface	0-2.9	18	0-13.9	19
Intermediate	3-17.9	59	14-19.9	42
Deep	18-33.8	14	20-56.3	26

[1]Mid-Depth refers to the average of headline and bottomline depths over the tow. Tows without catch were removed from the mid-tow depth calculations.

Initial review of the catch by depth interval suggested that most fish were caught at intermediate depths, with an average of 219.8 herring/tow caught compared to 81.6 herring/tow at the surface or 137.8 herring/tow in deep water. Catch was converted to biomass based on length and the depth distribution re-examined using intervals based on Mid-Tow depths. Tows prior to July 21 were excluded from the analysis because high catches of herring on July 12, when only intermediate depths were fished, weighted the comparison heavily in favour of high catches at intermediate depths.

Figure 4-11 illustrates the average catch per tow expressed as biomass for herring and all species combined for all tows after July 12. This comparison indicates that average catch of herring and all species combined was highest in the near surface interval. The catch of herring versus all species was most different at the deep interval, indicating depth preferences likely varied by species.

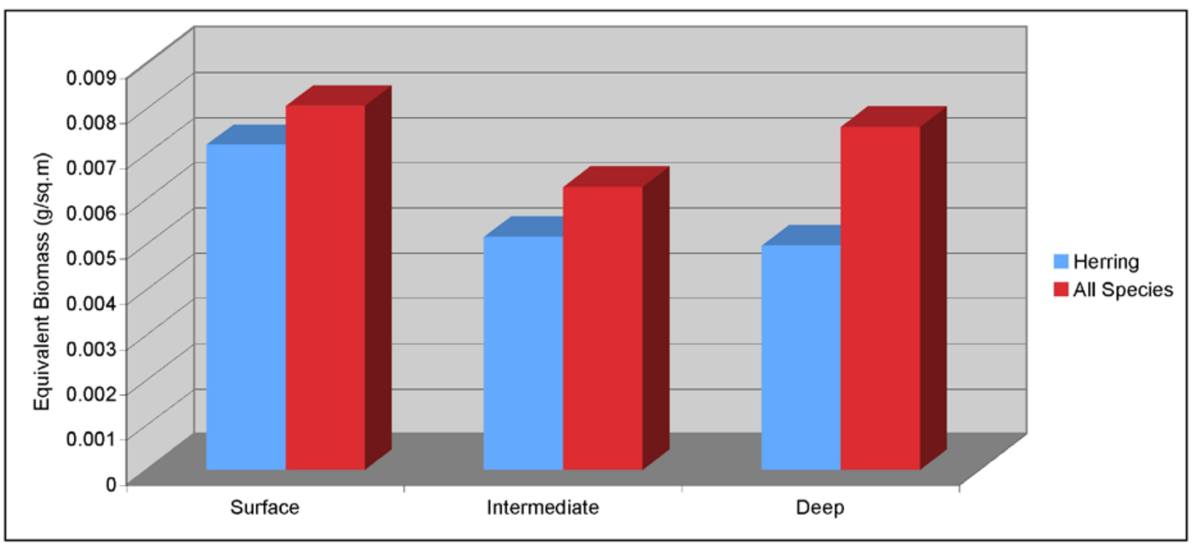

Figure 4-11: Average Biomass per Tow by Depth Category for Herring and All Species

Note that tows prior to July 21 with high numbers of herring were excluded from this analysis to avoid a heavy bias to herring at intermediate depths.

Figure 4-12 illustrates the average relative catch per tow in terms of biomass for each of the three depth intervals. Herring and mackerel had the most similar profile by depth interval, with relatively even catch by biomass at all depths fished. Dollar fish, smelt and lumpfish were caught more at intermediate depths than near surface or deep, but gaspereau showed a definite preference for deeper water (Figure 4-12).

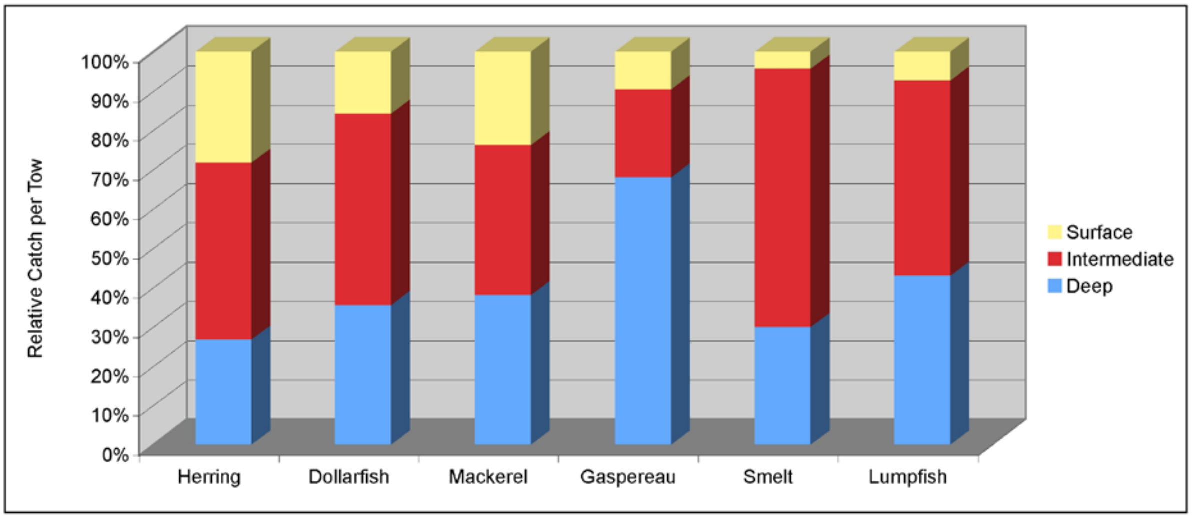

Figure 4-12: Relative Catch per Tow by Depth Interval for Selected Species

Once headline and bottomline depths were estimated for all tows to extract comparable acoustic data, individual correlations between catch of different species and mid-tow[10] depth could be tested statistically. In addition, the distribution of tows across water depths could be compared spatially (Figure 4-13). The data used to construct Figure 4-13 comes from the acoustic system and reflects the changing depths along each tow. The deep-water mid-line was used to delineate the deep-water, central trough and to divide the Minas Channel into deep central, northern and southern sections.

[10] Mid-tow depth refers to the mean depth below the water's surface when all positions for the headline and bottomline are averaged to determine a single mean depth for the tow – usually two depths for the headline and bottomline were used.

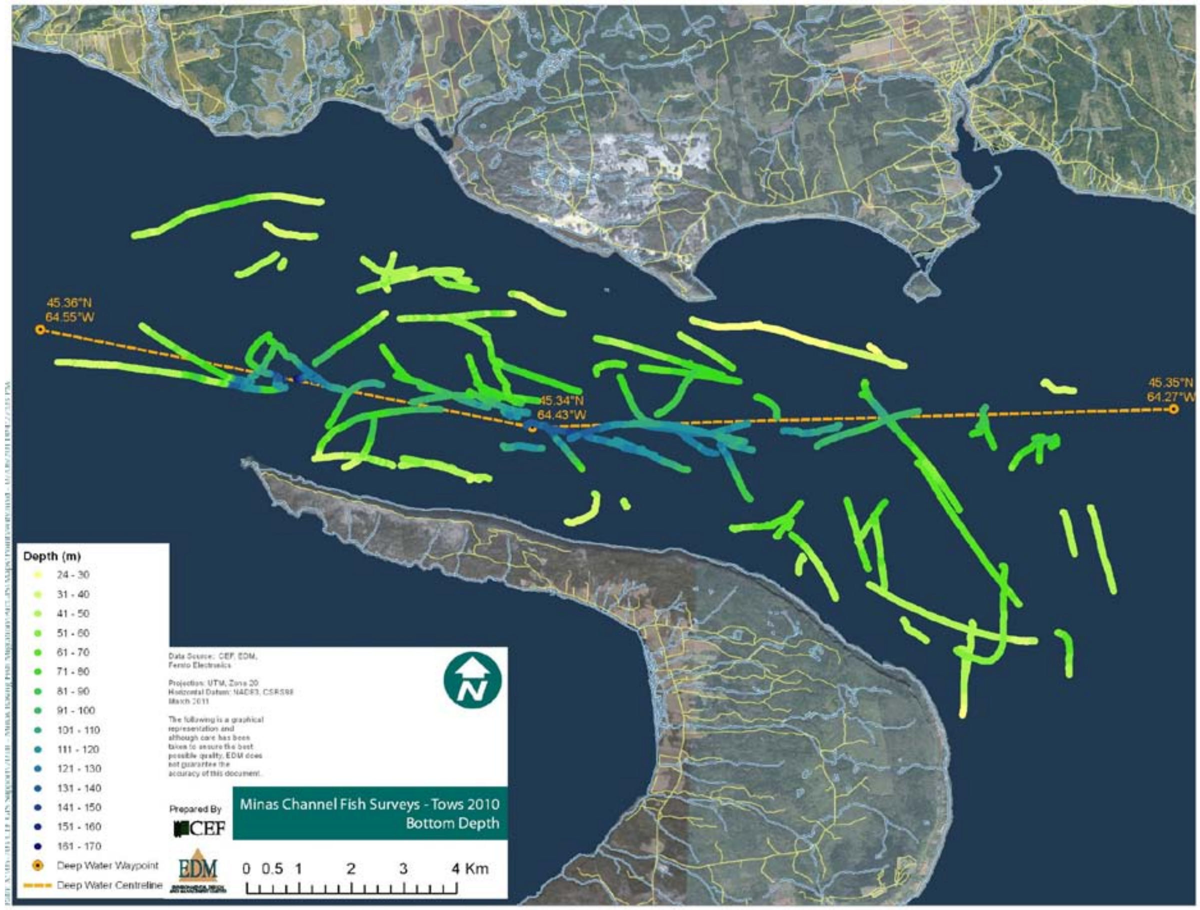

Figure 4-13: Water Depths Along Tows Conducted from July to October, 2010

Using the calculated biomass derived from target strength calculations, no correlation was found between mid-tow depth and catch of herring, dollarfish, mackerel, and smelt, but a significant ($p<0.0001$, $n=42$) correlation was found between gaspereau catch and mid-tow depth (Figure 4-14), supporting that gaspereau had the greatest tendency to be caught in deeper water than other commonly caught species.

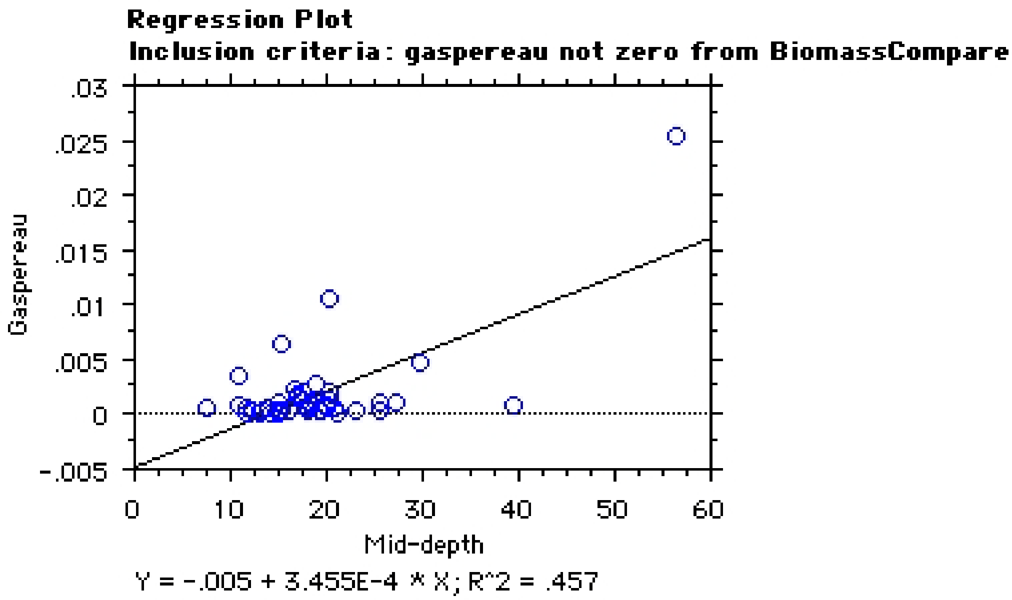

Figure 4-14: Correlation Between Mid-tow Depth and Gaspereau Calculated Biomass

As Figure 4-14 indicates, the positive correlation between gaspereau biomass and depth from the surface is largely attributable to a single data point, which corresponds to Tow 2 on September 16 at a mid-depth of 56.3 m and a calculated biomass of 0.025 g/m^2. This tow represents the biggest proportion of larger gaspereau caught during all surveys (23 of 33 fish larger than 21 cm in length). If this one tow is removed from the analysis, no significant (p=0.489) correlation with depth remains. It is possible that adult gaspereau prefer deeper water to juvenile gaspereau but insufficient information is available to draw statistically valid conclusions.

4.6 Influence of Light Conditions

The survey vessel was equipped with lights for working at night, but the majority of tows were made during daylight (Table 4-7). There was a tendency to run acoustic transects at night and trawl during daylight for two reasons: deck work in daylight was easier and safer; and, some species of fish move up off bottom at night making them more detectable by hydroacoustics. An effort was made to also collect tow data at night to detect species differences in catch in response to light conditions. As Table 4-7 indicates, a higher proportion of acoustic transect data was collected at night and a great proportion of trawls were conducted during the day.

Table 4-7: Light Condition During Tows and Transect Surveys

Time of Day	Number of Tows	Transect Observations*
Day	61	162
Morning Twilight	4	82
Evening Twilight	6	40
Night	20	847

*Observations are the number of samples in a 10% random sample of transect points, but reflect the general distribution of sampling effort

Catch of all species caught on a consistent basis in the midwater trawl were higher during daylight than at night. Visual cues from the doors and bridles help herd the fish into the net, and these cues are more effective in daylight.

Analysis of variance was conducted to examine whether significant (p=0.05) interactions occurred between trawl catch and light conditions for the commonly caught species. The light conditions evaluated were represented by three conditions: nautical twilight, day, and night. Only the catch of mackerel was found to be significantly related to light conditions (p=0.021) when twilights were combined to a single light category (Figure 4-15). The catch of mackerel is known to be influenced by light, with catch reduced at night when mackerel are more dispersed (Deroba 2009).

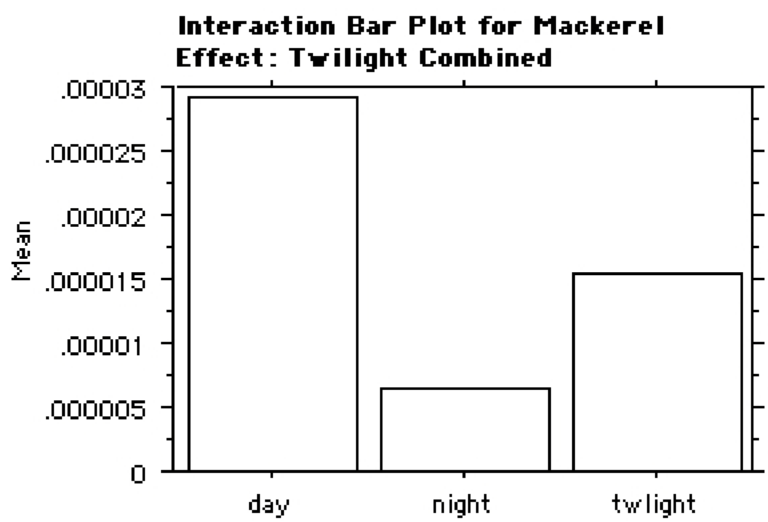

Figure 4-15: Average Catch (Equivalent Biomass) of Mackerel by Time of Day

Potential differences in depth distribution of dollar fish were examined with respect to time of day because the numbers were higher in both day and night than other commonly-caught species. The larger proportion of the catch at the surface at night suggests dollar fish move up in the water column at night (Figure 4-16). Only one deep tow was conducted at night and no dollar fish were caught.

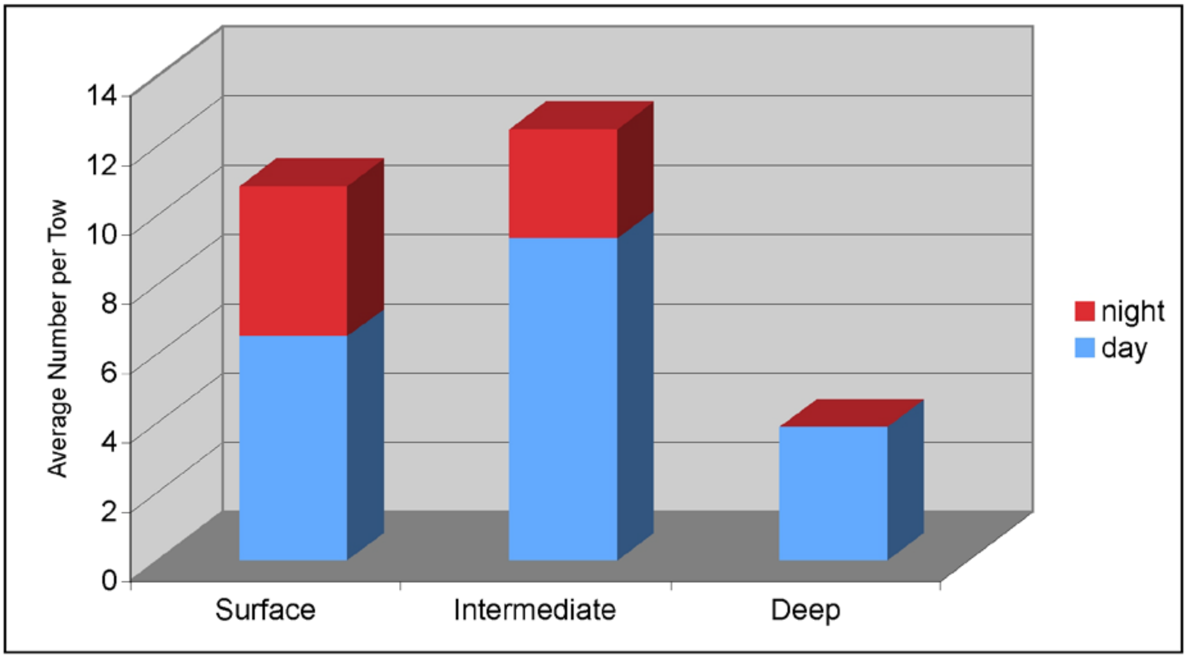

Figure 4-16: Average Catch per Tow of Dollar Fish by Depth and Time of Day

The catch of dollarfish was examined using analysis of variance with light and depth interval as factors (Table 4-8). No effect of light, depth interval or covariance of light and depth was found to be significant.

Table 4-8: Analysis of Variance for Dollarfish Biomass by Light and Depth

Factor	df	Sum of Squares	Mean Square	F-Value	P-Value
Light	2	1.620×10^{-6}	8.102×10^{-7}	0.424	0.6557
Depth	2	7.313×10^{-7}	3.657×10^{-7}	0.191	0.8261
Covariance	4	1.444×10^{-6}	3.609×10^{-7}	0.189	0.9435
	83	1.585×10^{-4}	1.910×10^{-6}		

4.7 Influence of Tidal Conditions

Tidal conditions were defined as categories of falling, rising or slack according to tide predictions for Hantsport, Nova Scotia. Slack conditions were considered to occur an hour before or after low or high tide. Falling or rising tides were considered to be extreme when high tides were 14 m or greater or low tides were less than 1 m. The number of observations by tidal condition for acoustic transects and tows are indicated in Table 4-9.

Table 4-9: Tidal Condition During Tows and Transect Surveys

Tidal Conditions	Number of Tows	Transect Observations*
Falling	23	264
Rising	31	270
Falling - extreme	6	38
Rising - extreme	2	97
Slack high	5	286
Slack low	22	176

*Observations are the number of samples in a 10% random sample of transect points

Effect of tidal conditions on acoustic transect biomass densities is small – not significant within the 1-14.9 m interval ($p=0.186$), but significant within the 15-29.9 m ($p<0.0001$) and 30-44.9 m intervals ($p<0.0001$). Examination of the relationship between tide and biomass indicated a reduced biomass at extreme tides was primarily responsible for the significance of the relationship. Overall, the small effect of tide on estimates of biomass supports that the acoustic data is of good quality, since turbulence would be expected to be greater during periods of flood or ebb tide, or especially extreme tides.

The effect of tides on transect data was also carried out by examining the biomass estimates within the 15 m closest to the bottom. Since many species of fish are known to exhibit diel behaviour and rise up off the bottom at night, a strong relationship would be expected between light conditions and near bottom biomass. The potential impact of turbulence would also be expected to be the least within the near bottom environment. Previous analysis had shown that separate consideration of nautical twilight from day and night did not identify useful patterns in the data, thus the simpler separation of light conditions into day and night was used for subsequent analyses. As anticipated, the strongest relationship was between near bottom biomass and light conditions when twilight and daylight conditions were merged ($p=0.0001$). Addition of tide to an ANOVA of near bottom biomass and light conditions did not result in increased explanation of variation.

The relationship between tidal conditions and catch was also examined. Using ANOVA, a significant relationship was found between tidal condition and biomass of overall catch ($p=.0093$), and catch of herring ($p=0.0086$), dollarfish ($p=0.001$) and smelt ($p<0.0001$). When this relationship was examined, it was found that two tows conducted during extreme rising tides were entirely responsible for the perceived relationship. Since no other similar trends were observed in the data, these two points were considered likely outliers.

5 CONCLUSIONS

Fish surveys conducted in Minas Channel in 2010 by the Carmelle #2 involved the application of standard technology (i.e., a midwater trawl and hydroacoustic data acquisition system) in an unusual setting. Commercial fishing is uncommon in the Channel because of the extreme tidal currents. Herring seiners fish primarily in Scott’s Bay, west of the Channel, but do follow schools of herring into the Channel and fish when currents allow. To sample fish distributions that might interact with TISEC devices within the demonstration area, it was important to be able to sample under all tide conditions and water depths. The midwater trawl gear used proved able to fish under the range of extreme currents and eddies present and catch a representative sample of most fish species present at various depths. However, shad, a common surface water species in the area, was distinctly under represented in the samples.

The Marport trawl monitoring equipment showed that the net was maintained in appropriate fishing configuration under a wide range of currents. At the same time, it is important to understand that the net cannot be maintained in a specific position or along a specific course. Two tows carried out in succession will likely follow different paths because of the constant variation in currents. Although it took time to get all components of the Marport system working, no serious data deficiencies resulted from early problems primarily with the headline transponder.

Potential catch of Atlantic salmon was a special concern associated with sampling fish in the Channel. The Inner Bay of Fundy stock of Atlantic salmon is listed as *Endangered* and protected under the Canadian Species At Risk Act (SARA). Measures were taken to avoid capture of Atlantic salmon, such as adopting a 20-minute tow duration, and none were caught in any of the 2010 surveys.

5.1 Agreement Between Acoustic and Catch Data

Acoustic surveys were successful in that they documented seasonal changes in temporal and spatial distributions of fish density throughout the water column. Correlation between estimated acoustic biomass and catch biomass by tow was significant ($p<0.05$), but was clearly reduced by a few exceptional values. Differences between tow and acoustic biomass (Figure 5-1) could be due to difficulty of targeting by the trawl where herring are most concentrated, differences in sampling volume, or possibly variation in the ability of the acoustic biomass estimator to reflect the true densities of herring.

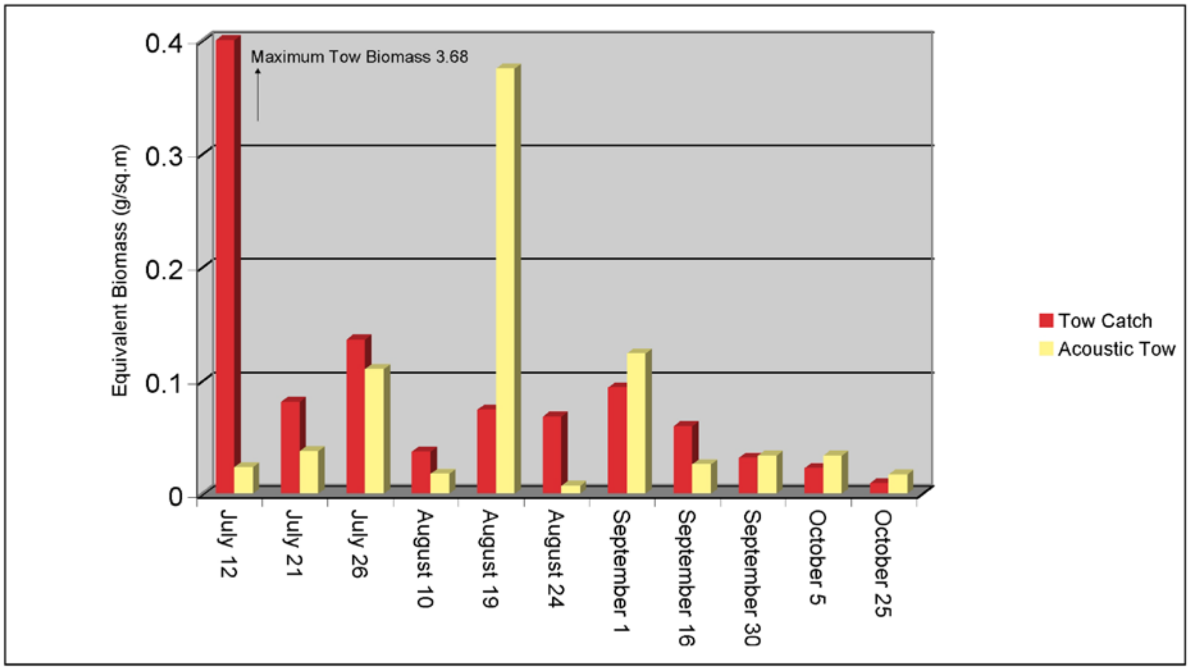

Figure 5-1: Comparison of Biomass Estimates from Catch and Acoustic Observations Along Tow Path

A large catch of herring on July 12 coincided with a relatively low biomass estimate from the concurrent acoustic backscatter. The difference in biomass estimates can be explained by the schooling nature of the species and the difference in sampling volumes between the net and the sonar – the net has a much larger sampling volume.

On the other hand, the concurrent acoustic estimate of biomass was unusually high on August 19. Two of the ten tows conducted during the August 19 survey had high concurrent estimates of acoustic biomass, which did not translate into similarly high catch. Examination of the acoustic record for these tows showed what appeared to be a number of small compact schools and no influence of turbulence. The discrepancy between the estimates of biomass from the concurrent acoustic sampling and the net catch may well be due to the fluctuations in the path of the net caused by strong shifting currents – the net does not stay in consistent position behind the vessel.

Further analysis of acoustic data, especially the data collected concurrently with tows, could be examined to evaluate target strength estimates for key species. Individual acoustic targets could be isolated and examined in more detail in an effort to associate acoustic targets with specific components of the catch.

Figure 5-2 illustrates a similar comparison of biomass between the overall acoustic transects and the tow catch of all species. The relationship illustrated supports a general correlation between acoustic and catch data and the conversions used to estimate equivalent biomass (g/m^2).

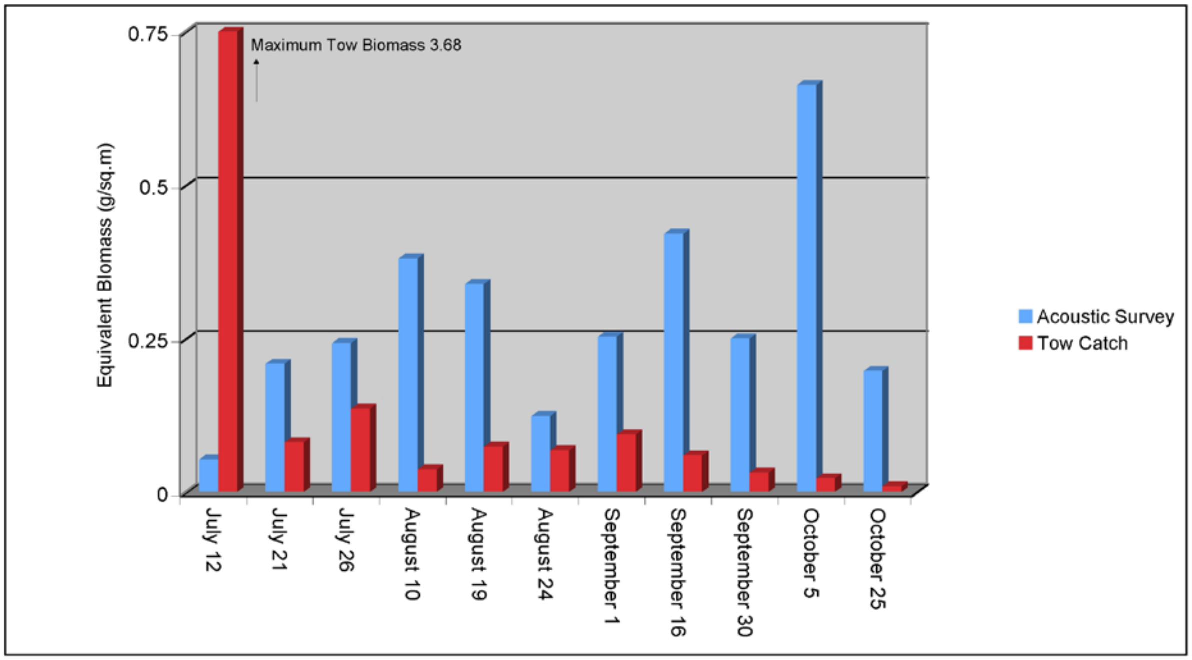

Figure 5-2: Comparison of Biomass Estimates from Catch of All Species and Acoustic Transect Surveys

5.2 Overall Trends in Abundance

Figure 5-3 illustrates the overall trend in estimates of biomass over the year in Minas Channel from all 2010 survey data. In Figure 5-3, the larger transect biomass numbers from the April and May 2010 surveys as described in Section 1.4 were used. For June, the average biomass between day and night transects as described in Section 3.3 was used. The remaining biomass numbers are based on the average survey biomass from on a 10% sample of the area surveyed, the same dataset used in most analyses conducted.

The major components of the biomass appear to be adult herring moving into the channel in June, followed by young herring in later July and August, gaspereau in September and a broader mix of species leaving the upper Bay of Fundy in October.

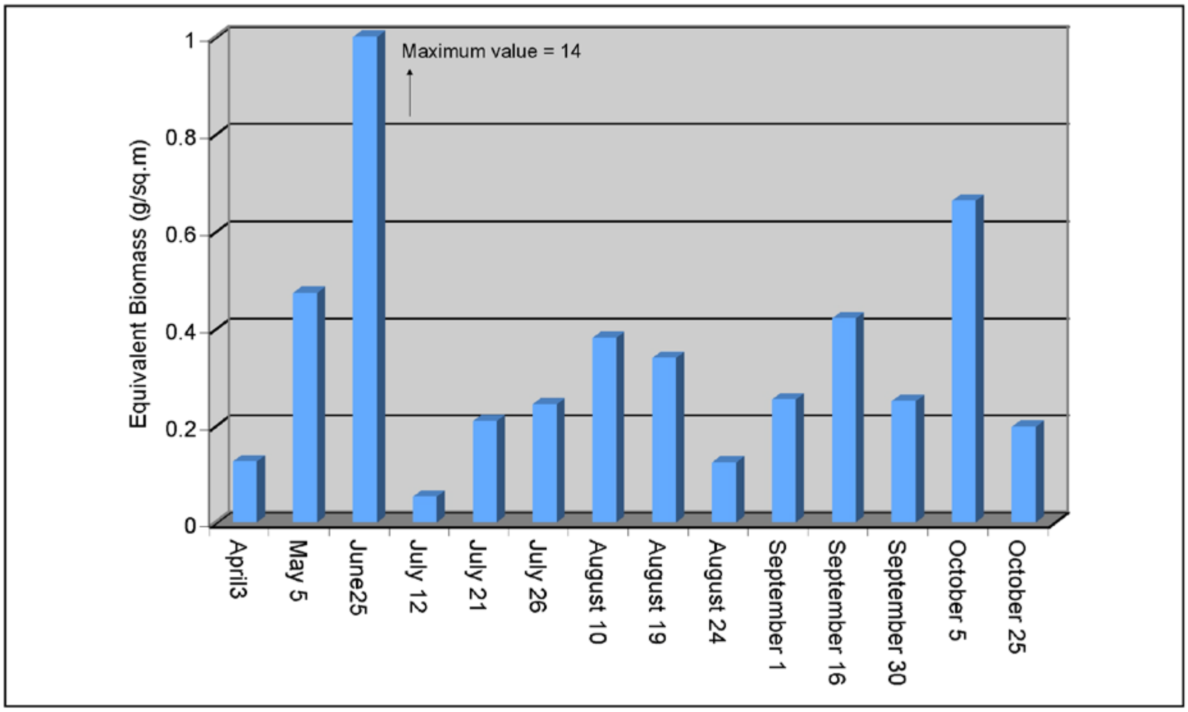

Figure 5-3: Estimation of Acoustic Biomass in Minas Basin from All 2010 Surveys

5.3 Spatial Distributions

Overall, the combined tow and acoustic transect data support some key findings with regard to spatial distributions. Overall biomass is distributed relatively evenly across Minas Channel, but specific species preferences exist. Depth preferences for some species, particularly gaspereau, affect where they are most common. Gaspereau showed a preference for deeper water and were located in the central, deep-water trough more often than other species. Dollarfish were found least often in the same area. The differences in variation of biomass for these two species, however, were not statistically significant ($p=0.311$).

Observations during the surveys left the impression that more fish (i.e., acoustic targets) tended to be observed in the central, deep trough running through Minas Basin. However, analysis indicated that spatial, seasonal or species differences were relatively small and did not support significant differences between the central trough and other areas in the statistical tests conducted.

The tidal power lease area had biomass densities similar to other parts of Minas Channel and was not found to be a migration route for any specific species. A clear increase in biomass with depth from the surface was not statistically significant ($p>0.05$) for any species, but some trends were observed with dollar fish and smelt caught more frequently at intermediate depths from the surface and adult gaspereau at deeper depths. Bathymetry no doubt has some effect on vertical distributions of fish as well, but water depth also restricted the maximum depth of fishing and thus limited our ability to detect deeper depth/biomass relationships.

As noted, sampling in nearshore areas was complicated by the presence of lobster buoys that could tangle with towed fishing gear. A higher perceived density of fish in and near the central deep water trough frequently triggered the start of a tow to sample species, however, the tow did not necessarily remain within 750 m of this deep-water feature. When the tow tracks and associated catch was examined spatially, a higher density in this deep-water area could not be confirmed. In addition, no indication of a near shoreline preference for movements in or out of the Minas Channel was detected in the surveys. The overall impression from variations in catch is that most fish distributions are randomized to some degree by the strong currents and eddies within Minas Channel.

It would be helpful to work with lobster fishermen to outline areas where midwater trawling could occur near shore without potential interaction with lobster gear. Potential fishing areas would need to be relatively large (e.g., one km square) because the path of the trawl can only be controlled within broad parameters.

5.4 Tides, Currents and Wind

Wind and currents can produce turbulence that reduces the quality of the acoustic data collected. Experience with weather in Minas Channel and the factors causing turbulence suggests that weather forecasts are not good predictors of turbulence and thus not reliable to adjust the work schedule. This is further complicated by the requirement to leave the wharf at high tide relatively far from the work area. Working in the Cape Split area during slack tide appeared to be the most predicable way to minimize the effect of turbulence on this type of acoustic data collection.

Fish normally associated with the ocean bottom habitat, for example summer flounder, were sometimes caught well off bottom. The high currents in the Channel may mix fish in ways not typical of other ocean areas.

Because of the travel time required to reach the survey area and the requirement to leave port over a relatively narrow window of high tide, it is difficult to schedule surveys with regard to weather. Review of the acoustic data did not identify concerns associated with turbulence. Perhaps the most promising support that the acoustic data are relatively free from effects of turbulence is the clear differences between day and night and the much stronger statistical correlations of acoustic biomass with light conditions than with tide. However, considerable turbulence was frequently encountered near Cape Split and sometimes throughout much of the channel.

5.5 Day and Night Comparisons

Overall, light conditions had substantially more influence on catch size and composition than did tidal conditions. The catch of mackerel was significantly correlated with light, as anticipated from the literature. Including twilight conditions with day generally improved the correlation between light conditions and catch. Even then, however, overall biomass estimates were not significantly different between day and night transects.

Consistent differences in vertical distribution between day and night were observed in the acoustic system with some fish moving up in the water column at night. This would suggest fish would be more concentrated and result in larger catch rates at night. However, higher catches per tow were noted on average during the daytime. Higher catch rates in daylight could indicate the net operates more efficiently when fish can respond to visual cues. For some species, fish may rise higher in the water column at night than the midwater gear was able to fish.

In a few instances a large number of targets were observed near bottom at night, but these could not be sampled with the midwater gear available. Acoustic biomass in the near bottom layer (to 15 m from the seabed) was significantly different between day and night ($p=0.0001$).

5.6 Trawl Performance

The midwater trawl and survey vessel worked well under difficult fishing conditions. The net was able to catch what appears to be a representative sample of species and size ranges regardless of tide stage and current speed. The high currents largely controlled the direction of tow, sometimes in hard to predict ways. For example, in more than one instance currents near the Blomidon shore pushed the vessel directly towards shore even though the tow was being made parallel to shore and in the opposite direction to the main tidal flow.

The Marport system operation was gradually improved throughout the surveys. By mid-September generally complete information on headline depth and net opening was being received reliably. The Vemco depth recorder provided good post survey comparison information.

A flow meter was installed for the last survey but consistent information was not obtained. Further experimentation with a housing for the flow meter and attachment to the net will be required. RPM, reflective of engine horsepower, currently provides the most useful indicator of flow through the net.

Trawl speed and duration has an influence on how effective a trawl is in relation to specific species and fish size – generally larger fish can swim faster and a longer duration of tow will catch more, larger fish. Trawl duration was varied during one early survey and not found to result in much change in species composition. In addition, in October large striped bass and dogfish were caught, suggesting that tow duration of 20 minutes is adequate for sampling.

Coefficients to adjust catch based on length and species were examined but were considered not well-suited to the purpose of these studies. In most cases correlation between biomass and environmental variables such as tide were sufficiently low that adjustments for catchability were unlikely to result in relationships becoming significant. In cases where a significant relationship was initially found, it was most often associated with two or three data points in a particular survey, which would not be altered noticeably by adjusting for catchability.

On the other hand, comparative fishing trials between different fishing gears would be useful to better understand variations in catchability and their effect on these analyses. For example, comparative fishing between the midwater gear used in this study and drift near-surface gillnets could be helpful.

5.7 Seasonal Differences

The main seasonal change noted in catch was the decline in numbers of herring in July and the catch of large striped bass and dogfish in September and October. Surveys should start earlier in the year, at least May, to include sampling of fish migrating up the Bay of Fundy into Minas Basin.

Herring overwhelm the fish biomass in June and July and remain the dominant component of the catch throughout most of the season. The dominance of herring and the similarity of depth distributions for most species may mask differences in biomass or depth distributions of other species in acoustic backscattering summaries. For this reason, fishing may remain a primary method of obtaining information on distributions of species other than herring within Minas Channel.

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FORCE

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX I

FORCE Progress Report – Fish Tracking, 2011

Fish Tracking Study
Progress Report to FORCE – February 2011

Acoustic Tracking of Fish in the Minas Passage and at the NSPI (OpenHydro) turbine site

(extension of an OEER/OETR funded project)

Prepared by
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Summary

To examine the potential risk of fish – turbine interactions, we focused on the movements of three fish species in the Minas Passage area and near the NSPI/OpenHydro turbine in the FORCE demonstration area. Underwater acoustic telemetry receivers were deployed in the Minas Passage and in nearshore areas of the Minas Basin during July-Nov 2010 to track the movements of striped bass, Atlantic sturgeon, and American eel.

This project is an <u>extension</u> of the fish tracking project funded largely by the OEER. Funding from FORCE has allowed the tracking of an <u>additional 50 fish</u> implanted with VEMCO acoustic transmitters (Total tagged = 120 fish). All of the 50 acoustic tags funded by FORCE were implanted in striped bass, for a total of 80 striped bass tagged in May (N=43) and August (N=37). Most of the 30 tagged Atlantic sturgeon were captured, tagged and released in Minas Basin during August. Only 10 eels were captured in the Stewiacke River in early October 2010 and all of these were tagged and released.

Data from all acoustic receivers were downloaded in November. Data analysis is underway, with preliminary results for striped bass indicating very high post-surgery survival (>98%), and significant detections by receivers in the NSPI turbine berth area (31% of tagged bass) and by the OTN line of receivers stretching across the Minas Passage (66% of tagged bass).

Of the 10 eels tagged in October, three were detected as they migrated out of the Minas Basin and one of these was detected near the NSPI/OH turbine. All but 2 of the 30 tagged Atlantic sturgeon were detected, with 21 and 8 sturgeon detected by the OTN line and turbine receiver array, respectively.

Main Objectives (of the overall study, funded by both OEER and FORCE)

1) Define movement patterns (path, velocity, depth, seasonality, and number of passes) of tagged fishes passing through the NSPI (OpenHydro) turbine test area;
2) Detect dispersion and avoidance behaviour of tagged fishes moving in close proximity (< 500 m) of the NSPI (OpenHydro) turbine;
3) Assess movements of tagged fishes passing through the Minas Passage receiver line ("listening gate");
4) Collect *in situ* data to ground truth and refine the hydrodynamic models. These models can then be utilized to predict how objects moving through the water column might interact with the test turbines and, potentially, large scale commercial turbine arrays.

Tagging and Receiver Deployment

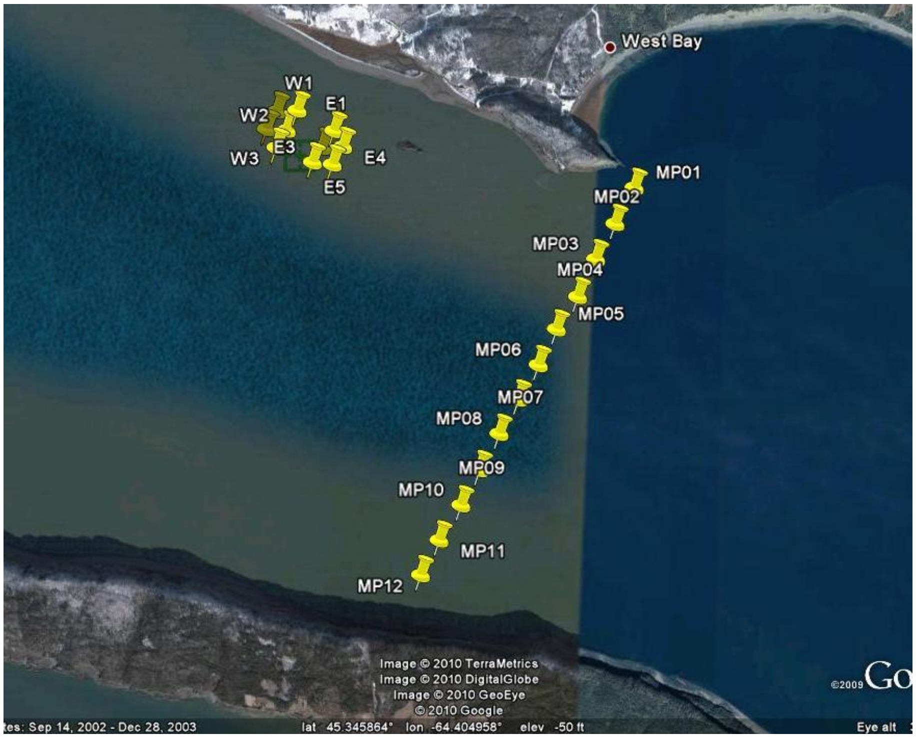
To date, 80 striped bass, 30 Atlantic sturgeon and 10 American eel have been implanted with VEMCO transmitters. Striped bass were captured through angling and tagged in two batches. The first group of large spawners (n=43, 22 males, 21 females, Mean TL: 71.1 cm) were tagged in the Stewiacke River during early May. The second group of schoolie-sized stripers (n= 37, Mean TL: 43.2cm) were tagged near the Gaspereau River mouth (Guzzle) in early August.

Atlantic sturgeon were tagged during August from shallow Minas Basin waters (Delhaven/ Cornwallis mouth area and Walton area) using a bottom trawler chartered from Delhaven. Eels were captured using fyke nets set in the Shubenacadie River near Enfield in early October.

During the summer and fall 2010, we monitored tagged fish movements using 30 receiver stations located throughout the Minas Basin and Minas Passage (see attached figures for locations and mooring units). An array of 10 acoustic receiver moorings was positioned around the turbine site on June 22, 2010. In addition, a 12 unit "listening gate" array of receivers was placed across Minas Passage on July 14 – this is a joint project between the Ocean Tracking Network and Acadia. All moored receivers within the Minas Passage were deployed using a chartered lobster fishing vessel from Parrsboro. An additional 8 receiver units were placed in intertidal sites of the Minas Basin and are part of an ongoing sturgeon tracking project at Acadia (Dadswell and Stokesbury).

One of the turbine array receiver units (deployed in June) was retrieved in August to examine wear on the unit. It was found that the unit was in excellent condition – and, after downloading of data, was redeployed. It appears that the new "compact" mooring design, which incorporates the VR2w receiver and acoustic release mechanism within the buoy bulkhead, is performing much better than the previous design. We also expect this design to improve the detection efficiency of the acoustic receiver as it will tend to tilt less.

a) Minas Passage array near OH turbine (N=10) and OTN receiver line (N=12) in 2010.



b) Minas Passage and Minas Basin receiver mooring locations in 2010.

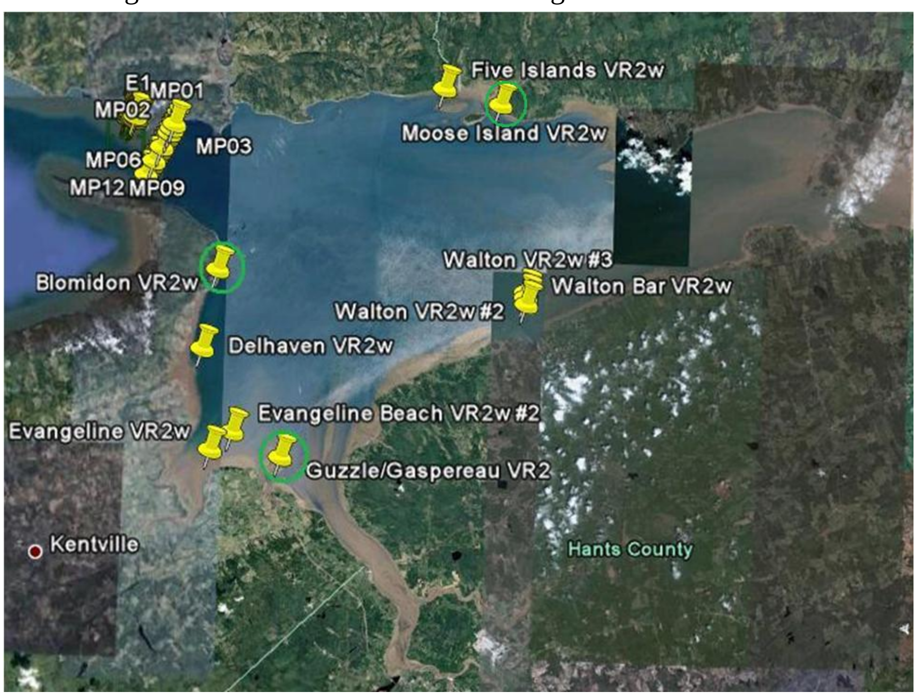


Figure 1. VEMCO receiver mooring arrays in the a) Minas Passage and b) Minas Basin.

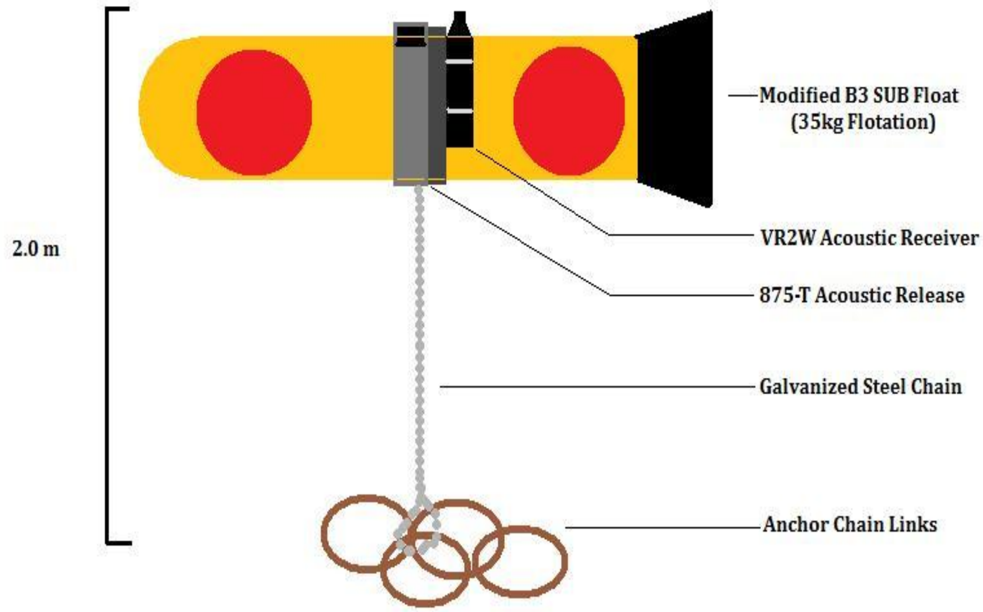


Figure 2. Mooring unit design deployed at the NSPI turbine site in June 2010 (n=10) and across the Minas Passage in July 2010 (n=12).

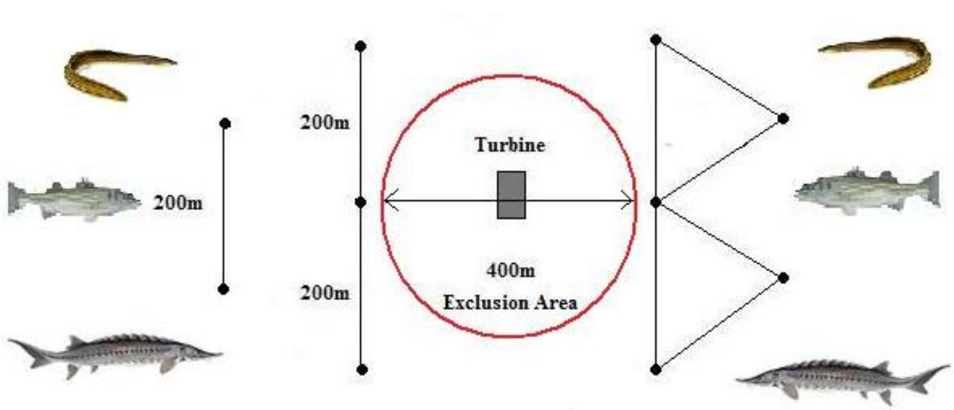


Figure 3. Diagram indicating relative position of acoustic receiver mooring units (black dots) within the array surrounding the Open Hydro turbine and 200m radius exclusion zone (red circle).

a)

Surgical implantation of VEMCO acoustic transmitters

b)

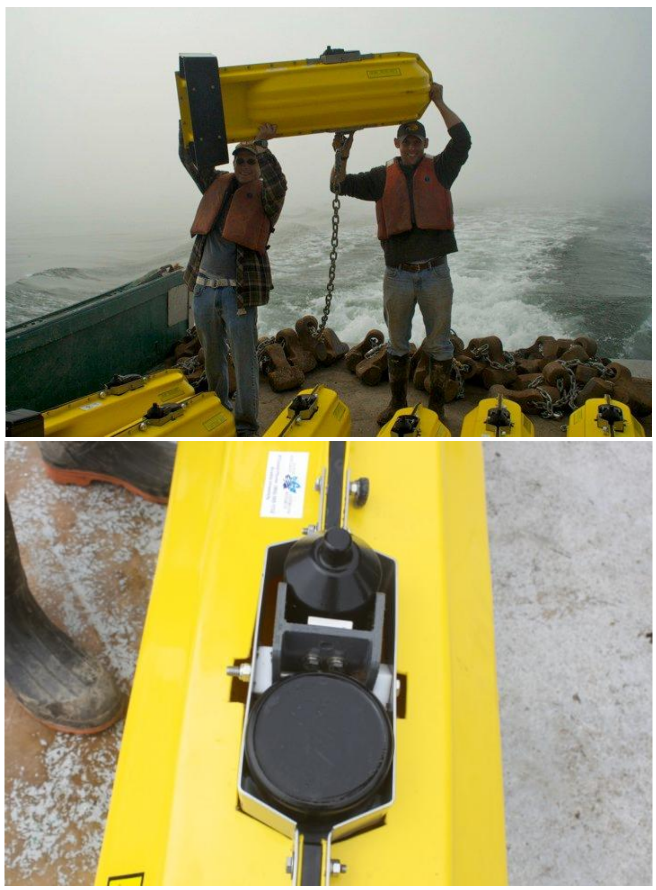


Figure 4. Photos showing a) implantation of a VEMCO acoustic transmitter in a striped bass and b) subsurface buoys with installed VEMCO receivers and acoustic releases.

Results to date

Acoustic tag detections, by species and by general location (see Figure 1), are summarized in Table 1. Ninety-two percent of all fish tagged in 2010 were detected by receivers deployed in Minas Basin and Passage (turbine receiver array and OTN receiver line). Of these, 28% were detected within 500 m of the NSPI (OpenHydro) turbine.

Table 1. Summary of fish tagged and those detected by Vemco receivers in different locations.

Species	**Month tagged**	**# Fish tagged**	**Total # detected**	**Minas Basin # detected**	**OTN line # detected**	**NSPI/OH turbine # detected**
Striped bass	May	43 adult	42 (98%)	33 (77%)	40 (93%)	21 (49%)
	Aug	37 juv.	37 (100%)	37 (100%)	12 (32%)	4 (11%)
Atlantic sturgeon	June	1	1 (100%)	1 (100%)	0	0
	Aug-Sept	29	27 (93%)	24 (83%)	21 (72%)	8 (27%)
American eel	Oct	10	3	1 (10%)	3 (30%)	1 (10%)
Total		**120**	**110 (92%)**	**96 (80%)**	**76 (63%)**	**34 (28%)**

Striped bass:
Of the 80 striped bass tagged, 79 were detected by receivers deployed in the Minas Passage (OTN line and turbine array) and Minas Basin. Post-surgery survival was excellent (at least 98%). The single undetected adult striper was tagged in May and may have been caught by one of the many recreational fishers in the Shubenacadie-Stewiacke River area.

The OTN receiver line detected 93% of all tagged adult stripers; 49% were detected by the turbine receiver array. All of the 37 tagged juvenile stripers were detected on receivers located in nearshore areas of the Minas Basin, with 32% also detected by OTN line receivers and 11% by the receiver array near the NSPI/OH turbine. Striped bass swimming depths were highly variable – near surface to > 95m within Minas Passage. Adult striped bass were detected more commonly in Minas Passage and at greater depth than juveniles, which tended to be located in the top 10 m.

Atlantic sturgeon:
Twenty-eight of the 30 sturgeons tagged were detected, with most detections occurring in the nearshore areas of the Minas Basin and while passing through the OTN receiver line. Eight sturgeon were detected by the turbine receiver array.

Ten of the 11 retrieved receivers of the OTN line detected sturgeon, with most of the detections (2/3) on those receivers located in the southern area of the Passage. Depth of detection indicates that sturgeon were moving in waters 25-35 m deep on the north side, 25-40 m deep in the central area and 30-50 m deep in the southern region of the Passage (Figure 5).

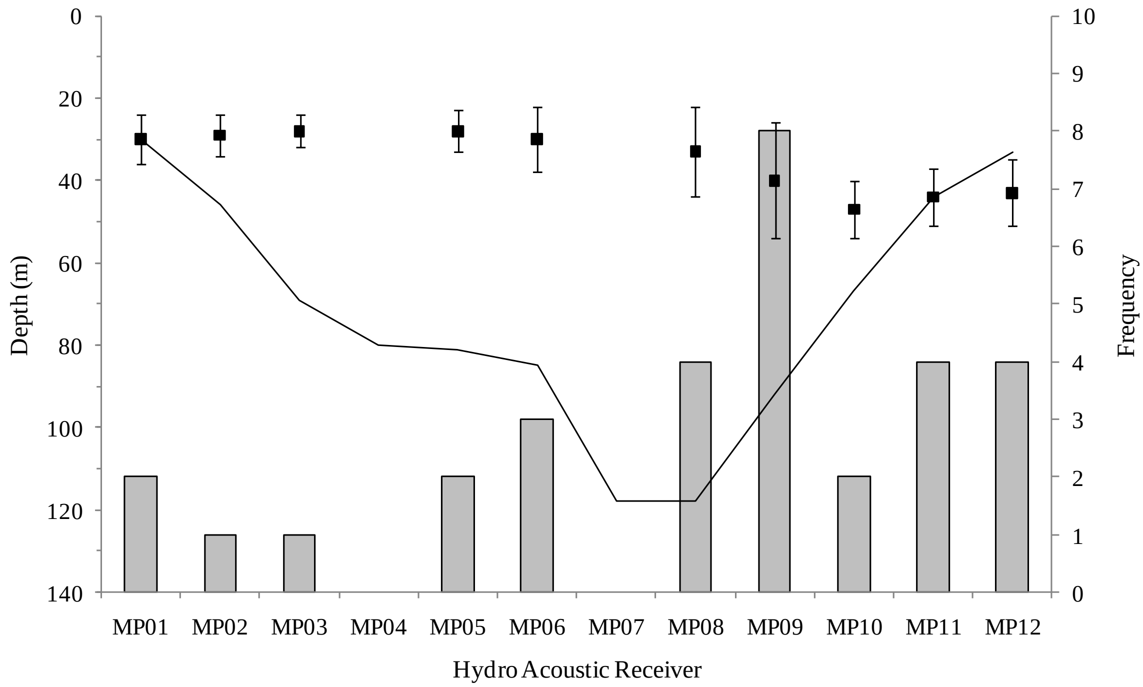


Figure 5. Bottom depth at mean water level (line; primary y-axis), depth (solid square = mean; whiskers = SD; primary y-axis), and frequency (grey bars; secondary y-axis) of Atlantic sturgeon, electronically tagged in the Minas Basin in summer 2010 moving through the Minas Passage in Autumn 2010 per hydro acoustic receivers placed approximately every 400 m spanning the Passage (MP01 = Northern most receiver; MP12 = Southernmost Receiver). Receiver MP04 was not retrieved, and receiver MP07 contained no detection information. Detections at MP12 are from sturgeon traveling closer to MP11 (From Stokesbury et al. in preparation).

American eel:

Of the 10 American eels tagged, 3 (30%) were detected in the Minas Passage 17-20 days after being tagged in the Shubenacadie River. The receivers detected eels in both shallow (< 20 m) and deep (60-100m) waters in the Minas Passage. The eels appeared to exhibit staging behavior near the bottom with travel out of the Basin occurring at lesser depths (3-20 m), a pattern similar to that documented for out-migrating American eels in Passamaquoddy Bay, NB. (Bradford et al. 2009 – AFS Symposium Proceedings).

Safety and Environment

All necessary permits were obtained and all field work was carried out as planned, without incident.

Deliverables / Reporting

Project progress and outcomes:

1. Enhancement of the OEER funded project with the tagging (VEMCO acoustic transmitters) of 50 additional fish (completed);
2. Detection of tagged fish via receivers located in arrays near the NSPI turbine, and in the Minas Passage receiver line (completed);
3. Assessment of spatial and temporal patterns in movement of tagged fish near the turbine (location, depth, speed, etc) (underway);
4. Assessment of the dispersion and avoidance behavior of tagged fish moving in close proximity to the NSPI turbine (underway);
5. Assessment of movement of tagged fish in relation to the Minas Passage receiver line. This will provide much needed information on the general movements of the three migratory species highlighted in this project (underway);

Note: The final report to the OEER is due 1 Nov 2011. As the overall project work is co-funded, the content of the final OEER and FORCE reports will be similar.

Recommendations for 2011 / 2012 (as submitted in report to OEER)

1. We recommend that fish detection and tracking in the Minas Basin and Passage be continued for the 2011 field season (Apr-Nov), especially given that all 120 fish implanted with acoustic tags in 2010 are still transmitting (sending out pings), with 79 acoustic tags remaining viable for only another 9-10 months (up to Nov 2011) before the batteries in their transmitters fully drain. The majority of the needed infrastructure for detection of tagged fish has been procured and can be re-deployed in the Passage in April with reduced cost (e.g. refitting of sub-buoy units and mooring weights) and with reduced effort, given that the project team have now gained considerable expertise with deployments in the Minas Passage. An additional year of funding would allow the best use of existing field equipment, fish already tagged (and transmitting signals) and research expertise of the team. It would also allow much needed tracking of fish movements during the spring and early summer period as the 2010 data covers July-Nov only. The coming field season (starting in April when many fish move back through the Passage into the Minas Basin) provides an opportunity to assess how tagged fish naturally use the area so that a suitable baseline, covering a full season, can be established.

2. Due to the harsh nature of the Minas Passage, instrumentation housed in moorings like those in the current study should be retrieved after about 4-5 months of deployment, checked for wear and tear, data downloaded and batteries replaced. After equipment maintenance and refitting, as needed, we recommend redeployment for another 4-5 months, preferably not during winter.

3. Our data on how tagged demersal and pelagic fish use the Minas Passage includes depth preferences, movements through the Passage, seasonality and tidal effects on movement. When analysis is complete, this information will be of much interest to the science and regulatory branches of DFO and will be of value to FORCE's Environmental Monitoring Advisory Committee. We recommend that device and project developers consider our results in future deployments and designs for "fish friendly" in-stream turbine infrastructure.

4. There is much public concern over the risk of fish-turbine interactions. This project will provide scientifically defensible data to help address some aspects of these sensitive issues. Unfortunately, our project can not address the behavior of fish relative to the operation of a turbine as it is now clear that the Open Hydro turbine became nonfunctional (blades broken off) prior to the deployment of our receivers. However, our study does provide much needed baseline information on "natural" patterns of fish movement in the Minas Passage.

FORCE

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX J

Side Scan Sonar Survey Final Monitoring Report

Environmental Monitoring of Seabed Sediment Stability, Transport and Benthic Habitat at the Reference Site and the Vicinity of the NSPI TISEC Location in the Minas Passage

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Executive Summary

As part of a monitoring plan for the FORCE in stream tidal power demonstration site, surveys were conducted at the pre determined Reference Site and the location of the Nova Scotia Power Inc/Open Hydro test deployment site in the northern region of Minas Passage, Bay of Fundy. Surveys were undertaken by Seaforth Engineering using a towed sidescan sonar system as well as towed video camera. The sonograms were processed and sidescan sonar mosaics were produced. This information was interpreted, compared and contrasted with previously collected multibeam bathymetry and derived backscatter and slope imagery, as well as sidescan sonograms to determined both natural change and possible effects of the turbine placement, operation and removal over a one year time frame.

The reference site showed no detectable seabed change since the original data was collected over 5 years ago. The seabed is dominantly exposed bedrock ridges with intervening flat regions of gravel with boulders. The turbine site showed a minor change to the seabed. Two of the gravity platform feet appear to have eroded small depressions on the seabed within volcanic bedrock approximately 1 m in diameter. The turbine was placed on a very hard exposed broad basalt platform with minor regions of gravel with boulders. No other changes in the morphology or gravel distributions of the seabed were detected and no fine grained sediments occur both in the nearfield and farfield. The turbine base produced only a minimal effect on the seabed.

Introduction

As part of the requirements for the development of an in stream tidal power test facility in Minas Passage, an Environment Effects Monitoring Program has been developed to assess the effects of the devices and cables on seabed sediment, stability and benthic habitat. This report is part of that plan and concerns two sites: a chosen Reference Site, herein referred to as RS, and the site of the December 2010 retrieved Nova Scotia Power Inc./Open Hydro turbine, referred to as NSPI/OH1. Seaforth Geosurveys Inc. (2011) conducted a field survey of the sites using high resolution sidescan sonar systems and towed video camera.

This report describes the original characteristics of the sites and changes in water depth, sediment type, distribution, scour, sediment erosion and transport and biological communities. The assessment of change at the reference site is intended to provide control information for comparison with the effects of the individual devices on the seabed and associated benthic communities. It will also provide an understanding of longer term natural changes to the seabed and sediment distributions of the region. This is the first time that a detailed assessment of the seabed at the RS has been undertaken.

This report provides a background regional overview of the Minas Passage bedrock and surficial geology and seabed processes, and specifically describes the seabed conditions of the Reference Site and the site of the first turbine deployment of Nova Scotia Power Inc. /Open Hydro. It draws from documents provided to the overall project Environmental Assessment, legacy published reports in the literature, data collected as part of the initial selection of the demonstration sites, and more recently, sidescan sonograms and towed bottom video specifically collected as part of this monitoring study.

Figure 1 shows the location of the study area in Minas Passage, Bay of Fundy, the location of the Crown Lease Area (CLA) south of Ram Head where the demonstration project will take place, and the regional bathymetry of the area taken from a Canadian Hydrographic Service Chart. Figure 2 shows the location of the CLA with the three test sites identified (A, B and C) as well as the RS to the west of the CLA and the NSPI/OH1 site within the CLA. A new test site D, to the south east of Site A in the Crown Lease Area has recently been established. Figure 3 is a multibeam bathymetric map of the area showing the CLA, the device berths, the RS and OH1. Chart datum for the study was LLWLT and the elevations were determined using RTK. The Nova Scotia Monument # 215028 was the reference point. The separation between geodetic elevation and chart datum is 6.59 m.

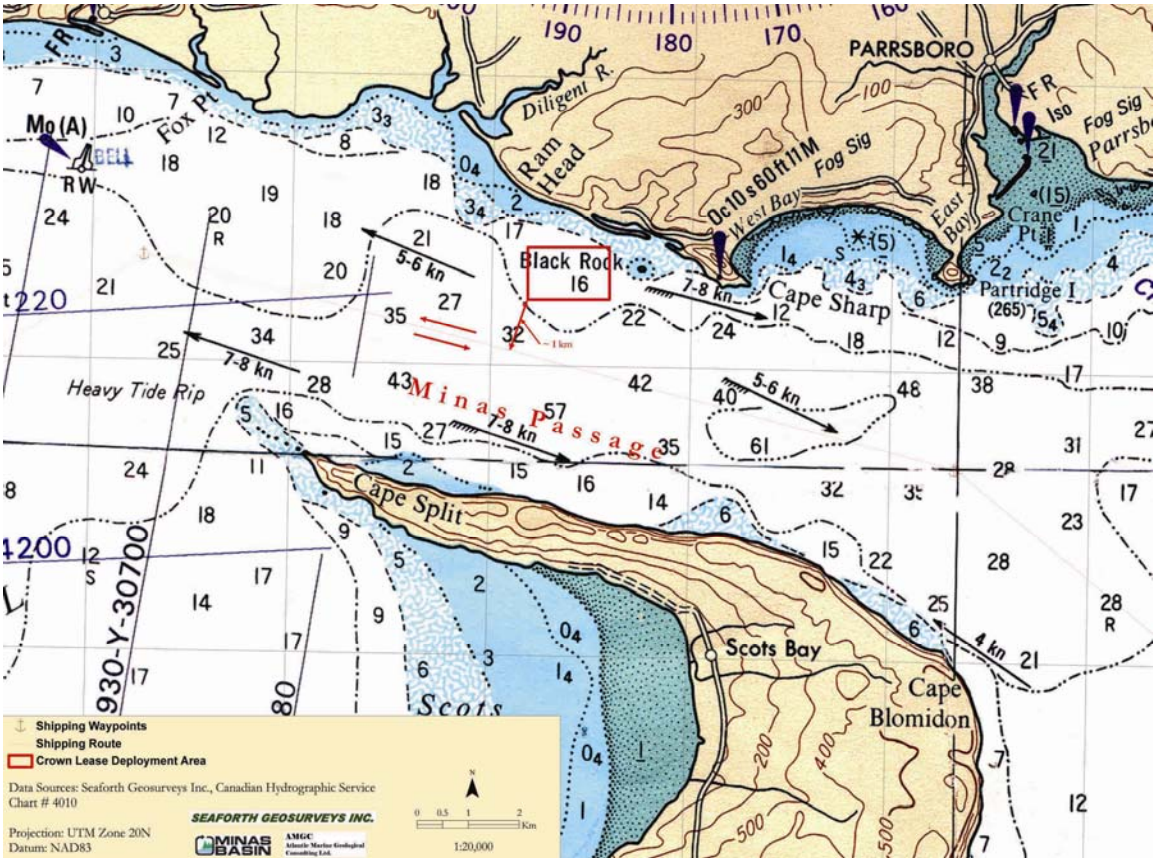

Figure 1 A section of Canadian Hydrographic Chart 4010 of Minas Passage, inner Bay of Fundy. The TISEC demonstration Crown Lease Area lies in the northern part of Minas Passage (red box).

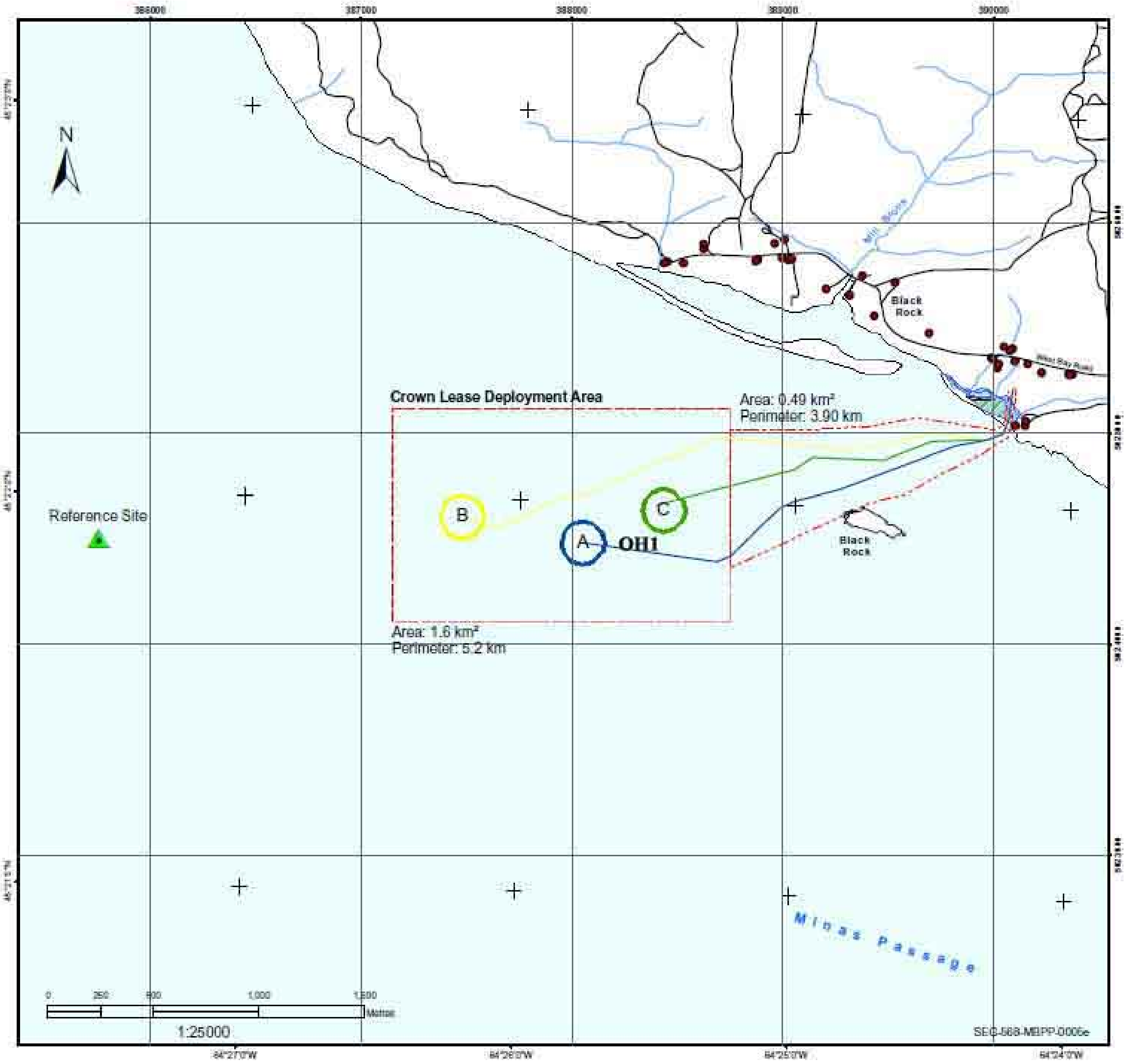

Figure 2 Map of the Crown Lease Area (red dashed box) with the three designated berths (A,B,C), the location of NSPI/OH1(OH1) and the Reference Site (RS) (green triangle) to the west. A new berth has been chosen to the south of C, termed D.

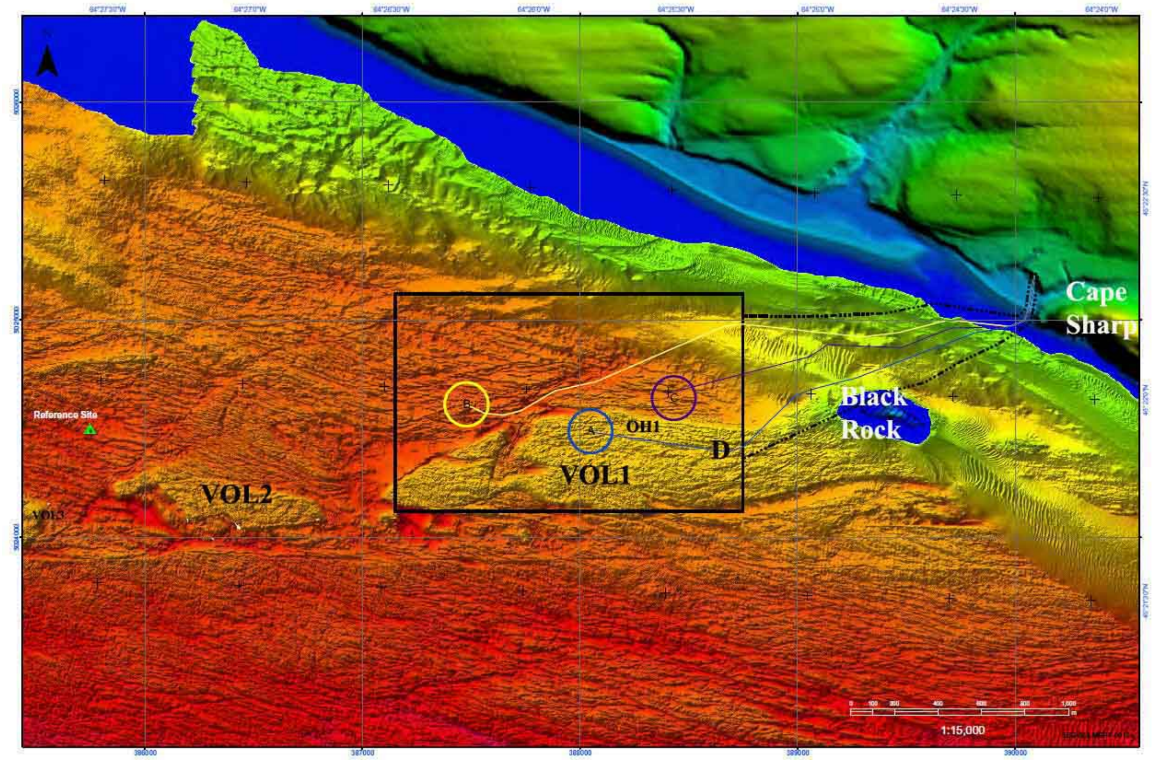

Figure 3 Multibeam bathymetric shaded-relief image of Minas Passage from data collected by the Geological Survey of Canada and the Canadian Hydrographic Service. Superimposed on the map is the Crown Lease Area (black box), the three original test berths, the new berth D, the location of NSPI/OH1, the Reference Site, and the three volcanic platforms of the region.

The RS was chosen to the west of the CLA, position 45 21' 53"N, 64 27' 32"W. The pre existing data base for the RS is different than that for the location of the NSPI/OH1 site. The position of the NSPI/OH1 is 45 21.897 N, 64 25.576 W. The CLA was studied in more detail and has several generations of multibeam bathymetry and sidescan sonar collected over the area. The RS multibeam bathymetry is of lower resolution (2 m) and was collected by the Geological Survey of Canada and the Canadian Hydrographic Service and provided to the project. Previously collected sidescan sonar imagery only exists for the OH1 site.

In order to keep survey costs to a minimum and to obtain the best assessment of seabed change, it was decided for the monitoring surveys to concentrate on the collection and interpretation of high resolution sidescan data as an indicator of change and not collect multibeam bathymetry. The resolution of the sidescan sonograms is approximately 0.25 m, whereas the multibeam bathymetry has a resolution of 0.5 m. Dropped still bottom camera studies were not undertaken, but bottom towed video was collected during the monitoring survey and has been interpreted as ground truth information. Multibeam bathymetry for both sites has been processed for bathymetric contours, seabed slope and backscatter and these results will be presented and discussed.

Regional Physiography, Geography and Bathymetry of Minas Passage

Physiography

The location of the tidal power demonstration facility falls within one major physiographic province of eastern Canada known as the Appalachian Region. Within the Appalachian Region there are two physiographic divisions: the Atlantic Uplands and the Carboniferous-Triassic Lowlands (Williams et al, 1972). The tidal power demonstration site (Minas Passage) falls within the Carboniferous- Triassic Lowlands that is so named because it is underlain largely by rocks of Carboniferous and Triassic age.

Minas Passage

Minas Passage is a rectangular – shaped body of water that connects Minas Channel to Minas Basin and is approximately 14 km long. At its narrowest constriction, it is 5 km wide and that area occurs between Cape Sharp and the southern shore of North Mountain. It is 10 km wide at its widest point between Parrsboro and Cape Blomidon on the southern shore. The Passage is oriented northwest – southeast. The four corner points and boundary lines of Minas Passage are Ramshead Point west of the mouth of the Diligent River in the northwest, south to the western tip of Cape Split, southeast to Cape Blomidon and northeast across the passage to Second Beach, at the eastern headland of the entrance to Parrsboro Harbour. Black Rock is a small basalt island that lies in the northern part of Minas Channel to the east of Cape Sharp, approximately 0.5 km offshore. Black Rock is a local reference point for the demonstration tidal power project that lies to the west (Figure 2 and 3).

Bathymetry

The Canadian Hydrographic Chart for Minas Passage is Chart # 4010 (Figure 1). The sparse bathymetry presented on this chart is in fathoms and it depicts Minas Passage as a narrow body of water constricted to the north of Cape Split as defined by the 20 fathom contour that broadens toward the east to the north of Cape Blomidon. The deepest depths in the Passage are 61 fathoms in the central area to the south of Cape Sharp.

Chart #4010 also shows a number of current velocity vectors with the highest values 7 - 8 knots off Cape Split and Cape Sharp. A current velocity of 5 – 6 knots is plotted on the north side off Ram Head. Minas Passage is the region of highest currents in the Bay of Fundy.

Minas Passage has previously been studied as part of previous tidal power proposals in the 1960s and 70s and geological/geophysical surveys were conducted to investigate seafloor conditions and sediment distributions although these were of low resolution.

Multibeam Bathymetry

Modern bathymetric mapping technologies have significantly evolved over the past several decades and now utilize multibeam sonar systems that provide for 100% seabed coverage, precise measurements of depth and location, and an ability to display the information in a variety of interpretation friendly images and fly-throughs. At the start of the demonstration project, multibeam bathymetry had just been collected (2006) from the Minas Channel and Minas Passage region of the Bay of Fundy by the Geological Survey of Canada and the Canadian Hydrographic Service at the Bedford Institute of Oceanography and was provided to the project. Subsequent multibeam surveys (2008) were conducted in the region of Minas Passage by Seaforth Geosurveys for Minas Basin Pulp and Power Ltd. on behalf of the proponents to obtain very high-resolution information for project needs and infrastructure micro siting. Multibeam bathymetry not only provides water depth information, but through processing of the data, images of backscatter (proxy for seabed hardness) and seabed slope can be generated.

The bathymetric imagery can be presented as shaded-relief maps that depict the seabed as a digital terrain model with an artificial sun shining across the imagery to enhance relief. They are similar to aerial photographs of land surfaces. The data can also be displayed using conventional, but very precise bathymetric contours. These maps and images can be interpreted in conjunction with seabed samples and photographs, and seismic reflection and sidescan sonar data to understand in considerable detail seabed materials and processes active on the seabed. The following is a description of the regional bathymetry of Minas Passage based on multibeam bathymetry.

Minas Passage Bathymetry

The regional multibeam bathymetric shaded relief image in Figure 3 shows the water depths of Minas Passage in a colour depth-coded presentation. The image extends from the western Reference Site to Black Rock in the east in the northern region of Minas Passage.

The region of the Crown Lease Area is a rough surface of exposed bedrock ridges and some fields of ripples in gravel. A prominent series of three, 30 – 40 m shallow flat-topped platforms extend to the west from Black Rock and collectively form a ridge that is over 4 km in length. These are areas of volcanic outcrop of North Mountain Basalt on the seabed confirmed by magnetic maps of the region and bottom photographs. For this presentation they are identified as VOL1, VOL2 and VOL3. Directly to the south of the volcanic platform is a prominent linear fault that runs east-west parallel to the trend of the platform extending from the southern area of Cape Sharp to the west. The region to the north of the volcanic ridge consists of rough morphology similar to the area to the south of the platform and is a region of outcropping bedrock and gravel with boulders. The seabed shallows abruptly toward the north shore of Minas Passage with a shore platform at about 20 m water depth that is approximately 0.5 km wide extending from the low water shoreline.

To determine appropriate locations for the in-stream tidal power demonstration project, an interpretation of the Minas Channel and Minas Passage region was first undertaken by Minas Basin Pulp and Power Co. Ltd. utilizing previous published material and reconnaissance seismic reflection, sidescan sonar and sample data collected by the Geological Survey of Canada. This analysis determined that the most appropriate location for a demonstration tidal power project was located in Minas Passage and that such a location occurred to the west of Black Rock in the northern area of Minas Passage. This siting analysis was based on criteria such as avoidance of seabed hazards, preference for hard and stable seabed, water depth limits for devices, length reductions for marine cables, avoidance of shipping lanes and fishing zones, proximity to the electrical grid and distance from adjacent parkland or protected areas. Once the area was selected, it was necessary to conduct very high-resolution surveys in order to characterize the seabed in considerable detail and to determine appropriate sites for device micro siting.

The prime system utilized for the high resolution survey (2008) was a Reson multibeam bathymetric sonar that could present the morphologic information at approximately 0.5 m resolution, considerably higher than the previous multibeam data collected by the Geological Survey of Canada that was gridded at 2 m. The multibeam information from the high resolution survey was collected over a smaller area than the GSC surveys. The following is a general description of the bathymetry based on the detailed multibeam information (Figure 4).

The high resolution multibeam bathymetric survey was conducted in an area in and around Black Rock extending to the west across the volcanic platform (VOL1). It also continued to the low water shoreline to the north of Black Rock and was conducted at high water to provide as much near shore coverage as possible from a large survey vessel (Figure 4). The survey covers a region of approximately 4 km by 1.6 km.

The high resolution multibeam bathymetric shaded-relief map, Figure 4 shows the east west trending volcanic ridge as the dominant morphologic feature of the southern part of this study region. Water depths across the ridge show that it is defined by the 30 m contour in the eastern portion near Black Rock, and increases in depth to 35 m at the western tip of the feature. It is a broad flat platform with very minor relief of a few m across its surface and is 500 m wide at its widest location tapering to a triangular-shaped western end. Several broad deep channels occur across the surface of the platform near the western part of the feature and reach over 50 m water depth. A few localized linear depressions occur along the northern flank of the volcanic ridge and appear as erosional moats where seabed scouring takes place. The volcanic ridge protrudes above the surrounding areas by as much as 15 m but averages 5 m in height and has very steep slopes. The slopes are steeper and higher in the western portion of the platform area. Some local scouring appears to occur around the volcanic ridge flank in the west.

A broad region of northwest trending bedrock ridges lies to the north, south and west of the volcanic platform in deeper water. The ridged region to the north has water depths that range between 35 and 40 m in the east and is slightly deeper in the west, ranging between 40 and 50 m. A few intervening deeper regions between ridges are over 50 m water depth. The ridges are rough and undulating with generally flat regions occurring between ridges in the troughs.

In the northern region of the study area at approximately 45 m water depth, the seabed becomes smoother and the bedrock ridges appear to be buried beneath sediments as the area approaches the shoreline. Continuing to the north and northeast, the seabed presents a gradual shallowing slope with increasing steepness, and at 10 m water depth a scarp occurs where the seabed flattens to the north. This flat region is a broad platform that continues to the shoreline across the intertidal zone. The edge of the scarp is convoluted in places and only a few areas are straight and well-defined. These regions of convoluted scarp are interpreted to represent slump scars. It is not know when the slumping took place or if the process remains active.

Bedrock Geology

The bedrock geology of most of the floor of Minas Passage is mapped as Triassic/Jurassic sedimentary bedrock (King and Webb, 2004, King and Maclean, 1976). This compilation is regional in nature and presents the geology at a scale of 1:1,000,000 and does not show details at any given location. The passage is depicted as being underlain mostly by Triassic sedimentary rocks but a long linear volcanic deposit occurs parallel to the passage just south of the north shore and is mapped as Triassic McKay Head Basalt. Along the northern coast the bedrock is complex and consists of the McCoy Brook Formation of fluvial, deltaic, lacustrine, playa and aeolian clastic rocks. Lacustrine limestone and basalt agglomerate are common.

Surficial Sediments

With the exception of the nearshore regions of Minas Passage, much of the seabed consists of exposed bedrock in the form of ridges with slightly deeper troughs between ridges, composed of gravel with boulders (Fader, 2009). Additional information on the regional marine geology is contained in the Appendix to the Environmental Assessment report for the demonstration facility. In the northwest region thick surficial sediments overlie the bedrock and have large linear furrows, ridges and isolated scour depressions on their surface. An area of bedforms in gravel, termed gravel waves, occurs in the deepest part of Minas Passage. Other areas of gravel waves occur in the eastern part of Minas Channel and to the northwest and southeast of Black Rock. These gravel waves overlie a thicker deposit of surficial sediments that may represent coarse deposits in the lee of the island associated with strong currents. They may also represent a buried remnant of a deposit of till or glaciomarine sediment that once covered much of the seabed of Minas Passage but has survived erosion.

The volcanic flat ridge that extends to the west from Black Rock is mostly exposed bedrock but pebbles, cobbles and boulders are common. No fine-grained clays, silts and sands appear to be present. In the region of exposed bedrock sedimentary ridges to the north and south of the volcanic platform, sediments occur in the flat areas between the exposed ridges. They have a gravel cover of granules, pebbles, cobbles and boulders. Several seismic reflection systems were used to determine the nature and thickness of the surficial sediments between the exposed bedrock ridges. Little acoustic penetration was achieved and side echoes were common acoustic artifacts on the profiles that result from the hardness and steepness of the nearby bedrock ridges. A covering of rounded boulders also scattered the acoustic energy from the systems degrading penetration and resolution of subsurface events.

Regional interpretations of the seismic reflection data from the Minas Channel region and indeed the inner Bay of Fundy show that glaciomarine muddy stratified sediments are widespread and very thick, in contrast to thin or absent glacial till. This suggests that Minas Passage once contained thick glaciomarine sediments in early post glacial time and today it is a large scoured depression formed by beach erosion during times of lowered sea level and strong currents. The surficial material that occurs between the bedrock ridges and underlies the gravel is more likely to represent glaciomarine muddy sediments than till. Wider areas of flat seabed between bedrock ridges would be expected to contain thicker glaciomarine sediments.

Surficial Sediments of Crown Lease Area

The surficial sediments at the seabed of the Crown Lease area are all gravel – that is granules, pebbles, cobbles and boulders and have been determined from a large grid of bottom photographs. This is also interpreted from the MB backscatter that indicates no mud or sand at the seabed. The sidescan sonograms also show high reflectivity indicating that the seabed is very hard – gravel. The high-resolution multibeam bathymetry shows large boulders on the gravel and exposed bedrock surfaces. Boulder measurements indicate that some are up to 5 m in diameter and they often appear in clusters. Indeed, conditions that occur at the demonstration site are similar to those over much of Minas Passage.

Questions have been posed about the stability and nature of the device sites and the potential for local scour and effects on sediment transport and both local and regional morphology associated with device installations. Sediment samples are a very important component of sediment modeling but they are very difficult to collect in Minas Passage. Subsurface sampling is even more difficult because of the widespread occurrence of protective lag gravel with rounded boulders. Large areas of the seabed of the demonstration site are exposed bedrock in the form of upturned jagged ridges or flat volcanic rock areas. Attempts were made at sampling the gravels and were only partially successful returning a few gravel clasts in most cases. Bottom photographs and video of the seabed provide critical evidence for an understanding of sediment transport, sediment deposition and erosion. Bottom photographs have been collected regionally in the area and over 2200 have been analyzed for particle size, shape, sorting, distribution, stability and biological growth. This information has been integrated with the results from the interpretation of the sidescan sonograms and high resolution multibeam bathymetry.

No sand sized sediments or silts and clays were observed on the seabed of the Crown Lease Area. Most of the photographs were taken during times of slack water or close to it, and sand sized material that may have been in suspension as well as silts, clays and organic matter would be expected to settle temporarily on the seabed. This was not observed from the photographic data suggesting that in the study area there is little sand in suspension and that silt and clay are either in low concentration in the water column or don't settle to the seabed. Additionally; - pebbles, cobbles and small boulders have no attached biological growth. Larger boulders and adjacent bedrock have broad coverings of low growth that appear to start at about 20 cm above the seabed. This suggests that the smaller gravel sizes that have clean surfaces may be moving and rolling around as bedload and preventing biological growth in the zone immediate to the seabed. The movement is likely local and confined by the bedrock ridges and large boulders of the region. No boulders on the photographic imagery showed tilted sediment lines that would indicate recent movement and repositioning. The seabed appears as a mature hard scoured bottom of bedrock and gravel.

Most of the gravel clasts in the study area are round to subround in shape. A few clasts are angular and may have been transported by ice. A simple interpretation is that the rounding is due to present day active movement. However the larger rounded boulders that occur in the same area do not move. The rounding is interpreted to have occurred during times of lowered sea levels. Relative sea level in the region could have fallen by more than 40 m in early post glacial time as the land quickly rebounded from the removal of nearby glaciers. At times of lowered sea levels, large regions would have been above or near sea level and beach processes of high energy during regressions and transgressions would have produced the roundness of the boulders. Additionally the lowered sea level would have resulted in erosion of both tills and glaciomarine fine grained sediments that were previously deposited over bedrock. Thus the present seabed is largely a relict exhumed bottom with modern elements of granule, pebble and cobble bedload movement. These lag gravel surfaces are termed "relict"; that is, they reflect deposition and formation under differing conditions (very high energy) in the past and have maintained these characteristics for thousands of years to the present. They are not necessarily in dynamic equilibrium with present energy conditions. For these reasons, it is difficult to use gravel in sediment transport models that consider the entire seabed to be in equilibrium with present energy conditions.

Monitoring Methodology

For the NSPI/OH1 site, the approach to study the effects of the turbine/gravity structure on seabed morphology, materials and sediment transport has been based on two surveys using multibeam bathymetry. The highest resolution information – 0.5 m collected for site surveys by Seaforth Geosurveys Inc. in 2008 has been processed to enhance relief and clearly shows details of the morphology (Figure 4). Fortunately, multibeam bathymetry was collected at the NSPI/OH1 site shortly after device installation and this data shows the location and orientation of the turbine and gravity platform on the seabed (Figure 5). The reported position for the device provided by the Canadian Hydrographic Service is a location that occurs near the southeastern rear foot of the device and does not represent the centre. Without the multibeam map of the device overlying bathymetry, it would be impossible to locate with precision each of the device feet. Figure 6 is a reprocessed shaded relief image of high resolution multibeam bathymetry showing the location and orientation of the NSPI/OH1 device and the position of the reported site relative to seabed morphology.

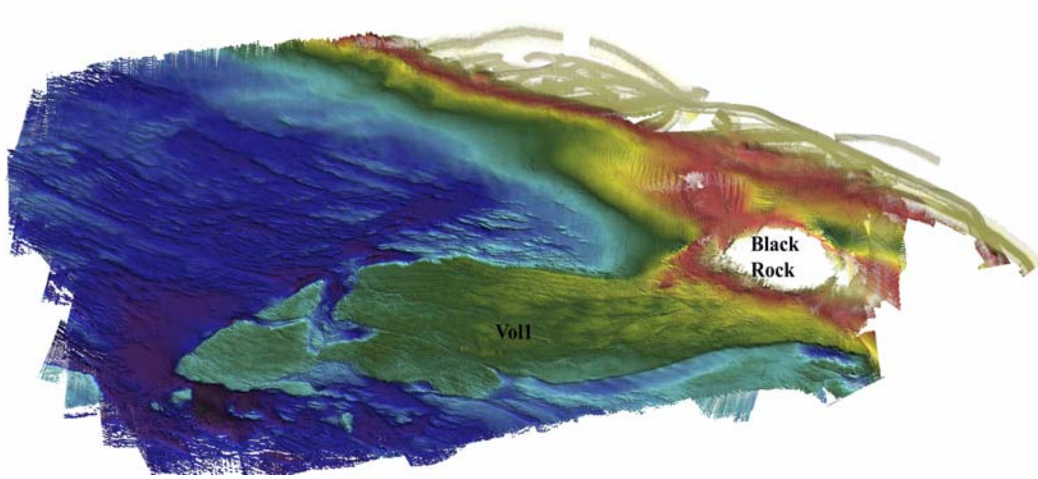

Figure 4 High-resolution multibeam bathymetric map of the area to the west of Black Rock in Minas Passage, produced by Seaforth Geosurveys Inc. This data formed the basis for a variety of seabed maps on backscatter, slope and relief.

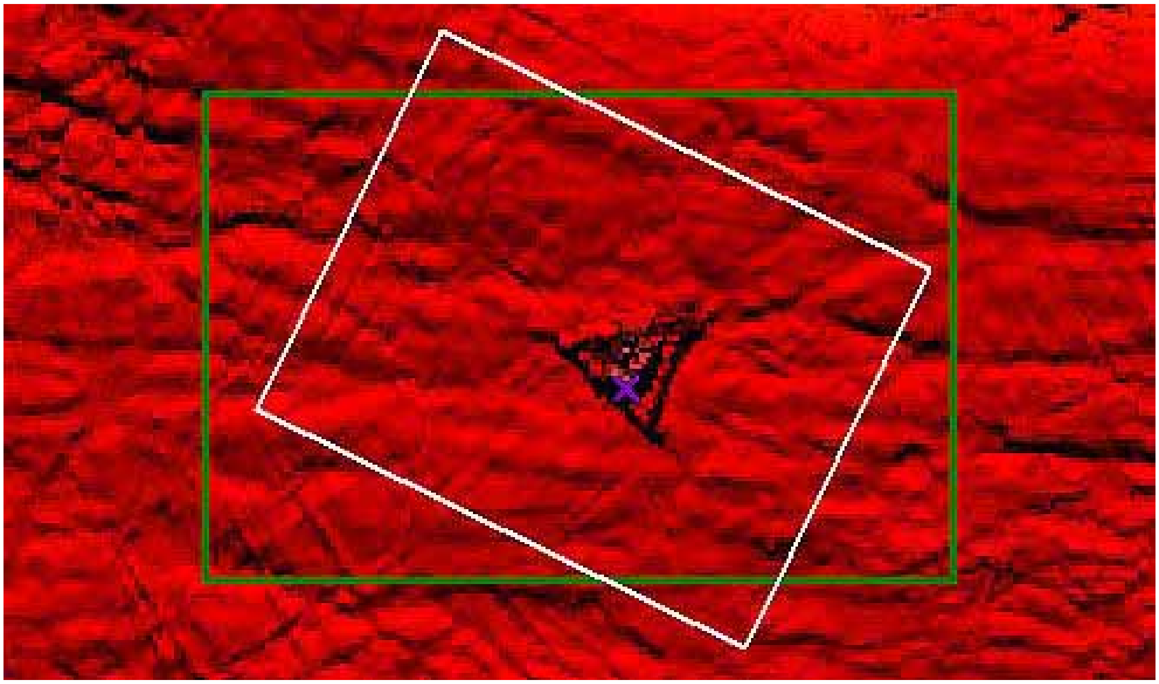

Figure 5 A multibeam bathymetric map of the seabed during the deployed phase of NSPI/OH1 by Seaforth Geosurveys Inc. showing the shape of the gravity platform and the surrounding topography of the seabed. This information provided the exact georeferenced location of the device. X marks the position of the coordinates of the device provided by the Canadian Hydrographic Service. North is to the top of the image and the device is 21 by 25 m in size.

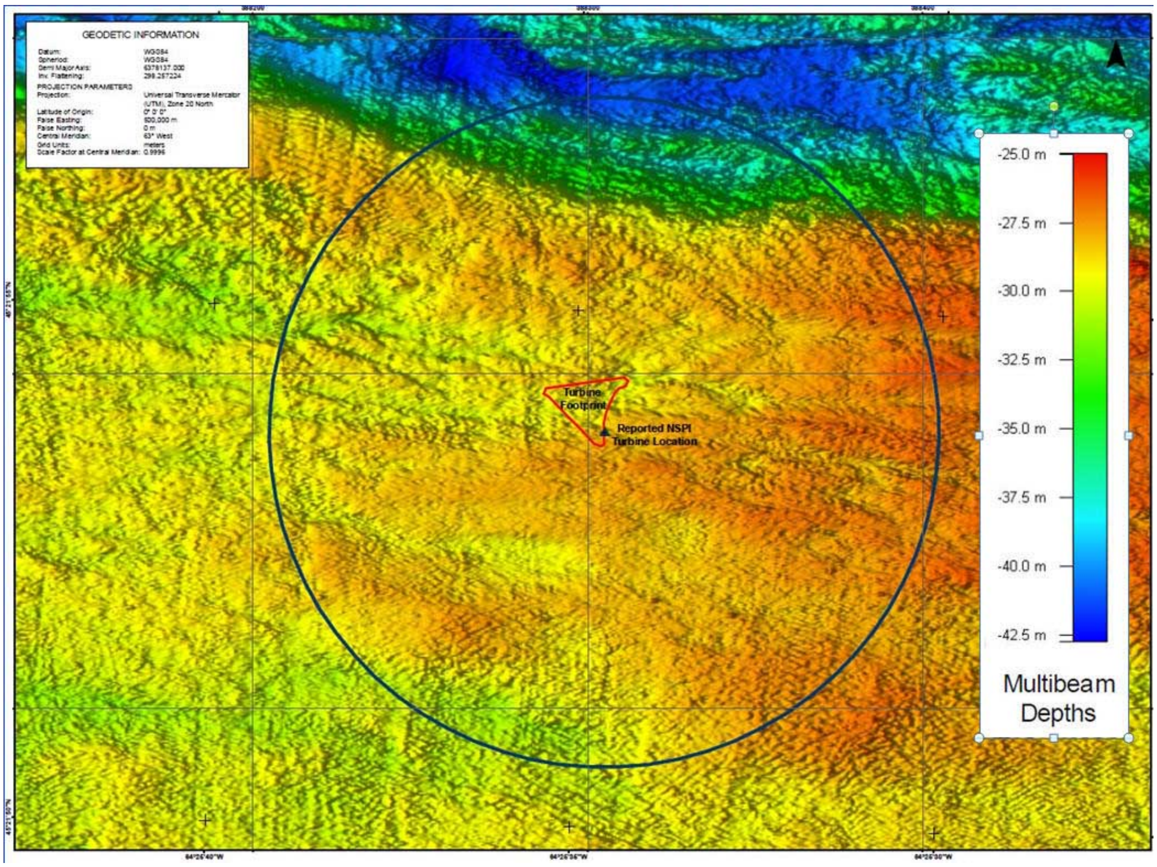

Figure 6 A multibeam bathymetric shaded relief map of the NSPI/OH1 site showing the location of the device (red triangle) relative to detailed bathymetry. The multibeam data was collected by Seaforth Geosurveys and is presented at 0.5 m resolution. The CHS reported location for the device is also shown as a small black triangle. The circle is 200 m in diameter centered on the officially reported position.

A sidescan sonar survey (Seaforth Geosurveys Inc., 2011) was conducted for the monitoring study over and around the device and a mosaic has been constructed (Figure 7). The sidescan information was draped over the multibeam bathymetry and was in good agreement with the location of the major morphological features on the seabed. However, to maximise an understanding of the effects of the device, in particular the feet, it was necessary to precisely locate their positions on the sidescan sonograms. This was a difficult process brought about by the strong currents and limits of sidescan surveying that produces distortion of features. The sidescan data was of high quality with few artifacts and this allowed for a direct overlay and comparison with the multibeam information and the location of the device. Through rubber sheeting methods and landmark identification, it was possible to adjust the sonograms in the GIS for direct correlation. This facilitated the accurate plotting of the locations of the device feet on the raw sidescan sonograms (Figure 8). The original sonograms are the highest resolution imagery from the survey. It is considered that they have been plotted with +- 1 m accuracy. The sidescan sonograms have resolution of 0.25 m and are thus able to show very small features of the seabed as will be discussed in the following sections.

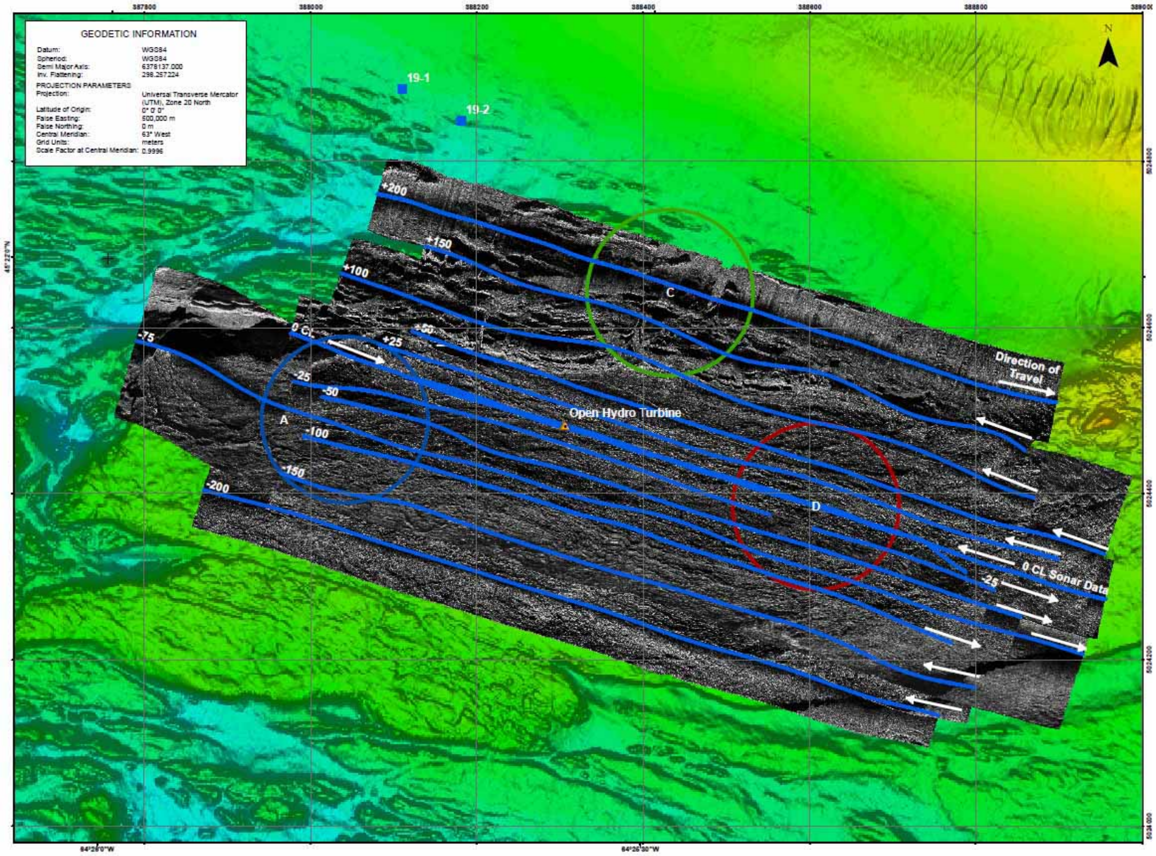

Figure 7 A sidescan sonar mosaic produced from data collected during the monitoring survey. It is superimposed over the multbeam bathymetry (Background). The location of sites A, C, D and NSPI/OH1 are shown. Direction of travel of the sidescan tow fish is shown by arrows.

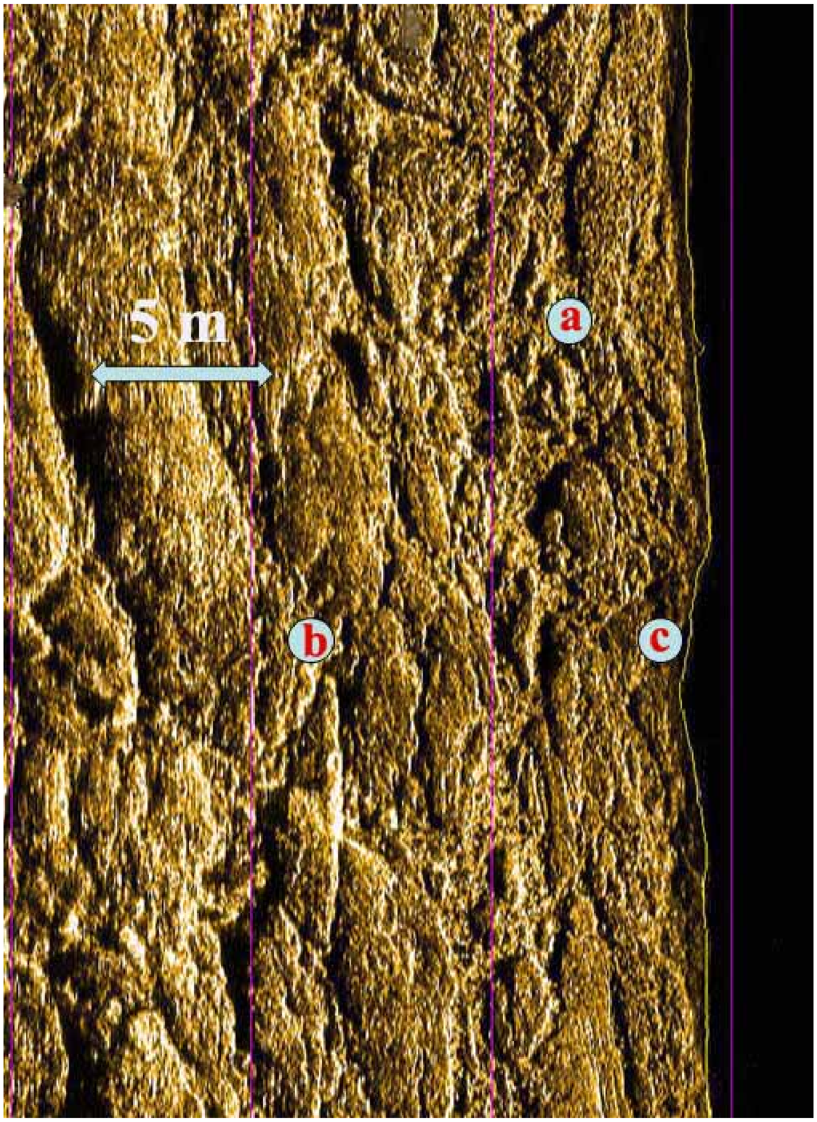

Figure 8 Line -25 sidescan sonogram from the monitoring survey over site NSPI/OH1. The interpreted position of each of the device feet is indicated.

The reference site (RS) previously only had 2 m resolution multibeam bathymetry collected across the area in 2006 and no sidescan data. The sidescan sonograms collected for the monitoring assessment were run in a grid pattern and a sidescan mosaic has been constructed (Figure 9). A series of screened mosaics at various levels of transparency were laid over the multibeam bathymetry to facilitate correlation of seabed features and to assess seabed change.

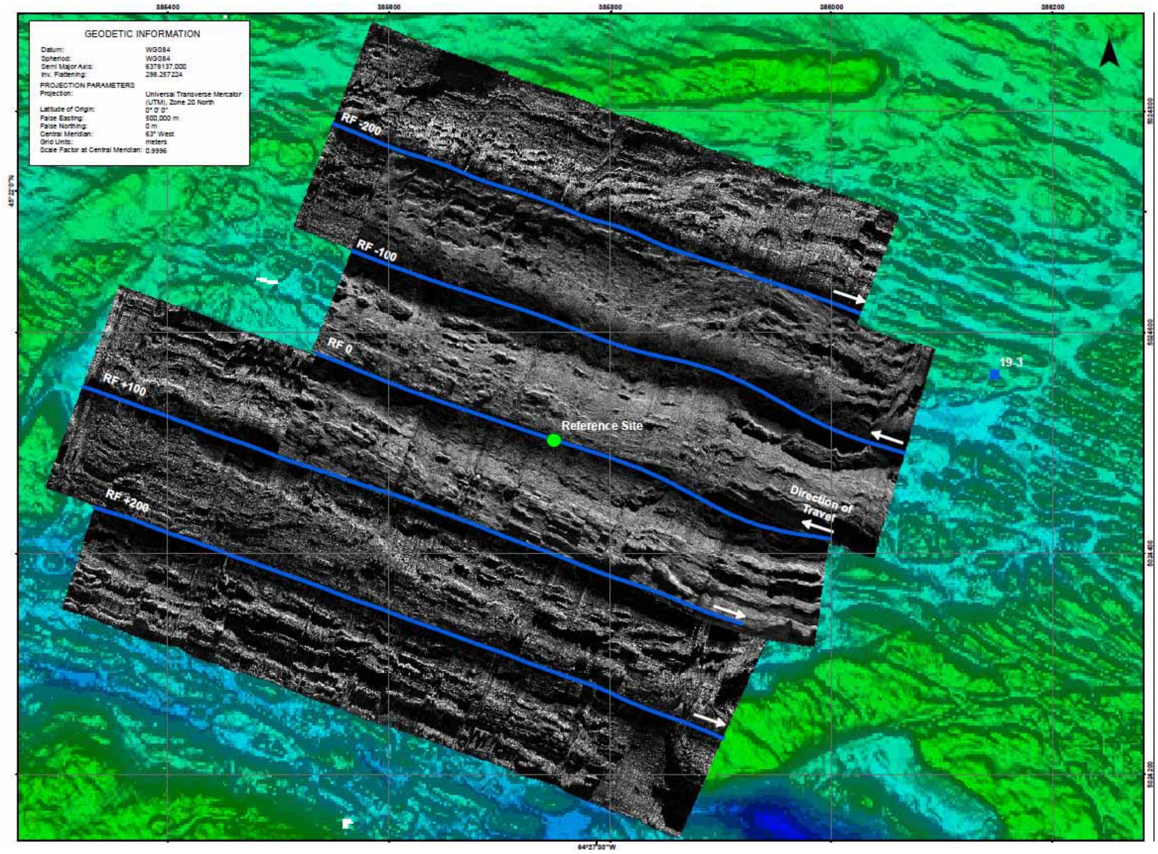

Figure 9 A sidescan sonar mosaic from the Reference Site overlying multibeam bathymetry. The Reference Site occurs in the centre of the mosaic (green dot). Survey lines and direction of travel are indicated.

Bottom towed video cameras were towed across both the RS and the NSPI/OH1 and the track plots are shown in Figure 10 and 11. The data is of moderate quality and the speed of the camera moving across the seabed and particulates in the water column have reduced visibility. The camera varies in height above the seabed during the tows and where it is near the seabed it provide definition of boulders and cobbles, their shape, biogenic growth and the presence of exposed bedrock. The video imagery was compared with the sidescan sonograms and previously collected multibeam bathymetry to assess seabed change.

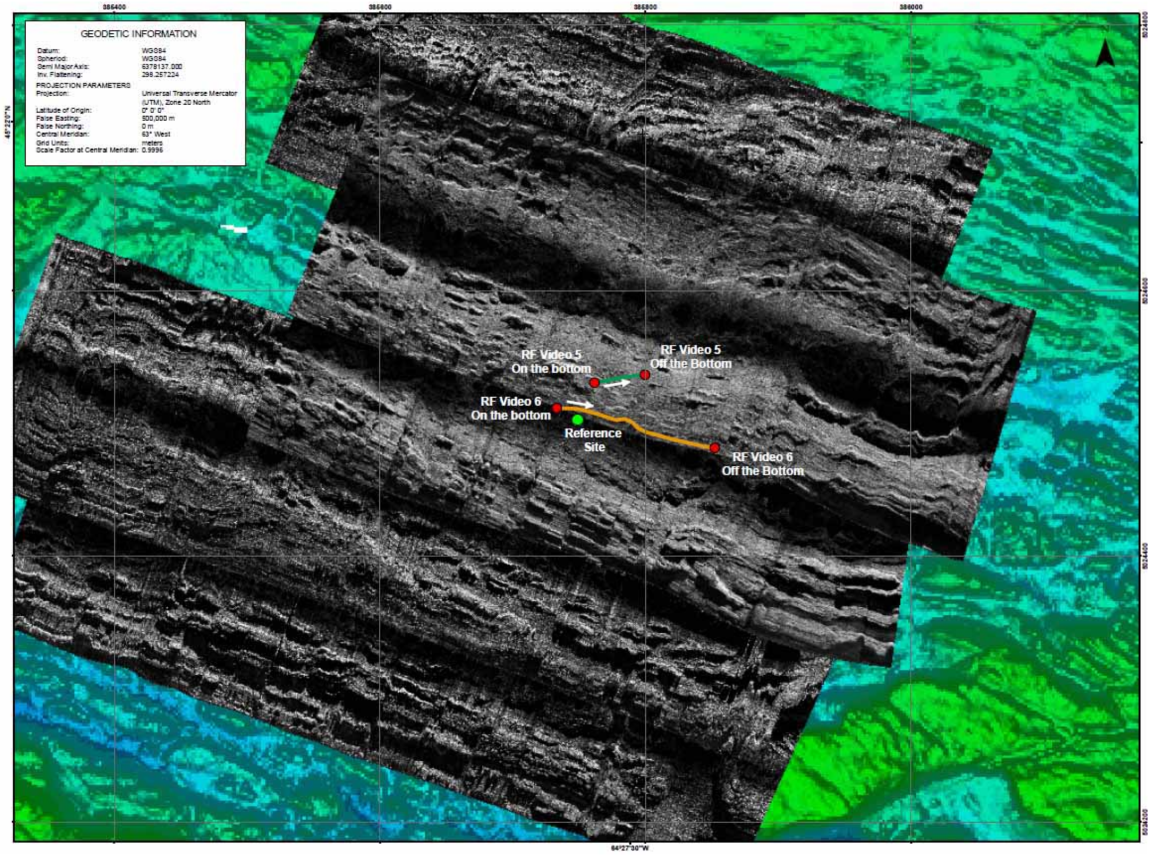

Figure 10 Sidescan sonar mosaic of the Reference Site showing the tracks of the towed video system and the reference site.

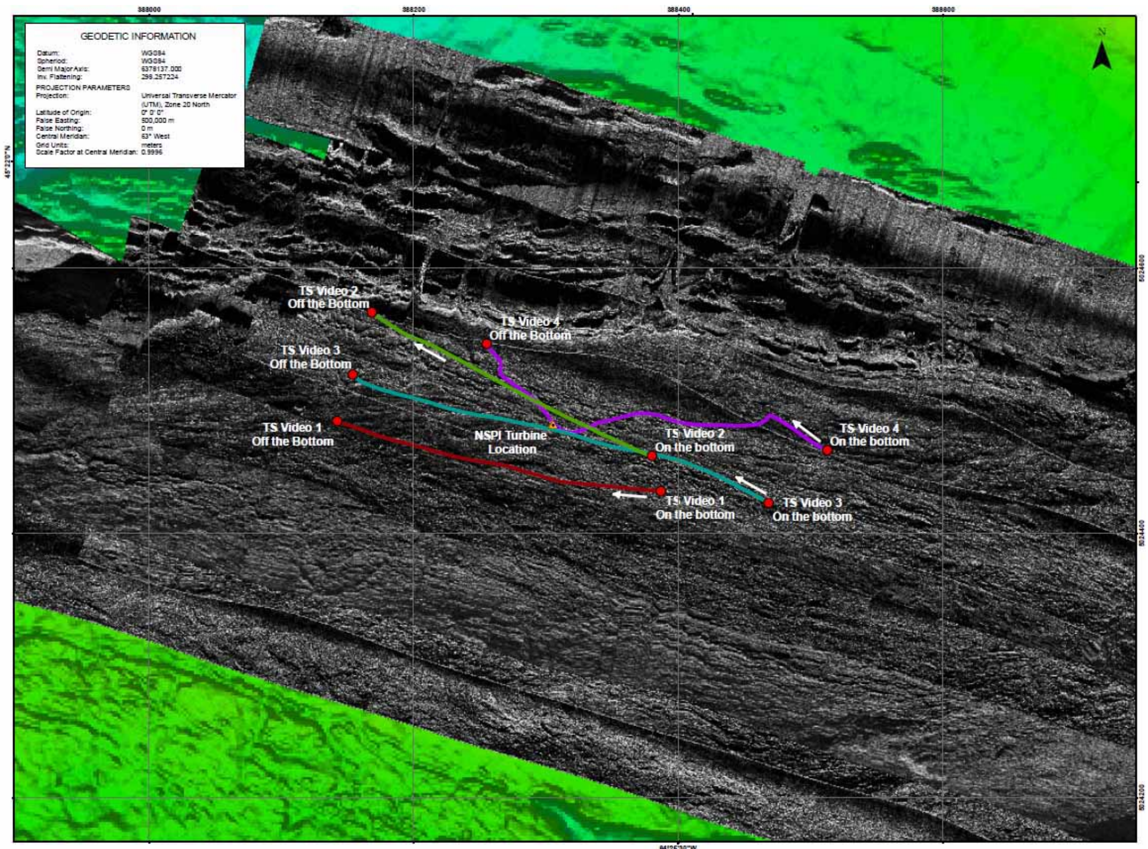

Figure 11 Sidescan sonar mosaic of NSPI/OH1 site showing the tracks of the video transects. The background is a multibeam bathymetric image.

An assessment of benthic habitat based on the collected information was attempted, but the resolution and speed of camera movement limited this activity. Where the towed camera moved close to the seabed, benthic organisms encrusting boulders and bedrock could be detected but details were lacking. There was no disturbance of the biological communities that covered the surfaces at both sites. The high resolution sidescan information showed no change to the bedrock and gravel areas of the seabed and this can be used as a proxy for assessment of benthic habitat.

Reference Site

The reference site lies 1.4 km to the west of the western edge of the CLA at lat and long and in 54 m water depth. Figure 12 is a multibeam bathymetric image at 2 m resolution from the region of the RS and Figure 13 is a contoured bathymetric map from the same area, contoured at 2 m intervals. The region of RS has never been described in detail. No bottom photographs or video have been collected from this site but it was the first site chosen for a current meter deployment and that information has been collected, processed and presented in earlier reports.

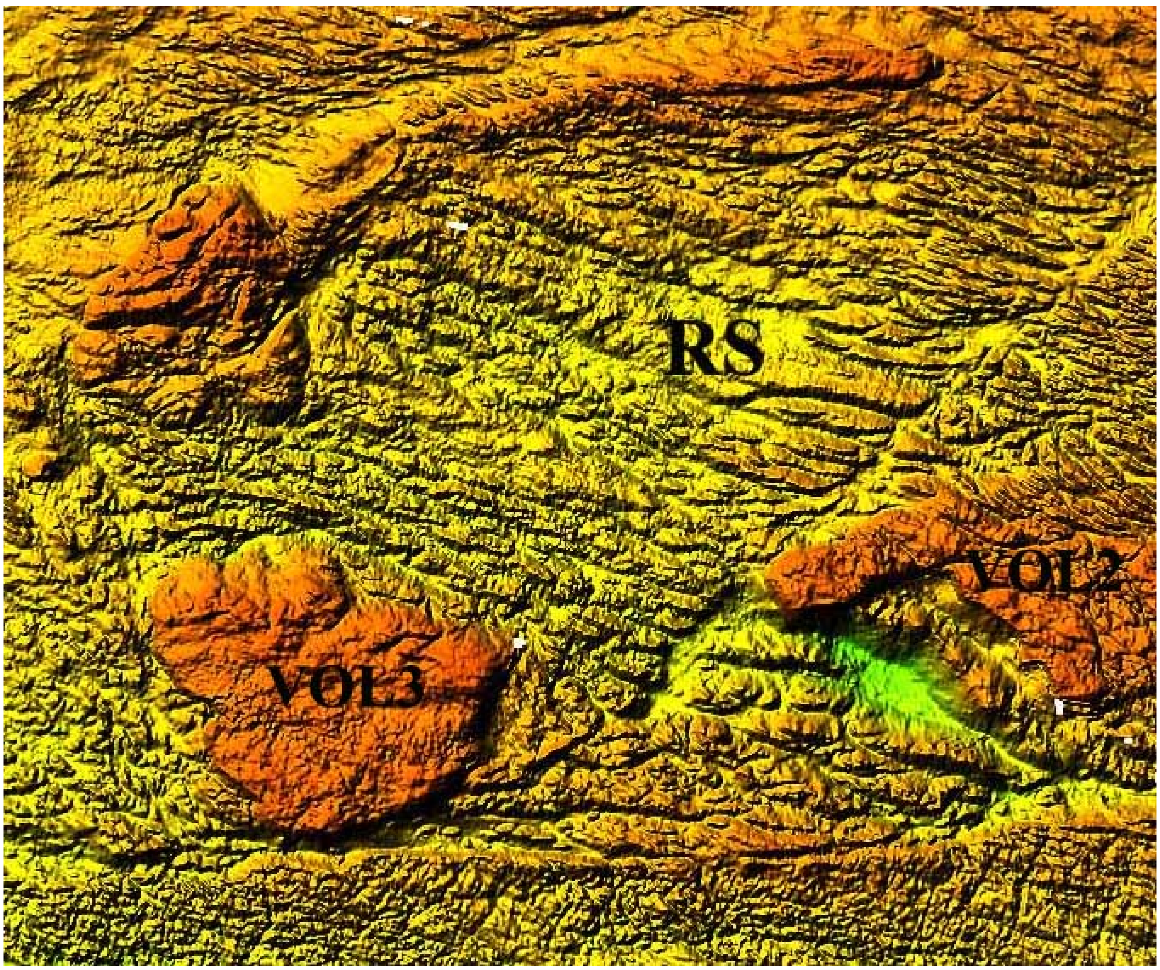

Figure 12 A multibeam bathymetric, shaded relief, colour depth-coded map of the Reference Site with the volcanic platforms identified as VOL2 and VOL3.

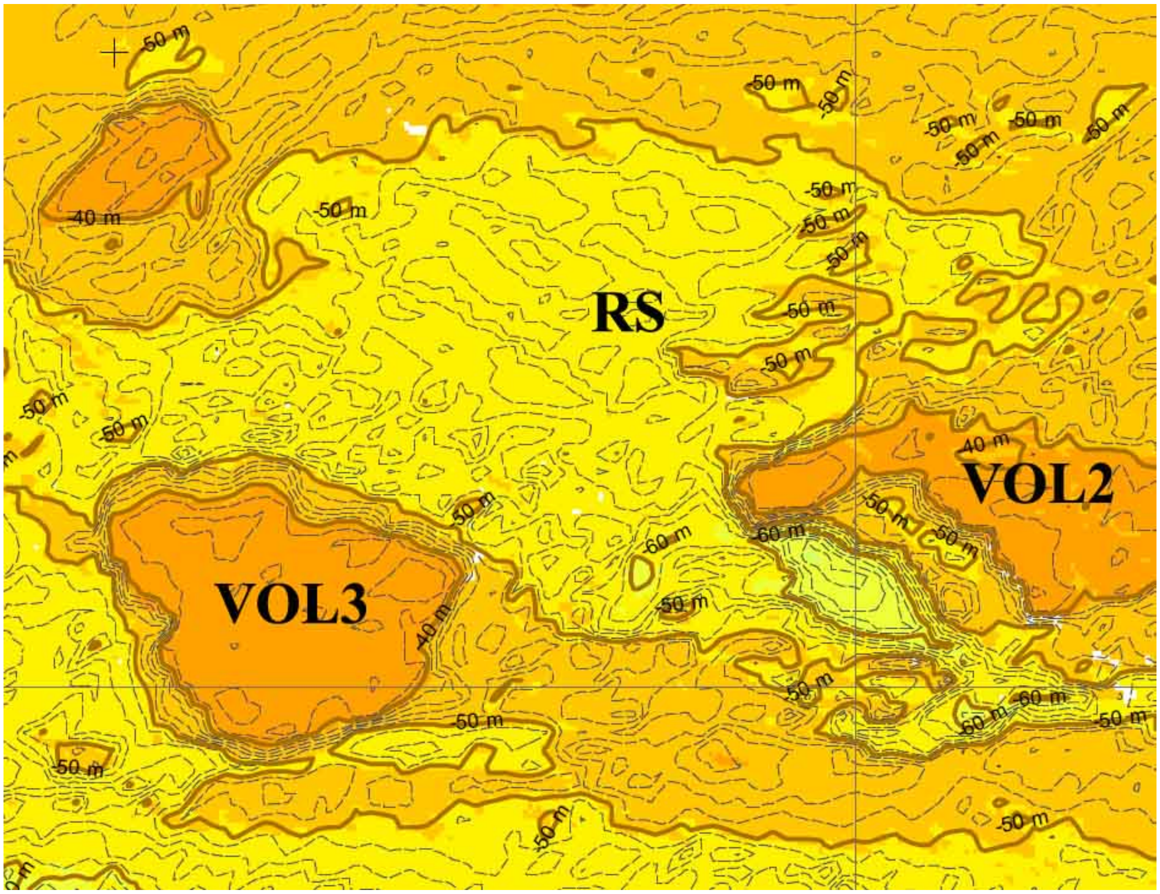

Figure 13 A contoured bathymetric colour-coded and contoured map of the Reference Site. Contour intervals are 2 m.

Bathymetry

RS lies in a slight depression surrounded in the southwest by the high of VOL3, in the southeast by the high of VOL4, and in the north by a shallower ridge trending northeast. The multibeam bathymetric image of Figure 12 shows that RS occurs in a region of southeast trending ridges interpreted to represent outcrops of bedrock with deeper flatter and linear troughs between ridges. Here the bedrock consists of Carboniferous sandstone, siltstone and mudstone. The beds dip to the northeast with the steepest flanks to the southwest as portrayed as shadows on the multibeam bathymetry. The multibeam bathymetry shows that the region around RS is flatter and smoother indicating a cover of surficial sediments. The flatter regions show up more clearly on the slope imagery extracted from the multibeam bathymetric data (Figure 14). The slope imagery shows the steepness of the seabed in dark tone with flat regions showing as light tone. Some of the flat regions can also represent exposures of bedrock. Figure 15 is a low resolution backscatter image of the region that represents a proxy for seabed hardness where dark tone is bedrock and gravel, and light tone sand and mud. The image shows RS as dark tone, therefore, a hard seabed of exposed bedrock or gravel. Linear light tone regions of this image are artefacts of data processing over steep slopes. The backscatter imagery indicates no sand or mud at the seabed of the region. The multibeam bathymetry has been reprocessed from this site to provide the highest resolution possible (Figure 16). This image shows that RS occurs over a rough bottom as part of a broad ridge. Deeper regions to the north and south are troughs of bedrock outcropping ridges and are flatter. RS shows typical characteristics of the region of exposed bedrock ridges throughout Minas Passage. Based on the multibeam imagery, exposed bedrock with gravel would be expected to occur at the seabed.

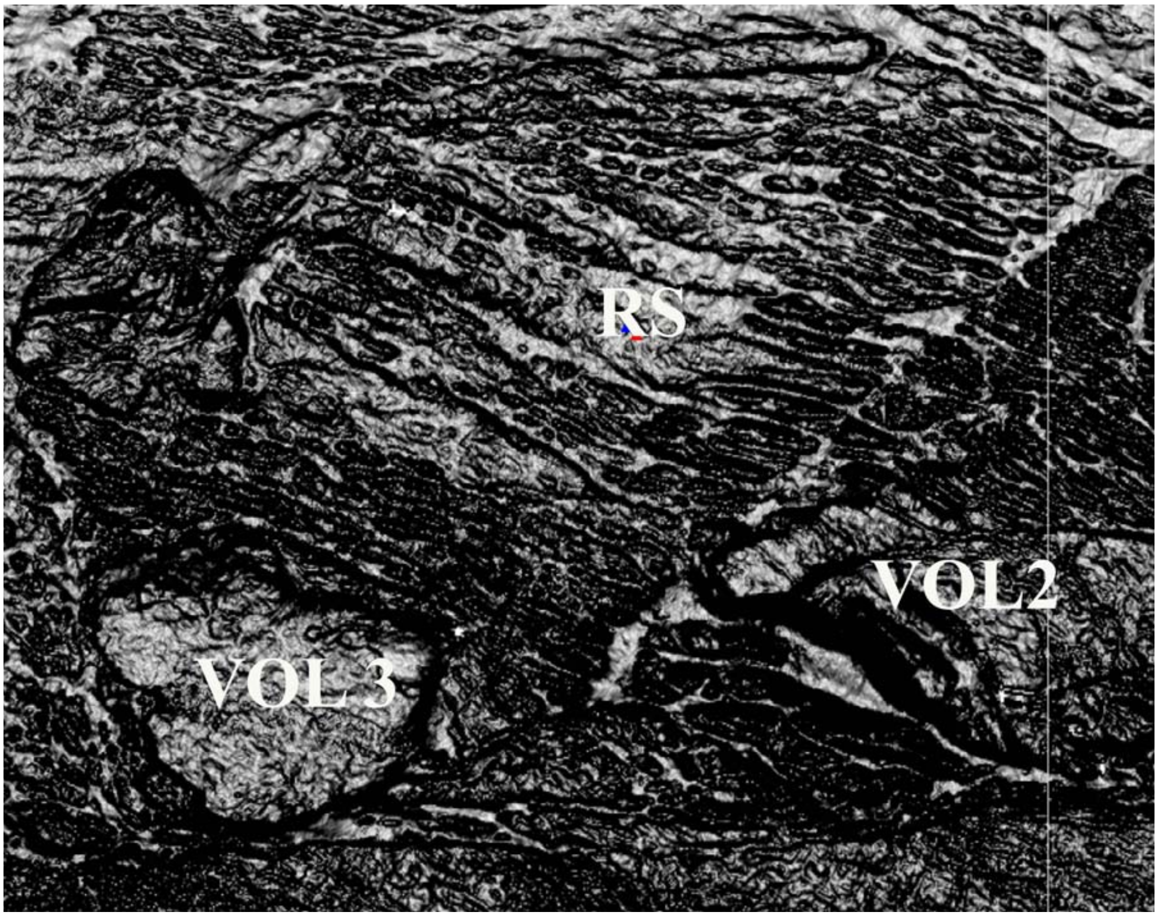

Figure 14 A slope map of the Reference Site produced from the multibeam bathymetric data. Flat areas are light toned and steep areas are dark toned.

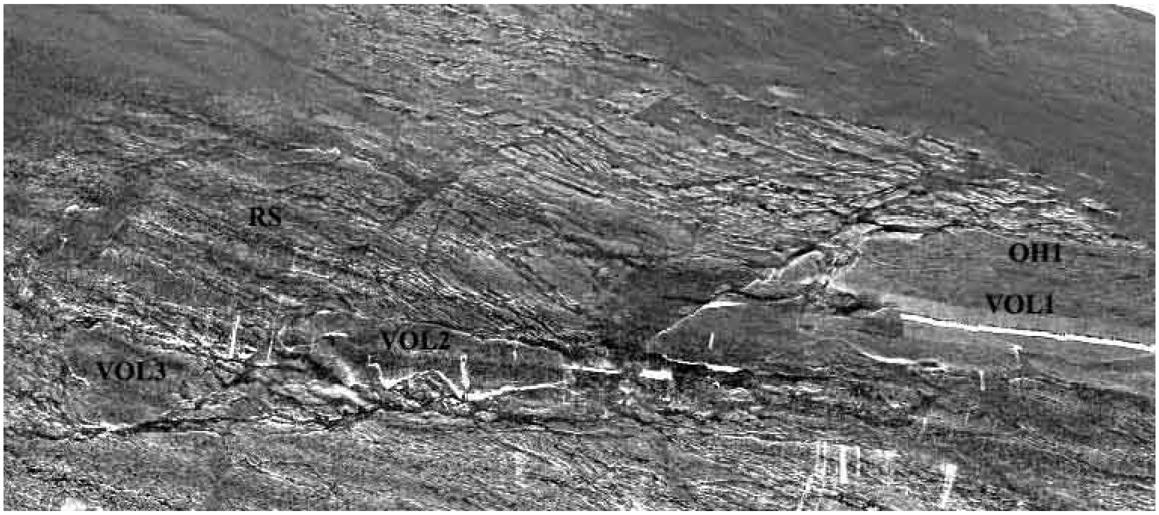

Figure 15 A regional backscatter image of the sites NSPI/OH1 and RS showing that they occur over a very hard seabed of gravel and bedrock. Volcanic ridge segments 1 -3 are identified for reference.

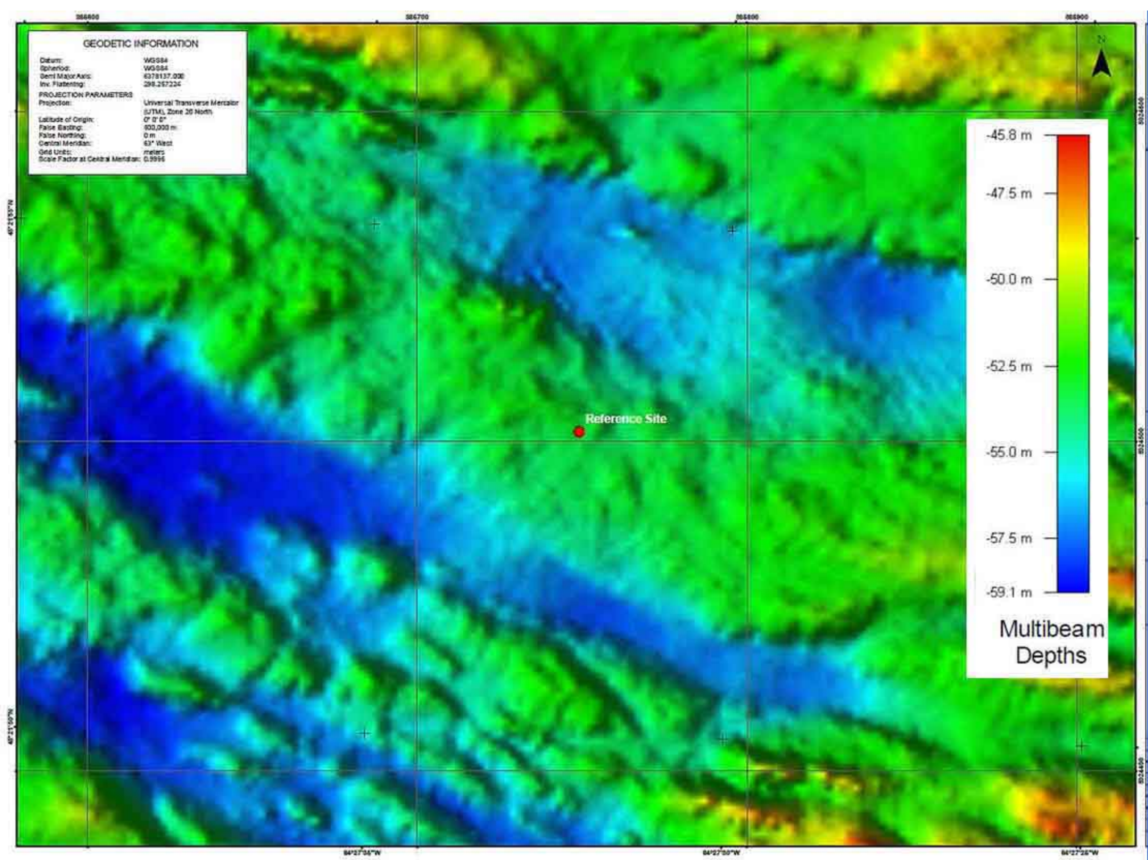

Figure 16 A high resolution multibeam bathymetric image of the Reference Site based on the 2 m resolution survey. It lies on a hummocky seabed of a broad ridge trending southeast.

The monitoring survey of the RS consisted of a sidescan sonar survey, the construction of a sidescan mosaic (Figure17) and the collection of towed video imagery across the site. The sidescan data were draped over the multibeam bathymetry to determine if the seabed has changed over the 5 years since the multibeam bathymetry was collected. A series of screened mosaics were prepared at varying transparencies to aid in this assessment (Figure 17, 18).

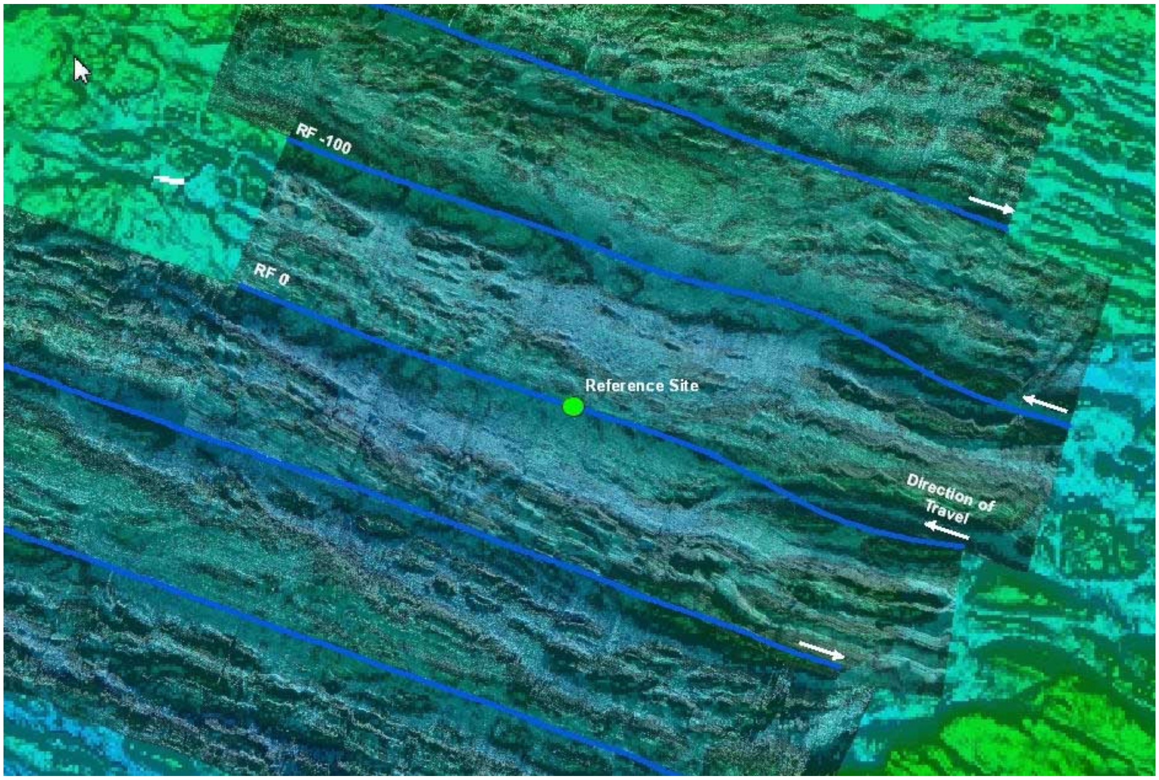

Figure 17 A sidescan mosaic from the Reference Site, screened at 50% transparency to allow for direct comparison with the underlying multibeam bathymetry.

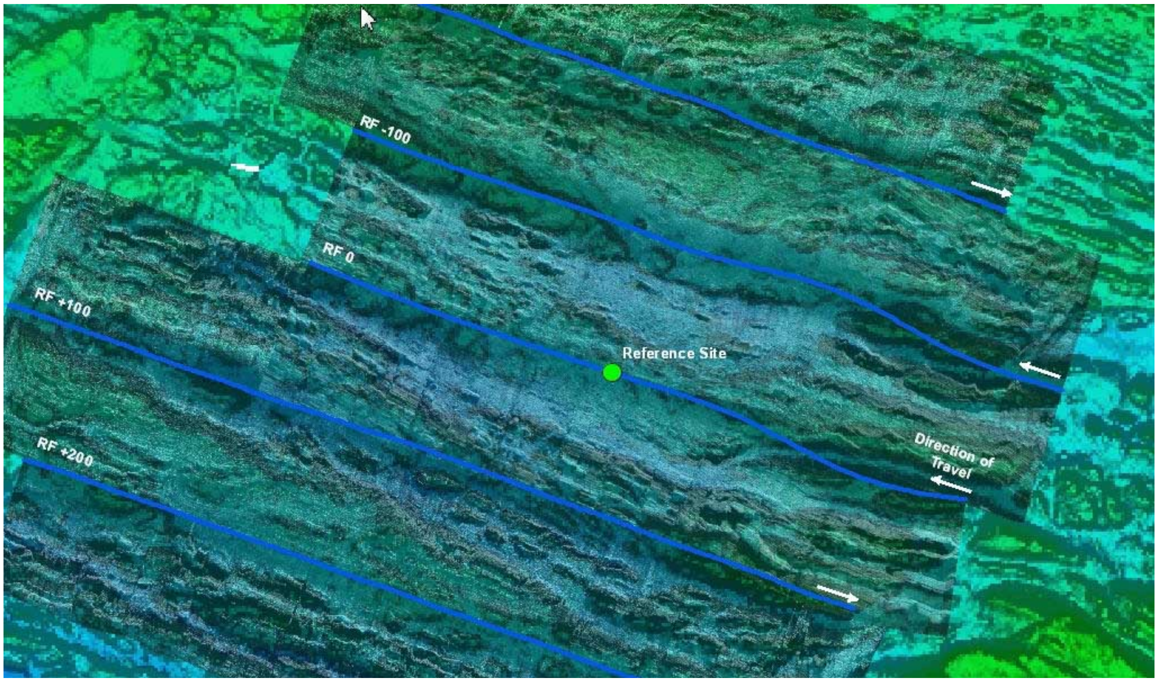

Figure 18 A sidescan mosaic from the Reference Site, screened at 20% transparency to allow for direct comparison with the multibeam bathymetry.

The RS is located near the centre of the sidescan mosaic. The survey lines were run parallel to the bedrock structure in a northwest direction. The mosaic shows that the RS is located in a broad region of sediments overlying bedrock. Although many bedrock ridges crop out on the seabed, they represent approximately 30% of the seabed area. The sidescan imagery show considerably more detail about seabed sediments and bedrock than the multibeam bathymetry. The sidescan has a resolution of 20 cm as compared to the 2 m resolution of the multibeam bathymetry for this site.

Video Imagery

Video or bottom photographs had not been collected at the RS before the monitoring study. The closest existing bottom photographs were from sites A1 to A20 to the east north of VOL2 (Figure 19) and they were taken over a similar seabed character as defined by the multibeam bathymetry and sidescan data. Figure 20 is a selection of bottom photographs from those sites that show a seabed mostly composed of gravel with boulders and exposed bedrock. Between the boulders granules, pebbles and cobbles are present. Large boulders and bedrock have biogenic growth covering their surfaces. These photographs are contained in a report by Envirosphere Consulting to FORCE. Examination of the video transects 5 and 6 across RS shows the seabed dominated by rounded boulders with occasional bedrock outcrop. Pebbles and cobbles lie at the base of the boulders. The large boulders and bedrock outcrop are covered with breadcrumb sponge and other benthic encrusting organisms.

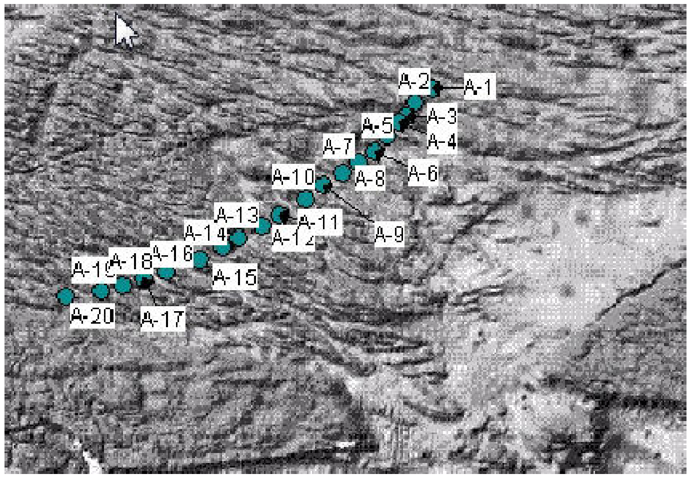

Figure 19 A map of the positions for the closest bottom photographs A1 – A20 to the Reference Site. The RS lies to the west of these locations.

Figure C1. Station A1, September 2008

Figure C2. Station A3, September 2008

Figure C3. Station A4, September 2008

Figure C4. Station A5, September 2008

Figure C5. Station A6, September 2008

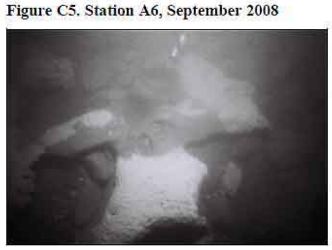

Figure C6. Station A7, September 2008

Figure C7. Station n A8, September 2008

Figure C8. Station A9, September 2008

Figure C9. Station A10, September 2008

Figure 20 Selected bottom photographs from sites A1 – A10 to show common characteristics of the seabed that occur in the region of the Reference Site.

Interpretation

Interpretation of the sidescan and video imagery from the monitoring survey of the RS and comparison with the previously collected multibeam bathymetry indicates that the seabed has not changed since the first multibeam bathymetry survey was conducted in 2006. Bedrock ridges remain in the same location and flatter regions of gravel with boulders have the same distribution and characteristics. A lack of growth on pebbles, cobbles and small boulders suggests that they may move slightly on the seabed and become rearranged. No gravel bedforms were found at RS as occur in other areas of Minas Passage. Future study of the reference site will now have the sidescan imagery for direct comparison at high resolution.

NSPI/OH1 Site

Assessment of change at the NSPI/OH1 site is based on the 2006, 2 m resolution multibeam bathymetric survey of the site obtained from the GSC; the high resolution 0.5 m multibeam bathymetry survey conducted over the study area in 2008 to choose suitable sites; sidescan sonograms and produced sidescan mosaics from the first survey; a post deployment multibeam bathymetric survey; sidescan sonar and towed camera surveys for this monitoring study; and a review of previously collected bottom camera and video imagery from nearby. The location of NSPI/OH1 has been plotted on backscatter (Figure 15) and slope imagery (Figure 21) for a better understanding of the regional seabed characteristics.

Figure 21 A slope map of the NSPI/OH1 site on Volcanic Platform 1. The seabed is uniform and flat in this region.

The most informative data set for assessment of the seabed at the site of the installation of NSPI/OH1 is the sidescan sonar imagery. The multibeam bathymetric survey of the turbine while in place on the seabed, (Figure 5) has provided an opportunity to determine a very accurate position for the device relative to seabed features, including the position of each of the gravity base feet. This can be correlated with both the first sidescan sonar survey data and the most recent sidescan survey to accurately determine where the device was positioned on the seabed. Without the multibeam survey of the device while in position, this could not be accomplished with any degree of precision. The official position of the installed device provided by the Canadian Hydrographic Service is different than the position obtained from the multibeam survey while the device rested on the seabed by 11 m.

The NSPI/OH1device was carefully oriented and positioned during deployment and was placed on the seabed once and not repositioned. A combination of sonar imagery and DGPS were used during deployment and for later confirmation. Marker buoys were used to assist with positioning but were later removed.

Regional Setting

The NSPI/OH1test installation position lies on the northern part of the volcanic platform that extends to the west from Black Rock (Figure 2 and 3). The site lies to the east of Site A and southwest of site C. It lies 255 m west of the centre of site A in 28.5 m water depth. The 2 m resolution multibeam bathymetric data (Figure 22) shows that the location occurs to the east of a linear and rough region of the volcanic platform. A contoured map of bathymetry (Figure 23) shows that the region lies in water depths slightly below 30 m water depth and that this part of the volcanic platform is relatively flat and broad with water depths between 30 and 28 m (contour interval 2 m). The backscatter imagery (Figure 15) shows that NSPI/OH1 lies in a region of homogeneous dark tone – suggesting a hard and consistent seabed. The backscatter imagery has been processed at low resolution of less than 5 m, so backscatter details of the setting cannot be determined. The slope imagery (Figure 21) shows the location in a region of low slope with minor ridging and isolated flat circular areas.

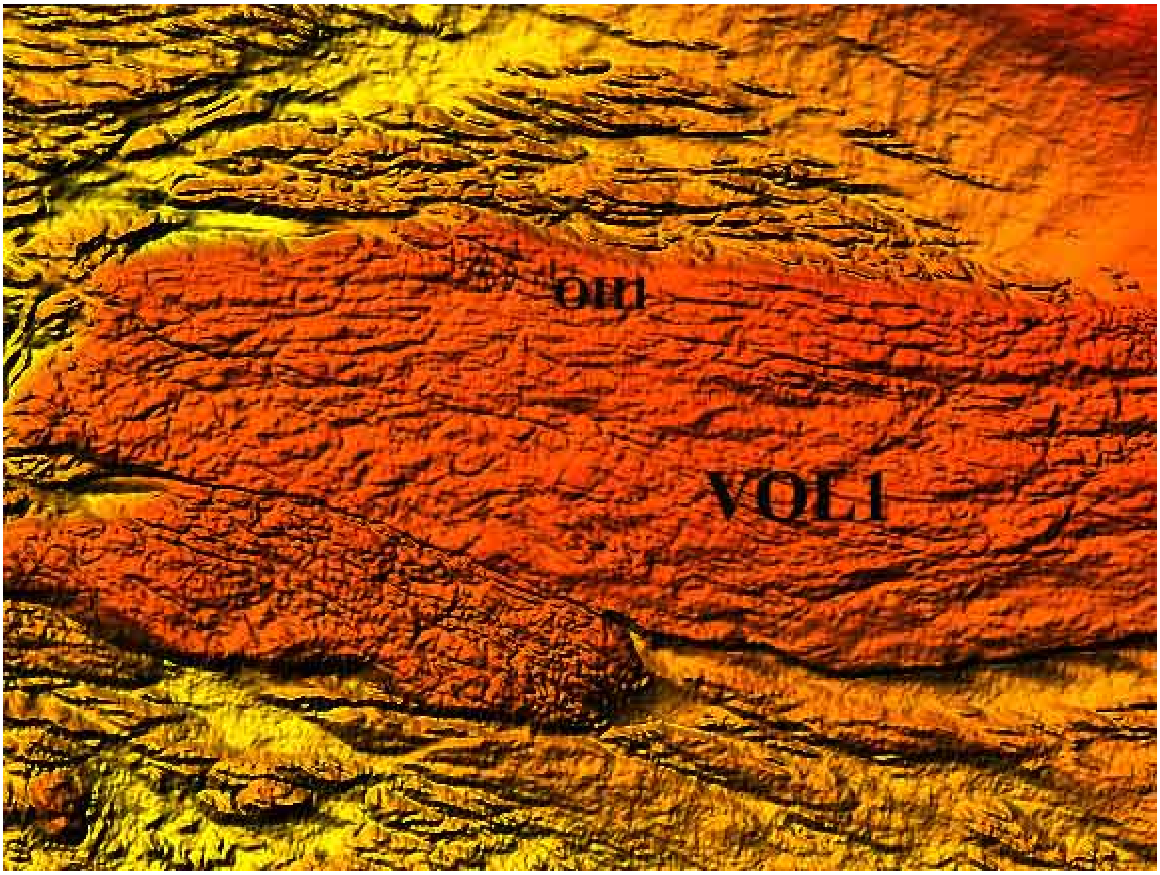

Figure 22 A 2 m resolution multibeam bathymetric map of NSPI/OH1 showing its location on the volcanic platform VOL1. Directly to the west of the site the seabed is rougher and more ridged.

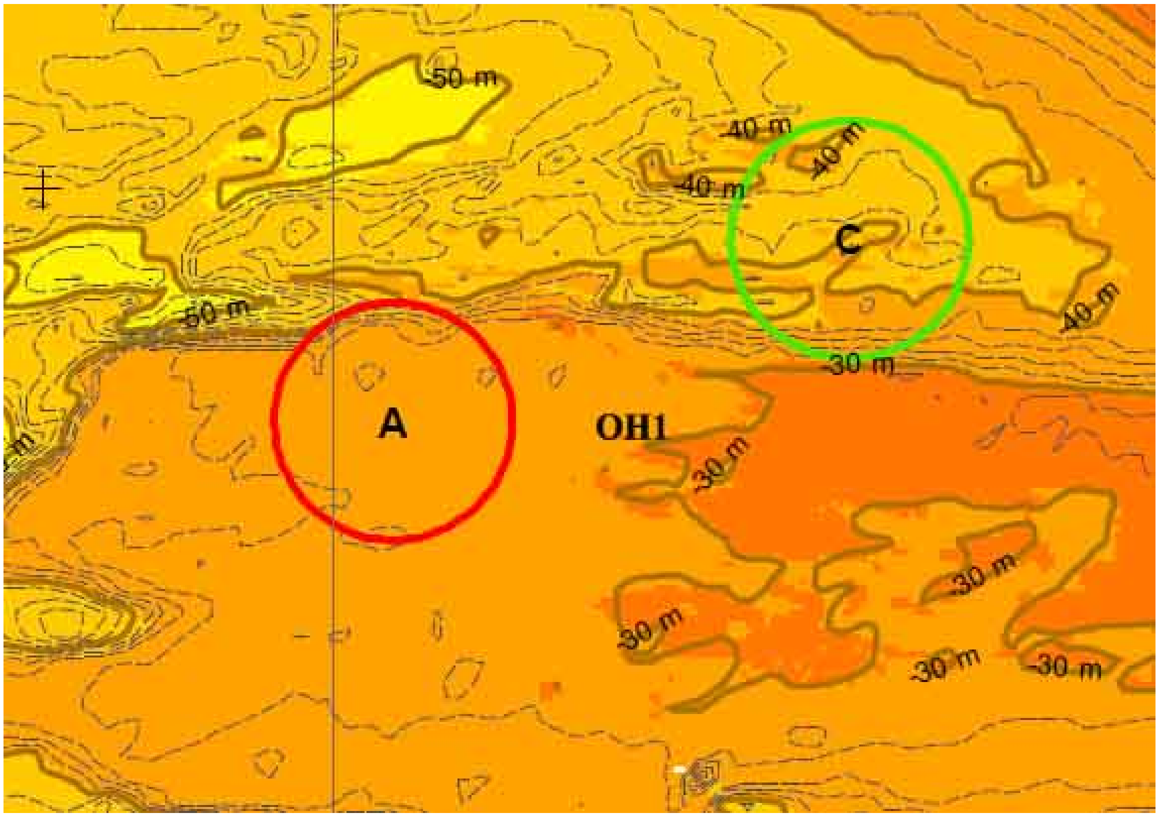

Figure 23 A bathymetric contoured map of the site of NSPI/OH1, site A and site C. The contour interval is 2m and shows that the volcanic platform is quite flat.

The multibeam bathymetric survey of the device on site (Figure 5) clearly shows its relationship to the topography of the volcanic platform as well as the shape of the gravity base. It lies on the seabed with the apex pointing to the northwest. The frame extensions that hold the eastern two feet can be seen on the east side of the gravity base. The device is 25 m by 21 m in size. For purposes of this discussion, the western most foot is termed Foot 1, the southernmost eastern foot, Foot 2, and the northeastern foot, Foot 3. Topographic elements of the volcanic platform can clearly be seen and used to control the correlation of the sidescan imagery with the position of the device. Figure 24 is a shaded relief multibeam bathymetric map of the NSPI/OH1 site showing the highest resolution attainable from the 0.5 m resolution survey conducted during initial site selection, with the outline of the gravity base and reported position superimposed.

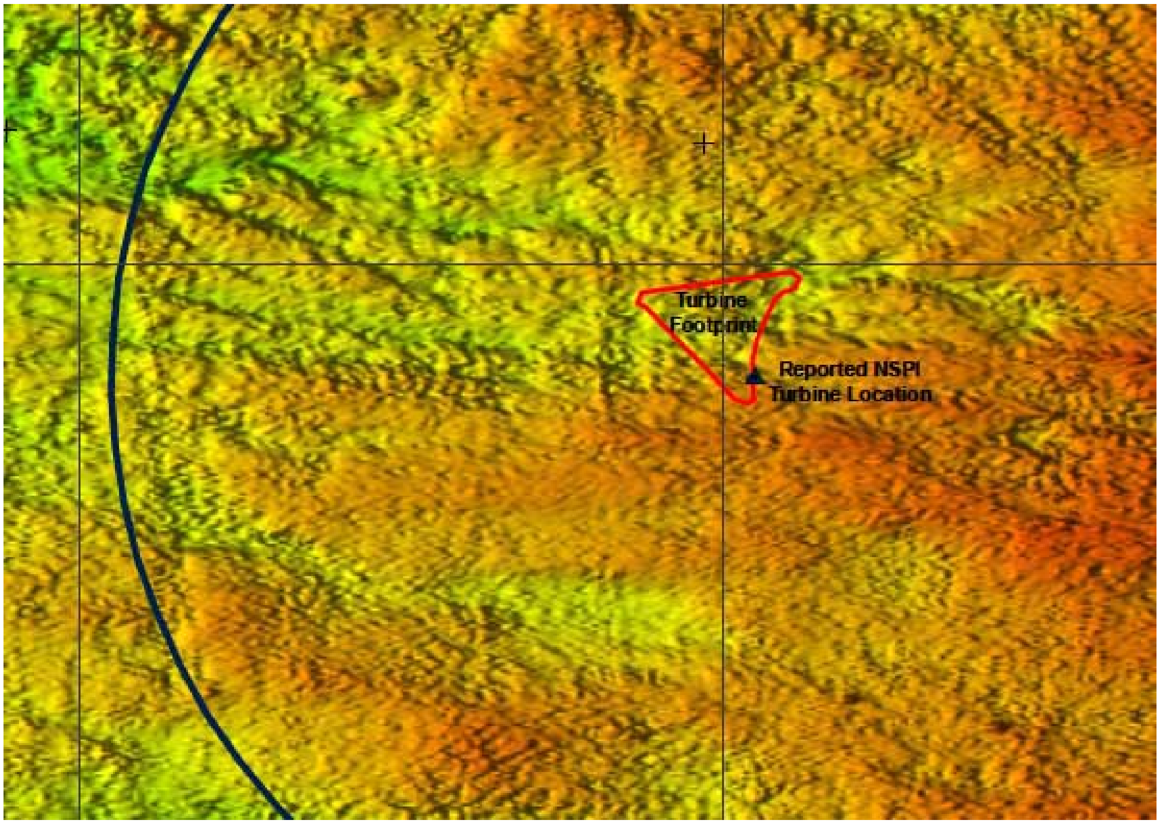

Figure 24 A high resolution multibeam bathymetric image showing the location of the NSPI/OH1 site on the seabed and the relief of the bottom. From this image the exact location and water depths of the position of the feet can be determined.

The sidescan sonograms and the mosaic were processed in the GIS and the position of the device was superimposed on the imagery. This provides a high resolution location of the device and its individual feet relative to the sidescan sonar data. This relationship has been extrapolated to the raw sidescan high resolution imagery and provides a near -optical view of the orientation of the device and the relationship between the feet and the seabed. We have also been fortunate in this correlation in that the monitoring survey sidescan data is of superior quality with minimal current induced motion as is common for surveys in Minas Passage. They data are not distorted and this allows for a direct comparison and placement of the device and individual feet. The position of the device has also been compared with the original sidescan data to confirm the location and to compare for seabed change. The earlier collected sidescan data was of lower quality mainly because of poor survey water conditions where the tow fish was subjected to severe motions. A very careful comparison and correlation was undertaken and a number of seabed landmark points were established amongst the various data sets to provide a high level of confidence in obtaining the exact site of the device and feet for location on the monitoring sonograms. Sidescan sonar systems are less quantitative that multibeam systems for georeferencing seabed features because of extreme operating conditions and a certain amount of minor adjustment is required for precise positioning.

OH1 Device Site Description

The NSPI/OH1 device lies on a hummocky and ridged volcanic surface (Figure 24). The multibeam imagery shows that the feet occur in different water depths indicating that the structure was tilted slightly to the north. The western front foot is in -29.2 m, the south back foot in -28.3 m and the north back foot in -29.6 m water depths. This shows a difference of 0.9 m across the device. The southern foot lies on a bedrock ridge while the western and northern ones are in slight depressions. For detail on the characteristics of the site it is necessary to examine the raw sidescan sonograms. The sidescan survey passed over the site three times, over the centre, and at -25 and +25 m on either side.

Sidescan Sonar Interpretation

The sidescan sonar image that best depicts the seabed and the position of the device feet is line -25 (Figure 25 and 8). It shows the seabed as a series of hummocky broad ridges and smaller isolated linear ridges. Sidescan information shows both seabed hardness and relief. Shadows from objects are differentiated from depressions by the presence of high backscatter (light tone) followed by dark regions (shadows). Depressions are represented by a shift to dark tone without a sonar facing region of high backscatter. Of particular note is that two feet appear to coincide with small depressions on the seabed (Figure 25). Given that the major part of the area around the device is flat, this suggests that it may have shifted to self locate the feet in slightly deeper areas for greater stability. A close inspection of the sidescan sonogram shows that at least two of the feet (A and B) may have eroded small depressions in the volcanic bedrock (Figure 25). If this occurred, the device may have sunk downward approximately 1 m until a flange on the base of the feet was reached and a more stable position was achieved. An examination of device tilt information and abrasion marks on the feet post recovery should provide information on such a hypothesis.

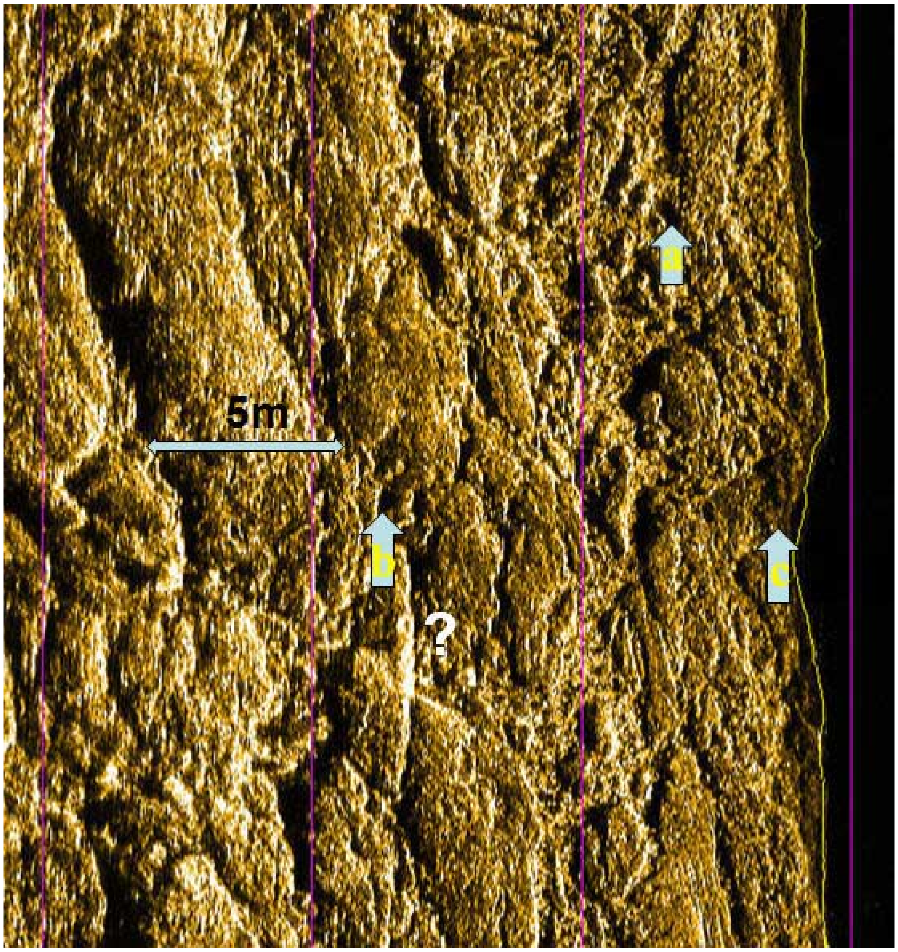

Figure 25 A sidescan sonogram of the site of NSPI/OH1 showing the position of the feet on the seabed. Arrows are used to indicate the locations and not obscure the actual positions. Note the linear unusual feature near the foot b noted with ?.

As mentioned above, the survey sidescan data is of very high quality with no operational degradation of the data as is common in high velocity flow conditions. A linear object has been detected lying on the seabed near the southern foot (B) of the gravity platform (Figure 25). It appears unnatural on the sonar imagery and may represent the lost centre ring of the turbine. It cuts across the natural structural features of the bedrock exposed at the seabed. Foot C lies in a slightly deeper region of the sonogram near nadir. The seabed of this area appears to be gravel covered bedrock. In the nearby region of all the feet there does not appear to be any disturbance of the seabed. No linear marks, sediment piles, or other patterns of movement can be detected. The feet may have excavated up to 1 m deep local depressions in the bedrock and gravel. This would have liberated small quantities of fine grained ground bedrock. However there is no evidence for these materials being deposited in the area around the turbine and they cannot be detected on the sidescan sonograms.

Figure 26 is the pre deployment sidescan sonogram from the same region that was collected during the first survey of the area to choose the sites in 2008. The tow fish was subjected to severe motion by the currents and turbulence during that survey and this presents the information with distortion. A direct comparison of the two surveys identifies some larger common features of the site but details as provided by the sonograms of the monitoring survey cannot be seen. This limits the ability to assess change at the seabed caused by the turbine.

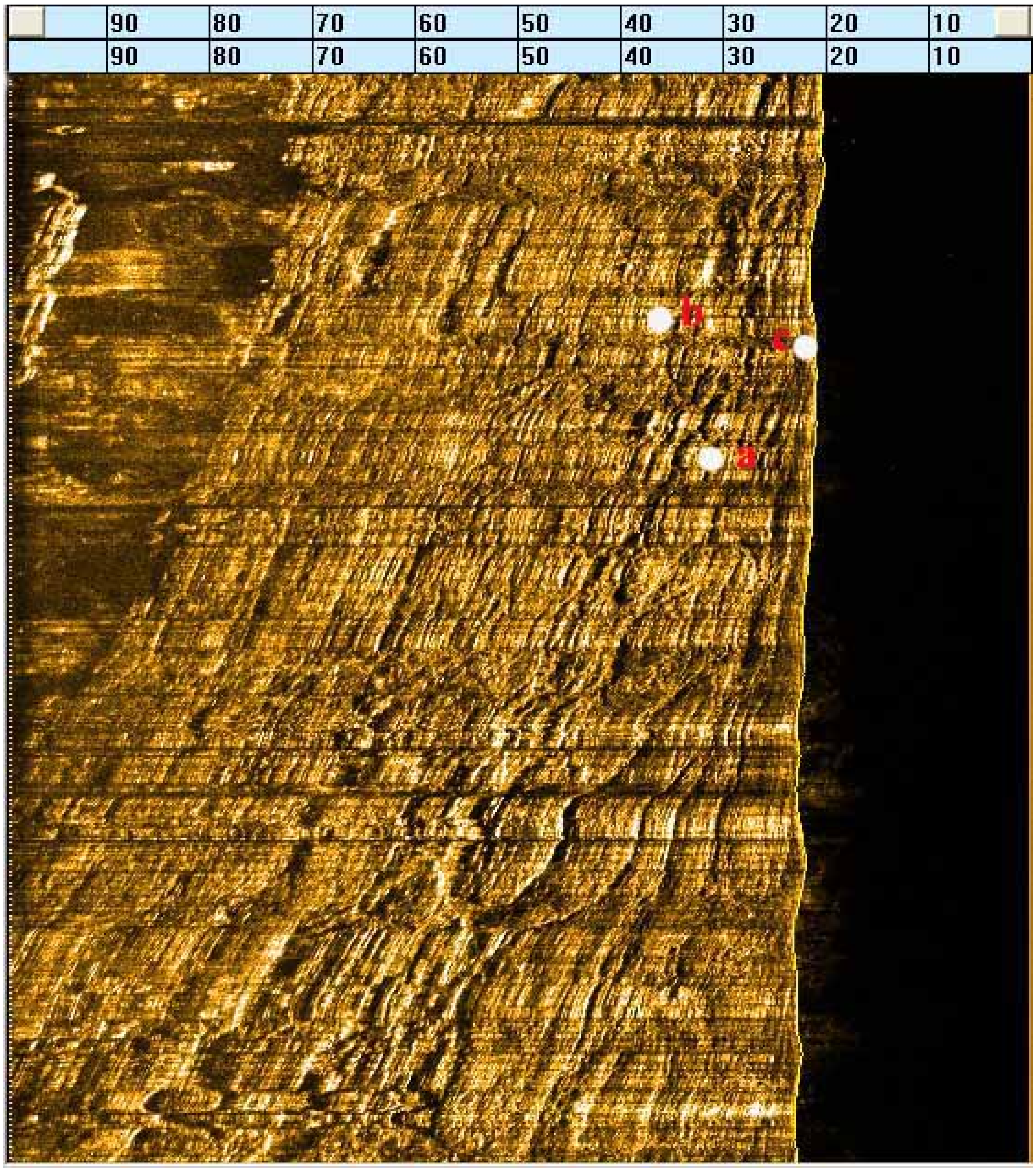

Figure 26 A sidescan sonogram from the site of NSPI/OH1 collected in 2008. It has been compared with the sonograms collected for the monitoring survey to detect change. However, the quality of the first survey data was less because of excessive fish motion due to strong currents and turbulence that was not present during the monitoring survey. The locations of the three feet of the gravity structure are indicated.

Video Information

Four transects across the site were undertaken with towed video camera. Assessment of the imagery shows that the seabed is dominantly bedrock with boulders in places. Many of the boulders are rounded in shape. Linear bedrock cracks and depressions can also be seen. The camera tow speed is quite rapid and suspended particulates reduce the clarity of the imagery. Many of the large boulders and bedrock surfaces are covered with biogenic growth and the breadcrumb sponge stands out because of its yellow colour. It occurs as both complete coverings and in a patchy distribution. The video imagery shows no features that could be attribute to impact or movement by the turbine. No anthropogenic debris was seen on the imagery. The transects covered a large area that extended beyond the deployment site and the seabed appeared to be similar along the entire transects.

Summary for NSPI/OH1 Site

Assessment of the monitoring survey sidescan sonograms shows little change to the seabed from the device. The bottom is very hard bedrock with gravel in slight depressions. Two 1 m diameter circular depressions could have been formed by the feet of the gravity structure. Their depth is not able to be determined. Towed video camera transects show a typical seabed for the Minas Passage region and no features associated with the deployment or retrieval could be detected.

Conclusions

The Reference Site appears not to have changed over a five year period since the first multibeam bathymetry was collected. This includes the distribution of bedrock, gravel and morphology. The deployment, operation and recovery of the Nova Scotia Power Inc. /Open Hydro device have had a minimal effect of the seabed. Two small 1 m diameter depressions are interpreted to have resulted from erosion by the feet of the gravity platform. These occur on exposed basalt bedrock. No other change in bathymetry, sediment distribution, or seabed scouring could be detected from the high resolution survey data.

Suggested Activities for Future Deployments

Based on the results from the monitoring study of NSPI/OH1, the following suggestions are put forth. This information will help future monitoring studies.

1) The position of the sites for future devices needs to be accurately known both before and after deployment. This should also include the positions of device feet if gravity platforms are deployed.
2) Post deployment surveys are recommended to determine the exact location and orientation of devices with respect to seabed morphology and features for accurate georefferencing. This is best accomplished by multibeam bathymetric surveying.
3) A pre deployment plan that includes the methods, intended position, orientation, and slope would be useful in assessing effects.
4) A post recovery report should include details of the recovery operation and measurements of the behaviour of the device over the period of deployment. This should include shifting, reorientation and settlement of the device and marks on the device that indicate abrasion by seabed materials. Sensors should be positioned on the device to periodically record these measurements. Only when the exact location for the device is known relative to seabed materials and morphology, can monitoring surveys be properly conducted.
5) The use of ROVs should be assessed for their applicability to monitoring studies in the future. Despite the strong currents, precise photographic imagery can help determine localized effects and could be undertaken at times of low velocity currents. The resolution of photographic imagery is mm compared to decimetres using sidescan sonography. Simple dropped cameras are difficult to position in these waters so ROVs offer the best method for targeted photo imagery.
6) It is recommended that a bottom photographic survey be conducted at the Reference Site at the time of the next opportunity where equipment is deployed for other investigations. This would provide a high resolution assessment of sediment distribution, texture, benthic habitat and benthic organisms.

Acknowledgements

Seaforth Geosurveys Inc. and staff are thanked for their seagoing efforts to collect high quality data and processing of the information for this assessment. In particular Arthur Abbott is thanked for data processing and manipulation of sidescan sonogram data for comparison purposes. Nova Scotia Power Inc. and Open Hydro are thanked for their provision of information on the deployment and recovery operations.

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FORCE

FUNDY TIDAL ENERGY DEMONSTRATION PROJECT
Environmental Effects Monitoring Report

APPENDIX K

Final Report – Suspended Sediment Monitoring, July 2010

Oceanographic Measurements from Ships of Opportunity, Minas Passage Study Site, July 2010 - January 2011

Submitted to:

Fundy Ocean Research Centre for Energy (FORCE)
January 31, 2011

Submitted by

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EXECUTIVE SUMMARY

Oceanographic measurements were made on vessels of opportunity in Minas Passage in July, August, and October 2010 and January 2011, to obtain information on water transparency, suspended sediment, and water temperature. Observations were consistent with the seasonal pattern based on earlier observations for the site, which includes high transparency and low suspended sediment levels in summer, reaching low transparency and higher suspended sediment levels in winter. Sea surface temperature showed a late-summer peak, ranging from 16.3 -17.4º C. in August to a low of 3.5 - 4.1º C. in January; and suspended sediment levels ranged from 3.3 to 6.2 mg/L in July - August to levels of 9.4 to 12.5 mg/L in January. Secchi Depth, a measure of water transparency, ranged from 2.75 to 3.5 m in July and August respectively to a low of 1.5 m in January 2011.

INTRODUCTION

Nova Scotia's Bay of Fundy has the highest tides in the world and the greatest potential for generation of electricity from the tides. In 2008, in part to further its commitment to a sustainable energy future for Nova Scotians, the Province of Nova Scotia undertook to establish a research and test facility for tidal power technology development, selecting a local company, Minas Basin Pulp and Power Limited of Hantsport, Nova Scotia, to develop and execute the project. A location in Minas Passage near Cape Sharp was selected and after completion of environmental baseline studies and an environmental assessment, the project was given environmental approval in September 2009. The project has continued under the *aegis* of the newly formed Fundy Ocean Research Centre for Energy (FORCE), the organization constituted for and which is currently operating the project.

In addition to requirements for environmental data to support engineering and design, and regulatory environmental monitoring requirements, FORCE participates in and supports various related scientific studies designed to increase knowledge of the biology and physics of the Inner Bay of Fundy. As part of this role, baseline physical oceanographic measurements of water column temperature, salinity, turbidity and suspended sediment levels were obtained in the summer of 2008 and during the winter and summer of 2009 (Envirosphere Consultants Limited, 2009 & 2010). Several ship-board surveys in the vicinity of the site in 2010-2011 provided an opportunity to obtain additional data on suspended sediment levels, water transparency, and sea surface temperature at the site, information which is useful in understanding the physical oceanography and impacts of tidal projects on sedimentation, but for which there is a limited data record due to the difficult logistics and expense of sampling there. This report presents the results of sampling efforts carried out between July 2010 and January 2011.

METHODS

<u>Sampling Methods</u>

Opportunistic sampling was arranged to take place during vessel-based seabird surveys on July 19th and August 18th, 2010; on a fisheries survey on October 25-26, 2010; and on a geophysical cruise on January 15, 2011. Sampling was coordinated with times of overflights of the European Space Agency's *Envisat* satellite[1] through DFO, Ocean Sciences Division[2]. On each survey, two stations were arranged to coincide with the project site, one on the incoming and one on the outgoing tide. An additional station on each sampling date, except for the October survey, was arranged to be at the vessel location at the time of the *Envisat* overflight. At each sampling location, Secchi Depth (a measure of transparency) was determined immediately upon reaching the station (or at the time of the satellite overpass) by lowering a standard 22 cm diameter Secchi Disk and noting the depth of disappearance and reappearance of the disk, with Secchi Depth reported as the average of the two measurements. A 10 L water sample was then taken in a clean bucket from over the side of the boat and temperature was immediately determined using a YSI Model 85 hand-held Dissolved Oxygen, Conductivity, and Temperature probe. The contents of the bucket were stirred and two, one-Litre samples were withdrawn for Suspended Particulate Matter (SPM) analysis. Bucket samples taken at

[1] The Envisat satellite carries MERIS, a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range, which provides data which can be used to measure suspended sediment levels. Data obtained in the present survey provides ground-truthing for the satellite sensor.
[2] Times for the satellite overflight were provided by Dr. Gary Bugden, Fisheries and Oceans Canada, Ocean Sciences Division, Bedford Institute of Oceanography, and the results were routinely forwarded to him.

the surface in Minas Passage are representative of the water column, due to the high degree of vertical mixing occurring at the site, demonstrated in earlier surveys. Water samples were stored in a cooler and returned to the laboratory at the end of the survey, usually within 10 hours of sampling, and held at 2-8 ˚C. prior to analysis, which typically took place within 24 hours of delivery[3]. Position was logged from the vessel's positioning system. Time was measured by a digital watch which was checked to be accurate to within 15 seconds of the NRCan Time Signal broadcast (July & August); the consultant's watch likely to be accurate to within 5 minutes (October); and the geopositioning system, likely to be within a second of absolute time (January 2011). The accuracy of the thermometer in the YSI probe was determined in the lab to be within 0.1 ˚C of an NIST traceable thermometer with an accuracy of 0.05 ˚C.

Survey Details

July 19th and August 18th— Sampling was carried out by Envirosphere Consultants Limited's technologist Matt MacLean, during seabird and marine mammal surveys on the *Lady Chantel,* a chartered lobster boat out of Scots Bay (Figure 1). One of the stations on each date was occupied at the time the *Envisat* satellite was directly overhead. Clear skies and good visibility on July 19th made for a good correlation with the satellite; while conditions early in the day on August 18th and at the time the overflight were foggy, although the skies cleared in the afternoon—consequently the observations may not be as useful.

October 26th—The survey vessel (MV *Carmelle #2*) conducted trawl and acoustic fish surveys from approximately 1930 hrs (ADT) on October 25 to around noon on October 26, 2010, during which the vessel was in the Minas Channel / Minas Passage area, departing from and docking in Hantsport. Fisheries biologist Norval Collins of CEF Consultants took water samples, and Secchi Depth and instrument measurements as per instructions and with equipment supplied. In the absence of a functioning satellite for this cruise, a third station was occupied in Minas Basin on the return trip to Hantsport (Figure 2, Table 1)

January 15th, 2011— Seaforth Geosurveys Inc. of Dartmouth, Nova Scotia, chartered the survey vessel *Fundy Spray* (Huntsman Marine Science Centre, St. Andrews) to conduct a geophysical (sidescan and underwater video) survey on Saturday, January 15, 2011, during which surface water samples were taken for Suspended Particulate Matter, and temperature and Secchi Depth were measured (Andrew Campbell, Marine Geologist, Seaforth Geosurveys) as per instructions and with equipment supplied (Figure 3). Water sampling took place from 1000 to 1420 hrs (AST), during which the vessel was in the Minas Channel/Minas Passage area. One of the samples coincided with the *Envisat* satellite overpass (1130 hrs versus the satellite overhead at 1121) but the weather, although calm, was overcast. High tide was at approximately 0804 hrs and low tide at 1425 hrs.

Laboratory Analysis

SPM measurements were obtained in the lab by filtering approximately 1 L of each sample (actual volume filtered was measured in a 1L graduated cylinder) through pre-rinsed (deionized water), pre-weighed Millipore 0.45 µm membrane filters, followed by 3 x 10 mL rinses with deionized water. Filters were dried for 1 hour at 65 ˚C. Envirosphere Consultants Limited is accredited for this analysis by Canadian Association for Laboratory Accreditation (CALA).

[3] The January 2011 samples reached the laboratory 72 hrs after sampling due to the travel time from St. Andrews, N.B. and were analysed 24 hrs later.

RESULTS AND DISCUSSION

Measurements made during the surveys provide additional information to assist in calibrating numerical models of suspended sediment distribution in Minas Passage, for which limited observational data, particularly in winter, is available. In addition, measurements coincident with the *Envisat* satellite overpass, provide ground-truthing to assist in improving predictions of suspended sediments levels and ocean temperature for the area based on satellite remote-sensing data. Sample locations are presented in Figures 1-3, and measurements obtained in the survey are presented in Table 1. Both the October and January sampling filled gaps for those months in the seasonal data record. Measurements were consistent with the seasonal pattern which is emerging for the site, which includes high transparency and low suspended sediment levels in summer, reaching low transparency and higher suspended sediment levels in winter. Sea surface temperature showed a late-summer (August) peak where temperatures ranged from a peak of 16.3 - 17.4º C. to a low of 3.5 - 4.1º C. in January (Table 1, Figure 4). Peak temperatures were comparable to those observed in earlier studies at the site, while temperature recorded in the January survey is not as low as has been recorded later in the winter (February-March) in previous surveys. Suspended sediment levels ranged from 3.3 to 6.2 mg/L in the July to August period with elevated January levels of 9.4 to 12.5 mg/L (Figure 5). January levels were below those observed in the earlier surveys in February – March, while the July to October levels were lower than observed previously for the same period. Secchi Depth as a measure of transparency ranged from 2.75 to 3.5 m in July and August to a low of 1.5 m in January 2011 (Table 1). All measurements of transparency were lower than the highest values measured at the study site (5.8 m at Station 19 in June 2009)(Figure 6).

Table 1. Oceanographic Measurements, Minas Passage and Minas Basin, July 2010 to January 2011. Values of duplicate samples for SPM are shown in brackets.

Date (m/d/y)	Station	Location	Time (ADT)	Secchi Depth (m)	Temp-erature (˚C.)	SPM (mg/L)	Detect-ion Limit (mg/L)
7/19/2010	19 (ebb)	45 22.28 64 25.32	1000	2.75	15.3	4.8 (4.6)	0.5
“	Satellite	45 23.06 64 33.17	1213	2.75	16.0	5.6 (4.0)	0.5
“	19 (flood)	45 22.32 64 25.36	1650	2.75	15.4	3.6 (6.2)	0.5
8/18/2010	19 (ebb)	45 22.098[2] 64 25.679	940[1]	3.50	16.3	3.5 (3.3)	0.5
“	Satellite	45 22.92 64 30.62	1130	3.05	16.6	3.7 (3.7)	0.5
“	19 (flood)	45 22.098[2] 64 25.679	1730[1]	3.25	17.4	3.3 (6.2)	0.5
10/26/2010	19 (ebb)	45 22.098 64 25.679[2]	0840	--	12.8	6.3 (4.2)	0.5
“	19 (flood)	45 22.098 64 25.679[2]	1105	2.0	12.9	6.1 (5.2)	0.5
“	Minas Basin	45 14.477 64 16.495	1230	--	13.1	6.2 (5.3)	0.5
1/15/2011	19 (ebb)	45 22.1132 64 25.7303	1000 (AST)	1.5	4.0	11.6 (12.5)	0.5
“	Satellite	45 21.9191 64 27.2292	1130 (AST)	1.5	4.1	9.7 (9.4)	0.5
“	19 (low)	45 22.0933 64 25.6753	1420 (AST)	1.5	3.5	11.1 (10.8)	0.5
1. Estimated. 2. Nominal position.							

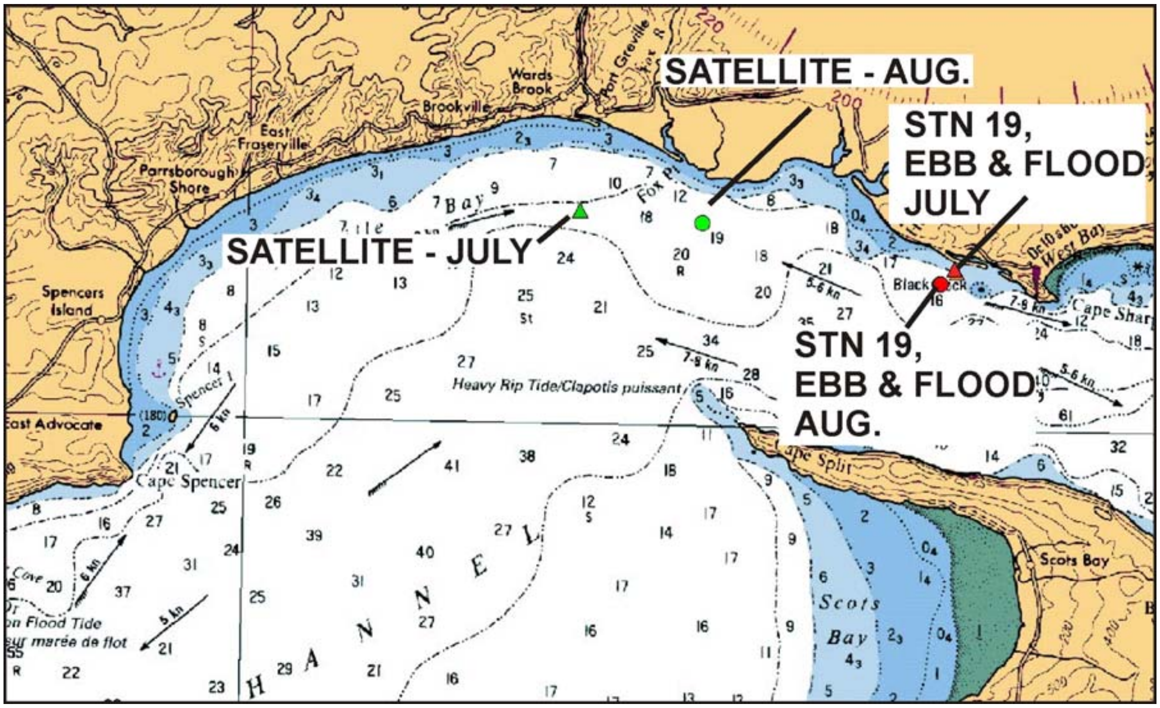

Figure 1. Sampling locations in Minas Passage, July 19 & August 18, 2010.

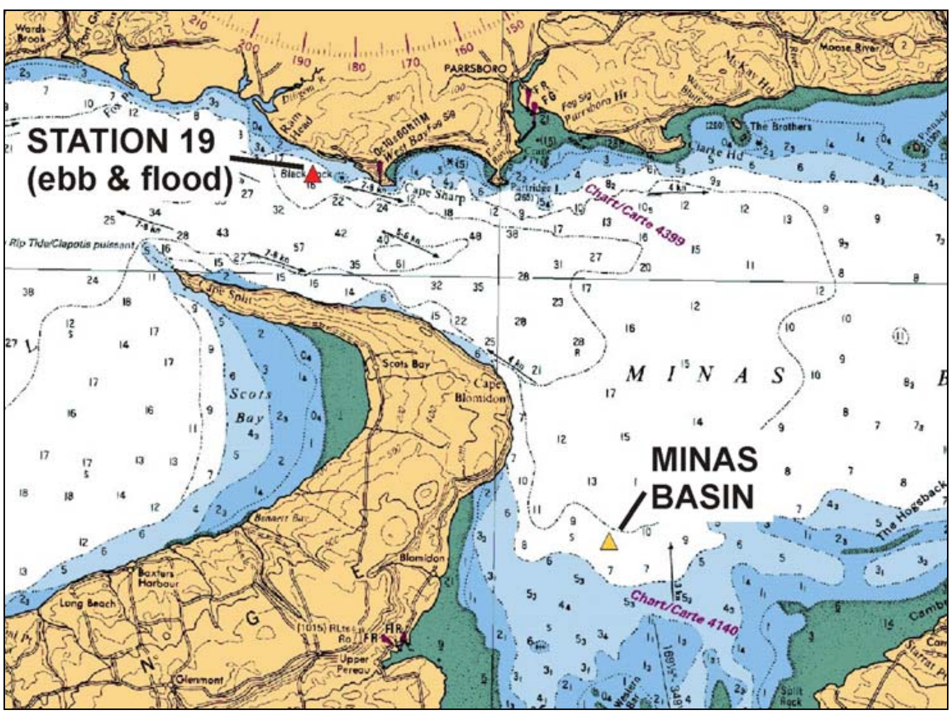

Figure 2. Sampling locations in Minas Passage & Minas Basin, October 26, 2010.

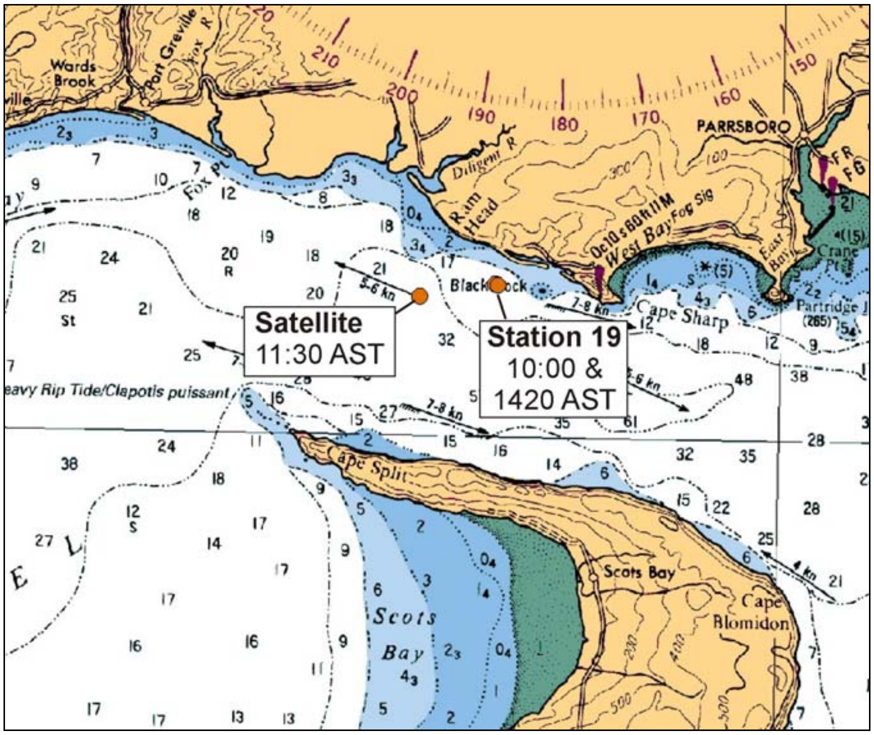

Figure 3. Sampling locations in Minas Passage, January 15, 2011.

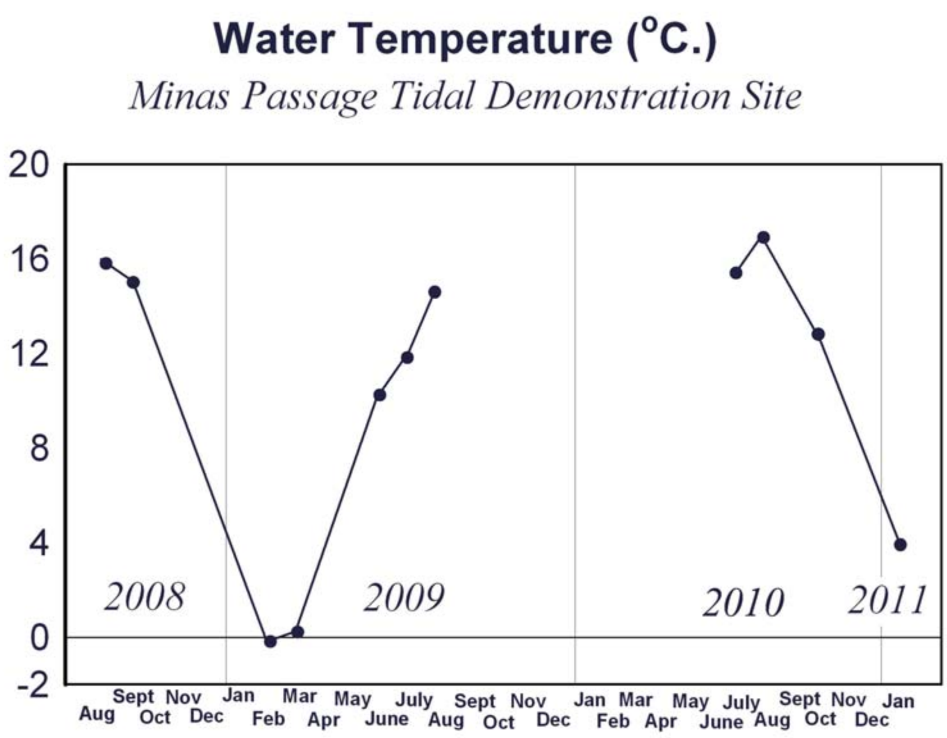

Figure 4. Seasonal pattern in surface water temperature, Minas Passage, from data obtained during Fundy Tidal Energy Demonstration Project, August 2008 to January 2011.

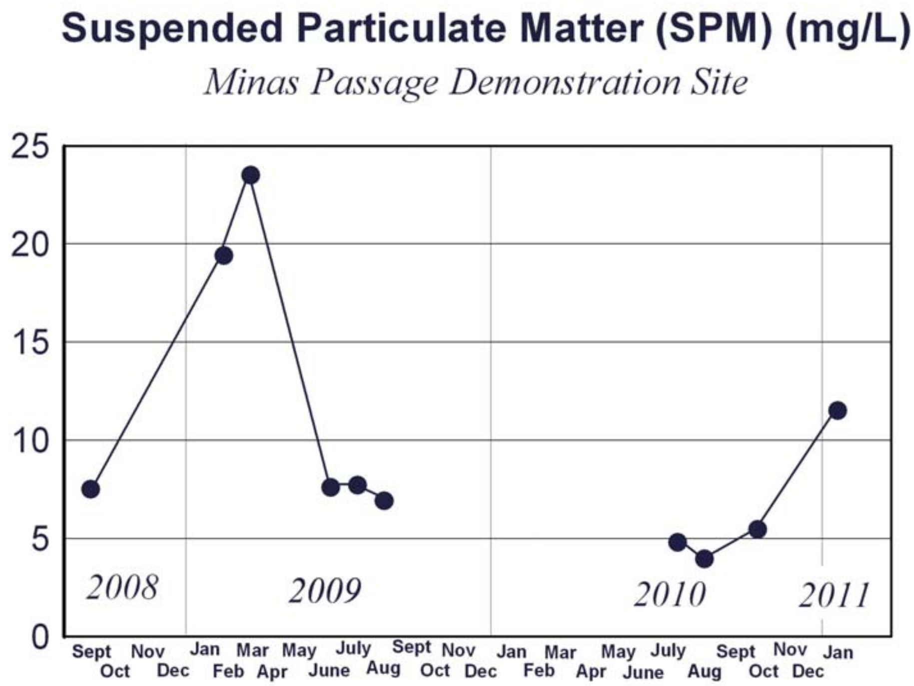

Figure 5. Seasonal pattern in suspended particulate matter (SPM) concentrations in Minas Passage, from data obtained during Fundy Tidal Energy Demonstration Project, August 2008 to January 2011.

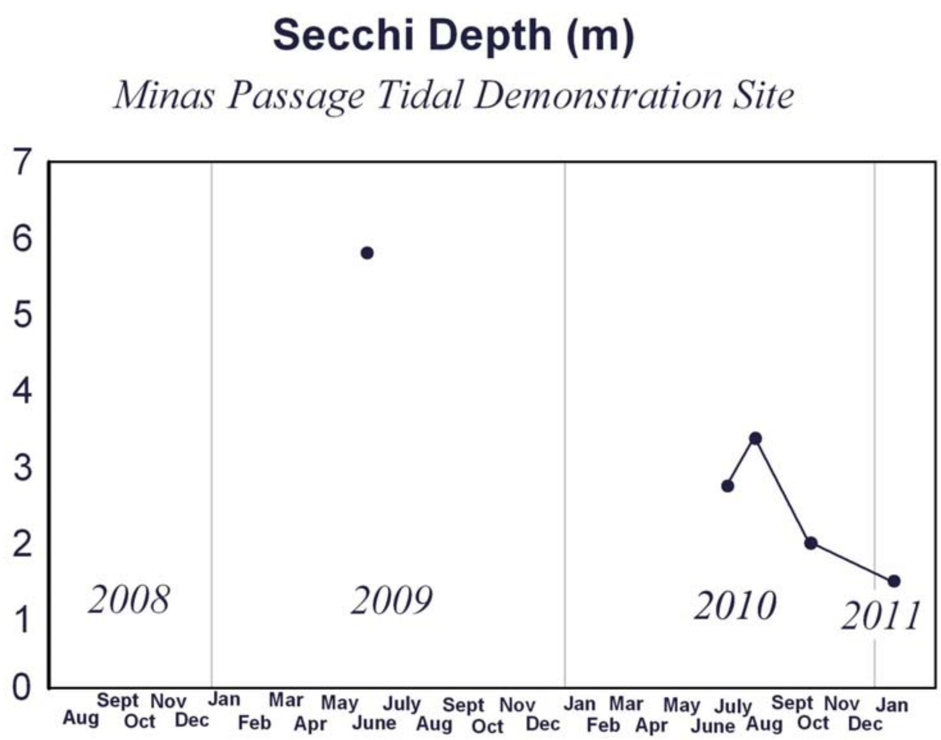

Figure 6. Seasonal pattern in Secchi Depth (m) in Minas Passage, from data obtained during Fundy Tidal Energy Demonstration Project, June 2009 to January 2011.

CONCLUSIONS AND RECOMMENDATIONS

The 'ships of opportunity' program carried out in 2010 was successful in providing high quality data at low cost, in particular to address data gaps in the seasonal pattern of water temperature, suspended particulate matter, and transparency, in Minas Passage. The sampling program will be continuing in 2011 and obtaining data in the winter-spring (January-May) period remains an important objective. Opportunities will continue to be examined for sampling in conjunction with other research and monitoring projects being carried out in Minas Passage this year.

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