COBSCOOK BAY TIDAL ENERGY PROJECT

2013 ENVIRONMENTAL MONITORING REPORT FINAL DRAFT

FERC PROJECT NO. P-12711-005

MARCH 3, 2014

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March 3, 2014

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Subject: **Cobscook Bay Tidal Energy Project (P-12711-005)**
2013 Environmental Monitoring Report

Dear Ms. Bose:

ORPC Maine, LLC (ORPC) is pleased to submit the attached 2013 Environmental Monitoring Report for the Cobscook Bay Tidal Energy Project. The 2013 environmental monitoring results continued to increase knowledge about marine life interaction with the TidGen® Power System and indicated negligible environmental effects for many elements of the monitoring plans.

This Report is submitted following a 30-day agency review period. In addition to technical comments, ORPC was pleased to receive positive feedback from the Adaptive Management Team on the Report and the value and benefit of the adaptive management process. ORPC has revised this report to address comments received where necessary.

If you have any questions regarding this submission, please contact me by telephone at 207/221-6254 or by email, njohnson@orpc.co.

Sincerely,

Nathan E. Johnson
Director of Environmental Affairs

CONTENTS

LIST OF FIGURES ..... **iv**
LIST OF TABLES ..... **vi**
LIST OF APPENDICES ..... **vi**
EXECUTIVE SUMMARY **ES-1**
1.0 INTRODUCTION **1**
1.1 PROJECT BACKGROUND 1
1.2 TGU OPERATION 3
1.3 TGU RETRIEVAL AND TECHNOLOGY OPTIMIZATION PHASE 3
2.0 ADAPTIVE MANAGEMENT (License Article 404) **5**
2.1 ADAPTIVE MANAGEMENT PLAN AND TEAM 5
2.2 2013 ADAPTIVE MANAGEMENT TEAM MEETINGS 6
2.2.1 MARCH 12, 2013 7
2.2.2 SEPTEMBER 10, 2013 7
2.3 COBSCOOK BAY TIDAL ENERGY PROJECT LICENSE MODIFICATIONS 8
3.0 ACOUSTIC MONITORING (License Article 405) **10**
3.1 METHODOLOGIES 10
3.2 RESULTS - PHASE I TIDGEN® MEASUREMENTS 12
3.3 POTENTIAL EFFECTS 13
3.4 ACCELEROMETER CORRELATION 15
3.4.1 CORRELATION METHODOLOGY 15
3.4.2 CORRELATIONS 20
3.5 CONCLUSIONS AND RECOMMENDATIONS 23
4.0 BENTHIC AND BIOFOULING MONITORING (License Article 406) **24**
4.1 METHODOLOGIES 25
4.1.1 BENTHIC SURVEYS OF CABLE ROUTE 25
4.1.2 BENTHIC SAMPLING 26
Subtidal 26
Intertidal 27
4.1.3 BIOFOULING ASSESSMENT 28
4.2 RESULTS 29

4.2.1 BENTHIC SURVEY OF CABLE ROUTE 29
4.2.2 BENTHIC SAMPLING RESULTS 30
Subtidal 30
Intertidal 30
4.2.3 BIOFOULING RESULTS 31
TidGen® TGU 31
Biofouling of Other TGU Components 34
Bottom Support Frame 35
Effectiveness of Anti-Fouling Paint. 38
4.3 CONCLUSIONS AND RECOMMENDATIONS 40
Cable survey 40
Benthic Sampling 41
Biofouling Assessment 43
5.0 FISHERIES AND MARINE LIFE INTERACTION MONITORING (License Article 407) 44
5.1 METHODOLOGIES 45
5.1.1 FISHERIES MONITORING PLAN (DOWN-LOOKING HYDROACOUSTIC SURVEYS) 45
5.1.2 MARINE LIFE INTERACTION MONITORING PLAN (SIDE-LOOKING HYDROACOUSTICS) 49
5.2 RESULTS 58
5.2.1 FISHERIES MONITORING PLAN (DOWN-LOOKING HYDROACOUSTICS) 58
5.2.2 MARINE LIFE INTERACTION MONITORING PLAN (SIDE-LOOKING HYDROACOUSTICS) 63
Fish density by zone 64
Direction of movement 65
5.3 CONCLUSIONS AND RECOMMENDATIONS 67
5.3.1 FISHERIES MONITORING PLAN (DOWN-LOOKING HYDROACOUSTIC SURVEYS) 67
Overall Fish Density 68
Vertical Distribution 69
5.3.2 MARINE LIFE INTERACTION MONITORING PLAN (SIDE-LOOKING HYDROACOUSTICS) 69
5.3.3 UMAINE REMARKS 70
6.0 HYDRAULIC MONITORING (License Article 409) 71
6.1 METHODOLOGIES 71

6.1.1 ADCP MEASUREMENTS AND HYDRODYNAMICS 71
6.1.2 SCOUR MONITORING 72
6.2 RESULTS 73
6.2.1 HYDRODYNAMIC MODELING 73
6.2.2 SCOUR MEASUREMENTS 74
6.3 CONCLUSIONS AND RECOMMENDATIONS 75
7.0 MARINE MAMMAL MONITORING (License Article 410) 76
7.1 METHODOLOGIES 76
7.1.1 INCIDENTAL OBSERVATIONS 76
7.2 RESULTS – INCIDENTAL OBSERVATIONS 77
7.3 CONCLUSIONS AND RECOMMENDATIONS 79
8.0 SEA AND SHOREBIRD MONITORING (License Article 412) 80
8.1 METHODOLOGIES 80
8.2 RESULTS: 2012-2013 WINTER MIGRATING SEASON 82
8.3 CONCLUSIONS AND RECOMMENDATIONS 84
9.0 CONCLUSIONS AND RECOMMENDATIONS 86
9.1 THE ROLE OF ADAPTIVE MANAGEMENT 86
9.2 ENVIRONMENTAL MONITORING RESULTS 86
9.3 TEMPORARY VARIANCE PERIOD 88
10.0 AGENCY REVIEW AND RESPONSE 89
10.1 AGENCY COMMENTS AND ORPC RESPONSE 89
10.2 PUBLIC DISSEMINATION OF 2013 ENVIRONMENTAL MONITORING RESULTS 92
11.0 LITERATURE CITED 93

LIST OF FIGURES

Figure 1. Cobscook Bay Tidal Energy Project location map. 2
Figure 2. TidGen® device illustrating turbine generator unit and bottom support frame........ 3
Figure 3. TidGen® TGU retrieval, July 15, 2013. 4
Figure 4. Drifting noise measurement system. 11
Figure 5. DNMS during deployment at the Project site, April 2, 2013........ 12
Figure 6. Power spectral density for the generating turbine at various ranges from the turbine. April 2-3, 2013. 13
Figure 7. Accelerometer mounting locations 16
Figure 8. Accelerometer with Generator ON: Welch's Power Spectral Density using Default Window Settings........ 18
Figure 9. Accelerometer with Generator ON: Welch's Method Power Spectral Density using window size 1000. 18
Figure 10. Accelerometer with turbine Freewheeling: Welch's Power Spectral Density using Default Settings........ 19
Figure 11. Accelerometer with turbine freewheeling: Welch's Method Power Spectral Density using window size 1000. 19
Figure 12. Generator ON, PSD using MATLAB function PSD with default settings........ 20
Figure 13. Acoustic results during freewheeling indicating spikes at 105, 210 Hz. 21
Figure 14. Accelerometer results during freewheeling, indicating numerous spikes between 0-210 Hz. 21
Figure 15. Acoustic results while generating, indicating spikes at 105 and 210 Hz as well as 5 kHz. 22
Figure 16. Accelerometer results while generating, indicating potential spikes at 105 and 210 Hz. 5 kHz is above range. 22
Figure 17. June 13, 2013 diver and drop camera video survey transects (Source: ORPC; MER)25
Figure 18. TidGen® TGU following retrieval, July 15, 2013. 32
Figure 19. TidGen® generator, July 15, 2013. 32
Figure 20. Bracelet anode. 33
Figure 21. TGU mounting bracket to bottom support frame........ 33
Figure 22. Inboard anode 3-3-4 showing minimal biofouling 36
Figure 23. The outboard side of pile 1 with urchins, several mussels and anemones. 36
Figure 24. The base plate on pile 5 showed minimal growth. 37
Figure 25. Significant growth between piles 1 and 2. 37
Figure 26. Schematic of bottom support frame biofouling 38
Figure 27. Diagram of anti-fouling paint upon application. 39
Figure 28. Area treated with anti-fouling tape upon inspection. 39
Figure 29. Location of TidGen® 001 and environmental monitoring equipment. 45
Figure 30. Fisheries Monitoring Plan study area and down-looking hydroacoustic survey locations for 2010-2013. CB1 and CB2 are indicated by dashed ovals. CB1a and CB1b are indicated by small round points. CB1 current directions are averages provided by ORPC. 47
Figure 31. Environmental monitoring observation tower. 50
Figure 32. Marine Life Interaction Monitoring Plan setup. TidGen® device and Simrad EK60 support structure shown from (a) the seaward side and (b) above. Hydroacoustic beam

represented as 7° cone (half-power beam width) in solid black lines. Red hatched area indicates sampled volume within the turbine zone, A indicates the volume sampled above the turbine, and B indicates the volume sampled beside the turbine. Current directions shown are Project site averages provided by ORPC. 51
Figure 33. (a) Sample of side-looking hydroacoustic data from September 30, 2012 during the flood tide. (b) Fish in red dashed oval in (a) tracked through beam cross section. Outer circle represents 3.5° off-axis, or 5.3 m at this range. Each dot is a single detection of the fish. Red dashed arrow indicates direction of movement. 52
Figure 34. Target strength (TS) distribution from before the turbine range (< 44.5 m from transducer) and within the turbine range (> 44.5 m and < 78.1 m from transducer). 57
Figure 35. Water column S_v for all years sampled (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles. Significantly different groups are indicated by letters a and b (*). In 2013, only March, May, and June were analyzed. 59
Figure 36. Water column S_v at CB1a, CB1b, and CB2 surveys in 2012 and 2013. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles. 59
Figure 37. Water column S_v at CB1 (which includes CB1a and CB1b data) and CB2. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles. Asterisks indicate significant differences between CB1 and CB2. † indicates surveys when only ebb tide data were sampled; ‡ indicates surveys when only daytime was sampled. Yellow hatched box indicates surveys when the TidGen® bottom support frame was present on the seafloor; red hatched boxes indicate when the TidGen® turbine was also present. The turbine was braked (present but not spinning) starting mid-April until it was removed in July. 60
Figure 38. Water column S_v for all surveys (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles. Significantly different groups within each year are indicated by letters a through d (group a is the highest, d is the lowest). 61
Figure 39. Mean proportion of S_a contributed by each layer of the water column. All layers analyzed are shown for each site (0-15 m above the bottom at CB1, 0-26 m above the bottom at CB2). Whiskers are one standard error. Depth of turbine is indicated by horizontal dashed lines. Yellow hatched areas indicate when the bottom support frame was deployed at the project site; red hatched areas indicate when the turbine was also present. Significantly different distributions between sites are indicated by letters "a" and "b" in the upper right of the graph. 62
Figure 40. Mean fish density (fish/hm^3) of each tide of each dataset. Whiskers are one standard error. 63
Figure 41. Number of fish detected during the slack tides in each dataset. 64
Figure 42. Mean fish density (fish/hm^3) in each zone (+/- 1 standard error). 65
Figure 43. Distribution of fish headings during each dataset (0 = North). Values are scaled to number of fish detected in each zone. 66
Figure 44. Distribution of fish inclination during each dataset (-90 = down, 0 = horizontal, 90 = up). Values are scaled to number of fish detected in each zone. 67

Figure 45. Foundation pile marking scheme for monitoring scour. Foundation pile prior to installation on left. On the right is installed pile #7 indicating the measured reference distance (h) from the bottom support frame skirt to the seabed. 72
Figure 46. Typical velocity (m/s) profiles upstream (+) and downstream (-) of a tidal turbine .. 73
Figure 47. Plan view of TidGen® Power System showing pile numbers 74
Figure 48. Sea and shore bird study area 81

LIST OF TABLES

Table 1. *Cobscook Bay Tidal Energy Project Adaptive Management Team* 5
Table 2. *Summary of 2013 Cobscook Bay Tidal Energy Project license modifications* 9
Table 3. *Biofouling description for TidGen® components* 31
Table 4. *Summary of Corrosion* 34
Table 5. *Evaluation of anti-fouling paint* 40
Table 6. *Months sampled for Fisheries Monitoring Plan (down-looking hydroacoustics). 1 and 2 indicate sampling at CB1 and CB2, respectively; 1a, 1b, and 2 indicate sampling at CB1a, CB1b, and CB2, respectively. Light gray indicates presence of TidGen® bottom support frame only; dark gray indicates presence of complete TidGen® device.* 46
Table 7. *Summary of data subset analyzed to date.* 54
Table 8. *Single target detection settings in Echoview.* 55
Table 9. 4*D fish track detection settings in Echoview* 56
Table 10. *Fish track acceptance parameters used in MATLAB processing* 56
Table 11. *Scour Measurements* 75
Table 12. *Incidental sightings of marine mammals* 78
Table 13. *Adaptive Management Team Comments on 2012 Environmental Monitoring Report.* . 89

LIST OF APPENDICES

APPENDIX A: Adaptive Management Team Meeting Minutes (March and September 2013)

APPENDIX B: CBTEP Phase I Acoustic Monitoring Report

APPENDIX C: Review of video recordings of June 13, 2013, MER Associates, July 23, 2013

Interim Report, Subtidal and intertidal benthic survey, Upper Cobscook Bay, Maine, MER Associates, December 31, 2013

ORPC Biofouling Inspection Reports

APPENDIX D: Fisheries and Marine Life Interaction Monitoring, Bi-Annual Report, September 2013

APPENDIX E: Sandia National Laboratory, Quarterly Hydraulic Reports

APPENDIX F: Marine Mammal Recorder Sheets

APPENDIX G: Report to ORPC on Bird Studies in Cobscook Bay, Maine, Third Winter Season Period of Investigation, November 2012 - April 2013

APPENDIX H: Agency Review Comments

APPENDIX I: 2013 Environmental Monitoring Summary

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EXECUTIVE SUMMARY

Introduction

ORPC Maine, LLC, a wholly-owned subsidiary of Ocean Renewable Power Company, LLC (collectively ORPC), submits this 2013 Environmental Monitoring Report for Phase I of the Cobscook Bay Tidal Energy Project (Project), in compliance with the Federal Energy Regulatory Commission (FERC) pilot project license P-12711-005. This report represents a significant achievement for the Project and its Adaptive Management Plan and demonstrates improved knowledge of our TidGen® Power System's operation and interaction with the marine environment.

The purpose of FERC's pilot project license process is to advance new marine hydrokinetic technology while minimizing the potential for environmental impacts. The process allows developers to test and evaluate new hydrokinetic technologies and determine environmental effects of the technologies, while maintaining FERC oversight and agency input. Pilot projects must be temporary, limited in size, removable, and able to shut down on short notice. License terms ensure environmental monitoring and safeguards during the short project term.

ORPC is using this licensed pilot project to advance, demonstrate, and accelerate deployment of its tidal-current based marine hydrokinetic energy conversion technology, associated power electronics, interconnection equipment, and environmental monitoring program within a replicable full-scale, interconnected array of devices capable of reliably delivering electricity to the domestic power grid. The Project consists of designing, building, installing and monitoring a commercial-scale array of multiple, grid-connected TidGen® devices on the sea floor in Cobscook Bay off Eastport and Lubec, Maine.

The Role of Adaptive Management

The Project has successfully demonstrated the ability to modify license requirements based on the results of science-based data collection, the engagement and concurrence of the Adaptive Management Team (AMT), and clear communication with FERC. This process has garnered international attention as a model for adaptive management.

ORPC provided the 2012 Environmental Monitoring Report to the AMT in February 2013 with a subsequent meeting held on March 12, 2013. This meeting was an opportunity for ORPC to summarize the early results of the monitoring program and solicit feedback from the AMT, including any recommendations for program modifications. ORPC subsequently met with the AMT on September 10, 2013 to provide updated environmental monitoring and project status information.

Through the adaptive management process, ORPC has requested modifications to environmental monitoring to clarify elements of the plan and reduce frequency of monitoring surveys based on increased knowledge of species presence and environmental effects. With concurrence from the AMT, ORPC's license modifications have been accepted by FERC. This process demonstrates a clear reduction in effort and cost on the part of ORPC based on the risk reduction demonstrated by environmental monitoring results.

Environmental Monitoring Results

The 2013 environmental monitoring results continued to build an increased knowledge of marine life interaction with the TidGen® Power System and indicated negligible environmental effects for many elements of the monitoring plans.

Article 405. Acoustic Monitoring Plan
Measurements of the in-water noise level related to the TidGen® Power System demonstrated that sound levels in the vicinity did not exceed 120 dB re 1 $\mu Pa^2/Hz$ at any frequency while the turbine was rotating, both while generating and when freewheeling. Further, the integrated rms levels from 20 Hz to 20 kHz did not exceed 120 dB re 1 μPa^2, the level some regulators have used to establish level B harassment of marine mammals.

Article 406. Benthic and Biofouling Plan
Observations of the exposed cable(s) indicated there continues to be little, if any, evidence of scouring or disturbance to the bottom or the associated faunal community. Results of the post-deployment benthic sampling survey indicated a healthy and highly productive benthic community with no discernible continuing effects from either the installation or operation of the cable. Assessments conducted in July 2013 indicated minor biofouling on the TidGen® turbine generator unit (TGU) with more significant growth on the bottom support frame; however, the functionality of the system did not appear to be compromised.

Article 407. Fisheries and Marine Life Interaction Plan
Hydroacoustic assessments conducted by the University of Maine (UMaine) demonstrate that while fish density was indeed variable, patterns were repeatable and will be useful in understanding the effects of devices. Data collected from the side-looking sonar during operation was minimal and only limited to when the TidGen® was not generating. However, available data allowed UMaine to identify some key issues that should be addressed in the future with the goal of collecting data while the turbine is generating power.

Article 409. Hydraulic Monitoring Plan
Hydrodynamic modeling conducted by Sandia National Laboratories continued to contribute to an understanding of hydraulic effects of the TidGen® Power System. Their work investigated velocity deficits created by the turbines and wake recovery as well as optimization of turbine arrays. Results of the scour monitoring continued to indicate minimal change in seabed elevation around the foundation piles.

Article 410. Marine Mammal Monitoring Plan
Marine mammal observations made by trained ORPC personnel in 2013, including during periods of operation, maintenance and retrieval, did not indicate changes in marine mammal presence or behavior. There was no evidence of marine mammal strike with system components during deployment and retrieval or with TGU foils during operation. In addition,

the continued presence of marine mammals in the vicinity of the Project indicated that the TidGen® Power System was not acting as a deterrent or a barrier to passage into the inner portions of the Bay.

Article 412. Bird Monitoring Plan

The Center for Ecological Research (CER) observed a decline in several species of seabirds in the Cobscook Bay study area in 2012-2013; however, they determined that it was unlikely that the operation of the TidGen® affected seabird numbers because it was not deployed in November 2012, a period when no eiders or Red-breasted Mergansers were observed.

Temporary Variance Period

ORPC requested to place environmental monitoring on a hiatus during the technology optimization period at the AMT meeting in September 2013. ORPC presented the following rationale for the appropriateness of the request:

- Comprehensive pre-deployment environmental studies have contributed to an understanding of inter-annual variability.
- Results-to-date indicated negligible effects to marine life from ongoing operations.
- TGU operational status made adherence to license conditions impractical and did not advance the conditions purpose.
- No undue impacts or impedance of other license requirements were anticipated. ORPC plans to return to adherence of conditions once TGU operation recommences.

Following the meeting, ORPC submitted the temporary variance request to FERC with the concurrence of the AMT. FERC issued a license order approving the temporary variance request on October 29, 2013.

Despite the temporary variance from environmental monitoring for the Project, ORPC will work with UMaine to conduct fisheries monitoring associated with a test of its floating OCGen® turbine technology in 2014. The OCGen® Module Mooring Project represents a significant advancement in marine hydrokinetic technology and deployment procedures while reducing potential environmental effects (elimination of the bottom support frame). Even though the mooring project will not be grid connected (and thus not under FERC jurisdiction), ORPC provided the AMT with detailed project information and requested concurrence on the relocation of the testing from off Shackford Head to within the FERC-licensed Project site.

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1.0 INTRODUCTION

1.1 Project Background

ORPC Maine, LLC, a wholly-owned subsidiary of Ocean Renewable Power Company, LLC, (collectively, ORPC), is a Maine-based developer of hydrokinetic power systems and projects that harness the power of oceans and rivers to generate clean, predictable renewable energy. In partnership with coastal and river communities, ORPC works to create and sustain local jobs while promoting energy independence and protecting the environment.

ORPC received a pilot project license for the Cobscook Bay Tidal Energy Project (Project) from the Federal Energy Regulatory Commission (FERC) on February 27, 2012 (FERC Project No. P-12711-005). The purpose of the Project is to evaluate the potential for a new source of clean, renewable energy generation using tidal energy resources in Cobscook Bay, Maine. ORPC obtained a preliminary permit for the Project area in Cobscook Bay from FERC on July 23, 2007; FERC issued a successive preliminary permit on January 13, 2011. Feasibility studies, including environmental surveys, and pre-filing consultation were conducted, resulting in ORPC's filing of a draft pilot project license application with FERC on July 24, 2009 and subsequently the final pilot project license application in September 2011. The FERC pilot project license boundary for the Project encompasses the proposed development area (Figure 1).

In March 2012, ORPC began construction of the Project off the coast of Eastport and Lubec, Maine (Figure 1). Following installation of the initial phase of the Project during the spring and summer of 2012, the Project began delivering electricity to the Bangor Hydro Electric Company grid in September 2012. This is the first grid-connected installation of ORPC's TidGen® Power System.

<u>TidGen® Power System</u>
ORPC designed the TidGen® Power System to operate in water depths of 60 to 150 ft. The core component of the TidGen® Power System is ORPC's proprietary turbine generator unit (TGU). The TGU utilized four advanced design cross flow (ADCF) turbines to drive a permanent magnet generator mounted between the turbines on a common driveshaft. The ADCF turbines rotated in the same direction regardless of tidal flow direction; rotational speed of the turbines was directly related to water flow speed. The TGU was 98 ft in length, 17 ft high and 17 ft wide. It was attached to a bottom support frame, which held the TGU in place approximately 15 ft above the sea floor. The bottom support frame was 98 ft long by 50 ft wide by 15 ft high. The bottom support frame was constructed of steel, and the TGU was constructed of steel and composite material. The coupled TGU and bottom support frame comprised the TidGen® device (Figure 2). The TidGen® device was connected to an underwater power consolidation module, which was then connected to an on-shore station through a single underwater power and data cable. The on-shore station was interconnected to the local power grid. The TidGen® device and the related cabling and on-shore station comprised a complete TidGen® Power System.

Figure 1. Cobscook Bay Tidal Energy Project location map.

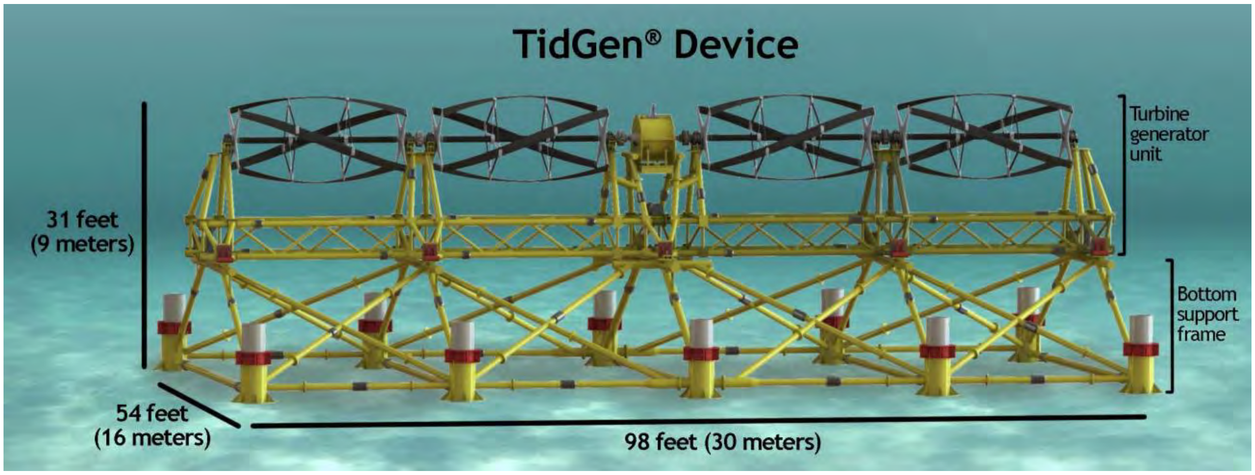


Figure 2. TidGen® device illustrating turbine generator unit and bottom support frame.

1.2 TGU Operation

Electricity generated by the Project was delivered by an underwater power cable to an On-shore Station in Lubec, Maine, where it was power-conditioned and connected to the Bangor Hydro Electric Company (renamed Emera Maine, January 1, 2014) power grid on September 13, 2012. Bangor Hydro issued a Permission to Operate: Certificate of Completion on September 25, 2012.

The TidGen® Power System was monitored from the On-shore Station, which had the capability to start, stop, and monitor the TidGen® Power System. Data, video, and instrumentation readings were transmitted by data cable bundled with the power transmission line. All major system components were instrumented and monitored for operational characteristics and environmental/ecological study, with data collected to document and validate Project performance. The environmental monitoring tower, equipped with Simrad instrumentation to monitor marine life interaction with the TGU, was deployed on August 20, 2012. The Simrad system was subsequently tested and calibrated the following week and has been operational since.

The TidGen® TGU was retrieved and redeployed several times during the winter of 2012/2013 for maintenance. After successfully redeploying the TidGen® TGU on February 22, 2013, ORPC successfully ran the system until a water leak occurred on the generator bullhead connectors, necessitating shut down of the generator on April 21, 2013. The TidGen® Power System operated at approximately 98% availability during this period, enabling significant data related to system operation (performance and environmental interaction) to be gathered.

1.3 TGU Retrieval and Technology Optimization Phase

The TGU was retrieved for inspection when the electrical cabinet and generator leak detectors activated. The crane and barge system utilized previously for retrieval purposes had been demobilized for multiple reasons, including concerns related to reliability of the lifting equipment and costs associated with maintaining the system on site. Alternative means of retrieval of the TGU had already been under development by ORPC and by ORPC's General Contractor. This process led to the development of a catamaran barge with dual winches to retrieve the TGU. This new system was selected, and final design was completed, constructed and delivered to Eastport. ORPC entered into an agreement with the General Contractor to build the new system and perform the full retrieval on a fixed cost basis that was approximately one-third of the average cost of the previous retrievals.

The TGU retrieval was successfully conducted on July 15, 2013 (Figure 3). The TGU was transported to shore, placed on blocking and lifted onto a trailer for transfer to the concrete blocking pads on July 16, 2013.

Figure 3. TidGen® TGU retrieval, July 15, 2013.

Prior to retrieval ORPC had logged considerable operational time, achieved multiple milestones and gathered important lessons learned regarding deployment and retrieval procedures, and turbine operation, performance and environmental interactions. To take immediate advantage of the lessons learned, ORPC decided to proceed with significant engineering improvements to the TidGen® Power System while the TGU was out of the water. This approach allowed ORPC to properly address issues with the generator and identify and implement longer-term design and component part improvements for future versions of the TidGen® Power System. This effort will result in a greater technology gain over time and help sustain successful operations locally.

In addition, ORPC was awarded two U.S. Department of Energy awards for technology performance improvements in January 2014. One of the awards will focus on the development and testing of innovative second-generation power take-off (PTO) components for marine renewable devices. Innovative PTO components will include new and improved designs for bearings and a subsea electrical generator. These technology improvements will be implemented in the TidGen® TGU prior to reinstallation.

2.0 ADAPTIVE MANAGEMENT (License Article 404)

2.1 ADAPTIVE MANAGEMENT PLAN AND TEAM

ORPC developed an Adaptive Management Plan (AMP) as required by the FERC pilot project license (P-12711-005, Article 404) for the Project. The AMP was an integral part of ORPC's implementation of the Project and provided a strategy for evaluating monitoring data and making informed, science-based decisions to modify monitoring as necessary. As required by Article 404, the AMP was drafted in consultation with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Coast Guard, Maine Department of Environmental Protection, and Maine Department of Marine Resources. ORPC also consulted with technical advisors, who were involved with the development of each of the elements of this Project. The AMP reflects the collaborative approach that has been an integral part of the Project since its beginning. Table 1 lists the members of the Adaptive Management Team (AMT) and their respective roles.

Table 1. *Cobscook Bay Tidal Energy Project Adaptive Management Team*

NAME	ORGANIZATION	ROLE	RESPONSIBILITY
Nathan Johnson	ORPC	Project Developer	Communication
Steve Shepard	U.S. Fish & Wildlife Service	Government Regulator	Compliance with established regulations
Sean McDermott	NOAA NMFS, Habitat Conservation Division	Government Regulator	Compliance with established regulations (Essential Fish Habitat)
David Bean	NOAA NMFS, Protected Resources Division	Government Regulator	Compliance with established regulations (Endangered Species)
Linda Mercer	Maine Department of Marine Resources	Government Regulator	Compliance with established regulations
Lt. Megan Drewniak	U.S. Coast Guard	Government Regulator	Compliance with established regulations
Jim Beyer	Maine Department of Environmental Protection	Government Regulator	Compliance with established regulations
Michelle Magliocca	NOAA NMFS, Office of Protected Resources	Government Regulator	Compliance with established regulations (Marine Mammals)
ADVISORY			
Gayle Zydlewski	University of Maine	Technical Advisor	Fisheries Monitoring
Moira Brown	New England Aquarium	Technical Advisor	Marine Mammal Monitoring
Jay Clement	U.S. Army Corps of Engineers	Government Regulator	Advisory

The collaborative approach that was adopted for the AMP was first utilized for the 2009 memorandum of understanding (MOU) between the State of Maine and FERC, that included a working structure to develop and permit Maine's first hydrokinetic power project. An important component of the MOU was to develop appropriate and cost effective environmental studies and monitoring plans. It was clear from the onset that knowledge of the eco-system and its many facets potentially affected by this new hydrokinetic power project would require new methods of inquiry to collect, monitor and evaluate environmental data. Many of the new scientific methods that were developed for the Project have become a new basis for learning, and the scientific community has begun modifying approaches to environmental studies using these new methodologies in other programs. This learning has helped to bring the agencies and industry to a point where they have more tools to confidently address the needs of permitting of a commercial development. ORPC's AMP was designed to utilize not only the environmental studies at the Project site, but also environmental studies from other hydrokinetic projects and related studies from around the world.

ORPC's AMP recognized that many scientific uncertainties exist and that environmental conditions constantly change. The AMP, therefore, was designed to be modified within the Project time line and acknowledged that elements such as key environmental uncertainties, applied studies and institutional structure may evolve over time. The plan has worked well for the agencies, stakeholders, and ORPC as the Project evolved from a concept to the first pilot installation and operation.

The AMP summarized the minor and major license modification process required to make changes to environmental monitoring. ORPC strongly supported the involvement and concurrence of the AMT in applicable license modification requests, and the AMP process establishes a path to proceed in this manner.

2.2 2013 Adaptive Management Team Meetings

ORPC's FERC pilot project license required regulatory review of annual monitoring reports prior to FERC submittal. Therefore, ORPC prepared this 2013 Environmental Monitoring Report with the intent of providing it for comment to the AMT, which included the regulators recommended by FERC. This Report presents results of the Project's environmental monitoring program in 2013.

Similarly, ORPC provided the 2012 Environmental Monitoring Report to the AMT in February 2013, followed by an AMT meeting on March 12, 2013. ORPC summarized the early results of the monitoring program and solicit feedback from the AMT, including any recommendations for program modifications. ORPC subsequently met with the AMT on September 10, 2013 to provide updated environmental monitoring and project status information.

2.2.1 MARCH 12, 2013

ORPC held an AMT meeting on March 12, 2013 at the Maine Department of Environmental Protection's Eastern Maine Regional Office in Bangor. As previously discussed in the 2012 Environmental Monitoring Report, this meeting was an opportunity for ORPC to present 2012 environmental monitoring results and recommendations for modifications in a collaborative setting with the Team. Specific agenda items included:

- Review of adaptive management's role in the Project
- Summary of 2012 activities and lessons learned
- Explanation of environmental monitoring results
- Discussion of recommended modifications and finalization of necessary changes
- Briefing on the overall Maine Tidal Energy Project (Cobscook Bay Phase II and Western Passage Tidal Energy Project (FERC Project No. P-12680)

Subsequent to the March meeting, ORPC received concurrence from the AMT on recommended license modifications. Concurrence and additional comments from the AMT were incorporated into the final draft of the 2012 Environmental Monitoring Report submitted to FERC on March 26, 2013.

2.2.2 SEPTEMBER 10, 2013

ORPC held an Adaptive Management Team meeting on September 10, 2013 at the Maine Department of Environmental Protection's Eastern Maine Regional Office in Bangor. Updated environmental monitoring and project status information was provided. Specific agenda items included:

- Project status update, including technology optimization phase
- 2013 environmental monitoring results, challenges, and accomplishments
- ORPC's temporary variance request related to environmental monitoring
- Details on ORPC's OCGen® Module Mooring Project
- Other ORPC activities (RivGen® Power System, ORPC Solutions)

Environmental monitoring results presented to the AMT continued to indicate negligible observed effects.

ORPC provided further details regarding a request to place environmental monitoring on a hiatus during the technology optimization period. Prior to the meeting ORPC had submitted a memo to the AMT summarizing the request. Temporary variance requests have been granted by FERC for traditional hydropower projects in the past. FERC requested concurrence from the AMT related to ORPC's temporary variance request. ORPC presented the following rationale for the appropriateness of the request:

- Comprehensive pre-deployment environmental studies contributed to an understanding of inter-annual variability.
- Results-to-date indicated negligible effects to marine life for ongoing operations.
- TGU operational status made adherence to license conditions impractical and did not advance the conditions purpose.
- No undue impacts or impedance of other license requirements were anticipated.
- ORPC plans to return to adherence of conditions once TGU operation recommences.

Following the meeting ORPC submitted the temporary variance request to FERC with the concurrence of the AMT. FERC issued a license order approving the temporary variance request on October 29, 2013.

At the September meeting ORPC also briefed the AMT on our proposed relocation of the DOE-funded OCGen® Module Mooring Project from off Shackford Head to the FERC-licensed Cobscook Bay Tidal Energy Project site. The relocation was preferred because it would occupy less area within Cobscook Bay and eliminate seasonal restrictions related to commercial fishing activities required at Shackford Head.

The OCGen® Module Mooring Project represents a significant advancement in marine hydrokinetic technology and deployment procedures while reducing potential environmental effects. Despite the fact that the mooring project will not be grid connected (and thus not under FERC jurisdiction), ORPC provided the AMT with detailed project information and requested concurrence on the relocation. The Mooring Project is anticipated to occur in the summer of 2014. A U.S. Army Corps of Engineers permit application was submitted for the Mooring Project on December 20, 2013 with concurrence received from multiple members of the AMT.

Minutes from the March 12, 2013 and September 10, 2013 Adaptive Management Team meetings are included in Appendix A.

2.3 Cobscook Bay Tidal Energy Project License Modifications

The Cobscook Bay Tidal Energy Project has successfully demonstrated the ability to modify license requirements based on knowledge gained, the engagement and concurrence of the AMT, and clear communication with FERC.

Table 2 summarizes license modifications completed in 2013. It should be noted that modifications related to rated capacity and inspection and maintenance did not involved the Project's AMT.

Table 2. *Summary of 2013 Cobscook Bay Tidal Energy Project license modifications*

Submittal/License Article(s)	Requested Modifications	FERC Order Date
Exhibit A, Project Description and Operation	Rated capacity of the TidGen® Power System revised from 60 kW to 150 kW.	February 21, 2013
FERC Division of Dam Safety and Inspection - Article 306. Inspection and Maintenance	Clarification of inspection and maintenance activities and frequencies	April 8, 3013
2012 Environmental Monitoring Report - Article 405. Acoustic - Article 406. Benthic & Biofouling - Article 407. Fisheries and Marine Life Interaction - Article 409. Hydraulic - Article 410. Marine Mammal - Article 412. Bird	Modifications vary by license article but generally clarify monitoring plans or reduce frequency of monitoring surveys based on increased knowledge of species presence and environmental effects.	May 8, 2013
Temporary Variance Request - Article 405. Acoustic - Article 406. Benthic & Biofouling - Article 407. Fisheries and Marine Life Interaction - Article 409. Hydraulic - Article 410. Marine Mammal - Article 412. Bird	Hiatus in environmental monitoring during technology optimization phase	October 29, 2013

3.0 ACOUSTIC MONITORING (License Article 405)

The primary goals of the Acoustic Monitoring Plan were to identify and characterize the noise radiated by the TidGen® Power System in the high-velocity environment of the Project site by gathering acoustic data under various environmental and mechanical conditions prior to and during Project deployment. This was accomplished by the following:

1. Ambient noise measurements at the deployment area were conducted in 2011 prior to the deployment of a single-device TidGen® Power System.

2. Noise measurements were conducted in 2011 during ORPC's Beta TidGen® Project to gather preliminary data and gain experience with the equipment and methodologies.

3. Noise measurements were conducted on the single-device TidGen® Power System in April 2013.

4. Noise measurements will be conducted on the multi-device TidGen® Power System after the Phase II deployment.

The equipment and methodologies used for gathering noise data that have helped determine the origins of noise. The Acoustic Monitoring Plan includes this data to characterize the TidGen® Power System's acoustic footprint, in accordance with the FERC pilot project license requirements.

Additional information on potential marine life interaction with the TGU will be monitored as outlined in the Fisheries and Marine Life Monitoring Plan. The presence of marine mammal species in the vicinity of the Project is addressed in the Marine Mammal Plan. Separate from these study plans, ORPC, in conjunction with Scientific Solution Incorporated (SSI), developed and tested an active acoustic monitoring technology and methods. The ultimate goal of this system under development was to monitor marine life automatically and in real time.

3.1 Methodologies

The drifting noise measurement system (DNMS) and measurement methodologies are detailed in the Project's Acoustic Monitoring Plan. The DNMS was developed to overcome the significant challenges of making accurate ambient and radiated noise measurements in high currents. The data acquisition system (Figure 4) was comprised of a pair of hydrophones, a custom two-channel variable gain low noise amplifier and LGR-5327 Data Logger. The hydrophones were attached to the spar buoy to acquire the waterborne acoustic sound pressures and gather noise data while isolated from vertical motion and decoupled from the high velocity currents. The lengths of the hydrophone cables were adjustable; therefore the appropriate length was determined during testing. An anchor hung approximately two meters below the lowest sensor to prevent the hydrophones from getting hooked on the ocean floor if the spar buoy drifted into shallow water. The anchor also provided drag along the ocean floor in shallow areas until the system could be recovered if this became necessary. A list of general specifications for DNMS was presented in the Project's Acoustic Monitoring Plan. A recent upgrade to the system switched to Reson hydrophones Model TC4013 and a 394A40 pistonphone calibrator for more accurate and traceable measurements.

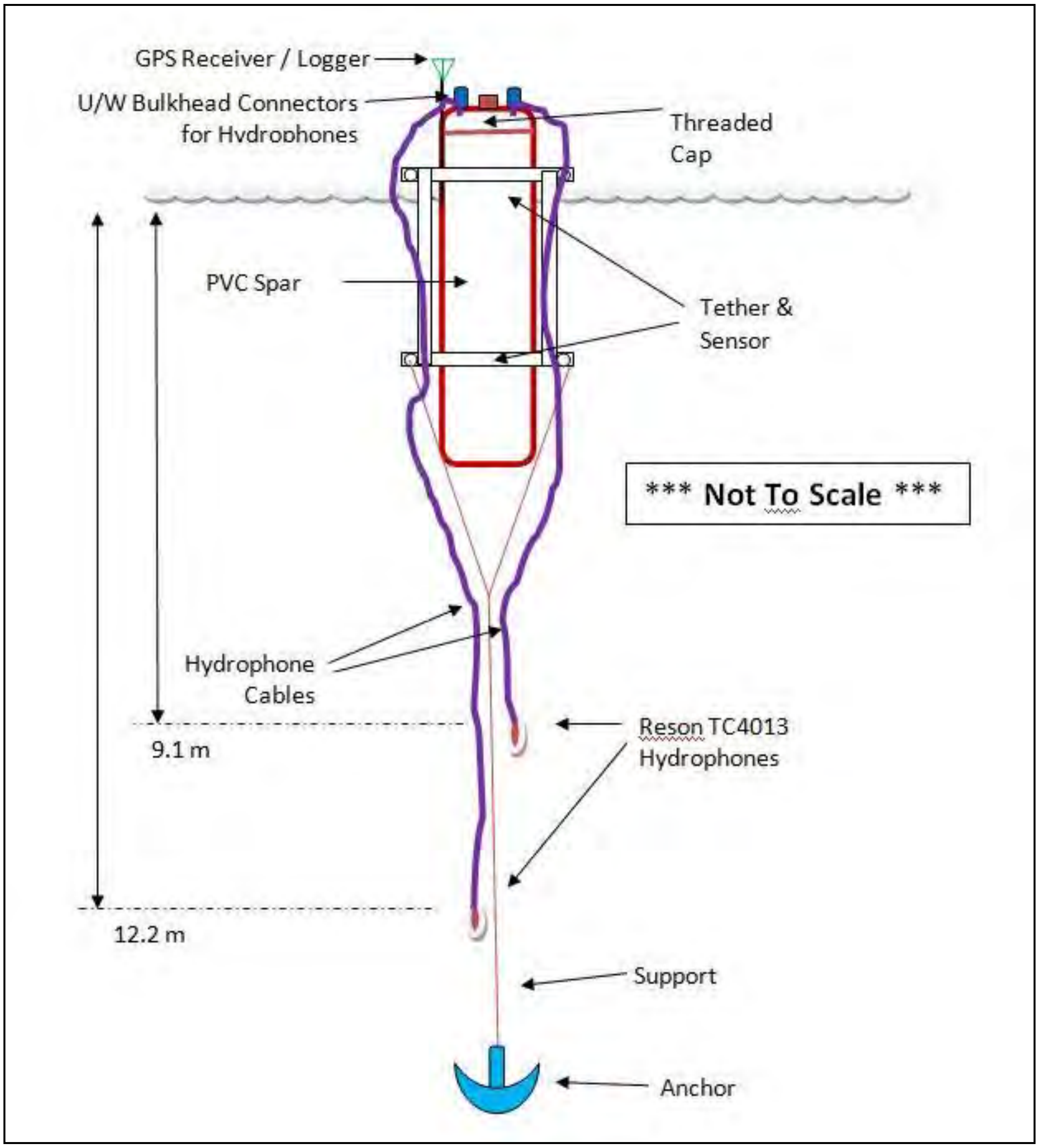


Figure 4. Drifting noise measurement system.

Measurements were collected at the Project site on April 2 and April 3, 2013 under varying sea states, tidal flows, and turbine generator conditions. Sustained winds of approximately 15 knots generated wave heights of 2 to 3 ft. The DNMS was deployed from ORPC's 40 ft research vessel, *Tide Tracker*, and allowed to drift untethered to collect acoustic measurements (Figure 5). During slack water periods the DNMS was deployed in the direct vicinity of the TGU (within 100 meters). For periods of ebb or flood tidal flows the DNMS was deployed several hundred meters upcurrent, allowed to pass as close as possible to the TGU, and then retrieved several hundred meters downcurrent. During deployments the *Tide Tracker's* engine was shut off. In addition, ORPC staff was in direct communication with operators at the Lubec On–shore Station to record generator output and turbine RPMs. ORPC staff also modified operations to record acoustic measurements while the turbine was "freewheeling," i.e., spinning but not generating power. Turbine RPMs during freewheeling were approximately 50% higher than when generating. An ORPC log sheet used during the measurements has been included as Attachment B. A total of 34 deployments of the DNMS were made at the Project site.

Figure 5. DNMS during deployment at the Project site, April 2, 2013

3.2 Results - Phase I TidGen® Measurements

Measurements of the in-water noise level related to the TidGen® Power System demonstrate that sound levels in the vicinity do not exceed 120 dB re 1 $\mu Pa^2/Hz$ at any frequency while the turbine is rotating, both while generating and when freewheeling. An observable increase in sound level was primarily visible at approximately 105 Hz with a harmonic at 210 Hz, as well as 2.8 kHz and occurred anytime the turbine was rotating. A higher frequency tone near 5 kHz and associated harmonics were only present when the turbine was actively generating, but were at sound spectral levels well below the lower frequency sources, as shown in Figure 6. Further, the integrated rms levels from 20 Hz to 20 kHz do not exceed 120 dB re 1 μPa^2, the level some regulators are using to establish level B harassment of marine mammals. This frequency range was suggested as the appropriate range for this measurement by experts at the workshop on Instrumentation for Monitoring around Marine Renewable Energy Devices in Seattle, Washington, on June 25-26, 2013.

Sound peaks near 105 Hz, 210 Hz, and 2.8 kHz appear to scale with turbine RPM values and are generally louder when the turbine is freewheeling as compared to when it is generating at the same RPM. Sound levels did not vary with range for the same rotation speed at distances ranging from 20 m to 300 m. This fact, coupled with the observation that the sound is present anytime the turbine rotates, independent of electrical generation, indicates the source is likely to be the sound radiating from the structure itself. Given the source, SSI determined that it was not appropriate to scale the measured data by some form of geometric spreading factor. The higher frequencies that only occur when the turbine is generating appear to scale slightly with turbine rotation as well (Figure 6).

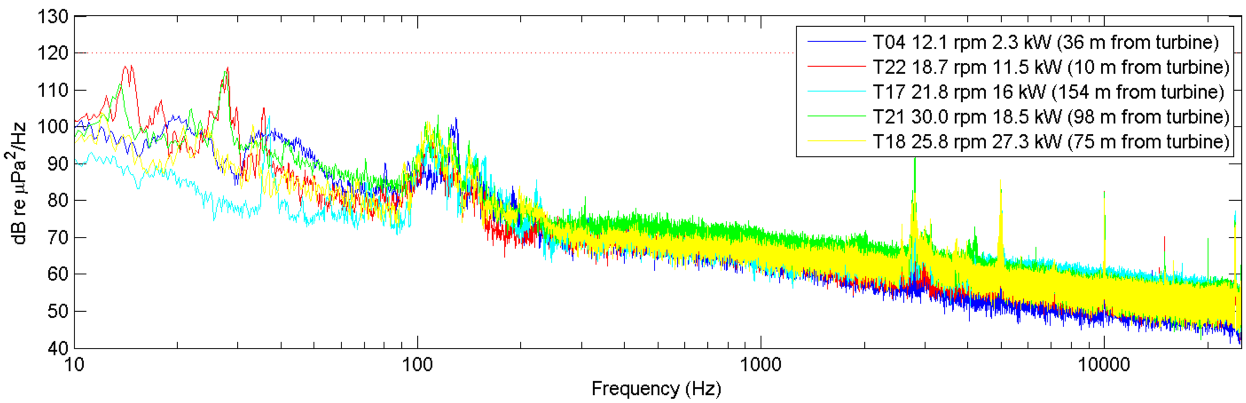


Figure 6. Power spectral density for the generating turbine at various ranges from the turbine. April 2-3, 2013.

3.3 Potential Effects

Resource agencies and stakeholders have indicated concern regarding underwater noise and vibration produced by the TidGen® Power System and the potential effects on marine species as many marine species use sound in communication, navigation, predator/prey interactions, and hazard avoidance. These organisms have biological receptors that are sensitive to sound pressure level, particle velocity, and the frequency of sound. Hastings and Popper (2005) conducted a review of sound effects on fish, primarily related to pile driving. Results of these studies indicated that fish do not experience adverse effects from received sound levels less than about 160 dB re 1µPa; though at higher levels, fish may exhibit avoidance, stress, temporary and permanent hearing loss, auditory and non-auditory tissue damage, egg damage, reduced growth rates, or mortality (Hastings and Popper, 2005). Many of the existing studies did not evaluate different behavioral responses by marine species to variable sound frequencies.

Data compiled by Hastings and Popper (2005) indicated the hearing threshold for Atlantic salmon was between 85 and 130 dB, at frequencies between 30 and 300 Hz. Some additional studies suggested they may also detect sound below 35 Hz (Knudsen et al. 1992, 1994, as cited in Hastings and Popper, 2005). However, detection of a sound does not necessarily equate to an effect. Information on behavioral responses of received sound levels and frequencies were generally limited for these species.

Marine mammals rely on sound for many aspects of their lives, including reproduction, feeding, predator and hazard avoidance, communication, and navigation (Weilgart, 2007). There is considerable variation among marine mammals in both absolute hearing range and sensitivity. Their composite range is from ultrasonic (frequencies greater than 20 kHz) to infrasonic (frequencies less than 20 Hz). Direct hearing measurements, for the most part, are not available for cetacean species, but it is generally believed that a whale's hearing range is related to the range of sound it produces (LGL Ecological Research Associates and JASCO Research, 2005). Pinniped hearing in general has been measured for air and water. In water, hearing ranges from 1 to 180 kHz with peak sensitivity around 32 kHz. In air, hearing capabilities are greatly reduced to 1 to 22 kHz. This range is comparable to human hearing (0.02 to 20 kHz). Harbor porpoise, harbor seals, and gray seals may be affected by Project produced noise (USACE, 2008).

Behavioral responses of marine mammals to sound vary greatly and depend on a number of factors. An individual's hearing sensitivity, tolerance to noise, exposure to the same noise in the past, behavior at the time of exposure, age, sex, and group composition all affect how it may respond. Sometimes it is difficult to know whether observed changes in behavior are due to sound or other causes. Observations suggest that marine mammals tend over time to become less sensitive to those types of noise and disturbance to which they are repeatedly exposed (Richardson et al., 1995).

National Marine Fisheries Service (NMFS) has identified the following noise levels as thresholds for marine mammal harassment:

> Current NMFS practice regarding exposure of marine mammals to high level sounds is that cetaceans and pinnipeds exposed to impulsive sounds of 180 and 190 dB rms or above, respectively, are considered to have been taken by Level A (i.e., injurious) harassment. Behavioral harassment (Level B - has the potential to disturb a marine mammal) is considered to have occurred when marine mammals are exposed to sounds at or above 160dB rms for impulse sounds (e.g., impact pile driving) and 120dB rms for continuous noise (e.g., vibratory pile driving), but below injurious thresholds. These levels are considered precautionary. (NOAA, 2008)

SSI's TidGen® Acoustic Monitoring Report was third party reviewed by Brandon Southall, Ph.D., at the request of ORPC to assure that a marine mammal scientist reached the same conclusion that ORPC minimized the potential risk of adverse environmental affects due to noise from its development project.

Dr. Southall's review determined that the spectrum levels recorded in a variety of conditions indicated that adverse effects to marine mammals were unlikely. The measurements of ambient and different operational conditions clearly indicated that the presence of associated sounds of varying characteristics in the region of hearing for at least some of the marine life known to occur in the vicinity of the Project site (more so for seals and fish than any cetaceans). Protected species in the vicinity of the TidGen® TGU may hear and could potentially be affected by the device. However, the potential for behavioral responses is likely to be extremely limited, and these levels would almost certainly not trip any thresholds for potential level B harassment. In addition, the recorded sound levels would not cause hearing loss or injury by acoustics for any species at any range.

ORPC submitted the Phase I Acoustic Monitoring Report to NOAA's Office of Protected Resources for review and comment on July 12, 2013. NOAA responded with no comments on the Report. The Phase I Acoustic Monitoring Report is included as Appendix B.

3.4 Accelerometer Correlation

Data for the Phase I acoustic survey was collected during varying operating conditions, yet there were no acoustic monitoring instruments mounted on the TidGen® Power System (or other ORPC equipment). However, accelerometers were placed on the TidGen® Power System to measure turbine-induced vibrational accelerations. ORPC hypothesized that as the speed of the turbines increased, the sound and vibrations produced by the generator would also increase. Knowing the DNMS positional change and loading conditions of the TidGen® Power System from the accelerometers, the data could be analyzed to reflect how sounds produced by the TidGen® Power System correlated to increases in the surrounding noise field. This correlation may allow for a potential dynamic real time monitoring system of ambient noise field impact as related to TidGen® Power System operations.

ORPC operators, located at the Lubec On-shore Station, coordinated with the *Tide Tracker* crew to take DNMS measurements to correlate acoustic results to accelerometer recordings on April 2 and April 3, 2013. To get maximum bandwidth from accelerometers, ORPC recorded only one channel at a time. Of greatest interest were the two accelerometers (four channels) attached to the generator and so those channels were prioritized.

The following Correlation Methodology describes the first stage of this correlation and outlines the methodology, feasibility, and limitations to the current procedure.

3.4.1 Correlation Methodology

ORPC utilized data collected by SSI using the DNMS at varying distances from the TidGen® (20 m to 300 m) during the April 2 and April 3, 2013 acoustic survey. SSI's acoustics data was not scaled by a "spreading factor." Thus, SSI's data was assumed to be the approximate sound emitted by the unit, without damping from the water. This assumption was supported by the following observations:

1. Sound levels did not vary with range for the same rotation speed at distances ranging from 20 m to 300 m.
2. Sound was present any time the turbine rotates, whether generating or not, indicating that the source of sound radiation was likely to be from the structure itself.

The fact that these measurements were taking between 20-300 m from the structure and the accelerometers were mounted to various locations on the structure, limited the potential of making this correlation.

Results of the acoustic monitoring indicated specific frequency tones were picked up during freewheeling and generating conditions as previously described in this section. Based on the acoustic results from SSI the following tones were investigated in the accelerometer data:

Freewheeling

- 105 Hz
- 210 Hz (harmonic to 105)
- 2.8 kHz (beyond range of accelerometers)
- Noisiness between 105 and 210 Hz

Generating

- 105 Hz (broader and weaker than freewheeling)
- 210 Hz (weaker than freewheeling)
- 2.8kHz (stronger than freewheeling, beyond range of accelerometer)
- 5 kHz (beyond range of accelerometer
- 10, 15, 20 kHz (harmonics to 5 kHz)

Accelerometers mounted on the TidGen® Power System were the following model:

Wilcoxon Research Model 757 "Biaxial, low profile, underwater accelerometer"
Frequency response: 2-2,000 Hz ±10%
Sensitivity: 100mV/g = 0.1V/g
Raw data output: volts

Figure 7 shows the locations of the eight accelerometers mounted to the TidGen® TGU.

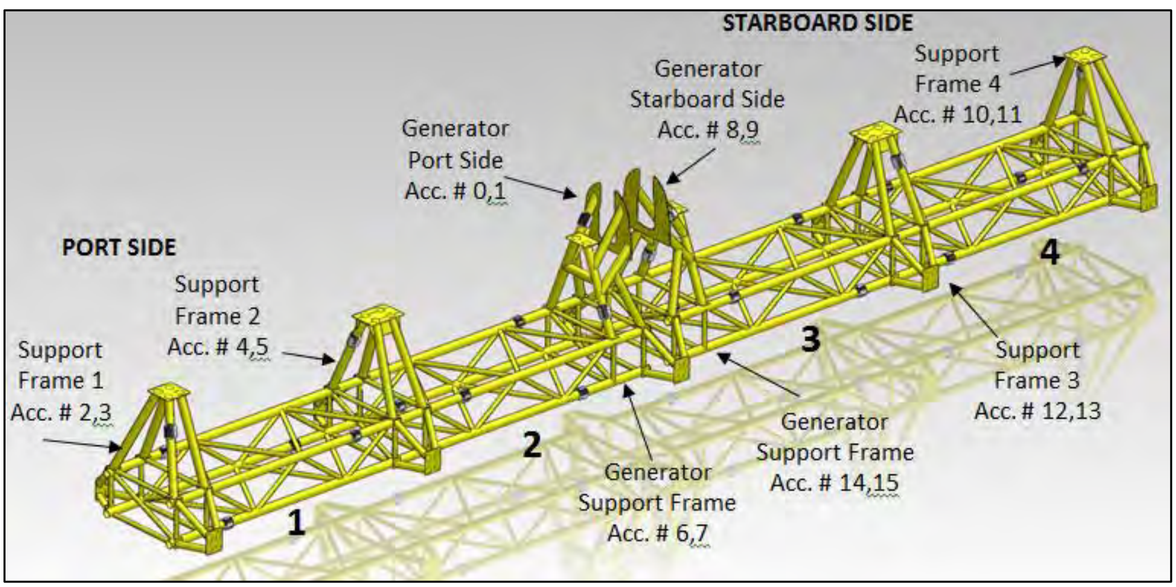


Figure 7. Accelerometer mounting locations

ORPC developed MATLAB scripts and functions to perform data processing and power spectral density (PSD) generation.

Data was collected by ORPC over two days, i.e., the same time periods during which the acoustics data were collected. ORPC found it best to use MATLAB to convert raw data into vectors of acceleration and time.

Power Spectral Density (PSD) creates a plot of power or energy per frequency (Hz) for a given signal. Conceptually, the PSD decomposes a signal into different frequencies present in that signal, to help identify periodicities and common frequencies. The PSD will ultimately give the power carried by the wave. For the accelerometer data, the PSD is displayed in intensity (decibels, dB) per frequency. Because the intensity in the case of the accelerometer data is not sound, rather accelerations, the intensity is referenced to acceleration units (dB re m/s^2). The units of the PSD are intensity per frequency, given as dB re $m/s^2/Hz$.

In signal processing, a window function is used on data that is not periodic. A specific window function must be chosen, both in shape and in length. Using window functions prevents leakage from the signal, and helps avoid errors in performing fast Fourier transforms. The window is essentially the "batch" of signal on which the PSD is performed, repeated with a designated overlap (commonly 50%). The ideal types of windows for a random signal include Hamming, Hanning and Welch.

<u>Welch's Method</u>
Welch's method is an approach to spectral density estimation for producing a PSD. The major benefit to Welch's method is that it uses a Hamming window by default, which is an appropriate windowing option for a random signal. In addition, this method is effective in reducing signal noise better than other methods.

The following four figures are PSDs of accelerometer data collected while the generator was running and when the turbines were freewheeling, all using Welch's method. The first figure of each pair used the default windowing. The second of each pair used a hamming window of size 1000, with 50% window overlap. The signals looked similar, but the second has reduced noise (Figure 8-11).

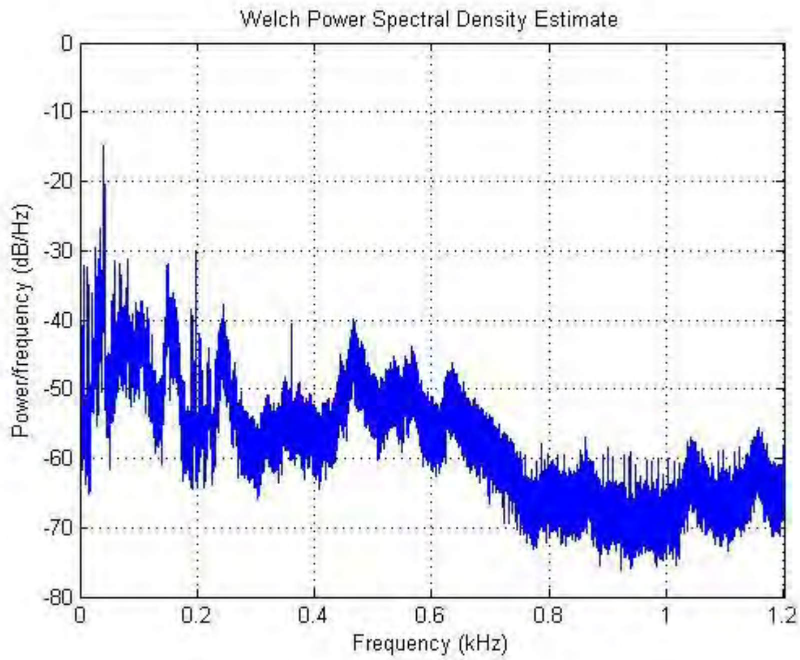


Figure 8. Accelerometer with Generator ON: Welch's Power Spectral Density using Default Window Settings

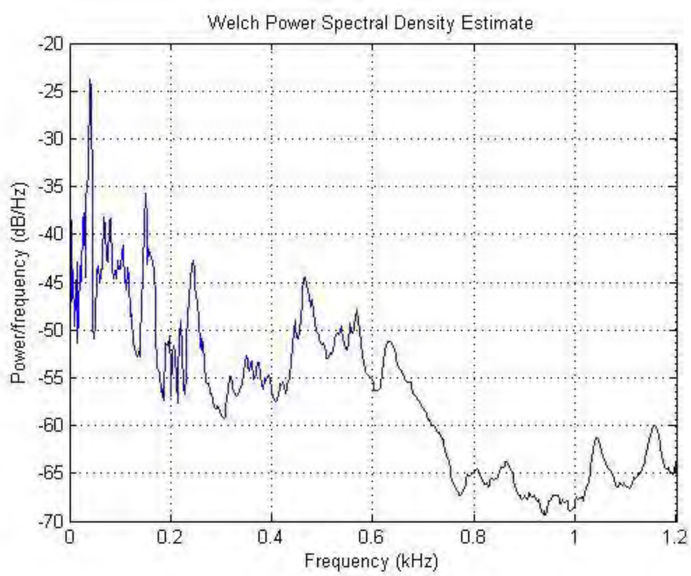


Figure 9. Accelerometer with Generator ON: Welch's Method Power Spectral Density using window size 1000.

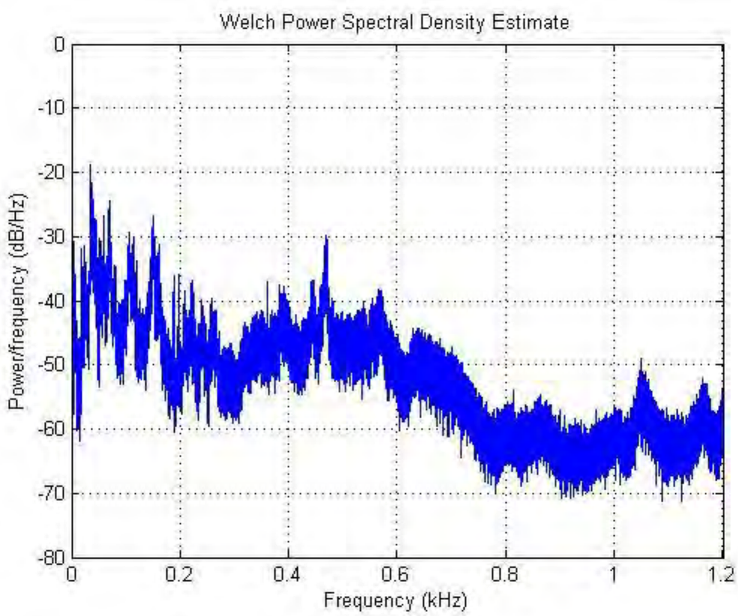


Figure 10. Accelerometer with turbine Freewheeling: Welch's Power Spectral Density using Default Settings

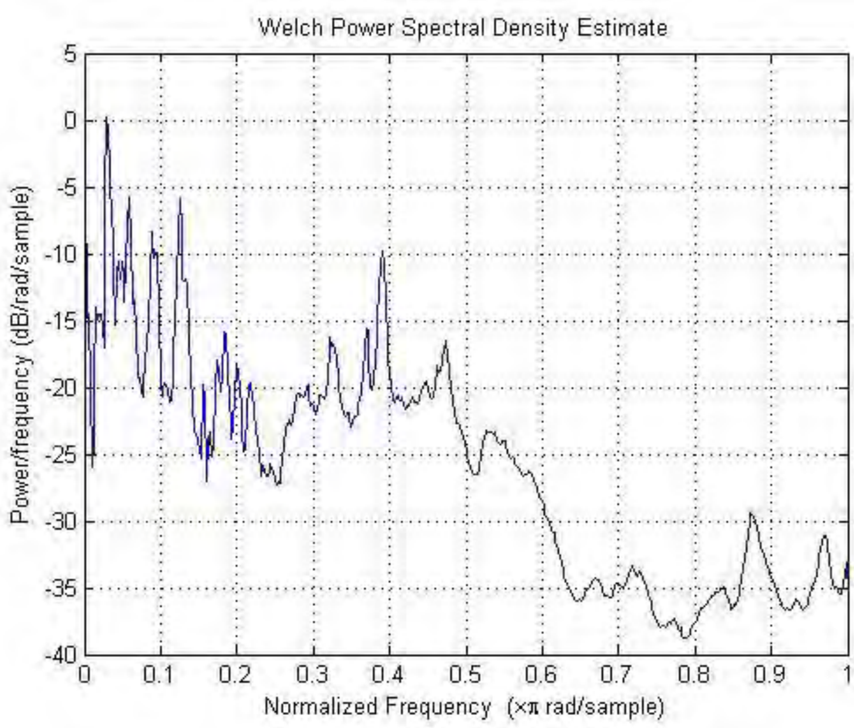


Figure 11. Accelerometer with turbine freewheeling: Welch's Method Power Spectral Density using window size 1000.

The MATLAB function PSD was another method evaluated by ORPC. Using PSD takes more user effort and essentially accesses Welch's method, but offers slightly more transparency. The PSD was run using accelerometer data during power generation. All default settings were used. The PSD looked similar to that of Figure 12, but with reduced noise.

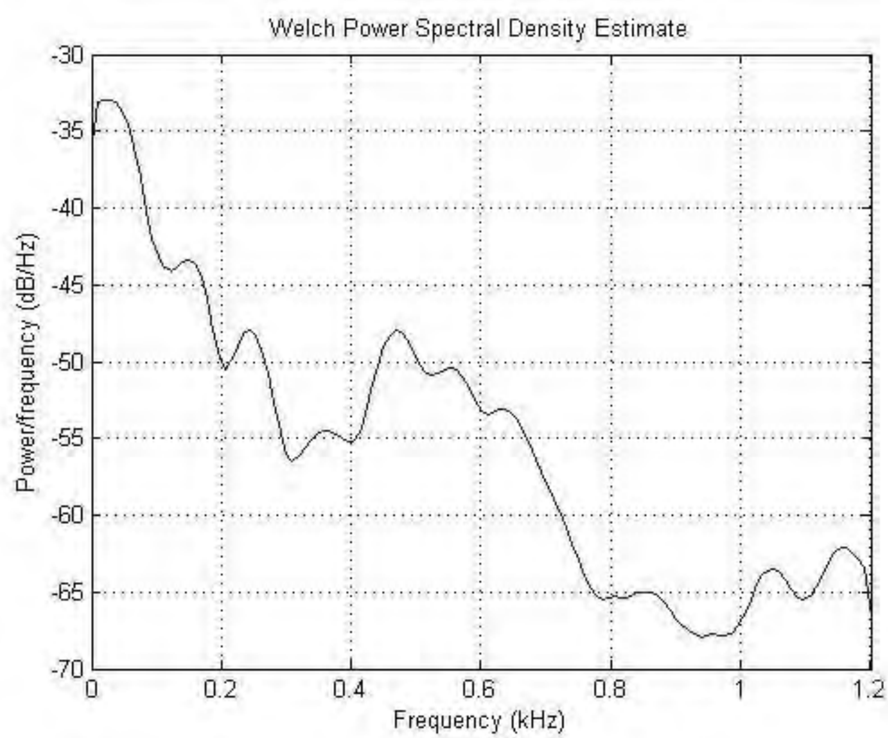


Figure 12. Generator ON, PSD using MATLAB function PSD with default settings

3.4.2 Correlations

Once an accurate PSD was generated for the accelerometer data, ORPC correlated the acoustics data collected by SSI. Both data sets were in the same format, i.e., energy of the signal at each frequency. Then, "tones" were chosen out of each data set, indicative of "spikes" at the frequencies occurring in both datasets. For example, it was expected that the peaks at 105 Hz and 210 Hz in the acoustics data would appear at the same frequency in the accelerometer data (Figure 13-16).

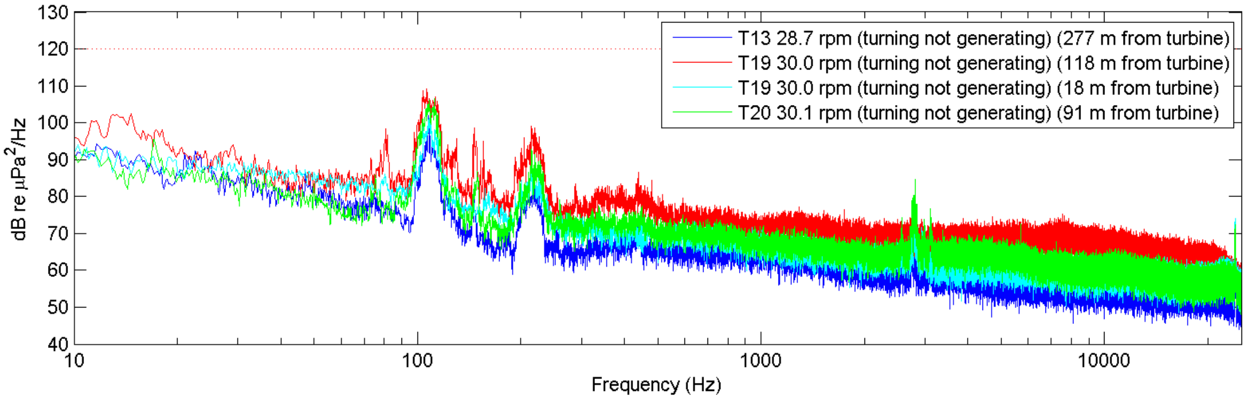


Figure 13. Acoustic results during freewheeling indicating spikes at 105, 210 Hz.

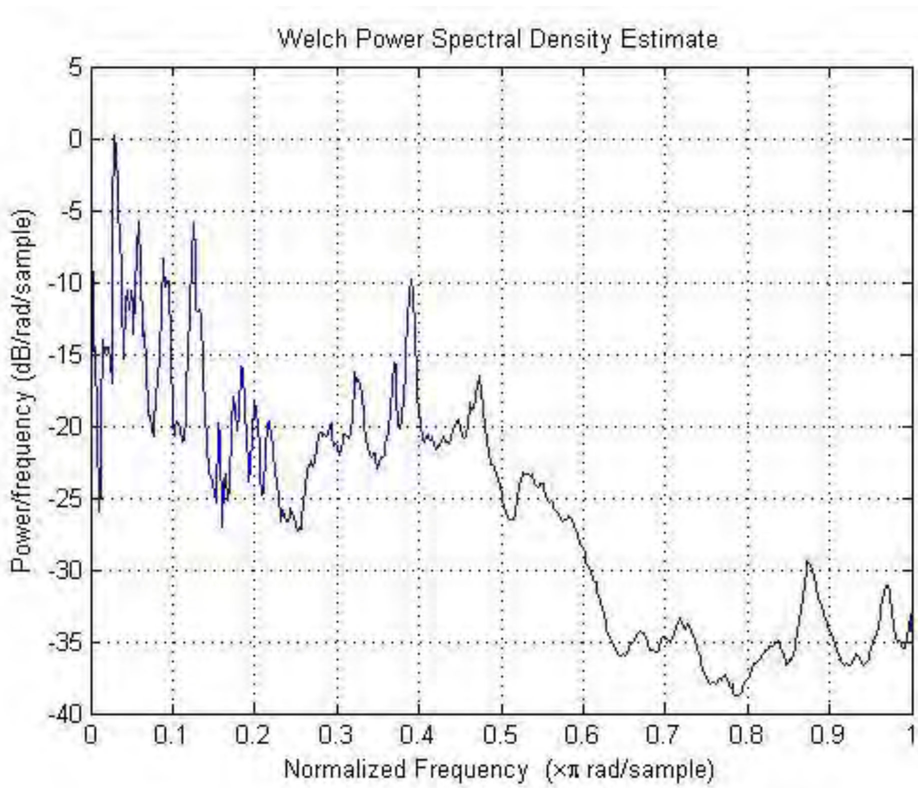


Figure 14. Accelerometer results during freewheeling, indicating numerous spikes between 0-210 Hz.

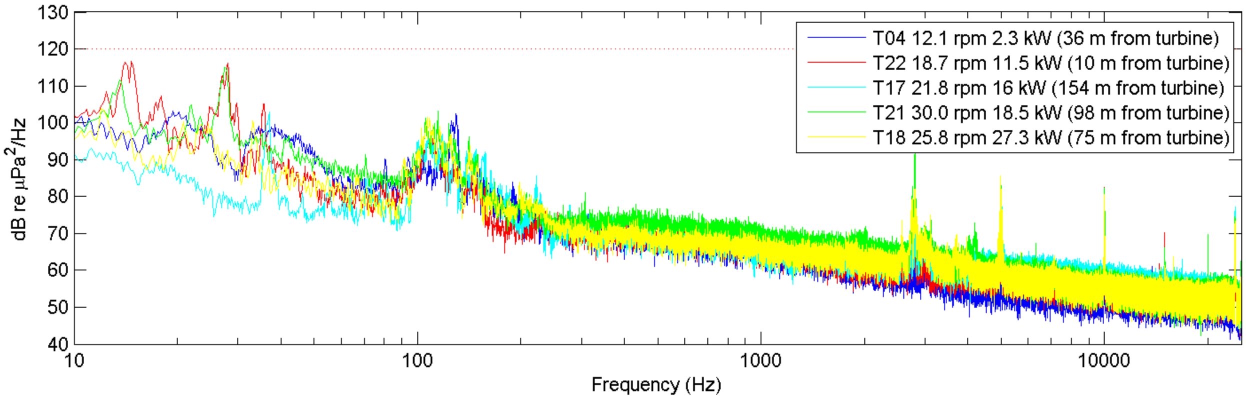


Figure 15. Acoustic results while generating, indicating spikes at 105 and 210 Hz as well as 5 kHz.

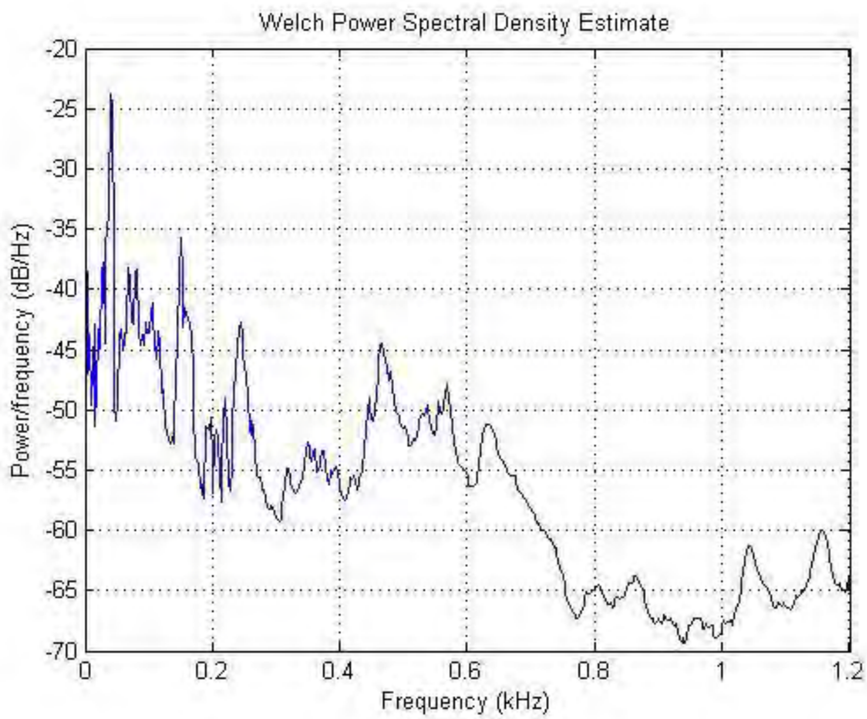


Figure 16. Accelerometer results while generating, indicating potential spikes at 105 and 210 Hz. 5 kHz is above range.

Preliminary results indicated that correlations were feasible; however, the following limitations were identified that need further evaluation.

1. The subsea accelerometer currently used by ORPC had a sampling frequency of 2,400 Hz. The underlying principles of the fast Fourier transform limited the frequencies that can be detected by the accelerometer to 1,200 Hz. The passive acoustics study performed

by SSI detected acoustic signatures higher than 1,200 Hz. Only those sounds with frequencies below 1,200 Hz can be detected by the accelerometers currently installed on the TidGen® TGU.

2. The sampling rate of the accelerometer is too high for the available bandwidth. Data cannot be streamed from the accelerometer at the same time as other data. "Real-time" data streaming is only possible when no other instruments are recording. The accelerometer, at present, is only operated for short periods of time (up to 10 minutes).

3. The DNMS data treated the entire TidGen® Power System as a "point source" sound emitter. The culmination of all sound from the unit (generator, turbines, structural vibration, etc) is picked up in the far field. However, accelerometers were placed on eight locations throughout the turbine, both on the frame and on the generator. It might be possible that the acoustic signature of the device was a combination of all accelerometer readings, which complicated the correlation procedure.

4. Additional effort is required to understand the signal processing tools in MATLAB, and the most appropriate function.

3.5 Conclusions and Recommendations

Measurements of the in-water noise level related to the TidGen® Power System demonstrate that sound levels in the vicinity did not exceed 120 dB re 1 $\mu Pa^2/Hz$ at any frequency while the turbine was rotating, both while generating and when freewheeling. Further, the integrated rms levels from 20 Hz to 20 kHz did not exceed 120 dB re 1 μPa^2, the level some regulators have established for level B harassment of marine mammals.

In collaboration with its technical advisors, ORPC has determined the spectrum levels recorded in a variety of conditions indicated adverse effects to marine mammal to be unlikely. The measurements of ambient and different operational conditions clearly indicated the presence of associated sounds of varying characteristics in the region of hearing for at least some of the marine life known to occur in the vicinity of the Project site (more so for seals and fish than any cetaceans). Protected species in the vicinity of the TidGen® TGU may hear and could potentially be affected by the device. However, the potential for behavioral responses is likely to be extremely limited, and these levels would almost certainly not trip any thresholds for potential level B harassment. In addition, the sound levels recorded would not cause hearing loss or injury in terms of acoustics for any species at any range.

ORPC has developed an initial methodology to correlate acoustic monitoring results collected by the DNMS on April 2 and April 3, 2013 to accelerometer readings collected simultaneously from the Lubec On-shore Station. Preliminary results indicated that correlations were feasible; however, the limitations were identified that need further evaluation.

4.0 BENTHIC AND BIOFOULING MONITORING (License Article 406)

The primary goals of the Benthic and Biofouling Monitoring Plan are to evaluate the benthic community during the Project and to study whether the structures introduced into the marine system contribute to biofouling accumulation that may alter the habitat within the Deployment Area. These goals will be accomplished by (1) characterizing the existing benthic community (pre-deployment); (2) examining the recovery of the benthic resources disturbed during the installation of the subsea cable; (3) examining the benthic community near the deployed TidGen® Power System; and (4) examining the presence and relative extent of coverage of biofouling organisms on the deployed TidGen® Power System. The Benthic and Biofouling Monitoring Plan will use the data gathered to evaluate the potential Project effects on the benthic community in accordance with the requirements of the FERC pilot license process.

The bottom support frame for Phase I of the Cobscook Bay Tidal Energy Project was installed starting in March 2012. Installation of the power and data cables occurred in July 2012 by means of a shear plow. This more passive installation technique resulted in minimal disturbance to the benthos as compared to use of a jet-assisted plow. Additional information regarding the monitoring of the hydraulic flow fields and sediment transport in the Deployment Area is included in the Hydraulic Monitoring Plan.

In addition to a survey conducted in February 2013 (preliminary results included in 2012 Environmental Monitoring Report), ORPC and its subcontractor MER Assessment Corporation (MER), conducted an inspection of the power and data cable route associated with the Cobscook Bay Tidal Energy Project on June 13, 2013. This inspection was conducted using two techniques: (1) a diver-held camera and housing that covered the entire cable route running from the near shore area in Gove Cove on Seward Neck in Lubec to the TidGen® Power System deployment area and (2) a remote drop-camera video of five transects running across the cable route. The inspections included video recordings to document the condition of the cable as well as the benthic habitat along the cable route.

A Phase I (post-deployment) benthic sampling survey was conducted in the subtidal and intertidal areas of the power and data cable route on August 7 and August 8, 2013. MER conducted habitat characterizations of the deployment areas and the subsea and intertidal cable routes.

ORPC performed a biofouling assessment of the TidGen® TGU immediately following its retrieval and relocation to the Deep Cove pier on July 15, 2013. In addition, a biofouling assessment was conducted on the bottom support frame based on diver video collected in July 2013.

The 2013 benthic and biofouling reports are included in Appendix C.

4.1 Methodologies

4.1.1 Benthic Surveys of Cable Route

ORPC deployed a video transect line along the bottom on June 10, 2013 using the vessel *Tide Tracker* and a Hemisphere VS101 GPS positioning unit. The transect line was made up of four 274 m (900 ft) lines and one 122 m (400 ft) line for a total of 1,219 m (4,000 ft). The transect line was marked at 91-m (300 ft) intervals with orange tape bearing the distance and was held in place by weights dropped at specific distances following a course shown in Figure 17. The original baseline survey transect line was marked in meters rather than feet. Station locations consequently did not correspond exactly; additionally, the baseline survey and diver transect line following the 'As Built' cable route were slightly offset from one another.

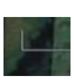


Figure 17. June 13, 2013 diver and drop camera video survey transects (Source: ORPC; MER)

Video recordings were made by Brayden's Future, Inc. SCUBA divers using MER's Amphibico VHHCEL57/Sony HDR-HC9 high definition digital video camera, Amphibico VLDIG3AL 35W/50W switchable underwater arc lamp lighting package, and recorded on Sony HD tapes.

The drop camera video recording was conducted simultaneously with the diver video recordings to determine the feasibility of using it as an alternative method of assessing the benthic habitat and associated epifauna. The 36-ft F/V *Lady H* operated by Capt. Butch Harris was used as the surface platform for the video recordings; the vessel is equipped with a hydraulic hauler and davit to facilitate lowering and hauling of the video camera frame.

The tethered drop camera videos were recorded by MER using a SeaViewer Sea-Drop 650 Series real-time color camera system attached to a heavily weighted stainless steel frame equipped with an Amphibico VLDIG3AL 35W/50W switchable underwater arc lamp. The camera video feed was connected to a SeaViewer SeaTrak unit that embeds GPS (WGS84) coordinates and date/time data (GMT) directly on the video recording; the video was recorded on-board the support vessel using a SONY GV-D800 NTSC digital video recorder.

4.1.2 Benthic Sampling

MER conducted the subtidal habitats portion of the Phase I sampling survey in collaboration with Brayden's Future, Inc., divers on August 7, 2013, during a period of two daylight-hour slack tides (one low tide and one high tide) with average amplitude tides of 0.0 m LW and 5.6 m HW (0.0 ft LW to 18.4 ft HW). As previously reported, Upper Cobscook Bay is characterized by large amplitude tides and very strong tidal currents and the selected Deployment Area is subject to some of the strongest tidal currents in the region. These strong currents present constraints on both the timing and duration of survey events (extremely short slack water period). Sampling was consequently conducted immediately before, during and after slack water (high tide or low tide) and the sampling stations sequenced to take advantage of slower current velocities in certain sections of the cable route during specific periods around slack water.

Benthic sampling was conducted in situ by the divers along the transect for the Upper Cobscook Bay Deployment Area and subsea cable route. No video recordings were made during the sampling event since video recording of the entire subtidal cable route had been recently completed on June 13, 2013.

The intertidal habitat characterization was completed during the afternoon of August 7, 2013 and the morning of August 8, 2013.

Subtidal

Benthic infauna samples were collected in triplicate at eleven stations along the transect lines (33 samples). Sediment cores were taken using 4 in. diameter PVC pipe coring devices that were inserted to a depth of 10 cm or full resistance. The contents of the cores were washed through a U.S. Standard No. 35 sieve (500 µm mesh). All material retained on the screen was transferred into plastic sample jars and the jars filled with 10% buffered formalin. Several drops of a 1% Rose Bengal staining solution were added to each sample to assist in the sorting of organisms.

After 5-10 days of fixing, the formalin solution was decanted from the sample jars through a 500 μm mesh sieve and the formalin volume replaced with 70% ethanol to insure preservation of the organisms' integrity, particularly the bivalves and other calcareous forms.

During processing, organisms were sorted from the sediment under lighted magnification lenses and/or binocular dissecting microscopes. Organisms collected from the samples are identified to the lowest practical taxonomic level and enumerated under a stereoscopic dissecting scope to 63x power. Data resulting from the sample processing are entered into an Excel spreadsheet developed by MER that calculates statistics for abundance, taxa richness, and relative diversity (Shannon-Weiner Index, J'). Standard operating procedures for the collection and processing of benthic infauna samples are attached as Appendix I.

Intertidal

Sampling was conducted at three levels within the intertidal zone: (1) upper intertidal (H), (2) mid-intertidal (M), and (3) lower intertidal (L). Three subsets with three replicates each were sampled within each level, thus 9 samples were collected within each level for a total of 27 samples.

Within each subset of each sampling level a 0.25 m^2 (0.5 m/side) 1.27 cm (½-in.) PVC pipe frame was randomly placed to avoid visual bias of the area to be sampled. Prior to sampling, a pre-sampling photo was taken of all sampling stations with frame and station label in place. Where present, all flora (rockweeds) within the frame were removed by cutting down to the base of the holdfast with either scissors or a knife and the collected material placed in a prelabeled plastic bag. On hard substrate, following removal of the rockweed, all organisms within the frame were removed either by picking with forceps or scraping with a narrow paint scrapper or knife (barnacles were counted in situ). In softer sediment where coring was allowed, core samples were collected using 10 cm (4 in.) diameter PVC pipe coring devices and samples processed as described above under Subtidal Benthic Infauna Sampling. All removed material, picked, scraped, or sieved, was placed in one or more pre-labeled 1000 ml Nalgene container and 10% buffered formalin added to cover the organisms. Following collection of all flora and fauna, a post-sampling photo was taken of each station with frame and station label in place. Processing of core samples is the same as described above for the subtidal benthic core samples.

At the completion of on-site sampling, wet-weight of all rockweed samples (including associated fauna, e.g. periwinkles) was measured using a Mettler Toledo BD601scale (600g ± 0.01g / SN 09031AB) tared for an 8 in. aluminum pie pan; some samples required multiple partial weighing. Following weight measurement and recording, the rockweed was placed in an 80 cm by 46 cm by 29 cm fish tote partially filled with freshwater and swirled and agitated to remove all associated organisms. The rockweed was then removed and discarded and the contents of the fish tote poured through a 500 μm mesh screen. Material retained on the screen was then transferred to the Nalgene container corresponding to the station and replicate. All collected material was placed in one or more pre-labeled 1000 ml Nalgene containers and 10% buffered formalin added to cover the organisms.

Once at the lab, each sample was poured onto a 500 µm mesh screen and rinsed. All large organisms, e.g. mussels and snails, were removed, identified, enumerated, and transferred back into the Nalgene container with 70% ethyl alcohol (ethanol, EtOH) for archiving. The remaining small organisms were transferred into smaller Nalgene containers for subsequent microscopic identification and enumeration. Organisms collected from the samples will be identified to the lowest practical taxonomic level and enumerated under an Olympus SZ-60 stereoscopic dissecting scope to 63x power. Data resulting from the sample processing will be entered into an Excel spreadsheet developed by MER that calculates statistics for abundance, taxa richness, and relative diversity (Shannon-Weiner Relative Diversity Index, J'). Standard operating procedures for the collection and processing of intertidal benthic infauna samples was the same as that for the subtidal benthic infauna samples (refer to Appendix I).

4.1.3 Biofouling Assessment

ORPC performed a biofouling assessment during the afternoon of July 15, 2013 while the TidGen® TGU was berthed at the end of the Morrison Landing Pier as well as the same evening following its relocation to the boat ramp. The TidGen® TGU was assessed for percent coverage of biofouling on distinct structural components, and biological samples were taken from representative locations. ORPC performed a visual inspection of corrosion to the host surface in two sections of dense growth; a sacrificial anode and a section of the mounting bracket to the bottom support frame. The following procedures were followed for the inspection:

a. Sections were chosen that were both accessible and have been largely affected by biofouling.
b. Several square inches of plant or animal life were removed by scrapping with a plastic card to expose the surface underneath.
c. The exposed surface was inspected and photographed for corrosion. This surface was compared to a nearby region that had not been affected by biofouling. A detailed description of the appearance was recorded, including notes on discoloration or peeling of paint, exposure of metal underneath, and extent of region affected.

ORPC also evaluated the effectiveness of a test patch of antifouling paint, described further in Section 4.2.3.

On July 10, 2013, two divers recorded footage of the TidGen® bottom support frame for an assessment of scouring around each of the ten piles. The footage from the scouring inspection was used to generate a qualitative report of biofouling on the bottom support frame. Screenshots were taken from the videos of the piles, anodes visible in the footage, and other locations showing significant signs of biofouling. Videos were analyzed in QuickTime Play, and snapshots were taken using Microsoft Snipping Tool. ORPC's assessment included three segments: pile observations, frame observations and anode observations.

4.2 Results

4.2.1 Benthic Survey of Cable Route

Diver Video
Direct comparison between the July 2013 diver video survey and the July 2011 baseline survey was not possible due to the spatial offset between the two. Nevertheless, the July 2013 observations are generally consistent with those of the original baseline video survey of July 2011, i.e., sea urchins, sea peaches, sea cucumbers and scallops were observed as abundant to common in the shallower sections, and sea potatoes, northern red anemones, urchins and sea stars were the predominant organisms in the deeper sections. The northern sea cucumber appeared more abundant in deeper water than previously observed, and northern red anemones also appeared to be abundant where they were previously only common. Sea scallops appeared to be more abundant between Stations 4 and 6; an increase in relative abundance of sea cucumbers and sea scallops was consistent with a reduction in dragging activity for these commercially important species in the immediate vicinity of the cable route.

As in previous monitoring events, the video transect was offset from the *As built* cable route at certain locatons as well as the original baseline survey route. However, the exposed transmission and data cables were seen for several meters in the shallower area and only minimally and partially buried in the deeper section. As before, where the cable is visible on the surface, the cable was observed to be firmly stapled to the bottom and there continued to be little, if any, evidence of scouring or disturbance to the bottom caused by the cable(s). Also, as previously reported, epifauna, including green sea urchins, northern red anemones, sea peaches and sea scallops were seen adjacent to, and in some cases attached to, the cable(s). Based on these observations, it does not appear that the cables are causing any discernible adverse impacts to the substrate habitat or the associated epifauna.

Drop camera
The fauna observed along the drop camera video segments are consistent with the diver recorded video in the same general vicinity. Relative abundance was also generally similar, although some variations exist between the reviews of the diver recording and that of the drop camera.

The combination of the incoming tidal current with an opposing wind out of the northeast made maneuvering of the vessel difficult when crossing the current. Acceleration of the vessel to maintain course caused the camera frame to be raised high off the bottom. Deceleration to allow the camera frame to ride at an appropriate distance off of the bottom resulted in a northwest drift as a combination of the current and wind forces. To complete the transect, the vessel was repositioned several times and allowed to drift with periodic engagement of the engine; this resulted in a zigzag course across the cable route area and periodic "flying" of the camera frame off the bottom.

The high current velocities along the cable route, particularly in the deeper area in the vicinity of the TGU, present substantial challenges for remote video recording. The slack water period during which video recordings can be made unaffected by the current is very short. As mentioned previously, on this occasion recording in the vicinity of the TGU was delayed until the current had shifted to incoming to avoid any possible entanglement with the TGU. Future recordings starting at slack water may provide sufficient time to complete the transect before the current becomes excessively fast.

4.2.2 Benthic Sampling Results

Subtidal
The results of the subtidal benthic infauna analyses for each station, based on the three replicates taken at each station, are summarized in MER's Report (Appendix C) and include total organisms found in the sample, abundance as organisms/0.1 m^2, taxa richness (at species and family levels), and relative diversity (Shannon-Wiener). Detailed information on infauna composition at each station by replicate and photos of the sediment composition at each station are included as Appendices to MER's report.

Intertidal
The upper (high) intertidal area (H) is composed of loose rocks overlying pebbles and coarse sand/fine gravel. The rocks, cobble and pebbles at this upper level of the intertidal area appear subject to shifting, either from currents or waves affecting the area. No flora was observed in any of the three sub-sampling levels (H1, H2, and H3) within this area and the only fauna observed were unidentified amphipods sheltered within the rockweed "wrack" (H1) and cobble and coarse sand (H2, H3).

The mid-intertidal area (M) consists of a shallow layer of rocks, pebbles, and very coarse sand over a sticky marine clay base. The clay appears to provide some sediment stability within this level compared to the upper level, thus allowing it to support flora and fauna, albeit still limited and patchy. The flora is rockweeds, *Fucus* spp. which occurs in small quantities, primarily as geminating plants. Epifauna observed during field sampling include barnacles, *Balanus balanoides*, common periwinkle, *Littorina littorea*, and green crabs, *Carcinus mae*nas.

The lower intertidal area (L) has a sediment composition similar to that of the mid-level area, but with slightly more softer silt, *i.e.* mud layer, as is evident from the post-sampling photographs. Flora is rockweeds, primarily *Fucus* spp. with some *Ascophyllum nodosum* present at all sublevels. Epifauna observed at this lower level include barnacles, *Balanus balanoides*, common periwinkle, *Littorina littorea*, green crabs, *Carcinus mae*nas, common limpet, *Tectura (Acmea) testudinalis*, blue mussels, *Mytilus edulis*, one soft shell clam, *Mya arenaria*, and unidentified amphipods.

Benthic infauna cores were taken using the same methods for collection and preservation described above for the subtidal benthic cores. These will be processed and analyzed using the same methods described above for the subtidal benthic cores and the final results will be reported in the final report along with the subtidal benthic infauna results.

4.2.3 Biofouling Results

TidGen® TGU

The biofouling assessment indicated minor biofouling of the TidGen® TGU. The most significant growth occurred on the generator, sacrificial anodes, and bearing mounts, and on mounting brackets with flat surfaces and complex geometry. Additionally, the evaluation of the applied anti-fouling paint determined that it was not effective in reducing marine growth on the generator (Figure 18-21).

Immediately after retrieval, all regions of biofouling occurrence were photographed for future reference. Additionally, each major component of the TGU was assessed for the percent of surface covered with plant or animal life. The plant and animal species were identified, and the growth was described in terms of plant size, color, strength of adherence, etc. Table 3 describes the location of growth, type of growth and approximate percentage of cover.

Table 3. *Biofouling description for TidGen® components*

Component	Approximate % Cover	Description of Growth
Generator	75	Predominantly tubularian hydroids and lesser barnacles and filamentous algae
Bracelet Anodes	95	Barnacles
Disc Anodes	95	Barnacles and algae, growth on flat surface, rounded edge, and in between stacked discs
Long and Short Flush Mount Anodes	95	Barnacles, >1 cm thick
Chassis	Flat structures – 25 Tubular structures - 5	Flat surfaces – barnacles and algal growth Tubular surfaces – minor algal growth
Foils	10-15	Tubularian hydroids and barnacles
Bearing Mounts and top of Pedestals	50-75	Tubularian hydroids, barnacles and filamentous algae
Mounting brackets to bottom support frame	75	Barnacles, mussels (lower half and behind tubular) and tubularian hydroids

Figure 18. TidGen® TGU following retrieval, July 15, 2013.

Figure 19. TidGen® generator, July 15, 2013.

Figure 20. Bracelet anode.

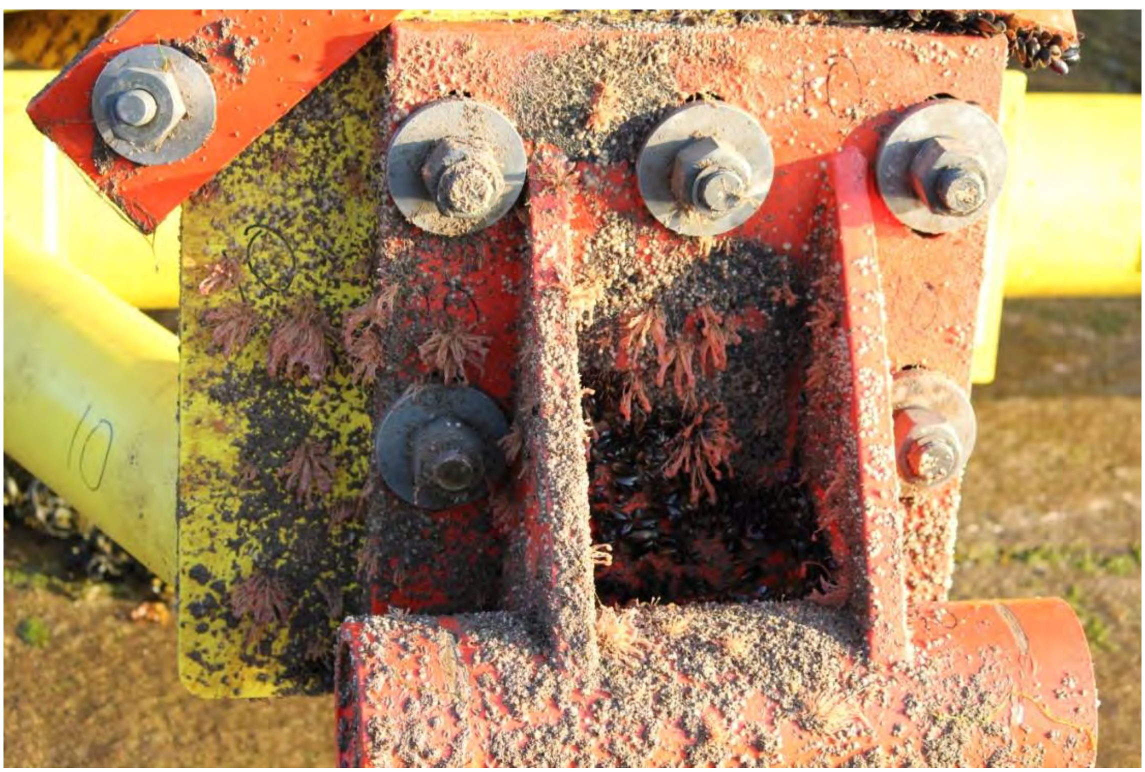


Figure 21. TGU mounting bracket to bottom support frame

The biofouling inspection identified the presence of the following species:

Plants
Filamentous Algae
Mermaid's Hair

Animals
Barnacles
Blue mussels
Tubularian hydroids

ORPC collected three biologic samples of representative marine growth on the TGU. Samples were removed from the structure with a plastic card to prevent damage and stored in plastic sample jars. Samples were labeled and preserved with Formalin.

ORPC performed a visual inspection of corrosion to the host surface in two sections of dense growth, a sacrificial anode and a section of the mounting bracket to the bottom support frame. A description of the corrosion after removal of the marine growth is summarized in Table 4.

Table 4. *Summary of Corrosion*

Component of TGU	Approximate % Cover	Description of Corrosion after growth removal
Bracelet Anode (Figure 9)	90% barnacle	Small cavities forming underneath growth, as anticipated. Refer to complete Anode Inspection for results of anode-specific inspection.
Mounting bracket to BSF Figure 10)	60% barnacle, 10% filamentous algae, 5% tubularian hydroid	No corrosive effects to surface. Slight residue left underneath barnacles, to be removed during power washing.

Biofouling of Other TGU Components
As additional inspections were performed, components of the TGU were made accessible that could not be inspected as part of the initial biofouling report, performed July 15, 2013. Minor biofouling was observed on the anodized aluminum Prevco housing, Prevco connector locker rings and inside the "doghouse."

On the Prevco housing, several hydroids and barnacles were affixed to the face of the housing unit. Effects of biofouling were also seen on the doghouse lid, with some growth of filamentous algae. The Prevco locking rings showed growth of predominantly barnacles --hard fouling creatures.

Bottom Support Frame
Analysis of the screenshots taken from the July 10, 2013 videos of the bottom support frame, piles, anodes visible in the footage, and other locations show signs of significant biofouling in certain areas.

The following species were identified during the video review:

- Blue mussels
- Urchins (rock boring)
- Sea stars
- Barnacles
- Algae
- Mermaid's hair
- Hydroids

Overall, fouling did not seem to inhibit functionality of the bottom support frame; however, it could potentially interfere with conduits and fire hoses. The following observations were made:

- Anodes on outermost frame members had dense barnacle growth.
- Anodes that were internal to the structure were relatively clean.
- Piles 9 and 10 have significantly more biofouling than other piles.
- The stretches of frame between piles 1 and 2 and between piles 9 and 10 had very dense barnacle growth, favoring the side closer to piles 2 and 10.

Figure 22, Figure 23, Figure 24 and Figure 25 show varying degrees of biofouling among the bottom support frame components. Figure 26 summarizes areas of biofouling on the bottom support frame.

Figure 22. Inboard anode 3-3-4 showing minimal biofouling

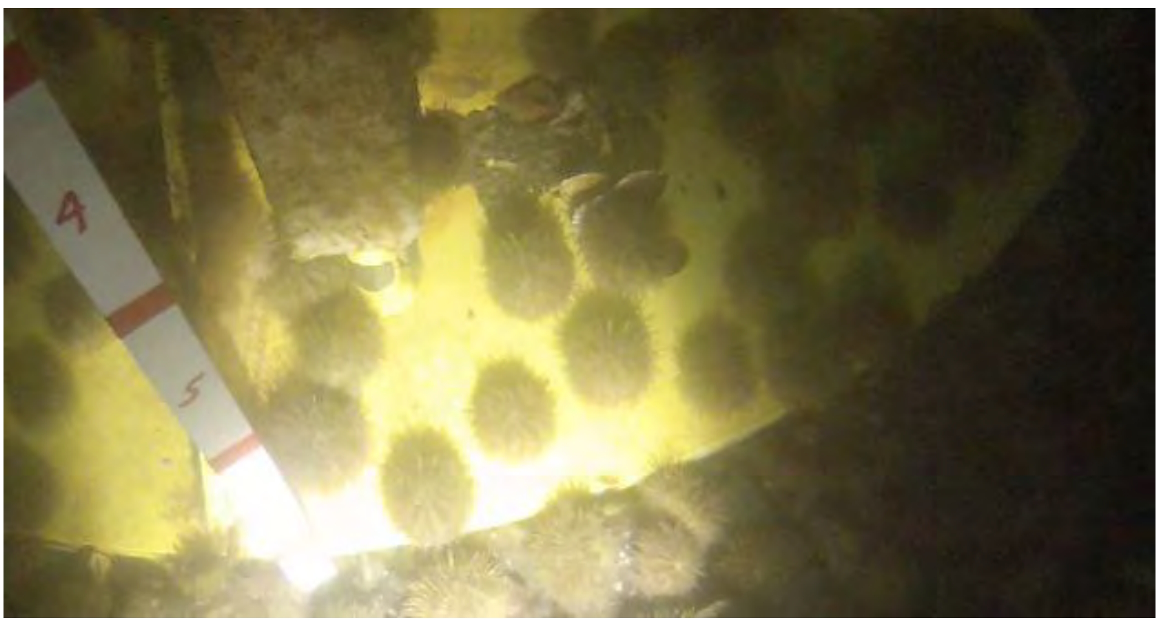


Figure 23. The outboard side of pile 1 with urchins, several mussels and anemones.

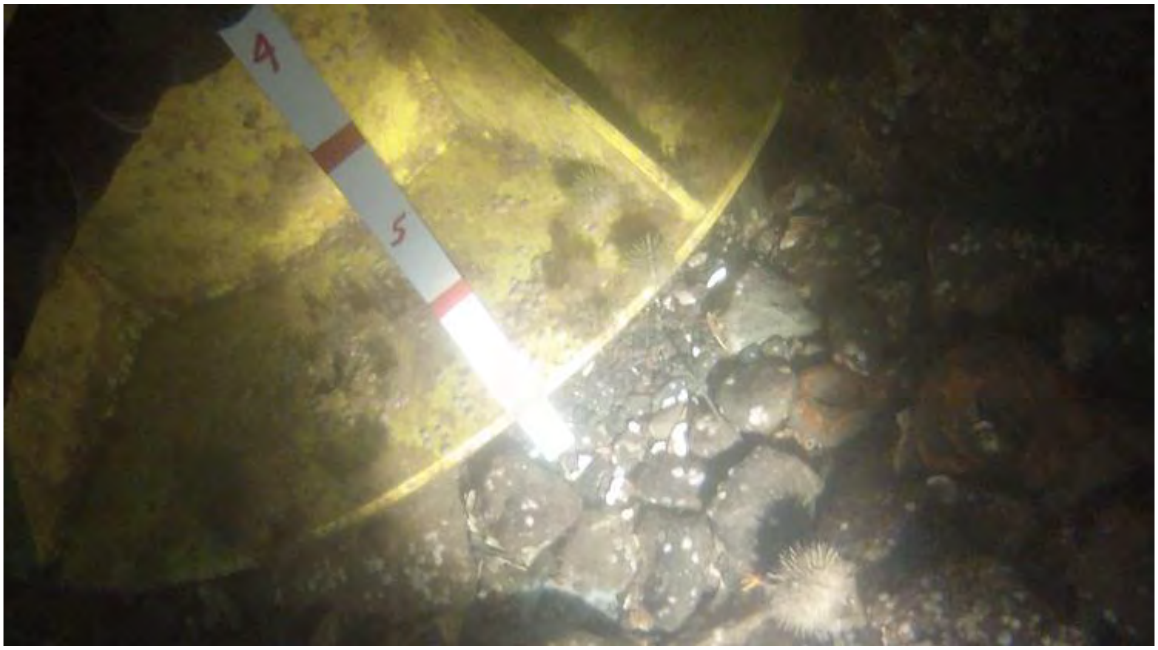


Figure 24. The base plate on pile 5 showed minimal growth.

Figure 25. Significant growth between piles 1 and 2.

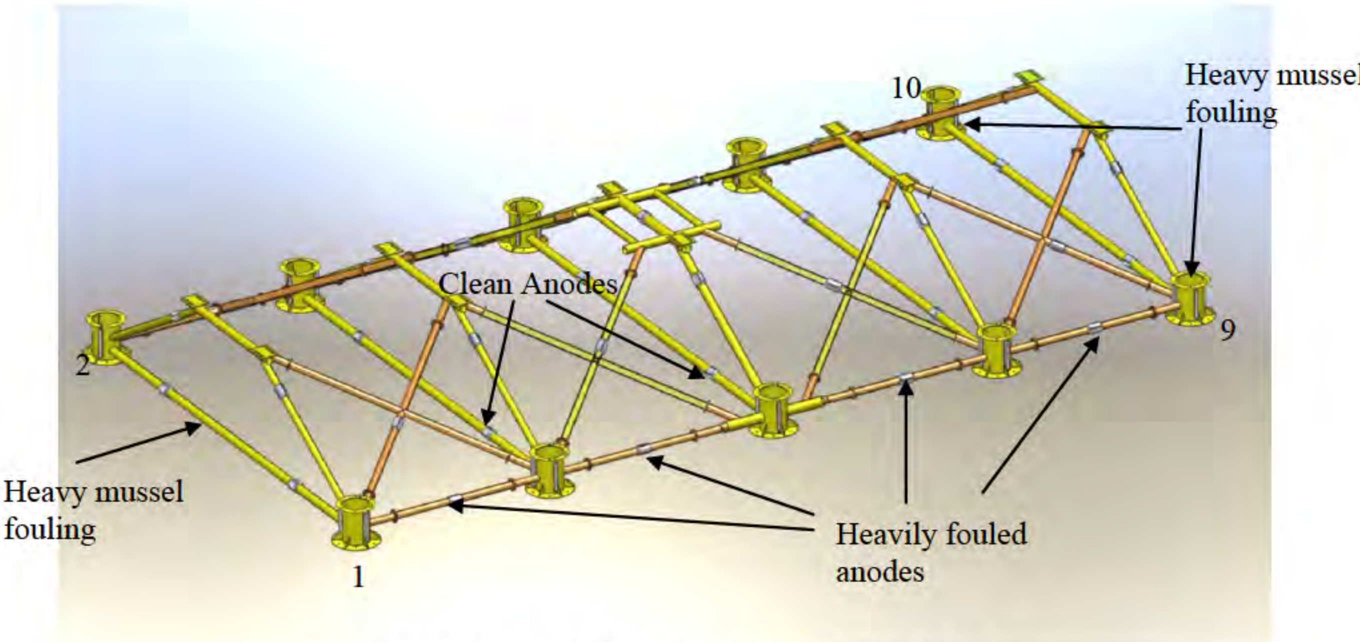


Figure 26. Schematic of bottom support frame biofouling

Effectiveness of Anti-Fouling Paint.

Nanomyte TC-4001M Metal Coat anti-fouling paint was applied to a section of the generator while it was out of the water and following notification of the Project's Adaptive Management Team on February 13, 2013,. The coating test application area is approximately 17.3 in. wide by 21.3 in. high (masking tape included) located on the TidGen® generator back lower quadrant. The top of the test area block was about 5.5 in. down from the generator back structural rib, and the sides of the block are adjacent to the edge of the electronic case struts to the generator (Figure 27). Test Area 1, 2, 3, and 4 are approximately 6.0 in. wide x 8.0 in. high. Area 5 is approximately 3.3 in. x 3.3 in.

The Amerlock Yellow Coating at Areas 1, 2, 3, and 4 were first sanded with 220 grit paper, wiped with a tack clock, and then wiped with a clean lint-free cloth. The Area 5 surface was neither sanded, nor wiped.

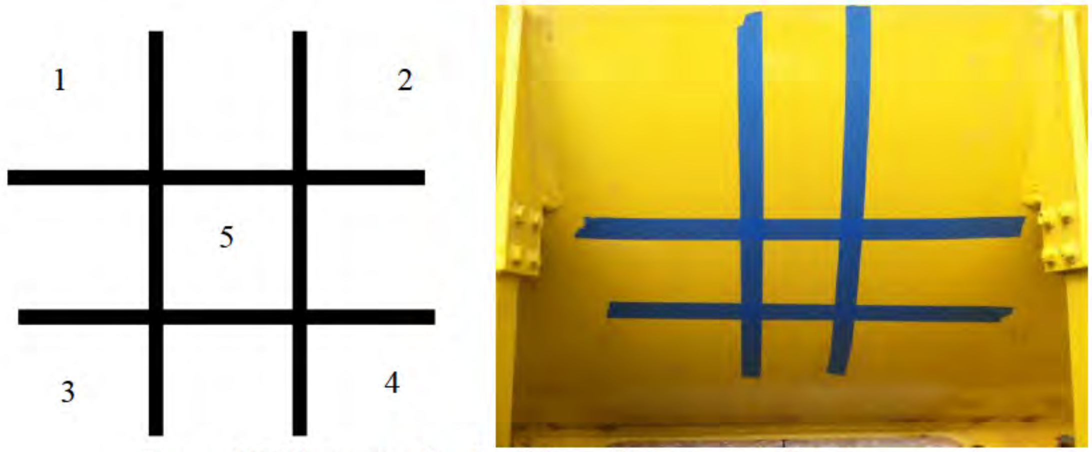


Figure 27. Diagram of anti-fouling paint upon application.

Following retrieval ORPC evaluated the area which was applied with anti-fouling paint (Figure 28). A description of each section is provided in Table 5.

Figure 28. Area treated with anti-fouling tape upon inspection.

Table 5. *Evaluation of anti-fouling paint*

Section 1 *Sanded and wiped* Description of growth: 40% Hydroid, 5% barnacle, 20% algae; Hydroids clustered on outer edge	Not treated	**Section 2** *Sanded and wiped* Description of growth: 25% Hydroid, 5% barnacle, 15% algae; Hydroids clustered on outer edge
Not Treated	**Section 5** *NOT sanded or wiped* Description of growth: 35% Hydroid, 25% barnacles, 35% algae; Barnacles clustered on upper tape line	Not Treated
Section 3 *Sanded and wiped* Description of growth: 5% Hydroid, 30% barnacle, 60% algae; Barnacles clustered on upper tape line	Not Treated	**Section 4** *Sanded and wiped* Description of growth: 15% hydroid, 20% barnacles, 70% algae; barnacles clustered on upper tape line

ORPC's evaluation of the applied anti-fouling paint has determined that it was not effective in reducing marine growth on the generator as applied. Conversations with the material supplier strongly suggest that the coating was not applied in a proper fashion. Any results from this test were therefore inconclusive.

4.3 Conclusions and Recommendations

Cable survey
MER's assessment indicated the diver recorded video quality is very good and offers a clear view of the benthic habitat and associated flora and fauna. The drop camera video quality was generally good, although the current velocity and consequent speed of the camera frame along the bottom made the review process challenging along certain transects. The quality and usefulness of the drop camera videos can likely be improved by making changes to the timing and sequence to the recording of the transects to avoid high current periods.

The faunal community observed along the diver recorded video and drop camera video segments were consistent for the same general vicinity covered by both and were also generally similar to the faunal community distribution observed during the baseline survey of July 2011.

Relative abundance was also generally similar although some variations exist between the diver recording and that of the drop camera due to the different areas covered. Based on observations of the exposed cable(s) there continued to be little, if any, evidence of scouring or disturbance to the bottom or the associated faunal community.

Benthic Sampling
As was previously found, with the exception of the softer, nearshore bottom, the sediment composition over much of the sampling area made collection of accurate benthic cores difficult to near impossible with some samples being "scooped" into the corer by hand by the diver. The benthic infauna data from these cores therefore needed to be treated as semi-quantitative and generally characterizing the benthic infauna community rather than strictly quantitative.

The benthic infauna samples collected along the shallower portion of the subtidal cable route (Station 1-5) at the Upper Cobscook Bay site contained 113 species representing 81 families with polychaetes representing 51.6% of the organisms found. The families most represented, in rank order, were Sepulidae (Spirorbis sp.), Spionidae, Paraonidae, Cirratulidae, Terebellidae, Ampharetidae, Syllidae, Lumbrineridae and Opheliidae, together representing, 47% of all organisms, all families normally found in clean environments with sandy to coarse sediments. Other polychaete families represented included Capitellidae, Phyllodocidae, Polynoidea, Sigalionidae, Nephtyidae, Hesionidae, Nereidae, Scalibregmidae, Maldanidae, Eunicidae, Dorveillidae, Cossuridae, Pectinaridae, Flabelligeridae, Sabellidae and Orbiniidae. Mollusks, representing 18.3% of all organisms, were dominated by Anomia sp., found attached to rocks and shells, representing 13% of the organisms. Crustaceans account for 9.0% of all organisms and were dominated by barnacles and amphipods. Together these represented 87.3% of the 4,442 organisms identified from the 5 stations.

The benthic infauna samples collected along the deeper portion of the subtidal cable route (Station 6-11) at the Upper Cobscook Bay site contained 104 species representing 74 families with mollusks representing 52.9% of the organisms and dominated by *Mytilus edulis* (36.2%) and Anomia sp. (12.4%). Polychaetes represented only 11.6% of the organisms found. The families most represented, in rank order, were Sepulidae (Spirorbis sp.), Polynoidea, Eunicidae, Sigalionidae, Capitellidae, Terebellidae, Syllidae, Ampharetidae, and Cirratulidae. Other polychaete families represented included Phyllodocidae, Spionidae, Paraonidae, Opheliidae, Nereidae, Pectinaridae, Sabellidae and Orbiniidae. Crustaceans accounted for only 3.5% of all organisms; entoprocts represented 25.6% of the population. Together these represented 91.7% of the 8,079 organisms identified from the 6 stations.

Combined, the shallow and deep sampling locations contained 12,521 organisms representing 143 species and 102 families; this was somewhat greater than the 127 species and 90 families found in the 2011 baseline samples as well as the 131 species representing 78 families found in a similar study in Deep Cove in Lower Cobscook Bay in 2009. All of these sampling events were indicative of the biological and functional diversity for which Cobscook Bay and the region is renowned.

The intertidal area remains essentially unchanged other than a reduction in *Fucus* spp. and *Ascophyllum nodosum* in the Middle level and the decrease in number of blue mussels, *Mytilus edulis* in the Lower level where they were found to be abundant during the July 2011 baseline survey. This reduction in mussels, most of which were rather small in 2011, may be related to the increased presence of the green crab, *Carcinus maenas*, which was commonly to occasionally found in the Lower level (L1 and L2; none in L3) in this recent survey but absent in 2011. *C. maenas* has been implicated in a near complete elimination of small soft-shell clams, *Mya arenaria*, in several coastal areas of Maine during the 2013 summer season, especially Casco Bay (pers. obs.); *C. maenas* is known to prey on mussels as its preferred diet (Ropes, 1968).

The intertidal grid sample results again showed the upper, high intertidal area (H) area being essentially barren of organisms except where the seaweed wrack provides shelter to small amphipods (see benthic core results below). The mid-intertidal (M) and lower-intertidal levels (L) offer habitat for isopods, *Idotea* spp., primarily associated with rockweeds, which are the most numerous species at 2,972 individuals representing 56.2% of all organisms found. The common barnacle, *Balanus* sp., ranks second at 1,124 individuals counted representing 21.3% of all organisms found. Other species found, in rank order, are the smooth periwinkle (9.6%), *Littorina obtusata*, common periwinkle (7.1%), *L. littorea*, and rough periwinkle (2.1%), *L. saxatilis*; common amphipods, *Gammarus* sp, represent 147 organisms or 2.8% of the organisms found. Together these species represent 5,239 or 99.1% of the 5,289 organisms found. Other organisms found in very small numbers include Cumaceans, *Diastylis quadrispinosa*, the green crab, *Carcinus maenas*, the limpet, *Tectura (Acmea) testudinalis*, mud snail, *Ilyanassa* sp., blue mussel, *Mytilus edulis*, and oligochaetes.

Compared to the 2011 samples results, the mid-level (M) shows a reduction in both number of species and abundance, but this reduction appears related to the reduced amount of rockweed cover, (which provides both habitat as well as protection from desiccation) in 2013 within the level; the reduced amount of rockweed may or may not be related to the installation of the cable since rockweed cover is naturally patchy in the intertidal as shown in Figures 5 and 6. Results for the lower intertidal level (L) are very similar to those of the 2011 sampling event with number of species higher in 2013, although the dominant species remain the same, and abundance being very similar.

The intertidal benthic cores are dominated by oligochaetes representing 2,298 or 79.1% of the 3,144 organisms found in the samples; these are found primarily in the lower intertidal level with some in the middle intertidal level. The isopod, *Idotea* sp., is found in the lower level (associated with rockweeds) and represents 9.4% of the benthic cores population. Amphipods, *Talochestia* sp., found in the upper (H) area associated with wrack weed, and *Gammarus* spp. found in the lower level, represent 7.1% and 6.0% of the population, respectively. Together, these species represent 3,008 or 95.7% of the organisms found in the benthic cores taken in the intertidal area.

The results of the intertidal benthic infauna core samples show strong similarity between the 2011 and 2013 samples, the number of species being the same and the dominant taxa being oligochaetes and nematodes in the mid-level. In the lower level (L) the number of species is higher in 2013 compared to 2011, but the population is again dominated by oligochaetes and nematodes. The 2011 lower level benthic core samples also contained blue mussels, *Mytilus edulis*, which were absent in 2013. Again, as mentioned above, the lack of small mussels may be related to the increase in green crabs observed at the site. The 2013 samples contained isopods and amphipods not seen in 2011. These latter differences are likely attributable to normal seasonal and inter-annual differences.

Biofouling Assessment
The biofouling assessment performed on the TidGen® TGU immediately following retrieval in July 2013 indicated minor overall biofouling. The most significant growth occurred on the generator, sacrificial anodes, bearing mounts, and on mounting brackets with flat surfaces and complex geometry. Additionally, the evaluation of the applied anti-fouling paint determined that it was not effective in reducing marine growth on the generator.

Analysis of the screenshots taken from the July 10, 2013 videos of bottom support frame piles, anodes visible in the footage, and other locations show signs of significant biofouling in certain areas. However, biofouling did not appear to be compromising the functionality of the bottom support frame.

5.0 FISHERIES AND MARINE LIFE INTERACTION MONITORING (License Article 407)

The goal of the Fisheries and Marine Life Interaction Monitoring Plan was to collect pre-deployment and post-deployment information to provide an initial description of fish distribution and relative abundance within Cobscook Bay to supplement existing information for the general Passamaquoddy Bay area. Specific objectives included:

- Characterize fish presence and vertical distribution in Cobscook Bay with acoustic technologies
- Conduct stratified sampling to evaluate tidal cycle, diel, and seasonal trends
- Characterize fish distribution, species, and relative abundance and summer seasonal occurrence with multiple netting efforts in open-water pelagic and benthic areas, near-shore sub-tidal areas, and intertidal areas of outer, middle, and inner bays within Cobscook Bay
- Use data gathered to develop a preliminary assessment of the potential effects of the Project on fish populations in the Deployment Area and to the extent possible in Cobscook Bay
- Monitor indirect fish interactions with the TidGen® devices(s) to evaluate potential Project effects
- Evaluate potential cumulative effects of the Project based on this comprehensive data set and the direct interaction monitoring data collected

UMaine prepared the Fisheries and Marine Life Interaction Monitoring Plans Annual Report, September 2013 (Appendix D). Phase I of the Project requires monitoring to assess potential effects of the TidGen® Power System on the marine environment. ORPC's monitoring plan regarding marine life has two parts: (1) Fisheries Monitoring Plan and (2) Marine Life Interaction Monitoring Plan.

Fisheries Monitoring Plan
The Fisheries Monitoring Plan was a continuation of research started by UMaine's School of Marine Science researchers in 2009. The study was designed to capture tidal, seasonal and spatial variability in the presence of fish in the area of interest (near the TidGen® deployment site). The design involved down-looking hydroacoustic surveys during several months of the year, and examined the vertical distribution and relative abundance of fish at the project and control site (for relative comparison). Predeployment data were collected in 2010, 2011, and early 2012, and post-deployment data were collected from August 2012 through September 2013 (August 2012 through June 2013 are reported here). Data from the Project site were compared to the control site to quantify changes in fish presence, density, and vertical distribution that may be associated with the installation of the TidGen® Power System.

Marine Life Interaction Monitoring Plan
The Marine Life Interaction Monitoring Plan used side-looking hydroacoustics collected by ORPC at the Project site to assess the interaction of marine life (fish, mammals and diving birds)

with the TidGen® device. This monitoring focused on the behavior of marine life (primarily fish) as they approached or departed from the region of the TGU and attempted to quantify changes in behavior in response to the TidGen® unit. The approximate location of the side-looking hydroacoustic device is shown on Figure 29.

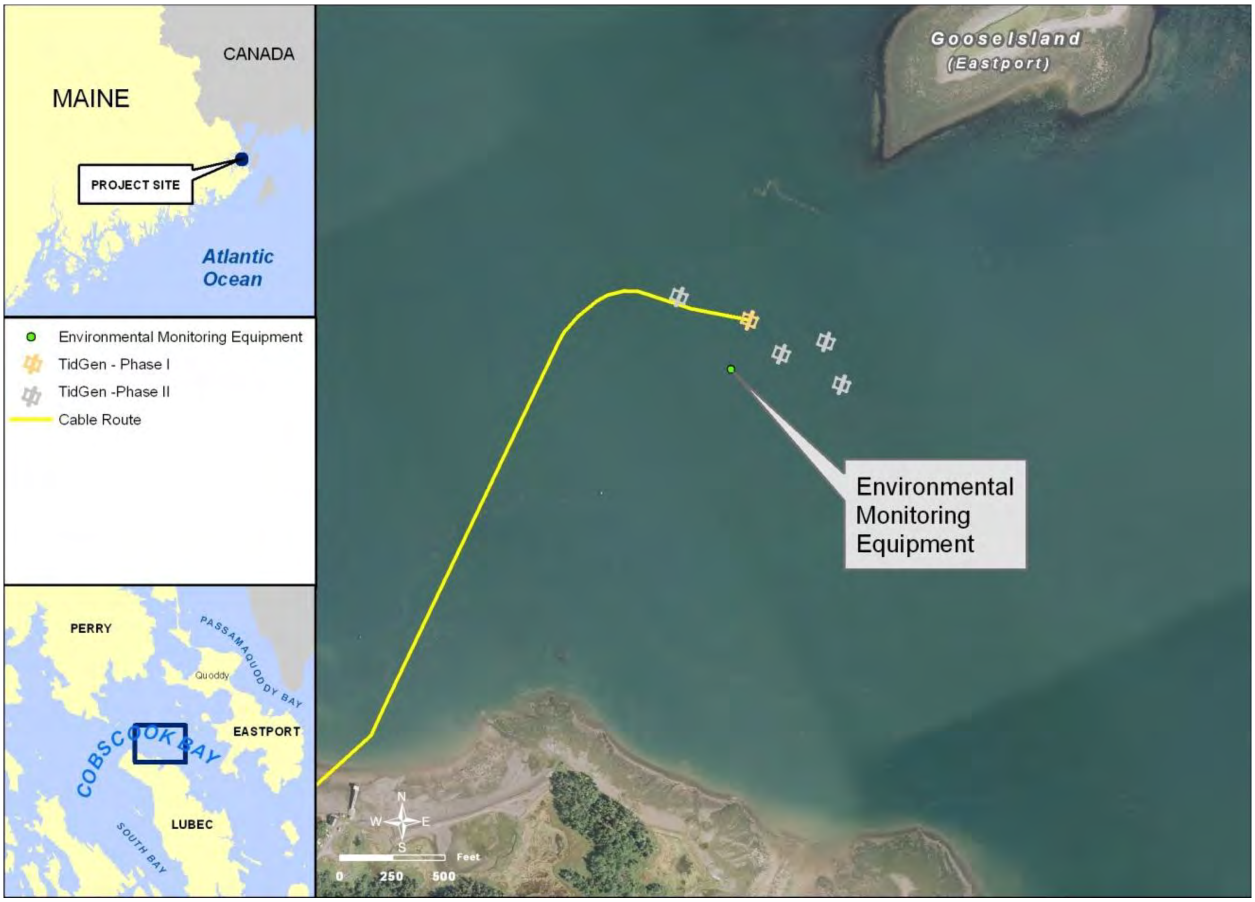


Figure 29. Location of TidGen® 001 and environmental monitoring equipment.

5.1 METHODOLOGIES

5.1.1 FISHERIES MONITORING PLAN (DOWN-LOOKING HYDROACOUSTIC SURVEYS)

Fisheries Study Design
Down-looking hydroacoustic surveys were conducted from an anchored research vessel for one 24-hour period several times per year at a project site (CB1) and a control site (CB2) (Table 6, Figure 30). During the time when the complete TidGen® device (bottom support frame and the TGU) was in the water (from here on referenced as "deployment"), three sites were sampled: two at the project location (CB1a, beside the turbine, and CB1b, in line with the turbine) and one at the same control site (CB2) (Figure 30). Sampling locations at the project sites in 2012 varied geographically because of construction activities and related safety concerns around the TidGen®

device. January and March 2012 were pre-deployment surveys, so only CB1 and CB2 were sampled. In January, CB1 was only sampled for 12 hours due to unsafe weather conditions. There was no November 2012 survey because the TidGen® TGU was removed for maintenance at the time.

The down-looking surveys were carried out using a single-beam Simrad ES60 commercial fisheries echosounder, with a wide-angle (31° half-power beam angle), dual-frequency (38 and 200 kHz) circular transducer. The transducer was mounted over the side of the research vessel 1.8 m below the surface, and ensonified an approximately conical volume of water extending to the sea floor. Current speed was measured every half-hour of each survey using a Marsh-McBirney flow meter (May 2011 to May 2012) or a Workhorse Sentinal Acoustic Doppler Current Profiler (ADCP) (June 2011 onward). A 300 kHz ADCP was used in 2011 and 2012, and a 600 kHz ADCP was used in 2013. Every 30 minutes, the ADCP operated for 1 minute, recording mean current speed in 1 m depth bins from 3 m below the surface to the sea floor.

Table 6. *Months sampled for Fisheries Monitoring Plan (down-looking hydroacoustics). 1 and 2 indicate sampling at CB1 and CB2, respectively; 1a, 1b, and 2 indicate sampling at CB1a, CB1b, and CB2, respectively. Light gray indicates presence of TidGen® bottom support frame only; dark gray indicates presence of complete TidGen® device.*

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2010					1, 2			1, 2	1, 2	1, 2	1, 2	
2011			1, 2		1, 2	1,2		1, 2	1, 2		1, 2	
2012	1, 2		1, 2		1a, 1b, 2	2		1a, 1b, 2	1a, 1b, 2			
2013			1a, 1b, 2		2	2						

Figure 30. Fisheries Monitoring Plan study area and down-looking hydroacoustic survey locations for 2010-2013. CB1 and CB2 are indicated by dashed ovals. CB1a and CB1b are indicated by small round points. CB1 current directions are averages provided by ORPC.

The single-beam transducer was used to obtain an index of fish density, which allowed UMaine to examine changes in fish density over time. This relative measure was also used to assess vertical distribution of fish throughout the water column.

Comparisons of fish density and vertical distribution were made among the control site and project site(s) and among different months at each site. Sampling before and after turbine deployment at the project as well as at a control site improved the ability to distinguish changes that may be related to the presence of the turbine from changes due to annual, seasonal, daily, and tidal variation. These methods were consistent with a before-after-control-impact (BACI) study design.

Fisheries Data Processing
Hydroacoustic data were processed using Echoview® software (5.3, Myriax Pty. Ltd., Hobart, Australia), and statistical analyses were carried out in R (2.15.2, R Core Team, Vienna, Austria). The data collected at the 200 kHz frequency were used in analyses. Processing included scrutinizing the data and manually removing areas of noise (e.g., from electrical interference, a passing boat's depth sounder, high boat motion, or interference from the ADCP). Hydroacoustic interference from entrained air was common in the upper 10 m of the water column, so the top 10 m of the water column were excluded from analyses. Weak hydroacoustic signals, such as

plankton, krill, and fish larvae, were excluded by eliminating backscatter with target strength (TS) less than -60 dB. Most fish have TS between -60 dB and -20 dB but TS varies greatly with fish anatomy and orientation (Simmonds and MacLennan 2005). This variability, combined with the TS uncertainty inherent in single beam systems, means that some fish with TS higher than -60 dB were likely excluded from analyses (Simmonds and MacLennan 2005).

In March and June of 2013, some weak background noise from electrical interference could not be eliminated using the -60 dB threshold. Echoview's background subtraction tool (based on the algorithm developed by de Robertis and Higginbottom, 2007) was used to remove this interference.

Because flowing tides were the focus of this study, hydroacoustic data during slack tides were not included in analyses. Slack tides were defined as the hour centered at the time of low or high water. The time of low and high tide was determined using the depth of the bottom line detected in Echoview. Thirty minutes to either side of these time points were then removed from the hydroacoustic dataset.

Fish density was represented on a relative scale using volume backscattering strength, Sv, which is a measure of the sound scattered by a unit volume of water and is assumed proportional to density (Simmonds and MacLennan 2005). Sv is expressed in the logarithmic domain as decibels, dB re 1 m-1. The vertical distribution of fish throughout the water column was examined using the area backscatter coefficient, sa, which is the summation of volume backscatter over a given depth range and is also proportional to fish density (Simmonds and MacLennan 2005). The sa is expressed in the linear domain (m2·m-2) and is additive.

The inspected and cleaned hydroacoustic data were divided into 30-minute time segments, which were large enough to minimize autocorrelation but maintain variation in density that occurred over the course of each survey. Echoview was used to calculate the mean Sv of the entire water column for each 30-min interval. Then, for each interval, sa was calculated for 1-m layers of water. Layers were measured upward from the sea floor, rather than downward from the surface, because the turbine is installed at a fixed distance above the bottom (the top of the turbine is 9.6 m above the sea floor). By calculating the proportion of total water column sa contributed by each 1-m layer of water, the vertical distribution of fish was constructed for each 30-min interval.

Fisheries Statistical Analysis
To examine annual, seasonal, tidal, and spatial variability of fish density in the area of interest, comparisons of water column fish density index (SV) were made using permutation ANOVAs (R package lmPerm; Wheeler 2010), followed by nonparametric Tukey-type multiple comparisons to determine significant differences (R package nparcomp; Konietschke 2012). Five questions were asked:

1) Inter-annual variability: was fish density constant across years? UMaine tested the effect of year on fish density in outer Cobscook Bay, combining data for all sites.

2) Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? UMaine tested the effect of site on mean water column SV for surveys in which CB1a and CB1b were sampled (May, August and September 2012, and March 2013). If CB1a and CB1b have similar fish densities, they may be grouped for comparison to CB1 surveys carried out in previous years.
3) Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? To validate the utility of CB2 as a control site, differences between the project site (CB1) and control site (CB2) were evaluated using month and site as factors.
4) Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? The effect of month on fish density was tested, combining data for CB1 and CB2.
5) Did deployment of the TidGen® device affect fish density at the project site (CB1)? Results from the tests in (2) were used to compare differences before and after device deployment.

The vertical distribution of fish was compared between sites within each survey, with the goal of detecting differences potentially related to the presence of the turbine. To test the similarity of two distributions, one was fit to the other with linear regression. Similar vertical distributions were indicated by a significant fit (significance level of 0.05) and a positive slope. Negative slope or insignificant fit indicated dissimilar distributions. If distributions at the project and controls sites were similar before the turbine was installed, differences afterward may indicate an effect of the turbine on how fish use the water column (e.g., avoidance of the depths spanned by the turbine). Differences between CB1a and CB1b may also indicate behaviors altered by the turbine's presence.

5.1.2 Marine Life Interaction Monitoring Plan (side-looking hydroacoustics)

Marine Life Interaction Study Design

ORPC mounted a Simrad EK60 split beam echosounder (200 kHz, 7° half-power beam width) to a steel frame located 44.5 m from the southern edge of the TidGen® device (Figure 31). This frame holds the transducer 3.4 m above the sea floor, with the transducer angled 9.6° above the horizontal with a heading of 23.3°. The echosounder sampled an approximately conical volume of water extending for 100 m, directly seaward (southeast) of the TidGen® device (Figure 32). The actual sampled volume used in data analysis did not include the entire beam. The sampled volume extended to the far edge of the turbine (78.1 m), not beyond because after that point, interference from sound reflection off the water's surface became too great to reliably detect fish. The sampled volume was upstream of the device during the flood tide (examining approach behaviors) and downstream of the device during the ebb tide (examining departure behaviors). The echosounder was powered and controlled via undersea cables from the ORPC On-shore Station in Lubec, where data files are stored on a server and collected periodically by UMaine.

Figure 31. Environmental monitoring observation tower.

When operational, the echosounder recorded data continuously. Continuous data collection at a sample rate of 4 to 6 pings per second allowed each fish or other marine animal that passes through the beam to be detected several times, recording information on the echo strength and 3D location of targets within the beam (Figure 33). These data were used to track fish movement during their approach to the turbine (flood tide) as well as during their departure (ebb tide) on a fine spatio-temporal scale. The sampled volume was divided into three zones: the turbine zone (red hatched area, Figure 32a), where fish would be likely to encounter the moving turbine; above the turbine zone (A, Figure 32); and beside the turbine zone (B, Figure 32). Fish numbers and movement in each zone provided indicators of turbine avoidance. The total sampling volume to 78.1 m range (for a 7° hydroacoustic cone) ws 1,866 m3, and of this, 607m3 (33%) were within the turbine zone, 345 m3 (18%) were beside the turbine zone, and 914 m3 (49%) were above the turbine zone.

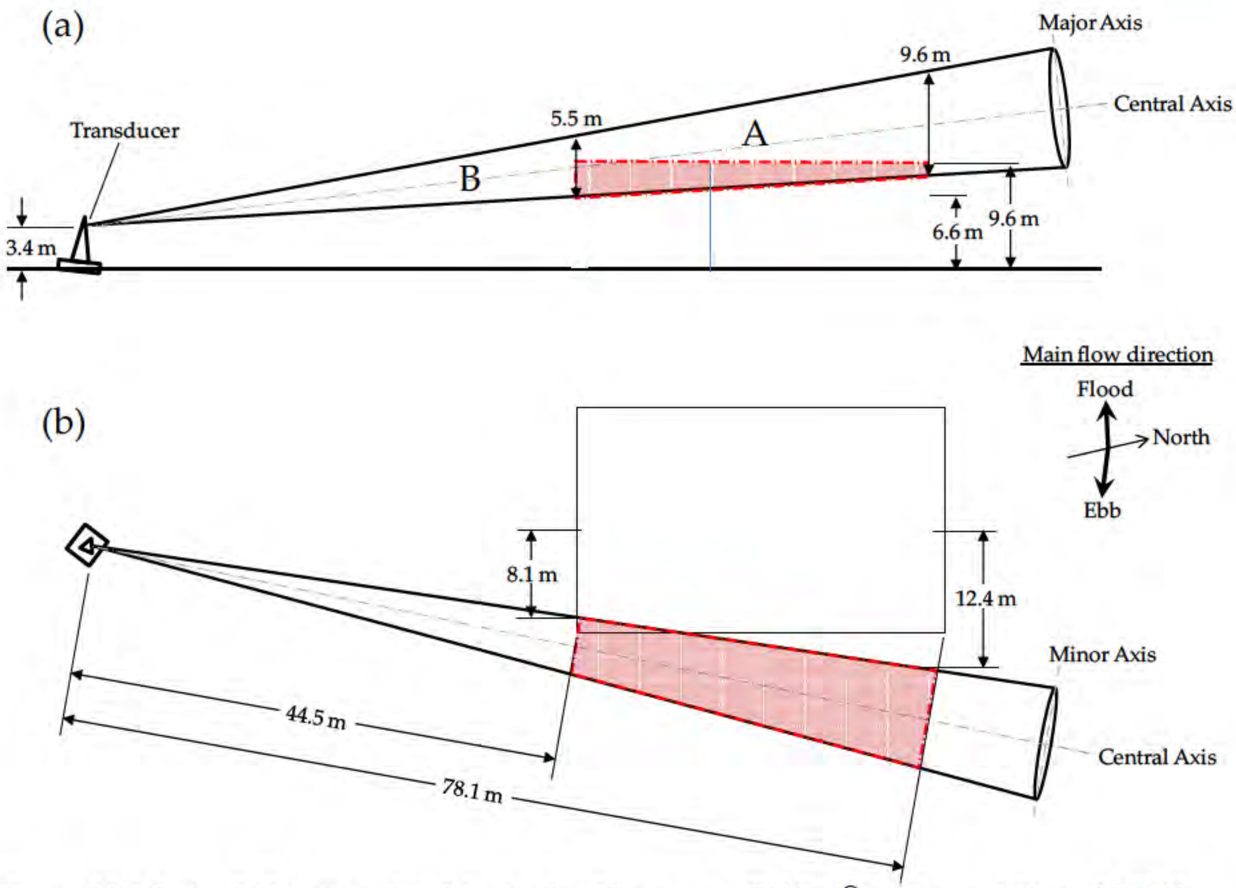


Figure 32. Marine Life Interaction Monitoring Plan setup. TidGen® device and Simrad EK60 support structure shown from (a) the seaward side and (b) above. Hydroacoustic beam represented as 7° cone (half-power beam width) in solid black lines. Red hatched area indicates sampled volume within the turbine zone, A indicates the volume sampled above the turbine, and B indicates the volume sampled beside the turbine. Current directions shown are Project site averages provided by ORPC.

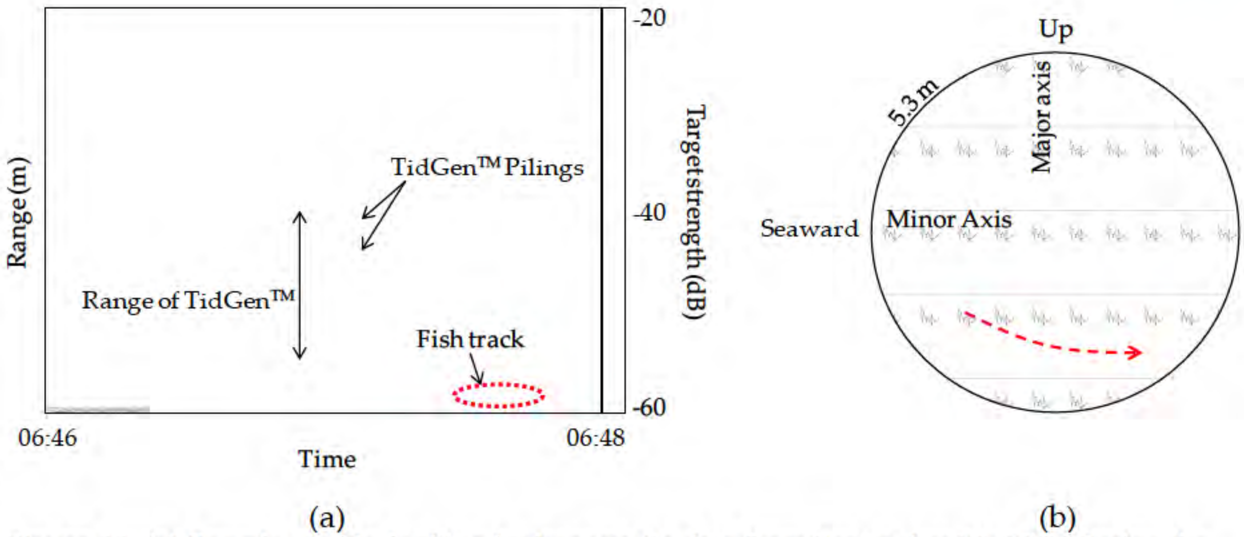


Figure 33. (a) Sample of side-looking hydroacoustic data from September 30, 2012 during the flood tide. (b) Fish in red dashed oval in (a) tracked through beam cross section. Outer circle represents 3.5° off-axis, or 5.3 m at this range. Each dot is a single detection of the fish. Red dashed arrow indicates direction of movement.

ORPC also collected current speed, direction (intermittently; see Section 3.1 and 3.2), turbine movement in rotations per minute (RPM), and turbine operation state (generating or not).

Data Availability

Data collection began on August 29, 2012. Data could not be collected while the turbine was generating power due to electrical interference between the data and power transmission cables running together along the seabed to the shore station. Therefore, hydroacoustic data were collected only for periods of time when the turbine was not rotating (either during slack tides when the current was too weak, or when the brake was applied), or when it was free-spinning (rotating but not generating power). Gaps also existed in the dataset whenever the turbine or hydroacoustic system was being repaired or adjusted, during periods of turbine deployment or removal, and whenever divers were present near the echosounder.

Collection of current speed and direction data by sensors mounted on the TidGen® Power System frame was intermittent. For times when data was available, current direction was not useful for fish behavior analysis due to the placement of ORPC's flow meters, which were oriented to collect information in the plane parallel to the TidGen® device. At times, ORPC collected current speed and direction information with an ADCP placed approximately 4.6 m from the turbine, between the turbine and hydroacoustic transducer. This ADCP operated for various lengths of time (spanning days), obtaining current speed and direction readings every second. When ADCP deployment overlaped with hydroacoustic data collection, the information may be used to analyze fish swimming direction and speed in relation to the current.

Given these constraints to data collection and availability, three subsets of the data collected since August 2012 were analyzed for this report (Table 7). The first two subsets spanned March

19 to 21 and April 18 to April 20, when ORPC ceased normal power generation to allow continuous hydroacoustic data collection with the turbine free-spinning. These dates were chosen because there were nearly two complete tidal cycles during each day and night. While a free-spinning turbine does not have the same hydraulic signature as one generating power, these data should provide a better idea of fish behavior around an operating turbine than data collected while the turbine is held stationary by its brake. Current speed and RPM (range 8.22-16.73) data were available for these time segments. More free-spinning data collection periods had been planned for May, June, July, and August 2013; however, unforeseen circumstances caused turbine operation to cease in April 2013, just after the free-spinning data presented here were collected. The turbine brake was then applied and the turbine held motionless until it was removed in July 2013.

Hydroacoustic data collection continued after the turbine brake was applied, so a third time period was selected from these data for comparison to the free-spinning datasets from March and April. This 'braked' dataset spanned April 26 to April 28. These dates were chosen for comparison because they were the closest data available to the April free-spinning period that had similar timing of tides (e.g., nearly two complete cycles during each day and night). Current speed data were not available for this time, however, and were instead estimated using previous current speed data (Section 3.1.3).

Table 7. *Summary of data subset analyzed to date.*

Data subset	Tidal stage	Start Date	Start time	End time	Mean current speed ($m \cdot s^{-1}$)	Duration (hrs)	Mean turbine rotation speed (rpm)*
March Free-spinning	Ebb	3/19/13	17:00	22:20	0.82	5.33	11.80
	Flood	3/19/13	23:15	4:50	0.91	5.58	12.95
	Ebb	3/20/13	5:50	10:40	0.86	4.83	13.52
	Flood	3/20/13	11:40	17:20	0.93	5.67	13.28
	Ebb	3/20/13	18:20	23:20	0.81	5.00	11.95
	Flood	3/21/13	0:20	5:30	0.99	5.17	15.05
	Ebb	3/21/13	6:30	11:40	0.86	5.17	8.22
	Flood	3/21/13	12:40	18:30	0.95	5.83	–
	Ebb	3/21/13	19:30	0:30	0.85	5.00	–
	Flood	3/22/13	1:30	7:00	1.01	5.50	–
	Ebb	3/22/13	8:00	13:00	0.95	5.00	–
April Free-spinning	Ebb	4/18/13	5:00	10:20	0.94	5.33	15.82
	Flood	4/18/13	11:20	16:40	1.02	5.33	16.24
	Ebb	4/18/13	17:40	22:40	0.84	5.00	–
	Flood	4/18/13	23:40	4:50	1.03	5.17	16.24
	Ebb	4/19/13	5:50	11:15	0.91	5.42	15.24
	Flood	4/19/13	12:15	17:30	1.01	5.25	16.22
	Ebb	4/19/13	18:30	23:40	0.86	5.17	14.51
	Flood	4/20/13	0:40	6:00	1.01	5.33	16.73
April Braked	Flood	4/26/13	7:00	12:00	1.22*	5.00	0.00
	Ebb	4/26/13	13:00	18:20	1.24*	5.33	0.00
	Flood	4/26/13	19:20	0:15	1.22*	4.92	0.00
	Ebb	4/27/13	1:15	6:45	1.24*	5.50	0.00
	Flood	4/27/13	7:45	12:45	1.22*	5.00	0.00
	Ebb	4/27/13	13:45	19:05	1.24*	5.33	0.00
	Flood	4/27/13	20:05	1:55	1.22*	5.83	0.00
	Ebb	4/28/13	2:55	7:35	1.24*	4.67	0.00
* Turbine rotation speed while free-spinning is faster than rotation speed during normal operation.							

Marine Life Interaction Data Processing and Analysis
Echoview software (5.3, Myriax Pty. Ltd., Hobart, Australia) was used to process side-looking split beam hydroacoustic data. Processing in Echoview began with manually inspecting the data to identify and exclude unwanted noise (e.g., interference from depth sounders, entrained air from the surface, reflection from surface waves, reflection from fish schools), and setting a target strength threshold of -50 dB to exclude background noise, plankton, and other small objects from analyses. Target strength (TS) is a measure of the relative amount of acoustic energy reflected

back toward the transducer by an object, compensating for transmission and signal losses and represented in decibels (dB re 1 m^2; Simmonds and MacLennan 2005). Though TS is dependent on several factors, including fish anatomy (e.g., swim bladder or none) and orientation relative to the transducer, it is generally proportional to fish size (Simmonds and MacLennan 2005). A threshold of -50 dB should eliminate most fish less than 8.7 cm in length (Lilja et al. 2004), assuming they have air-filled swim bladders (e.g., Atlantic herring). For fish lacking a gas-filled swimbladder, such as Atlantic mackerel, this threshold may eliminate larger fish to an unknown degree.

Echoes from single targets were then detected, excluding data collected beyond 78.1 m from the transducer (far edge of the turbine) due to frequent interference from the surface. Single target detection parameters (Table 8) were set liberally to allow a large number of single targets to be detected among the noise, though this also allowed more false detections to occur. Echoview's fish tracking module was then used to trace the paths of individual fish through the sampled volume. Fish track parameters (Table 9) were chosen to limit the effect of false single target detections on the number of detected fish. Fish track data (including time of detection, target strength, and direction of movement) were exported from Echoview to be further analyzed using MATLAB.

Table 8. *Single target detection settings in Echoview.*

Parameter	Value	Units
Target strength threshold	-50.00	dB
Pulse length determination level	6.00	dB
Minimum normalized pulse length	0.24	Unitless
Maximum normalized pulse length	10.00	Unitless
Beam compensation model	Simrad LOBE	
Maximum beam compensation	35	dB
Maximum standard deviation of minor-axis angles	1.000	Degrees
Maximum standard deviation of major-axis angles	1.000	Degrees

Table 9. 4*D fish track detection settings in Echoview*

		Major Axis	Minor Axis	Range
Algorithm	Alpha	0.5	0.5	0.7
	Beta	0.1	0.2	0.1
	Exclusion distance (m)	2.25	2.25	0.2
	Missed ping expansion (%)	0	0	100
Weights	Major axis	0		
	Minor axis	0		
	Range	1		
	TS	0		
	Ping gap	0		
Track Acceptance	Min number single targets in track	5		
	Min number of pings in track (pings)	5		
	Max gap between single targets	8		

In MATLAB, fish tracks that had been contaminated by false single targets were removed based on track properties, including minor and major axis angle, tortuosity, and change in depth and range (Table 10). These settings helped eliminate fish tracks affected by noise from the turbine and other environmental factors. However, one effect of the turbine that could not be removed without drastically limiting the dataset was its apparent masking of weaker fish echoes within its range (i.e., between 44.5 and 78.1 m from the transducer; Figure 34). This masking is apparent in the distribution of fish track TS from beside the turbine and within the turbine's range. As weaker fish tracks were not detected in the range of the turbine, the numbers of fish detected on either side of the turbine were likely to be inflated with respect to numbers of fish detected within the turbine zone or above it, and included more of the weaker echoes (e.g., smaller fish).

Table 10. *Fish track acceptance parameters used in MATLAB processing*

Fish track property	Value required for track acceptance
Minor axis angle	< 3.0°
Major axis angle	< 3.0°
Change in range	> 0.05 m
Change in depth	> 0.05 m
2D and 3D tortuosity	< 5.0

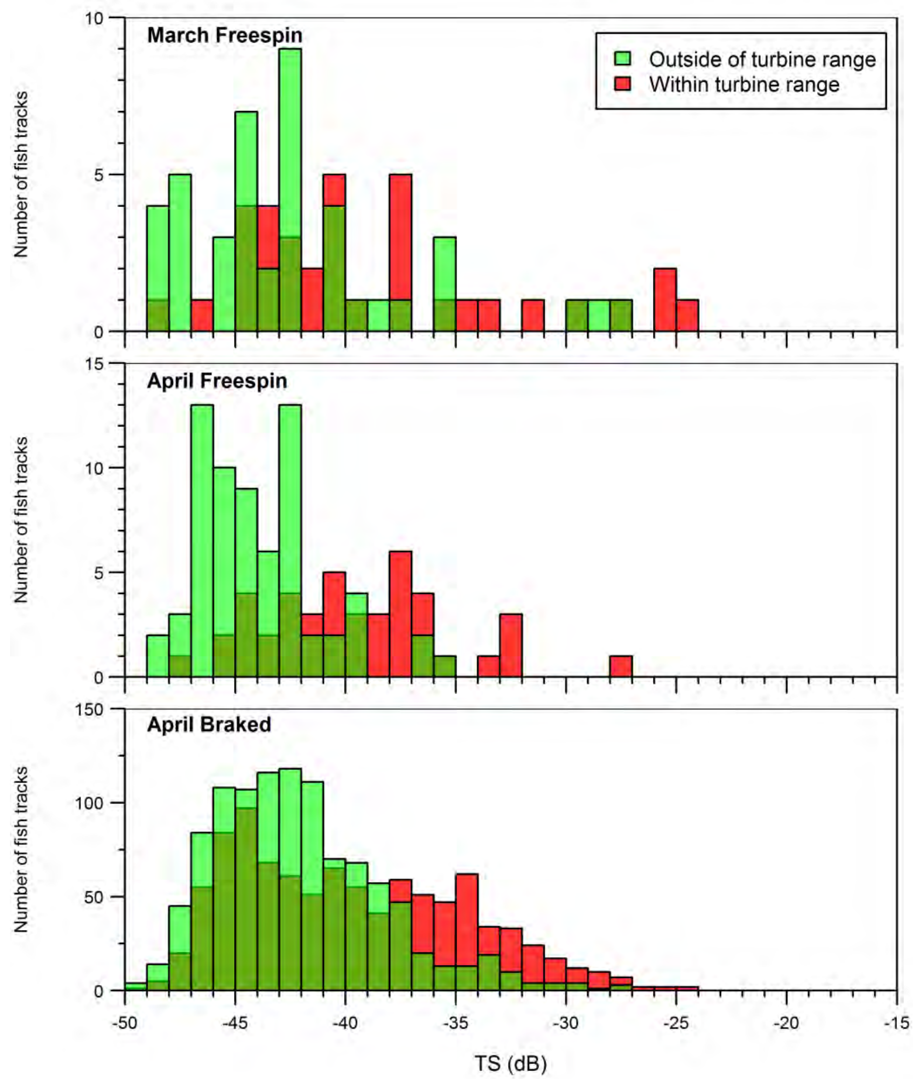


Figure 34. Target strength (TS) distribution from before the turbine range (< 44.5 m from transducer) and within the turbine range (> 44.5 m and ≤ 78.1 m from transducer).

Accepted fish tracks were grouped by tidal stage for analysis of target strength and direction of movement. Flood and ebb tide data were treated separately because a fish's approach to the turbine is sampled during the flood and its departure from the turbine is sampled during the ebb, and behaviors during each are assumed to differ (Viehman 2012; Viehman and Zydlewski accepted).

Fish density and location of tracks

The total number of fish tracks detected in the hydroacoustic data provided an estimate of the density of fish in the sampled volume over time. The location of each fish in the sampled volume was used to place it in one of the three zones near the turbine (Figure 8). Density of fish in a zone (in fish per cubic hectometer, hm^3)was calculated for each time span of interest (e.g., each ebb and flood tide) by dividing the total number of fish detected in the zone by the volume of water to pass through that zone. This volume was calculated by multiplying the area of the zone's vertical cross-section by the approximate linear distance of water to pass through it during the analysis period. The linear distance of water was determined using the mean current speed of each 10-minute time increment. Using 10-minute averages greatly reduced the effect of the noise in the ADCP current speed data. In this way, fish counts were normalized for varying sampling duration and current speed, allowing the direct comparison of densities from different datasets.

Current speed data were not available for the braked turbine dataset, so current speeds from the nearest free-spinning data (April 18-20) were used to obtain an approximation. Since free-spinning data were collected at neap tide (first quarter moon) and braked data were collected at spring tide (full moon), the mean flood tide current speed was multiplied by a factor of 1.2 and the mean ebb tide speed was multiplied by 1.4. These factors were determined using ADCP data collected during spring and neap tides in 2012. While this is a coarse approximation, some estimate was needed in order to make any comparisons between fish numbers obtained from the free-spinning data to those of the braked data.

Direction of movement
The direction of movement (heading, degrees from North; inclination, degrees from horizontal) of each fish was compared to the current direction at the time of fish detection (when data were available). Higher deviation from the water current direction within the turbine zone than in other zones may indicate avoidance behavior during approach (flood tides), or milling during departure (ebb tides).

5.2 RESULTS

5.2.1 FISHERIES MONITORING PLAN (DOWN-LOOKING HYDROACOUSTICS)

Relative fish density
1) Inter-annual variability: was fish density constant across years? Fish density (mean water column S_v) changed significantly each year. Density was significantly higher in 2010 and 2012 than 2011 and 2013 (Figure 35). Because of these differences, years were analyzed separately in subsequent statistical analyses.

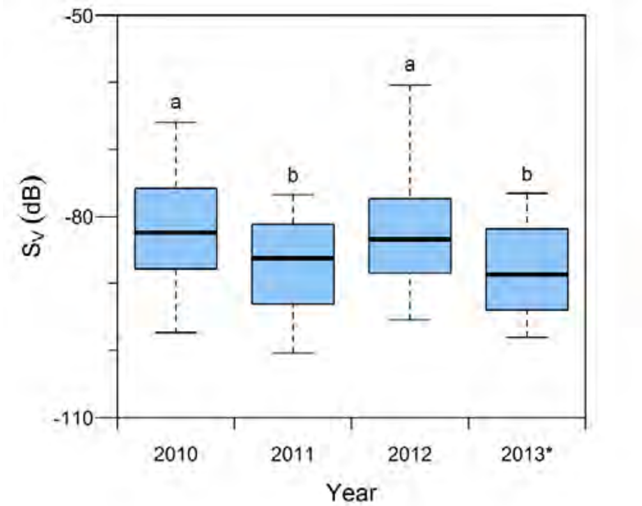


Figure 35. Water column S_v for all years sampled (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles. Significantly different groups are indicated by letters a and b (*). In 2013, only March, May, and June were analyzed.

2) Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? There were no differences in fish density (total water column S_v) between CB1a and CB1b (Figure 36). As such, we grouped these two sites as CB1 in further analyses of water column S_v.

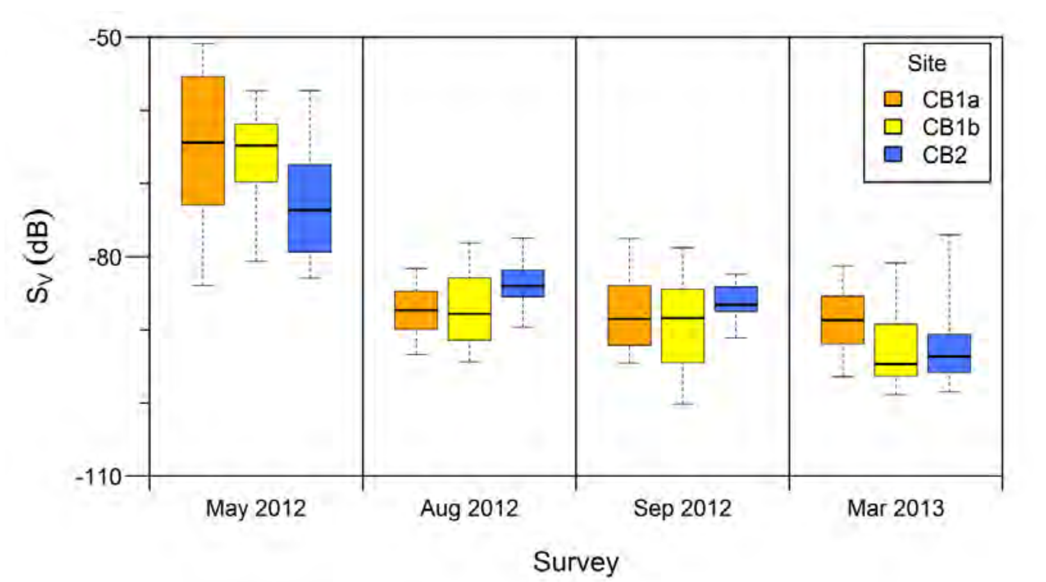


Figure 36. Water column S_v at CB1a, CB1b, and CB2 surveys in 2012 and 2013. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles.

3) Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? In each year, fish density varied significantly with month (Figure 37). Site had a significant effect on fish density in 2011, meaning density was greater at CB2 when data from all surveys were grouped together. However, within surveys (months), densities at CB1 and CB2 were not significantly different. The interaction of site and month significantly affected fish density in 2010 and 2012, indicating that site had a different effect on density in the different months. Multiple comparisons showed that fish density was significantly different at CB1 and CB2 in September 2010 and in March and August of 2012, but that there was no effect of site in the other surveys. Interaction effects could not be tested in 2013 since CB1 was only sampled in only one of three months.

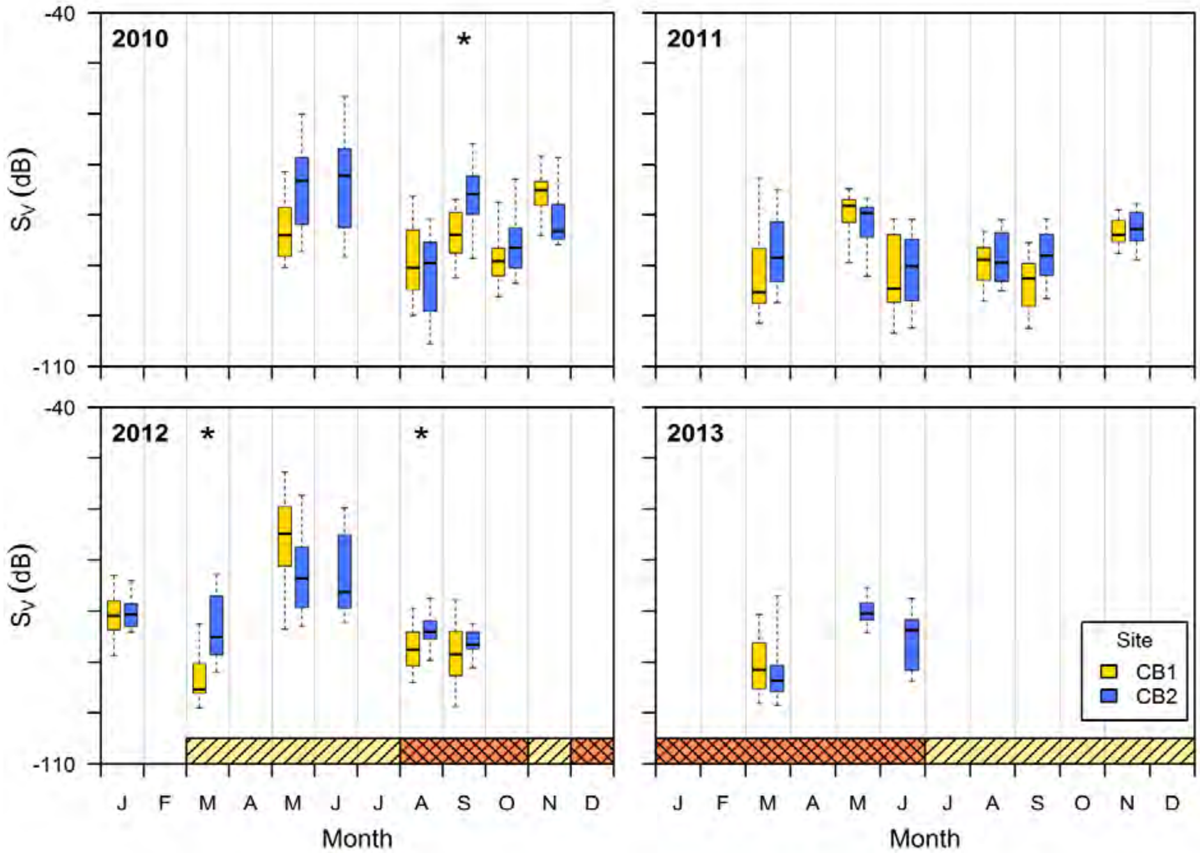


Figure 37. Water column S_v at CB1 (which includes CB1a and CB1b data) and CB2. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles. Asterisks indicate significant differences between CB1 and CB2. † indicates surveys when only ebb tide data were sampled; ‡ indicates surveys when only daytime was sampled. Yellow hatched box indicates surveys when the TidGen® bottom support frame was present on the seafloor; red hatched boxes indicate when the TidGen® turbine was also present. The turbine was braked (present but not spinning) starting mid-April until it was removed in July.

4) Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? Results of multiple comparisons indicated highest fish densities in May and June, followed by November (Figure 38).

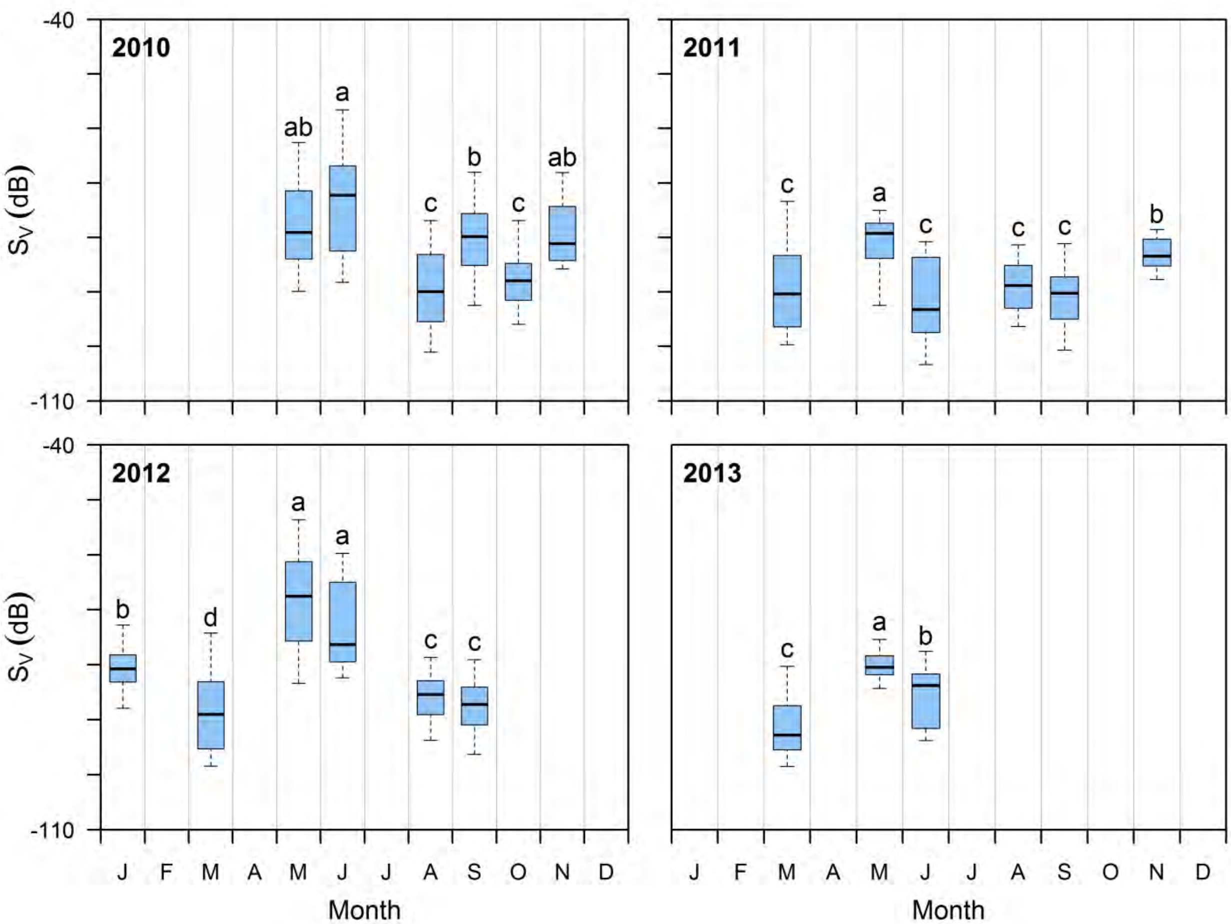


Figure 38. Water column S_v for all surveys (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles. Significantly different groups within each year are indicated by letters a through d (group a is the highest, d is the lowest).

5) Did deployment of the TidGen® affect fish density at the project site (CB1)? A significant difference between CB1 and CB2 was found only in the August 2012 survey, when CB2 had a higher density index (water column S_v) than CB1 (Figure 39). A similar difference was seen in March 2012, when the turbine's bottom support frame was deployed.

Vertical Distribution

Significant differences were only found between sites CB1 and CB2 in May 2011, CB1 and CB2 in March 2012, CB1a and CB2 in May 2012, CB1b and CB2 in May 2012, and CB1a and CB1b in March 2013 (Figure 7).

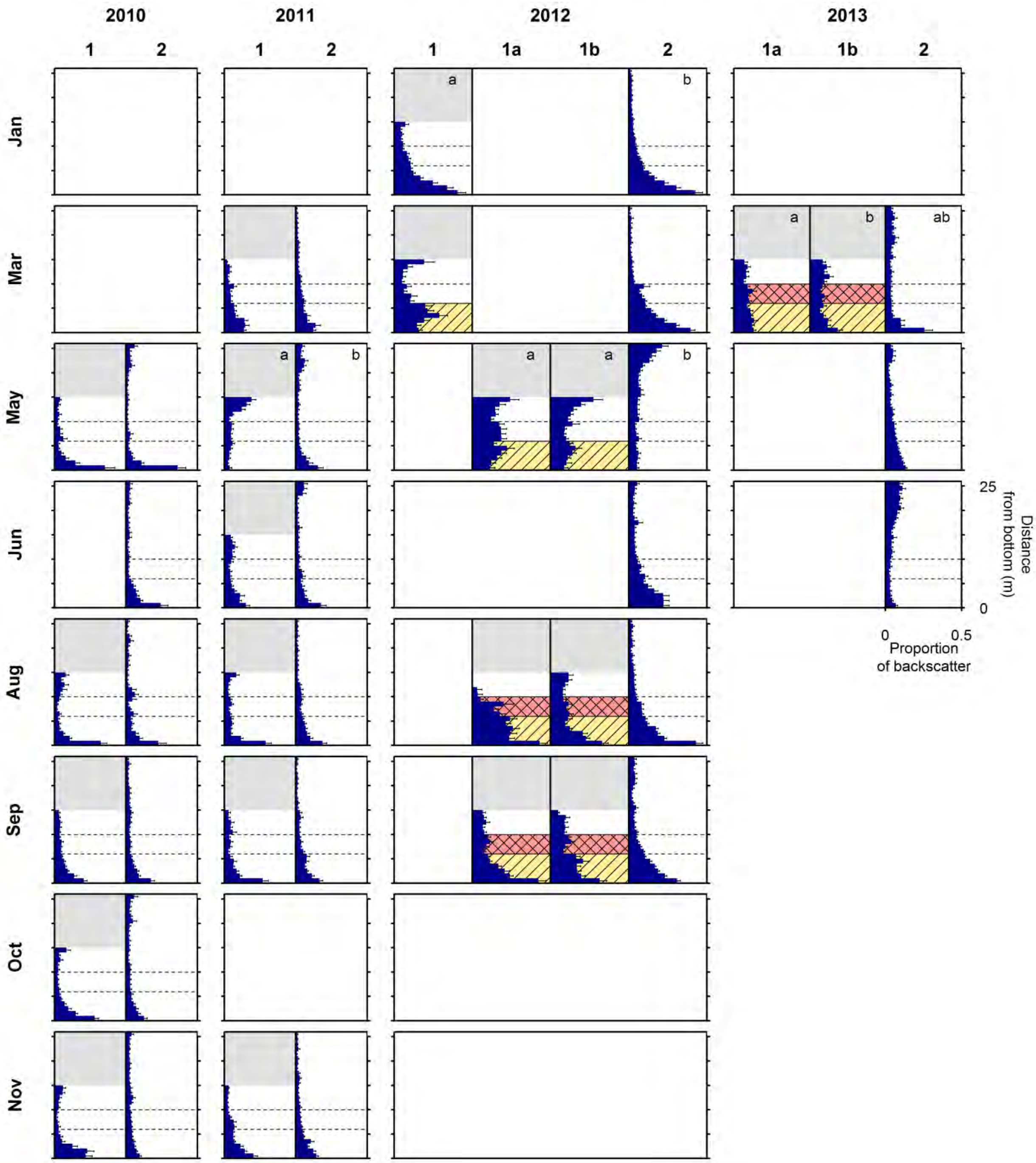


Figure 39. Mean proportion of S_a contributed by each layer of the water column. All layers analyzed are shown for each site (0-15 m above the bottom at CB1, 0-26 m above the bottom at CB2). Whiskers are one standard error. Depth of turbine is indicated by horizontal dashed lines. Yellow hatched areas indicate when the bottom support frame was deployed at the project site; red hatched areas indicate when the turbine was also present. Significantly different distributions between sites are indicated by letters "a" and "b" in the upper right of the graph.

5.2.2 MARINE LIFE INTERACTION MONITORING PLAN (SIDE-LOOKING HYDROACOUSTICS)

A total of 68 fish tracks were detected during the March free-spinning period, 87 were detected during the April free-spinning period, and 1,827 were detected during the April braked period (Figure 40). The number of flood and ebb tides sampled was too low to carry out statistical analyses of the differences between these sampling periods (5 tidal cycles in March, 4 in each April dataset). The large number of fish in the braked dataset in April compared to the other two datasets is unlikely related to turbine operation. To investigate this, the number of fish detected during the slack tides were also compared across datasets, and showed a similar pattern (Figure 41). As the turbine was not moving (and therefore assumed not to be a contributing factor) during the slack tides in either dataset, this comparison supports a natural increase in fish numbers between the free-spinning periods and the braked period. This would also be in line with results from down-looking hydroacoustic surveys (Section 2.2.1), which have shown a large increase in fish density between March and May.

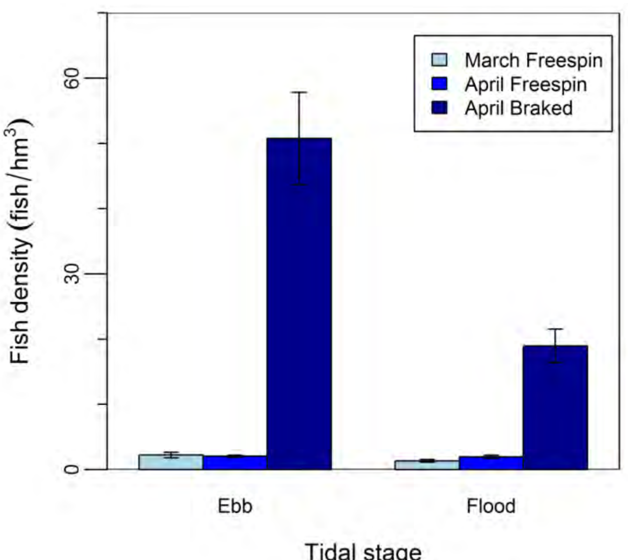


Figure 40. Mean fish density (fish/hm^3) of each tide of each dataset. Whiskers are one standard error.

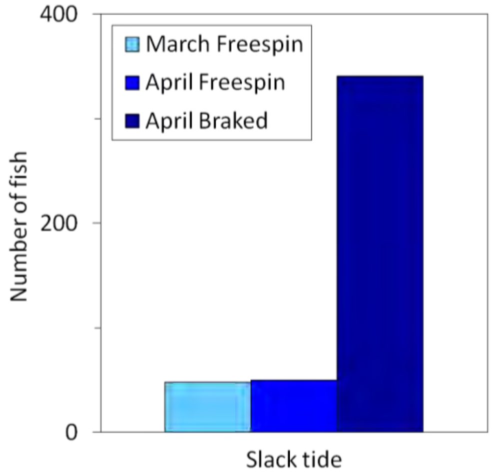
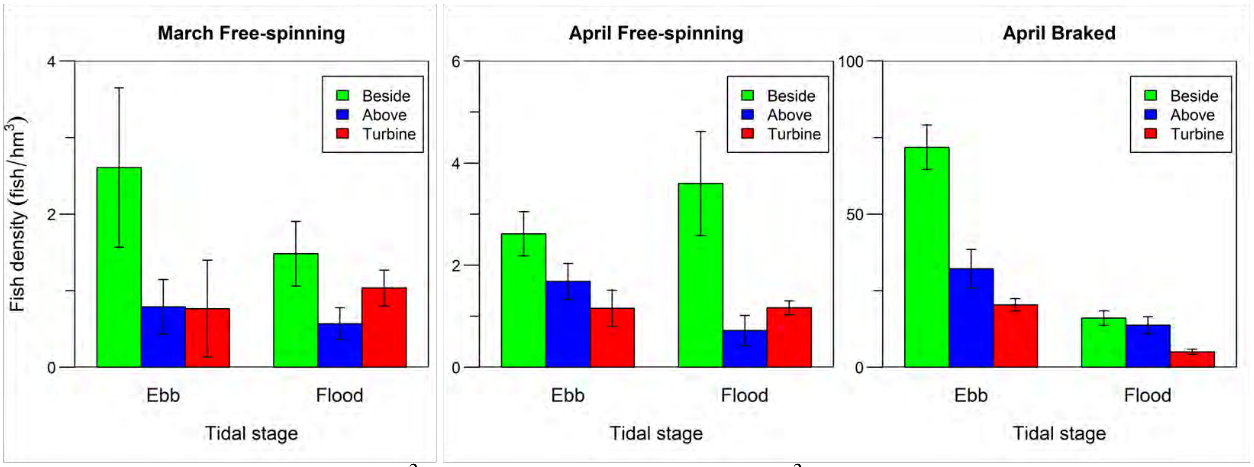


Figure 41. Number of fish detected during the slack tides in each dataset.

Fish density by zone
The mean density of fish in each sampling zone is shown in Figure 42. Density appears greatest beside the turbine and lowest in the turbine zone, though no tests for statistical significance have been carried out due to the low sample sizes (5 tides in March, 4 tides in each April dataset). This is unlikely to be entirely natural or a response to the turbine; rather, it is likely largely due to the masking of weaker fish echoes within the range of the turbine (see section 3.1.3). Though fish track filtering removed much of this effect, the target strength distributions of accepted fish tracks (Figure 42) show that the lower end of the TS spectrum (-50 dB to -41 dB) appear undersampled in the turbine range compared to beside the turbine.

In the braked dataset, more fish were detected during the ebb tide than during the flood tide. This could be explained by the natural movements of fish in the area (e.g., an outward movement of species at the time of the data collection), or may be related to fish sheltering in the lee of the device and its supporting structure. This behavior was previously observed within approximately 3 m of a test turbine (Viehman and Zydlewski, accepted) but more data are necessary before this behavior can be identified in these datasets, especially as the sampling volume of this study is approximately 10 m from the device. The low sample size and the few fish detected to date result in a high degree of variability that makes further comparison of fish counts not useful.



Total = 68 (1.10 fish/hm³) Total = 87 (1.66 fish/hm³) Total = 1,827 (27.09 fish/hm³)

N = 5 N = 4 N = 4

Figure 42. Mean fish density (fish/hm³) in each zone (+/- 1 standard error).

Direction of movement

The distribution of the headings of fish in each sampling zone peaked at the predominant current direction, indicating fish moved primarily with the prevailing current (Figure 43). Due to the small sample size, statistical significance was not tested. The low number of fish detected in March and April free-spinning periods made interpretation of distributions unconstructive. However, in the braked dataset, enough fish were detected to make slight differences in each zone visible. During the flood tide (approach to the device), more fish were swimming in directions other than that of the main current. During the ebb (departure from the device), more fish swam with the current. The greater variation in fish direction during their approach indicates higher variability in behavior, though sample sizes were too low to draw any conclusions associated with avoidance. Additionally, some of this variation may be due to variable current direction, but this cannot be confirmed without current direction data.

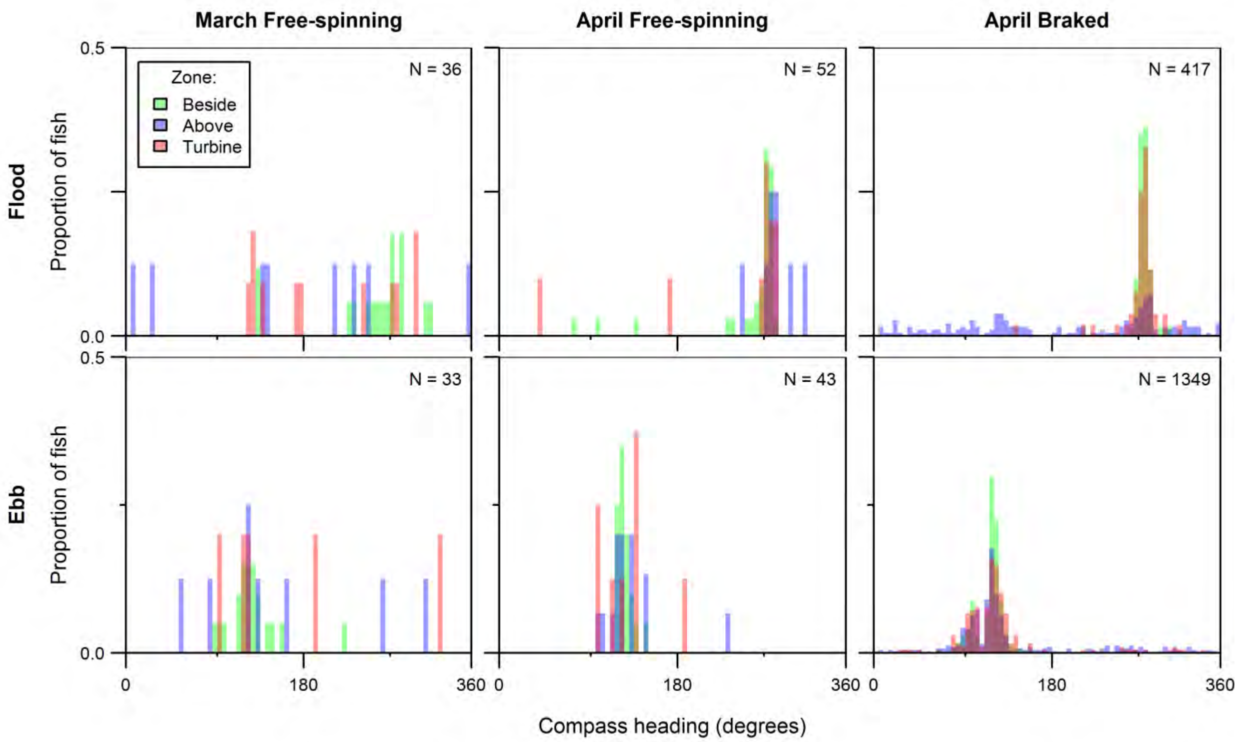


Figure 43. Distribution of fish headings during each dataset (0 = North). Values are scaled to number of fish detected in each zone.

The distribution of inclination angles of fish peaked between -10° and 0°, indicating that most fish were swimming horizontally or slightly downward (Figure 44). Again, the March and April free-spinning datasets did not yield enough fish to draw conclusions. In the braked dataset, variation in inclination angle appeared higher during the flood tide than the ebb tide, as indicated by the wider spread of the distribution. This increased variation could be linked to the fewer numbers of fish detected during the flood tide.

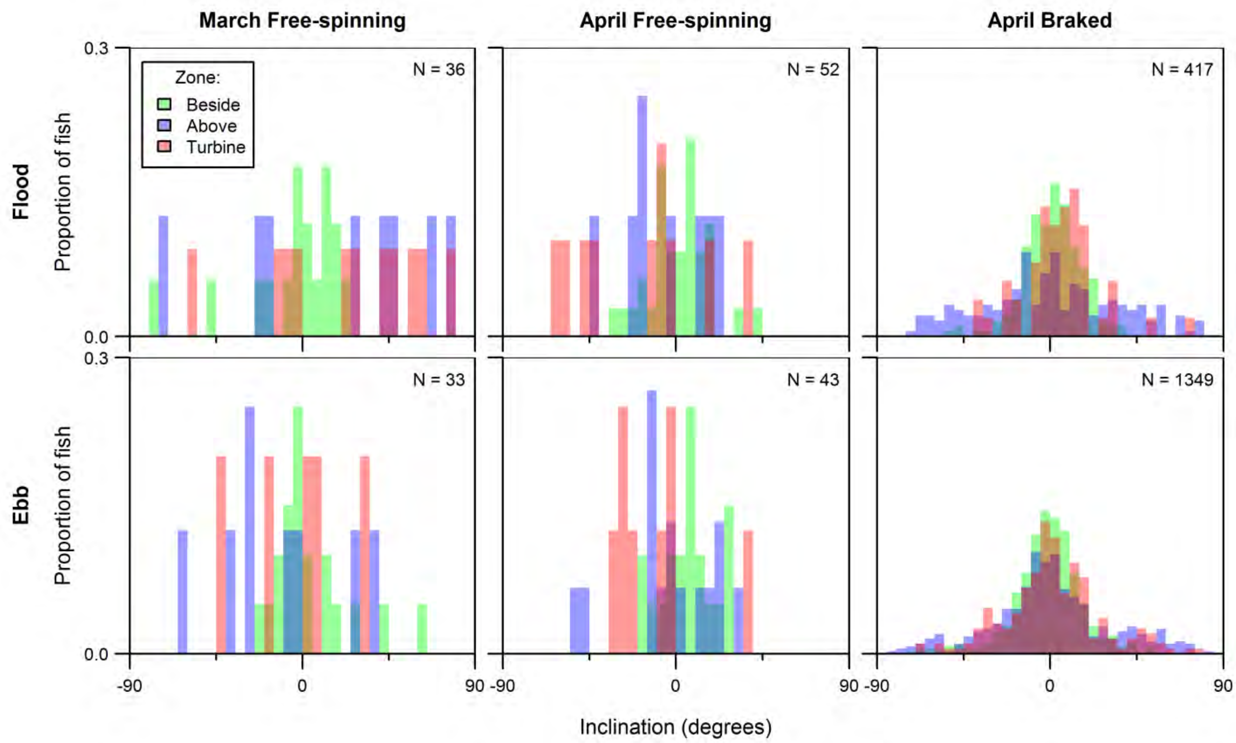


Figure 44. Distribution of fish inclination during each dataset (-90 = down, 0 = horizontal, 90 = up). Values are scaled to number of fish detected in each zone.

5.3 Conclusions and Recommendations

5.3.1 Fisheries Monitoring Plan (down-looking hydroacoustic surveys)

Understanding the interactions between the environment and its biological constituents in tidally dynamic coastal regions is essential for informing tidal power development. Research and monitoring in these areas is limited because of the physical dynamics. Recent interest in tidal power extraction in Cobscook Bay provided the opportunity to develop an approach to assess such areas. The Bay's complicated bathymetry combines with a large tidal range to create high current speeds and flow patterns that vary greatly with location and tide (Brooks 2004, Huijie Xue, unpublished data). Multiple fish species pass through the strong currents of the outer bay to move between deeper ocean habitats and the extensive inshore habitats of the inner bays. Given the extreme variation in currents over time and space and the mixed seasonal and year-round fish community, hydroacoustic measures of relative fish density were expected to vary widely in relation to season and location. UMaine's hydroacoustic assessments demonstrate that while fish density is indeed variable, patterns are repeatable and will be useful in understanding the effects of devices.

Overall Fish Density

1. Inter-annual variability: was fish density constant across years? Differences in overall annual mean S_v with sites combined was discernible. The years 2010 and 2012 had higher fish density than 2011 and 2013. These differences display natural annual variation occurring within the years we have sampled. This highlights the importance of a useful control site in distinguishing changes in density due to turbine deployment from natural variation in fish density over time.

2. Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? Both sites were similar and not statistically significantly different. The similarity between data collected at these two sites to date indicates that the inline site, CB1b, is representative of fish passage on a large lateral scale in the area of deployment. In addition, their similarity allowed us to combine them for analyses. It is important to note that the similarity between the inline and beside sites do not represent similarity of fish behavior in these locations. The beside site had little consistency in geographic location month to month and was often hundreds of meters away from the TidGen® device which could have resulted in similar data collected, not truly reflecting fish distribution beside the turbine. Further data closer to the turbine for the "beside" monitoring is necessary.

3. Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? The utility of the control site becomes apparent when examining the variation between the experimental site CB1 and the control site CB2 within each month sampled. These two sites typically had no significant differences with the exception of CB2 having significantly higher mean S_v in September 2010 and March and August 2012. With only these three exceptions to significant differences, we feel that the utility of the respective sites is valid. The difference in September 2010 could be linked to electrical noise in the hydroacoustic system during that year. The differences in March and August 2012 may be related to construction activities around the TidGen® device: in March, the bottom support frame was being installed, and in August, the turbine was being deployed.

4. Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? Consistent monthly differences were found for all years, with peaks in density in May and June, followed by November. May of 2012 had much higher mean S_v than other years. This peak may have been related to elevated water temperatures, which affect the movements and growth of fish. For example, midwater trawls carried out near CB2 at this time found fully metamorphosed herring, while in other years the same trawls found larval herring or none at all (Vieser, unpublished data). This early growth of herring would have caused a greater increase in mean S_v than normally seen. It is important to be able to distinguish this type of natural variation from turbine effects.

5. Did deployment of the TidGen® affect fish density at the project site (CB1)? The turbine was deployed during the August and September 2012 and March 2013 surveys. Only August 2013 had a significantly lower fish density at the project site than the control site. This may have been related to increased boat traffic and construction activities at the project site as the device was deployed. These activities included deploying and retrieving ADCPs, divers performing observation or maintenance on the device, or deployment and adjustment of the deployment area

marker buoys. At times, there was also a large construction barge over the TidGen® device. A similar difference between densities at the project and control sites was seen in March 2012, which was just after the bottom support frame was installed. This installation included pile driving, divers, a large barge, and high boat traffic at the project site, all of which may have led to fish avoiding the area. Unfortunately, only three surveys were carried out while the turbine was operating. While there was no difference between project and control sites in the September 2012 and March 2013 surveys (carried out post-deployment and during normal turbine operation), this is not enough information to conclude that the turbine had negligible effect on fish density at the site.

Vertical Distribution
The vertical distribution of fish was rarely different among sites. Distributions showed that fish density generally increased toward the sea floor regardless of time of year. This trend of higher density near the bottom could possibly be related to the decrease in current speed in the boundary layer against the sea floor. Fish may be using this area as a refuge from faster current speeds found higher in the water. There are exceptions to this trend of fish density increasing toward the sea floor in May 2011 at CB1, May 2012 at all sites, and June 2013 at CB2, potentially related to the large numbers of larval and juvenile herring utilizing the upper layers of the water column at those times.

5.3.2 Marine Life Interaction Monitoring Plan (side-looking hydroacoustics)

The original goal of this monitoring was to collect data continuously during turbine operation (while generating power). A power-generating turbine has a different hydraulic and acoustic signature than a turbine that is free-spinning or braked. As such, fish response under these conditions may differ and it is important to collect fish response data while the turbine is generating power.

The dataset analyzed is limited to a few days of free-spinning and braked conditions. It is difficult to draw conclusions about fish behavior with so few fish detected during each tide, particularly during free-spinning periods. Down-looking hydroacoustic survey results indicated that fish densities are low in March compared to other months sampled, which is supported by the low numbers detected during the free-spinning periods in March and mid-April. The braked dataset in late April had many more fish than the earlier two datasets, perhaps linked to the springtime peak in density that was apparent in down-looking data. More data should be collected during times of the year when fish abundance is higher (e.g., May and June), which would provide datasets with higher sample sizes and allow quantitative statistical analyses. Higher sample sizes and statistical testing would lead to more constructive conclusions about effects of the TidGen® on fish behavior. This was originally planned, and will hopefully occur once the turbine has been re-deployed.

Available data allowed UMaine to identify some key issues that should be addressed in the future with the goal of collecting data while the turbine is generating power.

Current speed and direction data are necessary for accurate estimation of fish density and for analyses of fish movement through the beam. Without speed information, the volume of water sampled over time may be miscalculated. In their report, UMaine estimated water speeds based on past data. This is unlikely to be accurate, but in this case even a large miscalculation in current speed would not account for the huge increase in fish density between the free-spinning datasets and the braked dataset. Current direction data is necessary for the identification of fish behaviors related to the turbine, as opposed to those related to current. This can be accomplished by adjusting or adding sensors on the TidGen® or more regularly deploying an ADCP near the TidGen®.

The turbine appeared to be masking echoes from smaller fish within its range. This rendered the TS distributions obtained incomplete, and excluded analyses of the behaviors of smaller size classes of fish. This could be solved by orienting the hydroacoustic beam further away from the device or focusing analyses on larger targets.

When more data are collected, more thorough analyses can be carried out. For now, the numbers of fish detected, their estimated densities, and their direction of movement are qualitative at best.

5.3.3 UMaine Remarks

The fish community of Cobscook Bay was also assessed by UMaine (2013 results are included in Appendix D). In the future, results from that study will be used to identify probable species represented by hydroacoustic targets. However, for now, the masking effect of the turbine on fish must be more carefully examined before target strength distributions will be useful.

6.0 HYDRAULIC MONITORING (License Article 409)

The primary goal of the Hydraulic Monitoring Plan was to characterize the hydrological zone of influence, area for the Project. This will be accomplished by: (1) conducting measurements of the pre- and post-deployment flow fields in the deployment area; (2) providing experimental inputs into a large-scale computational circulation model for the estimation of far field impacts; and (3) monitoring for scouring, or sediment transport processes, within the deployment area. The Hydraulic Monitoring Plan will include the data gathered to characterize the hydrological zone of influence of the Project in Cobscook Bay and the effects (if any) of the TidGen® device on flow and sediment transport, in accordance with the requirements of the FERC pilot project license process.

Additional information regarding the monitoring of the benthic community in the deployment area is included in the Benthic and Biofouling Monitoring Plan.

6.1 Methodologies

6.1.1 ADCP Measurements and Hydrodynamics

ORPC has been working with Sandia National Laboratories (SNL) and Sea Engineering, Inc. to apply their SNL-EFDC Model to assess hydrodynamics at the Project site. The study focuses on the development of a hydrodynamic model of Cobscook Bay. Potential changes to the physical environment imposed by operation of a multi-device marine hydrokinetic turbine array were evaluated using the modeling platform SNL-EFDC (James et al., 2011; James et al., 2012; James et al., 2006a; James et al., 2010a; James et al., 2010b; James et al., 2006b). Model results with and without a turbine array were compared to facilitate an understanding of how this small turbine array might alter the Cobscook Bay environment. In fiscal year 2013 SNL completed three quarterly reports for the Project, attached as Appendix E to this report.

In the first quarter report, SNL developed and evaluated three different high-resolution grids to study near-field hydrodynamics important to fish swimming patterns, local sediment transport, and array performance. These grids included a telescoping-mesh grid and two high-resolution, rectangular, refined grids. Model results demonstrated that the rectangular refined grids can simulate local-scale hydrodynamics in the study region in Cobscook Bay, with expected trade-offs between domain size/grid resolution and computational expense.

In the second quarter report, a high-resolution refined-grid rectangular grid centered on the proposed turbine array was created and calibrated against ADCP data collected by ORPC from July 5 through August 5, 2011 (654,267-E, 4,974,792-N labeled as "ADCP measurement" on Figure 1). Turbine devices were incorporated into the calibrated domain to investigate resulting flow-field changes. General sediment dynamics trends were identified, where regions with higher potential for erosion or deposition were noted. Differences in velocity fields with and without turbines were also investigated including the velocity deficits created behind the turbines and commensurate wake recovery.

The third quarter report focused on the development of an optimization framework using SNL-EFDC to optimize device placement to maximize array performance and minimize environmental effects (by minimizing 3 flow alteration magnitudes that could affect fish-swimming and sediment-transport behavior). In the process of developing this methodology, the need for a larger domain was recognized. A new (refined grid) domain was constructed and calibrated that encompassed the entire available MHK placement region (array footprint) and the optimization framework was used to identify an optimal array configuration at this site. Finally, power-production results were compared between ORPC's preliminary array layout, and the SNL-EFDC-optimized placement.

6.1.2 Scour Monitoring

TidGen® foundation piles were marked prior to installation for the purpose of measuring changes to seabed elevation from scour. All ten piles were painted with 6-in. squares as well as foot markers as shown in Figure 45. In 2013 ORPC continued dive operations to measure changes in seabed elevation at each of the pile locations. Divers used video, visual inspection, and customized measuring sticks to record the distance between the seabed and the fixed bottom support frame skirt.

Figure 45. Foundation pile marking scheme for monitoring scour. Foundation pile prior to installation on left. On the right is installed pile #7 indicating the measured reference distance (h) from the bottom support frame skirt to the seabed.

6.2 Results

6.2.1 Hydrodynamic Modeling

SNL developed a framework using SNL-EFDC to optimize the placement of turbine devices to maximize array performance and minimize environmental effects due to flow alterations. The procedure identifies ideal deployment locations to generate the greatest amount of power while also taking into account environmental considerations to avoid potentially adverse effects on sediment dynamics and system ecology. While developing this methodology, the need for a larger domain was recognized. A new domain that contained the entire available turbine placement footprint was constructed and calibrated. Water levels and calibrated flow rates extracted from a previously developed regional-scale model were used to drive flow in the newly created, refined-grid domain. Modeled velocities were in close agreement with ADCP data, suggesting the model accurately predicts system hydrodynamics.

To investigate the potential environmental impacts of the tidal turbines and examine optimum turbine placement, tidal turbines were incorporated into the simulations. General sediment transport trends were identified, where regions with higher potential for erosion or deposition were noted. Differences in velocity fields with and without turbines were also investigated, including a glimpse into velocity deficits created by the turbines and wake recovery. Typically, velocities recovered to 95% of their incident magnitude within 130 m downstream of the devices as shown in Figure 46.

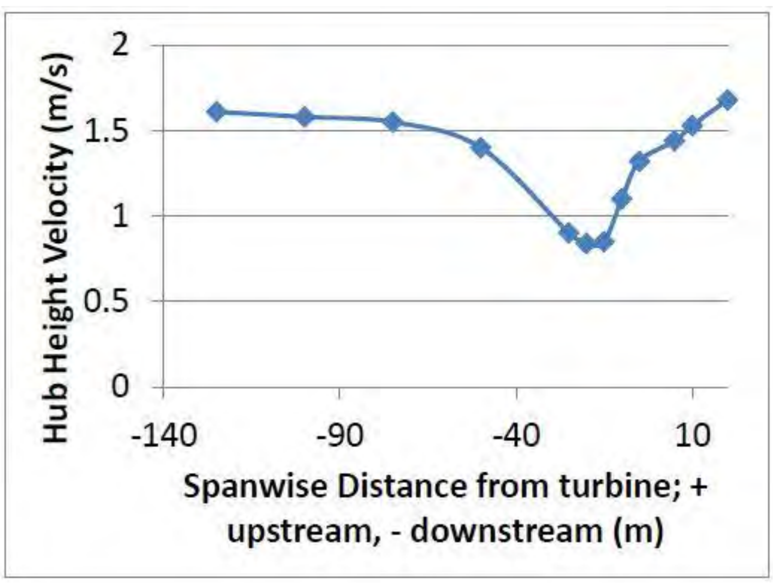


Figure 46. Typical velocity (m/s) profiles upstream (+) and downstream (-) of a tidal turbine

Once the optimization analysis was complete, simulations compared ORPC's preliminary (un-optimized) array configuration to the SNL-EFDC optimized arrangement over the calibration period (July 5 through August 2, 2011). The optimized array configuration produced 125 MW-hr of energy, a 17% increase in power generation over the ORPC-planned array (107 MW-hr).

The optimization analysis examined depth-averaged velocities when assessing hydrodynamic patterns and R%. Depth-averaged velocities were used to facilitate the transfer of data between SNL-EFDC and the post-processing software used to assess velocity fields and R%. However, when conducting the array optimization analyses, power production may be increased and environmental concerns more thoroughly examined by also considering flow in specific model layers; particularly flows at the depth of the turbines. This is because the flow velocity incident to the turbine at hub height is most important to turbine performance. By conducting the analysis based on depth-averaged velocities, the wake behind each turbine is partially obscured. In future optimization studies, the procedure will be modified to specifically consider velocities at the depth where the turbine is deployed.

6.2.2 Scour Measurements

The bottom support frame for the TidGen® Power System was set on the seabed on March 20, 2012. Steel piles were driven into the seabed through the sleeves of the bottom support frame between March 24 and April 4, 2012. Piles are numbered as shown in Figure 47. On March 26, 2012 ORPC's dive contractor conducted a dive inspection of the deployed bottom support frame and recorded distances between the bottom of the frame skirt and the seabed.

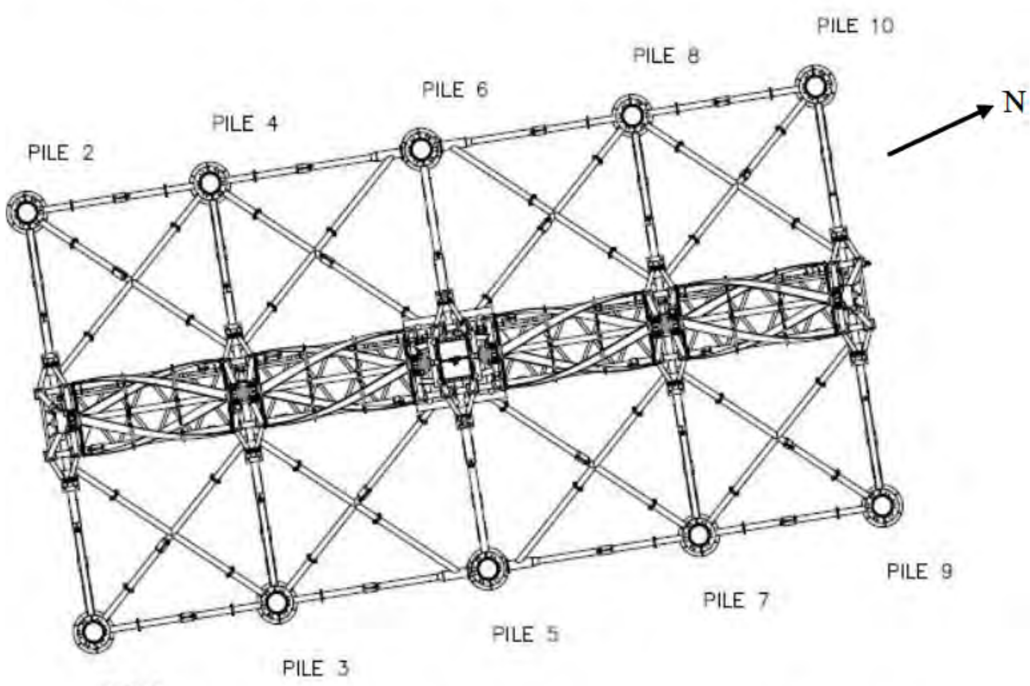


Figure 47. Plan view of TidGen® Power System showing pile numbers

ORPC's dive team continued inspections of the TidGen® Power System between March 2012 and July 2013. Table 6 summarizes change in seabed elevation at the pile locations between March 2012 and July 2013. Due to complexities associated with making measurements underwater, accuracy of measurements is estimated to be no better than 4 in. (Table 11).

Table 11. *Scour Measurements*

Skirt No.	**Distance (inches) of Skirt above Mudline 3/26/2012**	**Distance (inches) of Skirt above Mudline 10/15/2012**	**Distance (inches) of Skirt above Mudline 7/10/2013**	**Approximate Change in Mudline Elevation Since Installation (inches)**
1	2 3/4	0 to 4	7	-4 1/4
2	10	8 to 12	13	-3
3	5 1/2	0 to 4	7	-1 1/2
4	10	6	12	6
5	0	0	4	-4
6	-12	0 to 2	8	-20
7	12 3/4	12	19	-6 1/4
8	9 3/4	0 to 6	13	3
9	20 1/4	15	22	-1 3/4
10	19	-	25	-6

Results of the scour monitoring to date continue to indicate minimal change in seabed elevation around the foundation piles, except at pile 6 where the bottom support frame skirt was embedded upon deployment. There is a slight overall trend of decreased mudline elevation at the pile locations however it is generally within the margin of error (+/- 4 in.).

6.3 Conclusions and Recommendations

Hydrodynamic modeling conducted by Sandia National Laboratories continued to contribute to an understanding of hydraulic effects of the TidGen® Power System. Their work investigated velocity deficits created by the turbines and wake recovery as well as optimization of turbine arrays. Results of the scour monitoring to date continue to indicate minimal change in seabed elevation around the foundation piles.

7.0 MARINE MAMMAL MONITORING (License Article 410)

The primary goal of the Marine Mammal Monitoring Plan is to identify the species, number of animals and their behavior to characterize changes in marine mammal use in and around the deployment area due to the presence of hydrokinetic devices. As a result of knowledge gained during 2012 installation and operation, the concurrence of the Project's AMT, and a license order from FERC, ORPC transitioned from dedicated to incidental marine mammal observations for the Project in 2013.

Incidental observations are performed by trained ORPC personnel for the purpose of conducting multi-season marine mammal observations around the single-device TidGen® Power System after its Phase I deployment. The data gathered will be used to describe marine mammal presence in Cobscook Bay and characterize the effects (if any are detected) of the TidGen® Power System on marine mammals, in accordance with the requirements of the FERC pilot license process.

Additional information on potential direct interactions between marine mammals and the TidGen® Power System will be monitored as outlined in the Fisheries and Marine Life Interaction Monitoring Plans. The effect of noise produced by the installation and operation of the TidGen® Power System on marine mammals is addressed in the Acoustic Monitoring Plan. Separate from these study plans, ORPC worked with SSI under a DOE grant to develop an active acoustic monitoring system—a real-time, automated system capable of tracking the movements of fish and mammals in the vicinity of the TidGen® Power System. The active acoustic monitoring system was successfully tested in Cobscook Bay in June 2013.

7.1 METHODOLOGIES

7.1.1 INCIDENTAL OBSERVATIONS

ORPC conducted visual observations of marine mammals in and around the Project area concurrently with other project-related tasks conducted in 2013. ORPC personnel were trained in accordance with the Marine Mammal Monitoring Plan to identify and record sightings during normal on water activities. In addition, operations staff received detailed training on marine mammal species identification and behavior by Moira Brown, Ph.D., from the New England Aquarium as part of the protected species observer program associated with Phase I pile diving.

Marine mammal species visible from the water's surface were recorded as part of this monitoring effort. Observers scanned by eye and verified species with binoculars, and distance to the sighting with a laser range finder during periods on the water. These skills were developed through training to identify and observe marine mammals while performing other scheduled activities for the Project. If a marine mammal was observed, the observer documented the location where the observation was made, using latitude and longitude or a place name in order to provide perspective of the marine mammal sighting in relation to the TidGen® Power System location, species identification and count, observed behavior (e.g., apparent foraging; floating with tide), weather conditions, and estimated distance from observation point.

7.2 Results – Incidental Observations

Incidental marine mammal sightings in 2013 by ORPC staff do not indicate a change or use of the project area as the project transitioned from pre-deployment to operations. Four marine mammal species were identified in the vicinity of the project; harbor seals, a gray seal, harbor porpoises, and a single minke whale over a total of 89.75 hours. Although ORPC had not recorded minke whale sightings in the project area in the past, local feedback indicates they are known to occur in Cobscook Bay.

It should be noted that the observations recorded in 2013 were opportunistic depending on when ORPC staff were conducting on water activities in the vicinity of the CBTEP. Few observations were made following retrieval of the TidGen® TGU in July 2013.

Table 12 summarizes incidental sightings during 2013 operations and related activities. Completed log sheets are included in Appendix F.

Table 12. *Incidental sightings of marine mammals*

Date	Observation Period (hours)	Number of Observed Harbor Seals	Number of Observed Harbor Porpoises	Number of Observed Gray Seals	Number of Observed Minke Whales
1/22/2013	1.00	0	0	0	0
2/22/2013	1.30	0	0	1	0
2/25/2013	1.00	0	0	0	0
3/4/2013	6.50	0	0	0	0
3/22/2013	2.00	0	0	0	0
3/24/2013	6.00	0	0	0	0
3/25/2013	6.00	0	0	0	0
4/2/2013	6.50	0	0	0	0
4/3/2013	5.50	0	0	0	0
4/3/2013	3.00	0	0	0	0
4/4/2013	3.50	0	0	0	0
4/24/2013	1.50	0	0	0	0
5/21/2013	2.00	1	0	0	0
6/10/2013	2.50	1	0	0	0
6/13/2013	2.25	0	0	0	0
6/18/2013	4.00	3	0	0	0
6/19/2013	4.50	2	0	0	1
6/20/2013	5.75	6	2	0	0
6/20/2013	4.45	6	0	0	0
6/21/2013	5.00	3	0	0	0
7/5/2013	1.50	1	0	0	0
7/11/2013	3.25	1	0	0	0
7/12/2013	2.75	0	0	0	0
8/7/2013	2.75	1	0	0	0
10/4/2013	1.75	0	0	0	0
11/12/2013	2.00	0	0	0	0
12/12/2013	1.50	0	0	0	0
TOTAL	89.75	25	2	1	1

7.3 Conclusions and Recommendations

Marine mammal observations made by trained personnel in 2013, including during periods of operation, maintenance and retrieval did not indicate changes in marine mammal presence or behavior. There is no evidence of marine mammal strike with system components during deployment and retrieval or with TGU foils during operation. In addition, the continued presence of marine mammals in the vicinity of the Project indicates that the TidGen® Power System did not acting as a deterrent or a barrier to passage into the inner portions of the Bay.

8.0 SEA AND SHOREBIRD MONITORING (License Article 412)

The primary goal of the Bird Monitoring Plan was to determine the species, number, and time of peak use of sea and shore birds in the Deployment Area, the onshore landing site where the underwater P&D cables of the TidGen® Power System comes ashore, and the waters immediately off the landing site. Information about the behavior of these birds within these areas was gathered as well. This is accomplished by: (1) conducting multi-season bird observations to characterize the species presence, relative frequency of occurrence, and habitat use in these areas prior to the deployment of a single-device TidGen® Power System (Figure 48); (2) conducting multi-season bird observations in these areas after the Phase I deployment of the single-device TidGen® Power System; and (3) conducting multi-season bird observations in these areas after the Phase II deployment. The Bird Monitoring Plan will use the data gathered to characterize bird presence in Cobscook Bay and the apparent effects (if any) of the TidGen® Power System on sea and shore bird behavior, in accordance with the requirements of the FERC pilot license process.

8.1 METHODOLOGIES

Post-deployment sea and shore bird monitoring was conducted by the Center for Ecological Research (CER) using trained observers familiar with local bird species and behavior. As shown on Figure 48, bird surveys are conducted from Seward Neck within the white lines off North Lubec, Maine. The surveys are separated into the near shore area (A) just offshore from the Landing Site and (B) the Deployment Area for the TidGen® Power System.

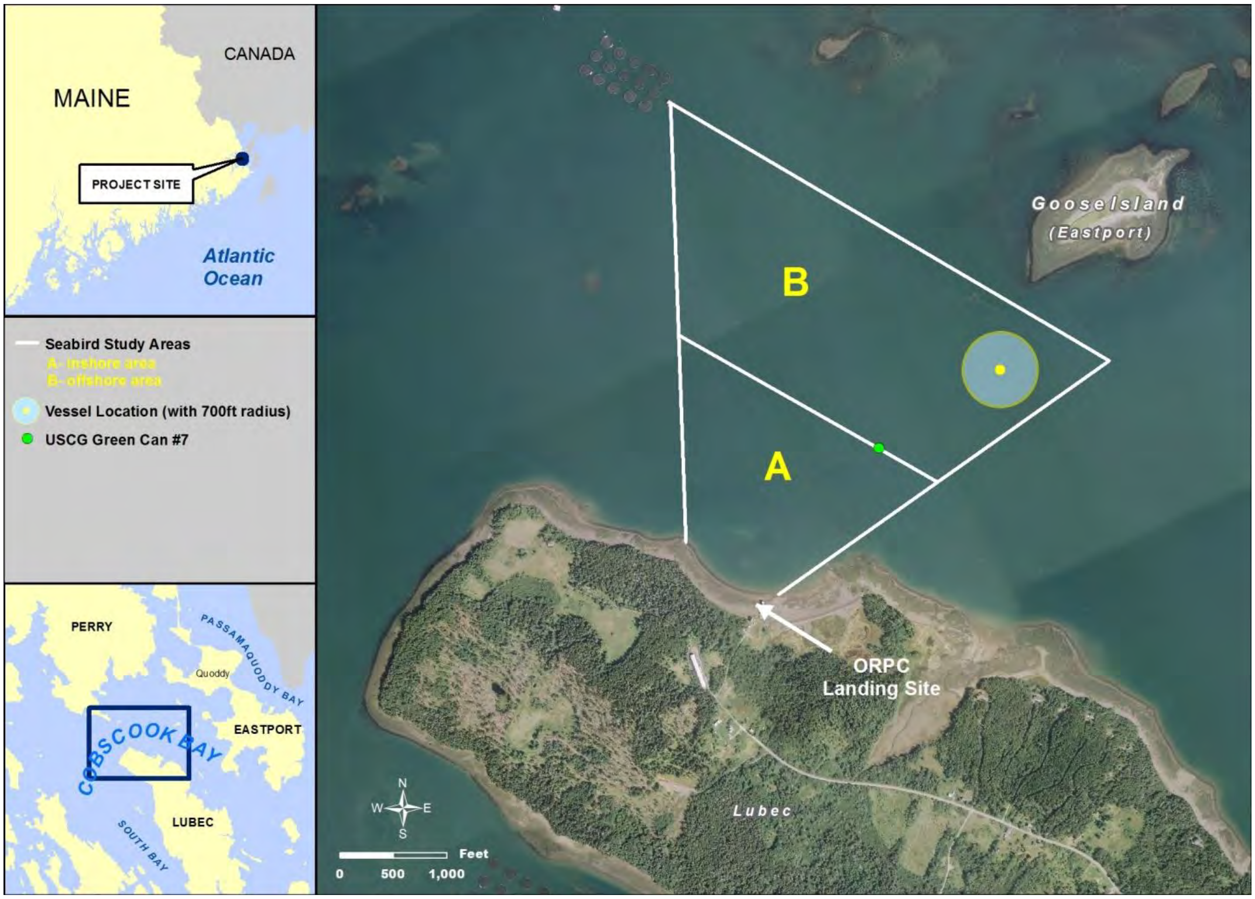


Figure 48. Sea and shore bird study area

Land-based surveys (Holm and Burger 2002) were conducted from the Landing Site in North Lubec. The land-based survey area was delineated by a line extending from the ORPC Landing Site to the east end of Goose Island. The west side of the survey area was defined by a line extending from the Landing Site to a white building located on the salmon farm directly northwest of the Landing Site. The inshore area (A) was marked by a U.S. Coast Guard navigational channel marker (Green Can #7) to the northeast of the Landing Site. The offshore area (B) was delineated by Green Can #7 and a yellow marker west of Goose Island. Observers used 8x or 10x magnification binoculars and 20x to 60x magnification telescopes for bird identification and a continuous scanning technique across the survey area to identify and count all species present. The highest count for each species was recorded for each 15-minute interval (Martin and Bateson 1986).

Special attention was paid to species known to dive to depths of 65 ft or more; these include Long-tailed Duck (*Clangula hyemalis*), King Eider (*Somateria spectabilis*), White-winged Scoter (*Melanitta fusca*), Common Loon (*Gavia immer*), Black Guillemot (*Cepphus grylle*), Razorbill (*Alca torda*), and other alcids. All surveys were conducted during periods of peak bird activity identified in preliminary surveys and last for a period of three hours. Each survey is divided into 15-minute intervals and the maximum number of each species and their behavior is recorded during each interval. All behaviors of birds on the water's surface are registered. Birds are identified as floating (loafing on the surface), diving (active feeding), or swimming. Birds that fly past the survey area but do not land on the water are also counted.

8.2 RESULTS: 2012-2013 WINTER MIGRATING SEASON

CER continued monthly surveys starting in November 2012, for wintering waterfowl and seabirds from the Landing Site at North Lubec. Each survey was conducted for a period of 3 hours. Each survey was divided into 15-minute periods and the maximum number of each species and its behavior (see below) were recorded during each period. For reporting purposes, CER condensed the 15-minute observation periods into hour units by selecting the largest count in each of the four 15-minute periods. They then used the average of these hour counts to determine the number of individuals present for each survey date. Data was presented as the average number of birds seen per month. In the winters of 2010-2011 and 2011-2012, CER sometimes conducted more than one survey per month. If this was the case, they computed and reported the average of these monthly surveys. The February 2013 survey was unable to be conducted due to inclement weather and icy road conditions. A report on the 2012 - 2013 winter migrating period is attached as Appendix G.

<u>Waterfowl and Seabirds</u>

These results are separated into two broad ecological categories based on feeding behaviors. Diving birds, including eiders and other seaducks, loons, grebes, cormorants, and guillemots, differ substantially from surface feeding birds, i.e., dabbling ducks and large gulls.

Diving Birds:

Common Eiders have declined during the three years of this study. There were fewer Common Eiders during the winter of 2012 - 2013 than in the previous two winters. In the first two winters, this species was observed more regularly in the mid-channel area. However, in 2012-2013, Common Eiders were absent in both the mid-channel and the near shore in October and November 2012. During the 2012-2013 field season, the largest count was in the mid-channel in December 2012 (average: 48 individuals) but numbers declined thereafter. The maximum count for 2010-2011 was 33.1 individuals in November and February 2011. In 2011-2012, the maximum eider count in the mid-channel was 77 individuals in March 2012. Common Eiders do not occur in any numbers in the near shore; the only substantial flock was 40 individuals in December 2011.

Long-tailed Ducks remained uncommon in the mid-channel, occurring on two occasions in 2012-2013 (max. 4, Feb 2013); three times in the winter of 2010-2011 (max. of 5.5 individuals, Jan 2011); and four times in 2011-2012 (max. of 10.5 individuals, Feb 2012). This species was seen twice in the near shore of North Lubec in 2012-2013 (4 in Feb 2013; 1 in April 2013); four times in 2010-2011 (max. 5.5 individuals, Jan 2011) and on six occasions in 2011-2012 (max. 3.5 in Feb 2011).

Red-breasted Mergansers continued to occur in small numbers, with a maximum of 3.5 individuals in March 2011, in the near shore and the mid-channel, North Lubec, Maine.

Other ducks were generally uncommon and irregular. CER observed scoters, primarily Surf Scoters, on four occasions in 2010-2011; the only time we noted >3 individuals was January 15, 2011 when we observed an average of 55.5 individuals. Two hundred White-winged Scoters appeared briefly in the mid-channel on January 15, 2011 but remained for less than 15 minutes and never reappeared in large numbers. Scoters were observed on three occasions in 2011-2012; never more than 2 individuals. This species was observed flying west into the upper reaches of Cobscook Bay on several occasions, but the fact that it did not return to the general Deployment Area appears to indicate that this area does not provide optimal feeding habitat for this species. Common Goldeneyes were seen almost exclusively in the near shore at North Lubec. CER did not observe Common Goldeneyes in the winter of 2011-2012. A single Barrow's Goldeneye (*Bucephala islandica*) was seen in near shore on Feb 12, 2011. We observed Hooded Mergansers (*Lophdytes cucullatus*) in the near shore on two occasions and also in mid-channel once.

Common Loons were regular in small numbers in the study area during all three field seasons. Red-throated Loon (*Gavia stellata*) were observed on two occasions in the near shore.

Red-necked Grebes were also regular in small numbers, <5 individuals, in both the near shore area and the mid-channel in Cobscook Bay, Maine. In 2012-2013, this species was only observed in February and March. During the past three winters, single Horned Grebes (*Podiceps auritus*) were seen a total of four occasions in the near shore area and twice in the mid-channel.

Cormorant spp. (Great and Double-crested) were present in small numbers and were slightly more numerous in 2010-2011. Cormorants occurred in very small numbers in the near shore area. Double-crested Cormorants were observed until November, and then departed the area, migrating south. Great Cormorants, the regular wintering cormorant species in Maine, were present from late December to March. A maxima of 3.5 Great Cormorants were counted in January 2011. There were substantially fewer Great Cormorants in the winters of 2011-2012 and 2012-2013.

Black Guillemots were uncommon in winter. CER observed fewer than five individuals per survey in the mid-channel or the near shore during the period between October and April. Razorbills were uncommon and were observed on five occasions; notably, three Razorbills were seen Nov 2010, and 9 individuals were seen January 2012.

Surface Feeding Birds:

Three species of dabbling ducks (Mallard [*Anas platyrhynchos*], American Black Duck, Northern Pintail [*Anas acuta*]) were observed almost exclusively along the shore line in the near shore area of North Lubec, Maine. Dabbling duck numbers increased from January to early March 2011, but diminished thereafter. This increase was likely due to northbound migrants. This trend was not observed in 2012. Three migrant Canada Geese (*Branta canadensis*) were seen once along the near shore, March 2012.

Large gull species were comprised of Great Black-backed Gulls (*Larus marinus*), Herring Gulls (*L. argentatus*), Ring-billed Gulls (*L. delawarensis)*, and Glaucous Gull (*L. hyperboreus*). Large gulls were generally present in small numbers except in the mid-channel in December 2011, when we observed an average of 80 individuals, primarily Ring-billed Gulls and Great Black-backed Gulls. Large gulls were largely absent from Cobscook Bay in the winter of 2012-2013.

During the winter of 2012-2013, a single Bonaparte's Gull (*Chroicocephalus philadelphia*) was observed on a single occasion, in November 2013. In the first field season this species appeared in large numbers for a short period in late November and December 2011. Three hundred individuals were observed feeding in the mid-channel in November 2011 and 500 individuals were feeding in the mid-channel in December 2011. This species was not present on January 2012 and was not seen for the remainder of the winter. CER did not observe Bonaparte's Gulls during the winter of 2011-2012.

Eleven species were uncommon and irregular in the Cobscook Bay, Maine study area in winter. Great Blue Herons (*Ardea herodias*) are common in summer and early fall but depart by early November. The other species were unusual between late October and April.

Diving Behavior

Common Eiders, Red-necked Grebes, and Black Guillemots spent substantially less time feeding in 2012-2013, compared to the previous two winters. During the first two winter seasons, most diving seabirds spent >75% of their time actively feeding but this was only true for Common Loons and cormorants in 2012-2013. Common Eiders were observed loafing 98% of the time which was substantially different from the previous two winters.

Bald Eagle and shoreline:

CER observed a single Bald Eagle in 2012-2013. It was seen flying past the study area on February 27, 2013. This was notably different from the 2011-2012 season when they recorded one to four Bald Eagles on all nine surveys. Bald Eagles were formerly listed as federally and state endangered, but this species was down-listed to threatened and is no longer listed at any level. Dabbling ducks were the primary birds to use the shoreline at this time of year. A single Great Blue Heron was observed on October 23, 2011.

8.3 Conclusions and Recommendations

Wintering Waterfowl and Seabirds:
CER observed a decline in several species of seabirds in the Cobscook Bay study area in 2012-2013, compared to the previous two winters. Common Eider, Red-breasted Merganser, and Cormorant numbers were all lower. There were very few large gulls as well. However, Common Loon, Red-necked Grebe, and Black Guillemot numbers were generally similar during this three year period.

It is unclear whether the observed declines in seabird numbers were related to reduced prey abundance. This seems to be a reasonable possibility but it should be noted that these seabirds feed on different prey. Eiders are bottom feeders, consuming benthic invertebrates, whereas mergansers, cormorants, feed primarily on fish and crustacea. One would expect that loons, grebes, and Black Guillemots, which also feed on fish and crustaceans, but did not decline, would have been present in reduced numbers. This was not the case. C. Bartlett (pers. comm.) reported that there were generally fewer large gulls in the Eastport area in the winter of 2012-2013.

It seems unlikely that the operation of the TidGen® Power System affected seabird numbers because it was not deployed in November 2012, a period when we observed no eiders or Red-breasted Mergansers.

Diving Behavior

Common Loons and Cormorants fed at a similar rate as in the previous two winters but Common Eiders, Red-necked Grebes, and Black Guillemots spent less time diving for prey. Common Eiders were observed diving only 2% of the time while they loafed on the surface for 98% of the time. This species dives for invertebrate prey such as Blue Mussels (*Mytilus edulis*) and other invertebrates. Although CER saw this species regularly in the study area, the limited diving activity in the Deployment Area appears to indicate that this site is not a major feeding ground for this species. It seems unlikely that there will be substantial interaction between these diving birds and the TidGen® Power System.

Endangered and Threatened Species:

CER surveys did not find any federally or state endangered or threatened species. A single Bald Eagle was observed on only one occasion. The fact that this species was largely absent suggests that food resources were not as available as in the previous two winters. This species was removed as a threatened species in 2009.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Operational accomplishments made by ORPC in 2013 enabled the collection of significant performance and environmental monitoring interaction data related to the TidGen® Power System.

The TidGen® TGU was retrieved and redeployed several times during the winter of 2012/2013 for maintenance. After successfully redeploying the TidGen® TGU on February 22, 2013, ORPC successfully ran the system until shut down of the generator on April 21, 2013. The TidGen® Power System operated at approximately 98% availability during this period.

This Environmental Report addresses monitoring that occurred during project activities conducted throughout the year, with notable emphasis on operational periods in the spring of 2013.

9.1 The Role of Adaptive Management

The Project successfully demonstrated the ability to modify license requirements based on the results of science based data collection, the engagement and concurrence of the AMT, and clear communication with FERC. This process has garnered international attention as a model for adaptive management.

ORPC provided the 2012 Environmental Monitoring Report to the AMT in February 2013 with a subsequent meeting held on March 12, 2013. This meeting was an opportunity for ORPC to summarize the early results of the monitoring program and solicit feedback from the AMT, including any recommendations for program modifications. ORPC subsequently met with the AMT on September 10, 2013 to provide updated environmental monitoring and project status information.

Through the adaptive management process, ORPC requested modifications to environmental monitoring to clarify elements of the plan or reduce frequency of monitoring surveys based on increased knowledge of species presence and environmental effects. With concurrence from the AMT, ORPC's license modifications were accepted by FERC. This process demonstrated a clear reduction in effort and cost on the part of ORPC based on the risk reduction demonstrated by environmental monitoring results.

9.2 Environmental Monitoring Results

The 2013 environmental monitoring results continued to build an increased knowledge of marine life interaction with the TidGen® Power System and indicated negligible environmental effects for many elements of the monitoring plans.

Acoustics
Measurements of the in-water noise level related to the TidGen® Power System demonstrate that sound levels in the vicinity did not exceed 120 dB re 1 $\mu Pa^2/Hz$ at any frequency while the turbine is rotating, both while generating and when freewheeling. Further, the integrated rms levels from 20 Hz to 20 kHz do not exceed 120 dB re 1 μPa^2, the level some regulators are using to establish level B harassment of marine mammals.

Benthic and Biofouling
Observations of the exposed cable(s) indicate there continued to be little, if any, evidence of scouring or disturbance to the bottom or the associated faunal community. Results of the post-deployment benthic sampling survey indicated a healthy and highly productive benthic community with no discernible continuing effects from either the installation or operation of the cable. Assessments conducted in July 2013 indicated minor biofouling on the TidGen® TGU with more significant growth on the bottom support frame however neither appear to be compromising the functionality of the system.

Fisheries and Marine Life Interaction
Hydroacoustic assessments conducted by UMaine demonstrate that while fish density is indeed variable, patterns are repeatable and will be useful in understanding the effects of devices. Data collected from the side-looking sonar during operation was minimal and only limited to when the TidGen® device was not generating. However, available data allowed UMaine to identify some key issues that should be addressed in the future with the goal of collecting data while the turbine is generating power.

Hydraulics
Hydrodynamic modeling conducted by Sandia National Laboratories continued to contribute to an understanding of hydraulic effects of the TidGen® Power System. Their work investigated velocity deficits created by the turbines and wake recovery as well as optimization of turbine arrays. Results of the scour monitoring to date continued to indicate minimal change in seabed elevation around the foundation piles.

Marine Mammals
Marine mammal observations made by trained ORPC personnel in 2013, including during periods of operation, maintenance and retrieval did not indicate changes in marine mammal presence or behavior. There was no evidence of marine mammal strike with system components during deployment and retrieval or with TGU foils during operation. In addition, the continued presence of marine mammals in the vicinity of the Project indicated that the TidGen® Power System is not acting as a deterrent or a barrier to passage into the inner portions of the Bay.

Sea and Shorebirds
CER observed a decline in several species of seabirds in the Cobscook Bay study area in 2012-2013; however, they determined it unlikely that the operation of the TidGen® device affected seabird numbers because it was not deployed in November 2012, a period when no eiders or Red-breasted Mergansers were observed.

9.3 Temporary Variance Period

ORPC requested to place environmental monitoring on a hiatus during the technology optimization period during the AMT meeting held in September 2013. ORPC presented the following rationale for the appropriateness of the request:

- Comprehensive pre-deployment environmental studies have contributed to an understanding of inter-annual variability.
- Results-to-date indicated negligible effects to marine life for ongoing operations.
- TGU operational status made adherence to license conditions impractical and did not advance the conditions purpose.
- No undue impacts or impedance of other license requirements are anticipated.
- ORPC plans to return to adherence of conditions once TGU operation recommences.

Following the meeting ORPC submitted the temporary variance request to FERC with the concurrence of the AMT. FERC issued a license order approving the temporary variance request on October 29, 2013.

Despite the temporary variance from environmental monitoring for the Project, ORPC will work with UMaine to conduct fisheries monitoring associated with a test of its floating OCGen® turbine technology in 2014. The OCGen® Module Mooring Project represents a significant advancement in marine hydrokinetic technology and deployment procedures while reducing potential environmental effects (elimination of the bottom support frame). Despite the fact that the mooring project will not be grid connected (and thus not under FERC jurisdiction), ORPC provided the AMT with detailed project information and requested concurrence on the relocation of the testing from off Shackford Head to within the FERC-licensed Project site.

10.0 AGENCY REVIEW AND RESPONSE

ORPC held an Adaptive Management Team meeting on September 10, 2013 at the Maine Department of Environmental Protection's Eastern Maine Regional Office in Bangor. The meeting was well attended both in person and those who joined by conference call. As previously discussed in Section 2.2.1, this meeting was an opportunity for ORPC to present 2013 environmental monitoring results in a collaborative setting with the Team. In addition, ORPC described the rationale for a Temporary Variance Request from FERC related to environmental monitoring. Since little additional environmental monitoring data was collected after the September meeting, ORPC did not feel another meeting during the 2014 regulatory review period was pertinent.

Minutes from the September 10, 2013 Adaptive Management Team Meeting are included in Appendix A of this Report.

10.1 AGENCY COMMENTS AND ORPC RESPONSE

The 30-day agency review period for the draft report ended on February 24, 2014. ORPC provided a reminder notice to the Adaptive Management Team on February 18, 2014 that also included final benthic sampling results for the intertidal zone.

Table 13 summarizes agency comments received and ORPC's response and/or action. In addition to technical comments, ORPC was pleased to receive positive feedback on the Report and the value and benefit of the adaptive management process. ORPC has revised this report to address comments received where necessary. In addition, this Final Report incorporates data from the final benthic sampling report.

Table 13. *Adaptive Management Team Comments on 2012 Environmental Monitoring Report.*

Page No.	Name/Agency	Comment	ORPC Response/Action
5 of 94	David Bean, NOAA NMFS Protected Resources Division	The NOAA NMFS Protected Resources Division representative on the AMT should be David Bean	Change made in Table 1 on Page 5
	Jim Beyer, Maine Department on Environmental Protection	Letter (February 19, 2014) *The Department concurs with the statements in the report that the creation of Adaptive Management Team (AMT) has been a success for this project. The AMT has allowed the applicant and the regulatory agencies to come to consensus regarding changes to the environmental monitoring plan in an effective and efficient manner.*	Comments noted.

Page No.	Name/Agency	Comment	ORPC Response/Action
		The Department recognizes the difficulty ORPC has had with both the operation of the TidGen and the collection of some of the data for the environmental monitoring, specifically, the fish and marine life interaction studies. We look forward to the time when ORPC can overcome these technical challenges and be able to provide meaningful data for these critical studies and produce power. The Department agreed with the AMT when it decided to forego further environmental monitoring while the TidGen was not in the water. The environmental monitoring will commence, as appropriate, once the TidGen is placed back in the water. The Department concurs with the remainder of the report; however we will differ to the experts in their area of expertise to make the final comments.	
	Lt. Megan Drewniak, Sector Northern New England, Waterways Management Division Chief, U.S. Coast Guard	Email comment (February 20, 2014)The *The Coast Guard does not have any comments or additional input at this time.*	Comment noted.
	Linda P. Mercer, Bureau of Marine Science, Maine Department of Marine Resources	Letter (February 21, 2014) *The Maine Department of Marine Resources (DMR) continues to support the adaptive management approach that ORPC has undertaken for the Cobscook Bay Tidal Energy Project monitoring program.* *As you noted, we discussed the 2013 environmental monitoring results during the September 10, 2013 the Adaptive Management Team meeting. The DMR has no additional comments on the environmental and biological monitoring results (Articles 405, 406, 407, and 410)*	Comments noted.

Page No.	Name/Agency	Comment	ORPC Response/Action
		that are presented in the report, or on the MER Benthic Report. *The DMR concurred with Adaptive Management Team on ORPC's decision to forego monitoring while the TidGen is out of the water. We look forward to continued participation on the adaptive management process when monitoring is resumed.*	
	Sean McDermott, NOAA NMFS, Habitat Conservation Division	Email comment (February 24, 2014) *This report documents the process and findings very well. We understand the monitoring will be in hiatus, as described in the report. To that end we do not have recommendations at this time. Please keep us posted as ORPC gets closer to the next deployment phase.* *One comment on the report. The acoustics monitoring subsection Under Environmental Monitoring Results (Section 9.2) identifies data for the test unit in freewheel and generating mode. The results seem to indicate the level of noise generated does not exceed limits known to cause injury. I also recall statements made suggesting the natural background noise at this site is very high. It might be worth noting the ambient level of noise to put the project into context.* *Lastly, we support the continued cooperative arrangement between OPRC Maine and the University of Maine, Orono. The monitoring completed by the University has been tremendously useful in understanding the level of potential impacts associated with the test units. We also look forward to improvements to the fisheries monitoring techniques to gain*	Comments noted.

Page No.	Name/Agency	Comment	ORPC Response/Action
		better understanding of fish-project interaction.	

10.2 Public Dissemination of 2013 Environmental Monitoring Results

In accordance with ORPC's Adaptive Management Plan, the 2013 Environmental Monitoring Report will be made available to the public. In addition to the Report being available on FERC's website, it will also be posted to ORPC's website. Hard copies of the full report will be provided to the municipal offices of the City of Eastport and the Town of Lubec, and ORPC will coordinate further dissemination with community organizations.

ORPC has also developed a brief summary of 2013 environmental monitoring results that can be easily distributed to the local communities and the industry as a whole. This summary will be posted to ORPC's website simultaneously with the 2013 Environmental Monitoring Report. The summary is included as Appendix I to this report.

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Appendix A

Adaptive Management Team Meeting Minutes, March 12, 2013
Adaptive Management Team Meeting Minutes, September 10, 2013

Ocean Renewable Power Company
Cobscook Bay Tidal Energy Project (P-12711)
Adaptive Management Team Meeting Minutes
March 12, 2013

Location: Maine Department of Environmental Protection, Eastern Maine Regional Office

Attendees (in-person):
Nathan Johnson, ORPC
Herb Scribner, ORPC
John Ferland, ORPC
Glen Marquis, ORPC
Jim Beyer, Maine DEP
Jessica Jansujwicz, University of Maine
Gayle Zydlewski, University of Maine
Jeff Murphy, NOAA NMFS
Sean McDermott, NOAA NMFS
Steve Shepard, USF&W
Linda Mercer, Maine DMR

Attendees (by phone):
Michele DesAutels, USCG
Dan Hubbard, USCG
Lt. Megan Drewniak, USCG
Andrea Claros, FERC
Michael Watts, FERC
Whitney Blanchard, DOE
Meghan Massaua, DOE
Courtney Smith, DOE
Graham Daborn, Acadia University

Welcome and Introductions (Glen Marquis)
Glen Marquis of Ocean Renewable Power Company (ORPC) opened the meeting at 10:05 am. He welcomed attendees and conference call participants. Everyone introduced themselves and their affiliations. Glen reviewed the agenda and asked for any input on changes. No changes were made in the agenda and Glen proceeded to review the meeting objectives:

- Review adaptive management's role in Project
- Summarize 2012 activities and lessons learned
- Explain environmental monitoring results
- Discuss recommended modifications and finalize necessary changes
- Provide briefing on overall Maine Tidal Energy Project

Nathan Johnson of ORPC provided an overview of the environmental reporting and review process:

Reporting Task	Proposed Date
Complete annual monitoring	December 31, 2012
Submit Annual Environmental Monitoring Report draft to agencies for review (start 30-day review period)	February 12, 2013
Adaptive Management Team meeting	**March 12, 2013**
End 30-day agency review period	March 15, 2013
Submit Annual Environmental Monitoring Report to FERC	April 1, 2013

ORPC's Adaptive Management Experience (John Ferland)

John Ferland of ORPC said the Adaptive Management Plan experience had been positive for the company. He stated the plan's beginnings were rooted in feedback from the resource agencies who advised ORPC that the company and the agencies should work together on the plan much like they had collaborated on the project's pre- and post-deployment study plans. John indicated that inquiries have come to ORPC from all over the world seeking guidance on how to mirror the Cobscook Bay Tidal Energy Project's (CBTEP's) Adaptive Management Plan process and expressing interest in the environmental findings. He said the work of the Adaptive Management Committee would help create a new generation of environmental literature about marine hydrokinetic projects and that the information will have global impact. John thanked the committee for their interest in continued collaboration and for providing ORPC with good guidance.

2012 Lessons Learned (Herb Scribner)

Herb Scribner described ORPC's lessons learned in 2012 from the CBTEP. He emphasized how important it was to move the project from a planning concept to an actual deployment, and that in terms of data collection, lessons learned and implementing plan adjustments, there was no substitute for actual in-water experience. In order to advance its technology and help increase knowledge about tidal energy projects, ORPC felt it needed to act quickly on resolving any issues and moving forward based on lessons learned. He explained the project's experience with electronics glitches and acoustic interference issues, and noted that ORPC has retrieved and redeployed several times as ORPC resolved operational matters. He emphasized that ORPC viewed its experience as consistent with the purposes of the FERC pilot license. Herb said ORPC has sought to apply lessons learned while remaining consistent with the monitoring methodologies, results and challenges, which are explained in the draft 2012 Environmental Monitoring Report.

2012 Environmental Monitoring Results (Nathan Johnson)

Monitoring methodologies, results and challenges

Nathan Johnson of ORPC explained ORPC's monitoring methodologies and provided an overview of the monitoring results and challenges.

- *Acoustic*
  ORPC implemented acoustic monitoring to determine source levels and isopleths ranges during Phase I pile driving activities in March and April 2013. This was accomplished using the same Drifting Noise Measurement System (DNMS) that was used for pre-deployment surveys and met the requirements of an Incidental Harassment Authorization (IHA) provided by NOAA. ORPC was able to demonstrate that pile driving activities remained within noise thresholds by developing best management practices. This report was presented as a case study during the Adaptive Management Team Workshop held July 24, 2012. ORPC will be conducting Phase 1 operational monitoring in early April 2013. Nate noted the complexity of scheduling within the confines of the FERC license, which is very time and date specific. While the license state's that ORPC would conduct this monitoring within 6 months of initial deployment, ORPC was not operating at that time frame. ORPC hopes to work with FERC to adopt different licensing language that is more in keeping with the realities of operating a first hydrokinetic project.

- *Jim Beyer of the Maine Department of Environmental Protection (MDEP) recommended revising proposed Phase I acoustic monitoring date in Report (page 17 of 81) from "late February or early March 2013" to "early April 2013" based on most recent schedule.*

- *Benthic and Biofouling*

    Nate explained how ORPC installed the transmission and data cable using a shear plow, including stapling (bent rebar) sections of the cable where sufficient penetration was not achieved. He explained the methodology for conducting the benthic survey of the cable. ORPC and the benthic consultant, MER Associates (Chris Heinig) are evaluating improvements to data collection. The as-built location differs from the plan location because of areas of hard bottom and the realities of working with large equipment in deep water. While the two locations are proximate when mapped, divers are challenged in following the exact line of the cable because of the current speed and low light conditions. Nonetheless, results reported by MER indicate minimal benthic disturbance observed from exposed cable and that the use of staples has restricted cable movement. The buried sections of the cable are stationary and not expected to cause impacts. Nate said a second survey was conducted in February and ORPC only recently received the consultant's report. This will be provided as a supplemental report but is not expected to change the original analysis.

    Nate also explained that biofouling had been minimal. The bottom support frame is at a depth that minimizes phototropic activity. Some growth occurred on the generator in the fall of 2012 and was removed by power washing during on-shore maintenance. ORPC will continue to monitor the potential for biofouling, including an experimental test patch of anti-fouling coating applied to the generator. ORPC will also collect samples of marine growth prior to pressure washing in during future TGU removals.

- *Fisheries and Marine Life Interaction*

    Nate introduced Gayle Zydlewski from the University of Maine. Gayle discussed the methods results and challenges of the fisheries and marine life interaction studies. Nate discussed the issues with current meters and acoustic interference with the Simrad and ORPC's plan to modify operations through free-wheeling to collect pertinent interaction data.

- *Jeff Murphy of NOAA/NMFS suggested adding the turbine location (depth in water column) to the University of Maine's relative fish density figure (Slide 19/Figure 20 in Report).*
- *Regarding Slide 21/Figure 23 in Report, target strength distribution. Gayle Z clarified that -50 dB target strength corresponds to herring, alewife, or larger mackerel. Gayle also suggested that decreasing target strength threshold to -50 dB may improve some of the clutter on the far side of the turbine; however returns from smaller fish would be lost.*
- *For Slide 22/Figure 25 in Report, distribution of horizontal direction of fish movement, Steve Shepard of the U.S. Fish and Wildlife Service asked if there were any indications of fish attraction to the device . Gayle Gayle responded that it is too early to conclude. Herb also asked if this figure could be separated by fish size.*

- *Regarding Slide 23. Jeff Murphy inquired if turbine rpm's is the same if free-wheeling vs. generating. (Subsequent conversations with ORPC's Engineering team indicate that rpm's during free-wheeling are approximately 50% higher (60 rpm peak) than when generating (40 rpm peak). However, these numbers do not differ from ORPC's estimated operations rpm of 40 to 60 rpm peak.)*
- *Gayle Z mentioned research proposed in collaboration with Argonne National Laboratory to collect more detailed information on fish distribution around the turbine. This is currently proposed for 2013.*

- *Hydraulic*

  The hydraulic plan is comprised of 2 major components; hydraulics (near and far-field) and sediment transport. Sandia National Laboratories generated a hydraulic model of Cobscook Bay that has contributed to the assessment of far field effects of five TidGen™ devices. For scour monitoring, ORPC has marked the pilings securing the bottom support frame to be able to document changes at the seabed. Results to date indicate minimal change in seabed elevation around the foundation piles, except where the bottom support frame skirt was embedded upon deployment. For current measurements ORPC will deploy Acoustic Doppler Current Profilers (ADCPs) at multiple locations in 2013. In addition, the Northwest National Marine Renewable Energy Center (NNMREC) has proposed conducting wake measurements at the project in September, 2013.

- *Marine Mammals*
  ORPC developed a marine mammal observation program with guidance from Dr. Moira Brown of the New England Aquarium. She prepared and led an observer training program that resulted in more than 20 people, including local community residents and ORPC employees, being trained in marine mammal sightings, identification and recording. ORPC has used dedicated observers during pile driving activities and when the TGU has been deployed and retrieved. Nate referenced the IHA report that is part of the appendix of the draft 2012 Annual Environmental Report. Results to date indicate no changes to marine mammal presence in the area of thee project and no evidence of strike.

- *Sea and Shorebirds*
  The sea and shorebird monitoring program utilizes the services of Peter Vickery of the Center for Ecological Research, Chris Bartlett of the UMaine Sea Grant program and local volunteers. Nate reported that results show that the winter 2011/2012 surveys show the same general number of seabirds as the two previous winters and that preliminary results for 2012/2013 mirror previous results.

Recommended Monitoring Modifications (Nathan Johnson)
ORPC described recommended modifications to monitoring based on results to date and lessons learned. We will be concurrently working with FERC's D2SI office to modify our Inspection and Maintenance Plan. ORPC discussed a Supplemental Information Document that will be provided to the Team (submitted on March 13, 2013) that includes further clarification on recommended license modifications. ORPC's will revise the Recommended License Modification Table in the Final Report to

FERC to include the Supplemental Information Document as well as any feedback from the Adaptive Management Team.

- *Several members of the team asked for more time to review the Supplemental Information Document but an overall extension of the April 1 deadline to FERC did not appear warranted. Comments are anticipated by close of business on Tuesday, March 19, 2013.*
- *Benthic Plan. ORPC indicated that due to the installation schedule, the benthic survey planned for July 2012 (following the first growing season after the deployment of a single TidGen™) is now scheduled for July 2013.*
- *The question of seasonality was raised in relation to the benthic surveys of the cable route. The group felt that quarterly inspections would appropriate to indicate any changes related to seasonality.*
- *Sean McDermott inquired if Michelle Magliocca, NOAA NMFS, was aware of the recommended modifications to marine mammal observations since she was not in attendance. Michelle was included in the distribution of the Draft Report and subsequent conversations occurred after the AMT Meeting to ensure these recommendations were conveyed.*

Maine Tidal Energy Project Update (Glen Marquis)

Glen Marquis provided an overview of the overall Maine Tidal Energy Project, of which the CBTEP is part. The CBTEP will include Phase I and Phase 2 activities and then ORPC will be seeking to expand capacity through licensing of the Western Passage Tidal Energy Project. Glen explained that the Maine Tidal Energy Project was the first tidal project connected to the grid under a FERC pilot license and the first in the country to have a long-term (20-year) power purchase agreement. A growing supply chain has been formed to provide services. He said that this year ORPC will focus on operations and environmental monitoring for the Cobscook Bay Phase 1, and designing engineering improvements, which would be incorporated into Phase 2. The company's projected schedule is to deploy a second but improved TidGen™ TGU in the spring of 2014. For the company's third deployment later that year, ORPC is proposing an OcGen™ TGU. This would represent the next evolution of ORPC's technology development and provide time for the company to properly work with a single unit before deploying stacked devices in Western Passage. ORPC is responding to both investor guidance and input from the national laboratories encouraging ORPC to accelerate its efforts to engineer the OcGen™ and obtain in-water operation experience. This is seen as critical for successful, future commercialization and for also facilitating a successful Western Passage project. ORPC is having on-going consultations about deploying OcGen™ in Cobscook Bay with FERC (regarding potential license modifications) and DOE (regarding DOE funding and program management). ORPC will engage the Adaptive Management Team in further consultation on the OcGen™ in Cobscook Bay when engineering design is more substantial. ORPC anticipates deployment in Western Passage to begin in 2015. ORPC will need an extension to its existing Western Passage preliminary permit for the area and has begun consultation with FERC about this process. Herb Scribner noted that it will be important for ORPC to receive the concurrence of the resource agencies (who also comprise CBTEP's Adaptive Management Team) in support of ORPC's schedule change for Western Passage. ORPC continues to advance its pre-deployment activities in Western Passage, with plans this spring for continued resource assessment, and environmental monitoring related to marine mammals and seabirds.

Reporting and Public Dissemination of Results (Nathan Johnson)
Nate Johnson conveyed that the Final 2012 Environmental Monitoring Report will be made available on ORPC's website. Members of the AMT provided feedback regarding additional and alternative methods of public dissemination.

- *The group discussed ORPC developing a brief summary of 2012 environmental monitoring results for public distribution. In addition, full copies of the Final Report will be made available to the communities of Eastport and Lubec.*
- *Maine DEP and USF&W requested paper copies of the final report.*
- *Meghan Massaua suggested that the Final Report also be available on the Tethys website.*
- *ORPC encouraged members of the Adaptive Management Team to visit the Project site in Eastport and Lubec.*

Action Items and Assignments (Nathan Johnson)

- *ORPC will distribute Supplemental Information Document to the Adaptive Management Team (submitted on March 13, 2013)*
- *ORPC will distribute draft meeting minutes for review*

ORPC – Cobscook Bay Tidal Energy Project
Adaptive Management Team Meeting Minutes
September 10, 2013

Location
Maine Department of Environmental Protection, Eastern Maine Regional Office
4th Floor Conference Room
106 Hogan Road, Bangor, Maine 04401
http://www.maine.gov/dep/contact/emro.html

Attendees (in-person):

Nathan Johnson, ORPC
Herb Scribner, ORPC
John Ferland, ORPC
Glen Marquis, ORPC
Alex Simpson, ORPC
David Bean, NOAA NMFS
Gayle Zydlewski, University of Maine
Haley Viehman, University of Maine
Jessica Jansujwicz, University of Maine
Garrett Staines, University of Maine
Susanne Miller, Maine DEP
Jim Beyer, Maine DEP

Attendees (by phone):

Sean McDermott, NOAA NMFS
Linda Mercer, Maine DMR
Megan Drewniak, US Coast Guard
Jocelyn Brown-Saracino, U.S. Department of Energy
Courtney Smith, U.S. Department of Energy

Welcome and Introductions (Glen Marquis)
Glen Marquis of Ocean Renewable Power Company (ORPC) opened the meeting at 10:10am. He welcomed attendees and conference call participants. Everyone introduced themselves and their affiliations. Glen reviewed the agenda and asked for input on any changes. No changes were made in the agenda, and Glen proceeded to review the meeting objectives:

- Provide project update
- Explain environmental monitoring results to date
- Discuss temporary variance request
- Describe Prototype OCGen® Module Mooring project
- Address next steps and priorities

Project Update (Nathan Johnson and John Ferland)
Current status of the Cobscook Bay Tidal Energy Project's (CBTEP) including technology upgrade phase, relevance of environmental monitoring results, adaptive management process and FERC pilot license.

Nate discussed ORPC's current technology upgrade phase. The ORPC engineering team is conducting a thorough inspection of the TidGen® power system and Lubec On-Shore Station. ORPC is identifying, documenting and implementing system design improvements during this operational down-time. The U.S. Department of Energy recently notified ORPC that two technology improvement projects have been awarded for funding, which will significantly contribute to the advancement of our technology.

2013 Environmental Monitoring Results (Nathan Johnson and Alex Simpson)
Nathan Johnson and Alex Simpson of ORPC explained ORPC's monitoring methodologies and provided monitoring results and challenges for each component of the 6-step monitoring plan.

- *Acoustic*
  ORPC conducted acoustic monitoring around the TidGen® turbine generator unit (TGU) under varying tidal flow and generator operating conditions on April 2 and 3, 2013. The instrumentation used for this survey was the same Drifting Noise Measurement System (DNMS) used for pre-deployment surveys and Phase I pile driving activities in March and April 2013. A total of 34 data collection runs were made under varying tidal and operating conditions. ORPC was able to demonstrate that sound levels in the vicinity of the turbine during operation do not exceed 120 dB re 1 µPa2/Hz at any frequency while the turbine is rotating. Additionally, integrated rms levels from 20 Hz to 20 kHz do not exceed 120 dB re 1 µPa2/Hz, which is the level some regulators are using to establish level B harassment of marine mammals. Nate noted that ORPC hopes to correlate results from this acoustic study to accelerometer data recorded on the TGU to make connections between turbine-induced vibration and sound emitted into the surroundings. ORPC hypothesizes that as the speed of the turbines increases, the sound and vibrations produced by the generator will also increase. If validated, recordings from the accelerometer will allow for a dynamic real-time monitoring system of ambient noise field impact. Nate concluded by saying the noise generated by the TidGen® Power System is unlikely to have a negative effect on marine life.

- *Benthic and Biofouling*
  ORPC and benthic consultant MER Associates (Chris Heinig) conducted surveys of the cable route in February and June 2013. Nate showed two videos from the dive footage from June. The first video clip showed a stretch of cable representative of the sections of exposed cable. Nate noted that the cable is stationary, there is no scouring around the cable, and that there is some growth on the cable. Plants can be seen growing on either side of the cable, indicating it is not moving on the seafloor. The second video showed an instance where the diver and drop camera intersected. The diver briefly pointed his camera at the drop camera, which was an interesting snapshot of the two studies side-by-side. ORPC is still assessing whether footage from the drop cameras is comparable to footage collected by divers. Nate also explained the Phase 1 benthic sampling procedure, conducted on August 7 and 8, 2013, which replicated the approximate locations of the July 2011 sampling stations. Although the final report will be distributed by MER Associates in fall 2013, preliminary results indicate negligible effects.

  Nate introduced Alex Simpson of ORPC, who discussed the two-part biofouling assessment of the TGU and Bottom Support Frame. The assessment of the TGU was performed on the day of its retrieval. Methodology for this included recording % coverage of each major component of the TGU, thorough photo documentation, preserving of samples in formalin, and scraping off small sections of fouling to observe the integrity of the surface underneath. The species present were: filamentous algae, red seaweed (a.k.a. mermaid's hair), barnacles, blue mussels, and tubularian hydroids. Alex noted four locations with considerable growth: the generator, anodes, turbine foils which had been stationary for a portion of the deployment, and regions of complex geometry such as the mounting brackets. Overall, the TGU showed very minimal fouling. Alex also addressed the anti-fouling paint that was applied in February 2013. Paint was applied in 5 sections of a grid on the generator, with varying levels of sanding to test its efficacy in preventing growth. This test is inconclusive in regards to the effectiveness of the paint because it was applied in-field to dry paint, instead of to tacky paint as the supplier suggests.

The second part of the biofouling assessment was conducted for the BSF using footage from the diving scour assessment. In addition to the species on the TGU, Alex noted the appearance of urchins, anemones, larger barnacles, and considerably more blue mussels. Overall, the BSF has more fouling than the TGU, but the fouling does not appear to be affecting the integrity of the structure. Some anodes have dense mussel growth, while others are very clean. The reasoning behind the different levels of growth is inconclusive.

- Herb Scribner asked whether or not the barnacle growth on the anodes affects their ability to provide cathodic protection. At this point, indications are that the anodes are performing correctly, as small cavities are forming on the surface from the loss of electrons, despite the appearance of barnacles.
- Gayle asked about the procedure for wiping off the Simrad transducer heads, which ORPC will perform in a future dive. Nate responded that this process has conducted as part of routine dive inspections.

- *Fisheries and Marine Life Interaction*
  Nate introduced Dr. Gayle Zydlewski from the University of Maine's School of Marine Sciences (UMaine). Gayle discussed the results to-date of UMaine's fisheries and marine life interaction monitoring. The goal of the fisheries monitoring is to examine the relative density and vertical distribution of fish at the project site and at a control site, and to quantify changes in fish presence, density and vertical distribution associated with the installation of the TidGen™ Power System. Gayle discussed that the control site is very important for the study because of the interannual variability of the region. She said that the approach for this research has been accepted for publication. Gayle summarized that there is some evidence showing effects on fish density due to construction activities. After deployment, the vertical distributions at the project site were more even. There have not been enough sampling periods when the device was operational to draw conclusions about effects of the device on fish.

  Gayle also addressed the interaction of marine life with the turbine. Data sets for this are from March with a free-wheeling turbine, April with a free-wheeling turbine and April with a braked turbine. While it looks like more fish were present during April with the braked turbine, the number of fish present is not related to the turbine status because of the larger population of fish at the end of April. The notion arises that the turbine masks fish from the data-gathering instrumentation. There is the potential to filter out the smaller fish to limit the masking effects. In summary, there were not enough fish present during free-wheeling periods to compare behaviors statistically. Additionally, the fish direction of movement is more variable in the area above the turbine. Gayle suggests that the data needs further peer review.

  UMaine has been granted new DOE funding for their research. This funding will last for 2 years, starting January 1, 2014. Plans for the study are:
    - March, May, June, Aug/Sep down looking acoustics
    - Trawling for species apportionment
    - dB differencing – a technique for separating herring and mackerel (for use in old and new data)
    - Side-looking acoustics for monitoring temporal variation

- Integration of datasets for determining probability of encounter

- *Hydraulic Scour Monitoring*
  Nate discussed the results of the scour survey, conducted using video footage collected by divers in July 2013. The distance between the skirt at the base of each pile and the seafloor was measured using a ruler. Results from the survey indicate minimal changes to the seafloor. The largest change in mud line elevation since installation was recorded at 20 inches for Pile 6, which was embedded in softer sediment upon deployment.

- *Marine Mammals*
  Nate discussed the marine mammal observation results. ORPC has continued the incidental observations during all on site operations. Harbor seal and minke whale sightings have been documented in the project vicinity. Nate concluded that there is no evidence that the turbine is acting as a deterrent to marine mammals.

  Although not part of the FERC license requirements, ORPC partnered with Peter Stein of Scientific Solutions Inc (SSI) in the testing of an Active Acoustic Monitoring (AAM) system in June 2013. The system is a 6 node, 90-120 kHz version of Swimmer Detection Sonar Network (SDSN), and would provide 500m sonar detection and tracking of marine mammals. The results of the AAM testing were positive. A whale size target was towed off the stern of the ORPC's Tide Tracker research vessel in Cobscook Bay. SSI successfully tracked this target in real-time from a computer at the Lubec On-Shore station. During the testing, there were several seal sightings within the range of AAM detection, and one sighting of a Minke whale outside of the range of the AAM. This indicates the AAM is not a deterrent. The seal sightings have not yet been paired with detection data collected from the AAM system.

  - As an example of other methodologies being used in marine mammal detection, David Bean provided ORPC with a copy of a recent journal article related to a thermographic detection system for marine mammal detection.

- *Sea and Shorebirds*
  A team led by Peter D. Vickery, Ph.D. continued to conduct surveys of sea and shorebirds from the ORPC landing site in Lubec during the 2012-2013 winter migratory season. The survey results show that diving behavior during TidGen TGU operation was consistent with the previous two winter seasons. No observations of federally or state endangered or threatened species have been made in or near the site. The survey did indicate a reduced number in several seabird species in 2012-2013, but Dr. Vickery attributed this to reduced prey. In conclusion, ORPC's installation and maintenance activities resulted in negligible effects on seabirds in the winter season.

After presenting all environmental monitoring results, Nate introduced the global significance of these results to date. ORPC has provided validation of environmental monitoring methodologiesand the success of the adaptive management process. The adaptive management process has had many achievements, and attracts international interest among industry, regulators and the environmental community. Additionally, the environmental monitoring results have provided scientifically-based and data-driven demonstration that allows for the retirement of risk. Many of these key components are transferrable to other tidal energy, and other ocean energy projects.

- Sean McDermott discussed the fisheries data, and asked when decisions can be made from the results. Gayle suggested that another device is needed in the water. More interaction data is needed to draw conclusions.
- David Bean asked about the configuration of the TidGen TGU and the new OCGen mooring project. Will they be in line? Nate responded by saying, in short, no they will not be in line, but more information on device configuration will be in upcoming slides.
- Jim Beyer asked if a solution has been found to the interference between data and power cables to the Simrad. Nate responded by saying ORPC has looked at multiple solutions with vendor and other expert input, but each one presents complexities and the company continues to work on the issue.
- Gayle mentioned that collaborative research funded through the Argonne National Labs may be helpful once the device is back in the water to further understand marine life avoidance behavior.

Temporary Variance Request (Nathan Johnson)

ORPC will explain the temporary variance request to place environmental monitoring on hiatus during the extended maintenance and technology upgrade period.

Nate introduced the request to place environmental monitoring on a hiatus during the extended maintenance and technology upgrade period. Temporary variance requests have been granted by FERC for traditional hydropower projects in the past. FERC has requested concurrence from the Adaptive Management Team. Nate summarized the reasons that ORPC's request for a temporary variance is appropriate:

- Comprehensive pre-deployment environmental studies have contributed to an understanding of inter-annual variability
- Results-to-date indicate negligible effects to marine life for ongoing operations
- TGU operational status makes adherence to license conditions impractical and will not advance the conditions purpose
- No undue impacts or impedance of other license requirements are anticipated.
- ORPC plans to return to adherence of conditions once TGU operation recommences

Nate described the process for requesting the temporary variance. ORPC submitted a memo to the AMT on August 21, 2013, explaining the request and seeking their concurrence. NOAA NMFS, Maine DMR and the USCG (and subsequently MaineDEP) have concurred with the request. ORPC requests additional concurrence or questions by September 13, 2013, and the temporary variance request will be submitted to FERC by September 20, 2013.

- Jim Beyer will verify consistency with the Maine General Permit (Complete)
- David Bean asked whether the benthic survey will be continued.
    - Nate responded that due to the negligible effects observed to date, we do not intend to conduct additional benthic surveys during the variance period.
- David Bean asked if UMaine will continue to collect data from the control site for inter-annual variability.
    - Nate and Gayle responded that it is intended to collect additional fisheries data (both hydroacoustic and netting) under a new DOE award.
- Gayle asked what the process is for re-starting the monitoring once the turbine goes back in the water.
    - Nate responded that ORPC will notify all team members prior to re-initiating operation.

- Herb mentioned that FERC typically requests anticipated schedules as part of the temporary variance process.
- Herb recommended that UMaine under the new DOE award be mentioned in the variance request. In addition, ORPC intends to continue incidental observations for marine mammals while present in the Project vicinity.
- UPDATE: The temporary variance request, with concurrence from the AMT, was submitted to FERC on September 19, 2013.

Prototype OCGen® Mooring Project (Nathan Johnson)
ORPC proposes to re-locate the DOE-funded Prototype OCGen® Mooring Project from off Shackford Head to the CBTEP site. We will discuss the details of this project and seek concurrence from the team on the proposed change in location.
Nate provided a timeline of the OCGen Mooring Project:

- The project was awarded by DOE in 2009. OCGen® represents a significant advancement in technology and deployment procedures while reducing environmental effects.
- U.S. Army Corps of Engineers Section 10 permit for Shackford Head expired in 2012
- ORPC recommends moving the project to CBTEP to:
    - Occupy less area in the Bay
    - Eliminate seasonal restrictions for commercial fishing activities.
- DOE's NEPA office requested concurrence from FERC and the AMT
    - ORPC will submit a request to the AMT, incorporating questions and/or comments from this meeting and seeking concurrence.

Nate explained that the test will be short in duration, lasting only several months. Nate presented a draft of the project plans for the OCGen. This test will use the beta foils (previously used by ORPC in 2010), and a no generator (there will be no power transmission connection to shore as no power will be produced). The plans use concrete clump anchors. The TGU will have a 45 degree maximum swing radius in both directions of tidal forcing. Nate discussed the project summary:

Criteria	Detail
Project timeframe	Summer 2014 (~3 months)
Prototype dimensions	51.1 ft long, 10.6 ft wide, 14.2 ft high
Turbine diameter	8.1 ft
Depth in water column	37 ft below MLLW, 28.8 ft above seafloor
Estimated RPM	0 to 84
Mooring system	(4) Stud link chain
Anchor type	(4) Concrete clump weight anchors
Environmental monitoring	UMaine hydroacoustic surveys from surface vessel, scour monitoring

- Nate and Gayle briefly discussed methodologies for collecting hydroacoustic data from a surface vessel.
- Jim Beyer suggested the potential need for scour monitoring around the clump weight anchors.
    - Nate indicated that a similar methodology for measuring scour to that conducted for the bottom support frame piles will be performed.

Related ORPC Activities and Opportunities (Glen Marquis)

In addition to addressing TidGen® and OCGen® priorities, ORPC will advance development of the RivGen™ Power System, and provide development and technical services to other marine renewable energy projects.

ORPC discussed the status and plans for priority project over the next 6 to 12 months, including the TidGen ® technology upgrade, the RivGen® Commercialization Project, the Western Passage Tidal Energy Project and a request for a successive permit, and the growing interest in ORPC providing services for other ocean energy projects.

- ORPC explained that we are not leading the permitting effort for the RivGen® project in Igiugig Alaska. However, we are communicating lessons learned, environmental monitoring results, and the adaptive management process to those involved in Igiugig. In addition, the Igiugig project offers the potential to gain significant knowledge of device interaction due to the abundance of salmon (and other species), the clear water and shallow environment.
- ORPC discussed the process of requesting a successive permit for the Western Passage Tidal Energy Project from FERC. In particular, the support of the Cobscook Bay adaptive management team, many of whom are also involved with Western Passage, would be extremely beneficial to this request. ORPC will generate a template letter that explains the request, including demonstrated progress, for use by AMT members as they feel is appropriate.

Action Items and Assignments (Nathan Johnson)

- ORPC will generate meeting minutes and distribute for review
- AMT concurrence and/or questions on the temporary variance are requested by September 13, 2013
- ORPC will distribute a memo to the AMT seeking concurrence on the Prototype OCGen Mooring Project's location within the CBTEP
- ORPC will continue to review and analyze 2013 environmental monitoring results for incorporation into the annual report

Adjourn Meeting (Glen Marquis)

Appendix B

Phase I Acoustic Monitoring Report, July 22, 2013

Nathan E. Johnson
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July 22, 2013

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Subject: **Cobscook Bay Tidal Energy Project (P-12711-005)**
Phase I Acoustic Monitoring Report

Dear Ms. Bose:

ORPC Maine, LLC (ORPC) is pleased to submit this Phase I Acoustic Monitoring Report for the Cobscook Bay Tidal Energy Project (P-12711-005). This report presents the results of acoustic monitoring conducted around ORPC's TidGen® turbine generator unit (TGU) under varying tidal flow and generator operating conditions in April 2013 and its affect on marine life. Scientific Solution Inc.'s report, TidGen® Acoustic Monitoring Report, is included as Attachment A. This report has been reviewed by the NOAA Office of Protected Resources who had no comments on its results or conclusions.

License Article 405 – Acoustic Monitoring Plan
ORPC and its acoustic consultant, Scientific Solutions, Inc. (SSI), conducted acoustic monitoring in April 2013 in accordance with the Project's Acoustic Monitoring Plan, adopted as License Article 405 in the FERC license order. With concurrence from the Project's Adaptive Management Team in March 2013, ORPC requested that the license article be modified to allow for Phase I monitoring to occur within six months of operation. In a letter dated May 8, 2013, FERC approved of the following modification to acoustic monitoring schedule for Phase I of the CBTEP:

> The Acoustic Monitoring Plan requires ORPC, in part, to perform monitoring around the single turbine generating unit (TGU) within six months or deployment. Due to turbine operational status and weather conditions, ORPC was unable to conduct measurements within six months of deployment. ORPC requested that the plan be revised to indicate that measurement be conducted within six months of TGU operation.

Drifting Noise Measurement System (DNMS)
The DNMS and measurement methodologies are detailed in the Project's Acoustic Monitoring Plan. The DNMS was developed to overcome the significant issues of making accurate ambient and radiated noise measurements in high currents. The data acquisition system (Figure 1) is comprised of a pair of hydrophones, a custom two-channel variable gain low noise amplifier and LGR-5327 Data Logger. The hydrophones are attached to the spar buoy to acquire the waterborne acoustic sound pressures and gather noise data while being isolated from vertical motion and decoupled from the high velocity currents. The lengths of the hydrophone cables are adjustable; the appropriate length will be determined during testing. An anchor will hang approximately two meters below the lowest sensor to prevent the hydrophones from getting hooked on the ocean floor if the spar buoy would drift into shallow water. The anchor would also

provide drag along the ocean floor in shallow areas until the system could be recovered. A list of general specifications for DNMS is presented in the Project's Acoustic Monitoring Plan. A recent upgrade to the system switched to Reson hydrophones Model TC4013 and a 394A40 pistonphone calibrator for more accurate and traceable measurements.

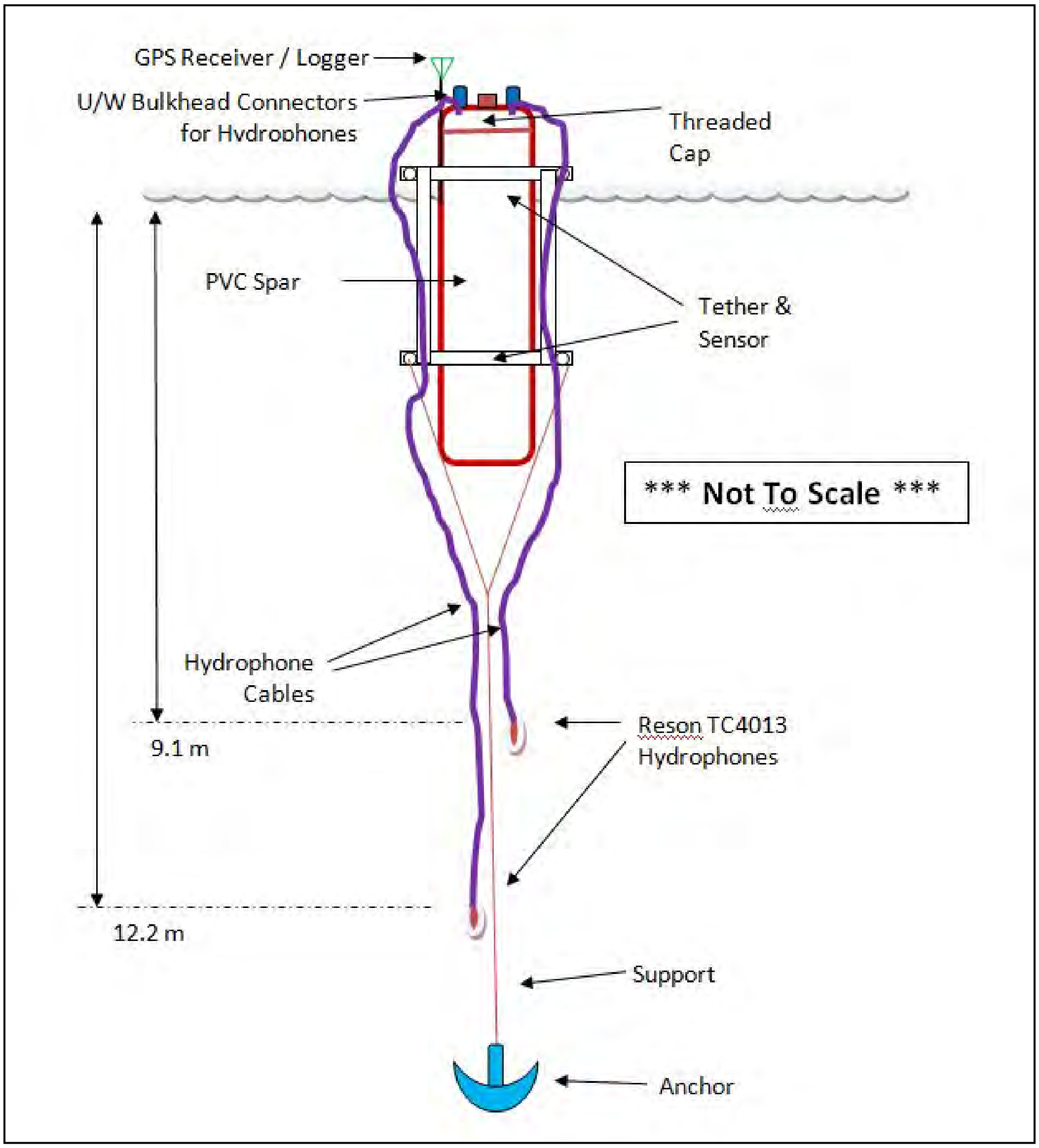

Figure 1. Drifting noise measurement system.

Measurements were collected at the Cobscook Bay Tidal Energy Project site on April 2 and 3 under varying but relatively rough sea states, tidal flows, and turbine generator conditions. Sustained winds of approximately 15 knots generated wave heights of 2 to 3 ft. The DNMS was deployed from ORPC's 40 ft research vessel, the *Tide Tracker*, and allowed to draft untethered to collect acoustic measurements (Figure 2). During slack water periods the DNMS was deployed in the direct vicinity of the TidGen®

TGU (within 100 meters). For periods of ebb or flood tidal flows the DNMS was deployed several hundred meters upcurrent, allowed to pass as close as possible to the TidGen® TGU, and then retrieved several hundred meters downcurrent. During deployments the *Tide Tracker's* engine was shut off. In addition, ORPC staff was in direct communication with operators at the Lubec On–shore Station to record generator output and turbine RPMs. ORPC staff also modified operations to record acoustic measurements while the turbine was "freewheeling," i.e., spinning but not generating power. Turbine RPMs during freewheeling are approximately 50% higher than when generating. An ORPC log sheet used during the measurements is included as Attachment B. A total of 34 deployments of the DNMS were made at the Cobscook Bay Tidal Energy Project site.

Figure 2. DNMS during deployment at the Cobscook Bay Tidal Energy Project site, April 2, 2013

<u>Results</u>

Measurements of the in-water noise level related to the TidGen® Power System demonstrate that sound levels in the vicinity do not exceed 120 dB re 1 $\mu Pa^2/Hz$ at any frequency while the turbine is rotating, both while generating and freewheeling. An observable increase in sound level was primarily visible at approximately 105 Hz with a harmonic at 210 Hz, as well as 2.8 kHz and occurred anytime the turbine was rotating. A higher frequency tone near 5 kHz and associated harmonics were only present when the turbine was actively generating, but were at sound spectral levels well below the lower frequency sources. Further, the integrated rms levels from 20 Hz to 20 kHz do not exceed 120 dB re 1 μPa^2, the level some regulators are using to establish level B harassment of marine mammals. This frequency range is that suggested as the appropriate range for this measurement by a panel of experts at the recent workshop on Instrumentation for Monitoring Around Marine Renewable Energy Devices held in Seattle, Washington on June 25-26, 2013.

Sound peaks near 105 Hz, 210 Hz, and 2.8 kHz appear to scale with turbine RPM values and are generally louder when the turbine is freewheeling as compared to when it is generating at the same RPM. Sound levels did not vary with range for the same rotation speed at distances ranging from 20 m to 300 m. This fact, coupled with the observation that the sound is present anytime the turbine rotates, independent of electrical generation, indicates the source is likely the sound radiation from the structure itself. Given the source, SSI determined that it is not appropriate to scale the measured data by some form of geometric spreading factor. The higher frequencies that only occur when the turbine is generating appear to scale slightly with turbine rotation as well.

Potential Effects

Resource agencies and stakeholders have indicated concern regarding underwater noise and vibration produced by the TidGen® Power System and the potential effects on marine species as many marine species use sound in communication, navigation, predator/prey interactions, and hazard avoidance. These organisms have biological receptors that are sensitive to Sound Pressure Level (SPL), particle velocity, and the frequency of sound. Hastings and Popper (2005) conducted a review of sound effects on fish, primarily related to pile driving. Results of these studies indicate that fish do not experience adverse effects from received sound levels less than about 160 dB re 1μPa, though at higher levels, fish may exhibit avoidance, stress, temporary and permanent hearing loss, auditory and non-auditory tissue damage, egg damage, reduced growth rates, or mortality (Hastings and Popper, 2005). Many of the existing studies did not evaluate different behavioral responses by marine species to variable sound frequencies.

Data compiled by Hastings and Popper (2005) indicated the hearing threshold for Atlantic salmon was between 85 and 130 dB, at frequencies between 30 and 300 Hz. Some additional studies suggest they may also detect sound below 35 Hz (Knudsen et al. 1992, 1994, as cited in Hastings and Popper, 2005). However, detection of a sound does not necessarily equate to an effect. Information on behavioral responses of received sound levels and frequencies are generally limited for these species.

Marine mammals rely on sound for many aspects of their lives, including reproduction, feeding, predator and hazard avoidance, communication, and navigation (Weilgart, 2007). There is considerable variation among marine mammals in both absolute hearing range and sensitivity. Their composite range is from ultrasonic (frequencies greater than 20 kHz) to infrasonic (frequencies less than 20 Hz). Direct hearing measurements, for the most part, are not available for cetacean species, but it is generally believed that a whale's hearing range is related to the range of sound it produces (LGL Ecological Research Associates and JASCO Research, 2005). Pinniped hearing in general has been measured for air and water. In water, hearing ranges from 1 to 180 kHz with peak sensitivity around 32 kHz. In air, hearing capabilities are greatly reduced to 1 to 22 kHz. This range is comparable to human hearing (0.02 to 20 kHz). Harbor porpoise, harbor seals, and gray seals may be affected project produced noise (USACE, 2008).

Behavioral responses of marine mammals to sound vary greatly and depend on a number of factors. An individual's hearing sensitivity, tolerance to noise, exposure to the same noise in the past, behavior at the time of exposure, age, sex, and group composition all affect how it may respond. Sometimes it is difficult to know whether observed changes in behavior are due to sound or to other causes. Not all changes in behavior are cause for concern. Observations suggest that marine mammals tend over time to become less sensitive to those types of noise and disturbance to which they are repeatedly exposed (Richardson et al., 1995).

NMFS has identified the following noise levels as thresholds for marine mammal harassment:

> Current NMFS practice regarding exposure of marine mammals to high level sounds is that cetaceans and pinnipeds exposed to impulsive sounds of 180 and 190 dB rms or above, respectively, are considered to have been taken by Level A (i.e., injurious) harassment. Behavioral harassment (Level B - has the potential to disturb a marine mammal) is considered to have occurred when marine mammals are exposed to sounds at or above 160dB rms for impulse sounds (e.g., impact pile driving) and 120dB rms for continuous noise (e.g., vibratory pile driving), but below injurious thresholds. These levels are considered precautionary. (NOAA, 2008)

Scientific Solution Inc.'s TidGen® Acoustic Monitoring Report was third party reviewed by Dr. Brandon Southall at the request of ORPC to assure that a marine mammal scientist reached the same conclusion that ORPC minimized the potential risk of adverse environmental affects due to noise from its development project.

Dr. Southall's review determined the spectrum levels recorded in a variety of conditions indicate adverse effects to marine mammal to be unlikely. The measurements of ambient and different operational conditions clearly indicate the presence of associated sounds of varying characteristics in the region of hearing for at least some of the marine life known to occur in the vicinity of the project site (more so for seals and fish than any cetaceans). Protected species in the vicinity of the TidGen® TGU may hear and could potentially be affected by the device. However, the potential for behavioral responses is likely to be extremely limited and these levels would almost certainly not trip any thresholds for potential level B harassment. In addition, the sound levels recorded would not cause hearing loss or injury in terms of acoustics for any species at any range.

<u>Accelerometer Correlation</u>

Accelerometers are located on the TidGen® Power System to measure turbine-induced vibrational accelerations. ORPC hypothesized that as the speed of the turbines increased, the sound and vibrations produced by the generator will also increase. Knowing the DNMS positional change and loading conditions of the TidGen® Power System from the accelerometers, the data can be analyzed to reflect how sounds produced by the TidGen® Power System correlate to increases in the surrounding noise field. This will allow for a dynamic real time monitoring system of ambient noise field impact as related to TidGen® Power System operations.

ORPC operators located at the Lubec On-shore Station coordinated with crew on the *Tide Tracker* taking the DNMS measurements on April 2 and 3 for the purpose of correlating acoustic results to accelerometer recordings. To get maximum bandwidth from accelerometers, ORPC recorded only one channel at a time. We are most interested in the two accelerometers (four channels) attached to the generator and so those channels were the focus. Attachment C summarizes accelerometer locations/orientations recorded during the DNMS measurements and lists correlated tests.

ORPC is currently in the process of validating the recorded accelerometer information and will continue to generate correlations to monitor the TidGen® Power System operation.

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If you have any questions regarding this submission, please contact me by telephone at 207/221-6254 or by email, njohnson@orpc.co.

Sincerely,

Nathan E. Johnson
Director of Environmental Affairs

Cc: Adaptive Management Team

Attachment A: TidGen® Acoustic Report, Scientific Solution, Inc., July 12, 2013

TIDGEN® ACOUSTIC MONITORING RESULTS

July 12, 2013

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CONTENTS

EXECUTIVE SUMMARY **3**

1.0 INTRODUCTION **4**

1.1 PROJECT BACKGROUND 4

2.0 ACOUSTIC MONITORING OBJECTIVES **4**

3.0 RESULTS **5**

3.1 COBSCOOK BAY 5

3.1.1 Ambient *6*

3.1.2 Free-Wheeling *8*

3.1.3 Generating *11*

3.2 WESTERN PASSAGE 14

3.2.1 Ambient *15*

3.3 BROADBAND NOISE LEVELS 16

4.0 SUMMARY OF FINDINGS **16**

4.1 COBSCOOK BAY 16

4.2 WESTERN PASSAGE 16

5.0 APPENDIX A **18**

5.1 SAMPLE RAW DATA 18

EXECUTIVE SUMMARY

Measurements of the in-water noise level related to the TidGen® Power System demonstrate that sound levels in the vicinity do not exceed 120 dB re 1 μPa^2/Hz at any frequency while the turbine is rotating, both while generating and when freewheeling. An observable increase in sound level was primarily visible at approximately 105 Hz with a harmonic at 210 Hz, as well as 2.8 kHz and occurred anytime the turbine was rotating. A higher frequency tone near 5 kHz and associated harmonics were only present when the turbine was actively generating, but were at sound spectral levels well below the lower frequency sources. Further, the integrated rms levels from 20 Hz to 20 kHz do not exceed 120 dB re 1 μPa^2, the level some regulators are using to establish level B harassment of marine mammals. This frequency range is that suggested as the appropriate range for this measurement by a panel of experts at the recent workshop on Instrumentation for Monitoring Around Marine Renewable Energy Devices held in Seattle, Washington on June 25-26, 2013.

Sound peaks near 105 Hz, 210 Hz, and 2.8 kHz appear to scale with turbine RPM values and are generally louder when the turbine is freewheeling as compared to when it is generating at the same RPM. Sound levels did not vary with range for the same rotation speed at distances ranging from 20 m to 300 m. This fact, coupled with the observation that the sound is present anytime the turbine rotates, independent of electrical generation, indicates the source is likely the sound radiation from the structure itself. Given the source, SSI determined that it is not appropriate to scale the measured data by some form of geometric spreading factor. The higher frequencies that only occur when the turbine is generating appear to scale slightly with turbine rotation as well.

1.0 Introduction

1.1 Project Background

ORPC Maine, LLC, a wholly-owned subsidiary of Ocean Renewable Power Company, LLC (collectively, ORPC), received a pilot project license for the Cobscook Bay Tidal Energy Project (Project) from the Federal Energy Regulatory Commission (FERC) on February 27, 2012 (FERC Project No. P-12711). The Project will evaluate the potential for a new source of clean, renewable energy generation using tidal energy resources in Cobscook Bay, Maine.

2.0 Acoustic Monitoring Objectives

A complete description of the acoustic monitoring plan, objectives, and techniques can be found in ORPC's document Study Plan 1: Acoustic Monitoring Plan, Final Pilot License Application, Cobscook Bay Tidal Energy Project, FERC Project No. 12711. The system described in that document is shown in Figure 1and has had one upgrade to use Reson Model TC4013 hydrophones and a calibrated 394A40 pistonphone for more accurate and traceable measurements.

This document reports the first set of sound level measurements to characterize the noise radiated by the deployed TidGen® Power System in Cobscook Bay. It also includes ambient measurements from the anticipated Western Passage deployment region to facilitate future comparison post-deployment of any system in that area.

Table 1: Data collection summary. Multiple trials were performed at each date/location specified.

Date	Location	Tide	Weather	Sea State	Turbine
04/02/13	Cobscook	Low, coming in	Sun, windy	1 to >3 feet	Generating and free-wheeling
04/03/13	Cobscook	Going out	Cloudy, windy	1 to 3 feet	Generating and free-wheeling
04/03/13	Western Passage	Going out, low, coming in	Windy	1 to >3 feet	N/A
04/04/13	Western Passage	Going out	Sun, Windy	0 to 2 feet	N/A

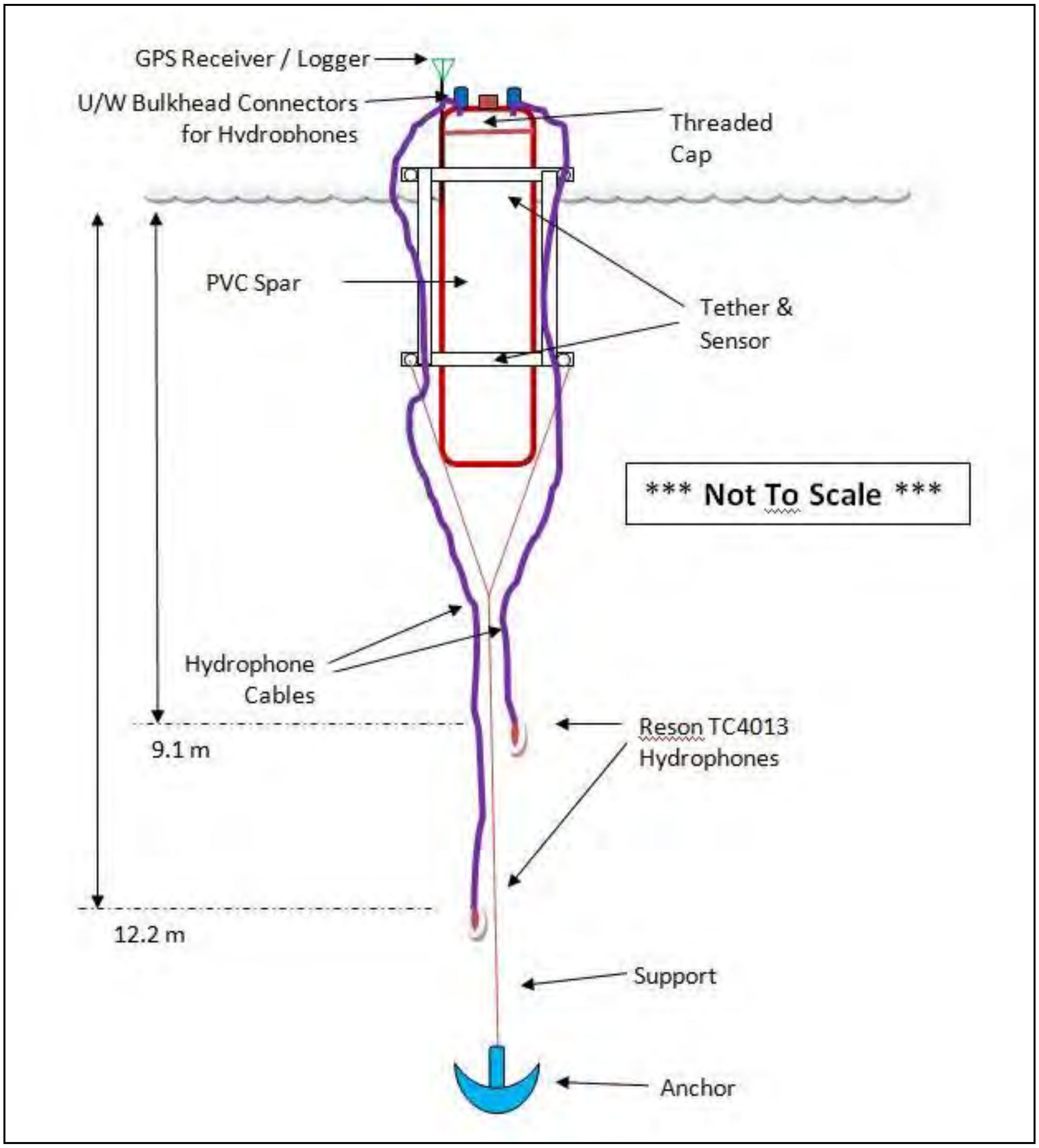

Figure 1: Drifting noise measurement system

3.0 RESULTS

3.1 COBSCOOK BAY

Figure 2 shows the GPS track and associated range information for a sample drifting noise measurement from Cobscook Bay. The blue circle with white X in the top plot marks the location of TidGen® Power System. The green circle indicates the approximate location where the measurement system was released and the red square indicates where it was retrieved. The bottom plot shows the range from the TidGen® as a function of time, and the value for the closest point of approach (CPA).

The Drifting Noise Measurement System (DNMS) hydrophone measurements can be affected by surface roughness conditions. Very rapid changes in hydrophone depth due to surface action (on the order of 1 – 3 feet depending on sea state) create broadband impulses in the hydrophone data due to hydrostatic pressure change. During the measurement period sea conditions were generally rough, thus much of the data included highly impulsive broadband interference. To accommodate measurements in these sea state conditions, the processing window to calculate sound levels was chosen based on when there is a "clean" window of opportunity in the data where the motion was minimal, and no broadband impulses were present, rather than what is necessarily the closest point of approach. This is labor intensive and somewhat limits our ability to compare the results at different operating conditions. Future measurements should aim to include a larger quantity of data in calmer sea states if possible.

For a large structure, such as the TidGen®Power System, any measurements within a few hundred meters of the structure can be in the near-field of the radiated noise. All measurements in this range are suitable for characterizing the radiated structural noise, such as that from the turbine rotation, but it is not generally appropriate to compensate for range from the structure to predict the noise levels close to the structure. For sound levels that are not clearly associated with the structure radiated noise (*i.e.,* high frequency tones that are only seen when the turbine is generating, not when it is simply rotating), it is possible that the source of these tones is closer to a point source depending on their origin. As a result the levels associated with these tones could be adjusted by the approximate measurement range from the generator, whether the measurement window is from the CPA or another location.

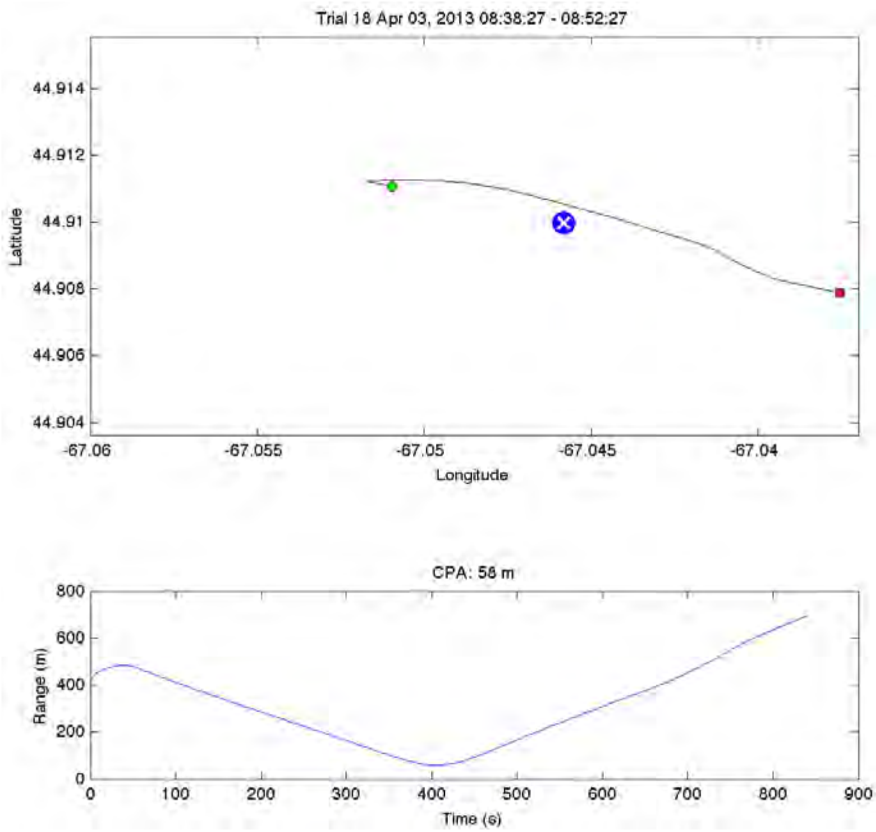

Figure 2: GPS track and associated range information for a sample drifting noise measurement from Cobscook Bay. The blue circle with white X in the top plot marks the location of TidGen® Power System. The green circle indicates the approximate location where the measurement system was released and the red square indicates where it was retrieved. The bottom plot shows the range from the TidGen® as a function of time, and the value for the closest point of approach (CPA).

3.1.1 AMBIENT

Figure 3 and Figure 4 are power spectral density (PSD) plots for ambient data (the turbine not rotating or generating) in Cobscook Bay at various locations around the turbine. Flow speeds during these periods were less than 0.7 m/s. The first plot shows raw PSD data at five locations from the first three trials. The second plot shows the maximum, minimum, and mean values for the PSD at each frequency. The data in the second plot has also been smoothed to better highlight the core features in the spectra. Smoothing results in slightly lower values than are seen in the raw data. Values reported as maximum levels in this report are taken from the raw, unsmoothed data.

Based on the minimum curve in Figure 4, ambient levels are relatively flat to declining as function of frequency, outside of occasional transients that occasionally generate peaks seen in the raw data and maximum values. The exception is a strong tone at approximately 24 kHz that is present in all data (Cobscook Bay, Western Passage, and calibration data taken with the measurement system out of the water on the vessel). This tone is not present during calibrations in the lab, is much stronger in water than on the vessel (but still present), and is present at similar levels in Cobscook Bay and Western Passage. This indicates it is certainly unrelated to the TidGen® Power System and is most likely vessel-related.

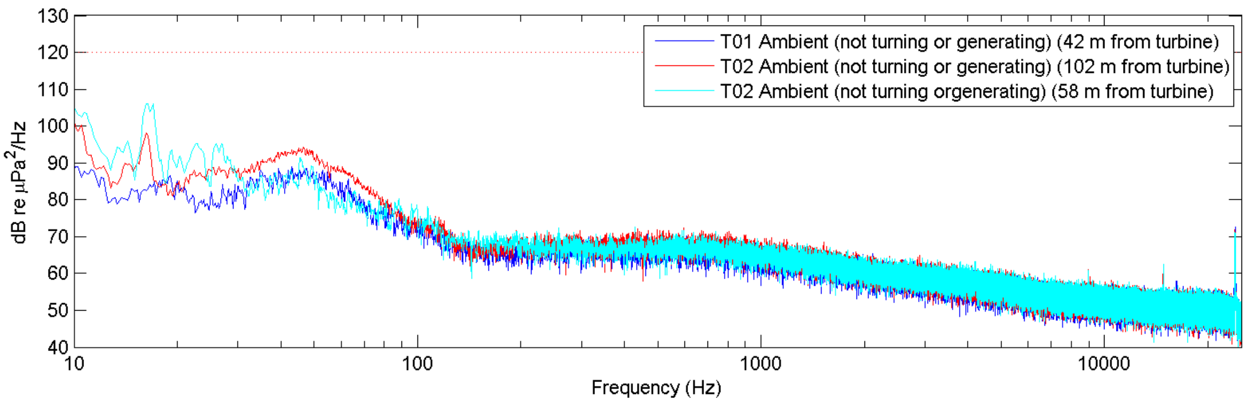

Figure 3: Power spectral density for ambient data (the turbine not rotating or generating) in Cobscook Bay at various locations around the turbine.

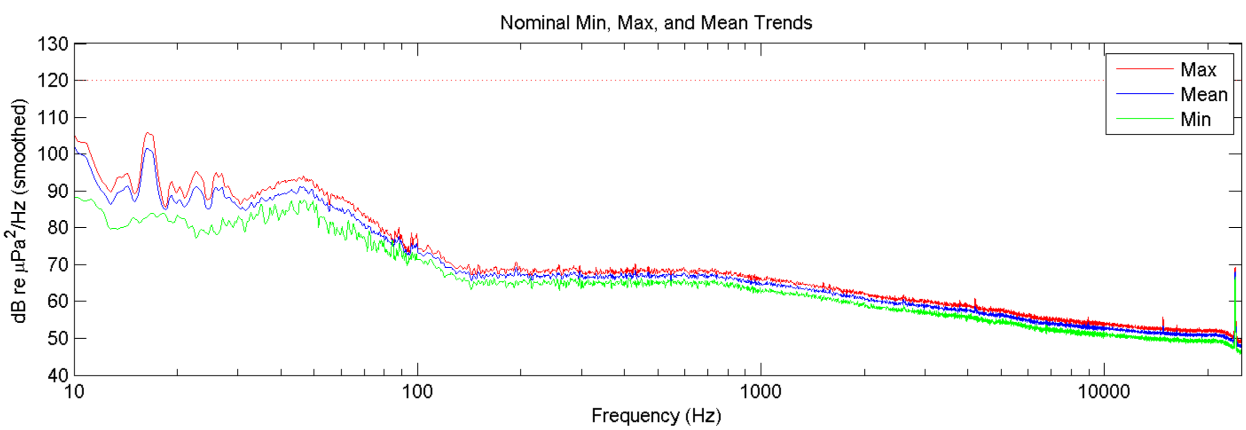

Figure 4: Nominal minimum, maximum, and mean power spectral density for ambient noise in Cobscook Bay. The data has been smoothed to highlight the features of the data, which leads to values 1-3 dB lower than actual values. Smoothing is for presentation in this figure only; values used in reporting levels are true levels without smoothing. The relatively high tone at 24 kHz is a measurement system artifact and not ambient noise..

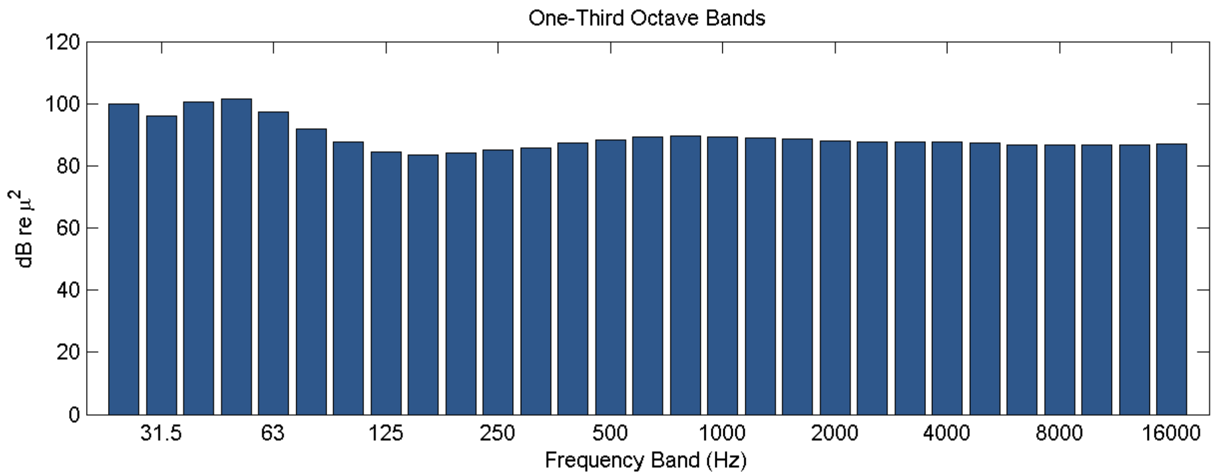

Figure 5: One-third octave spectrum data for Cobscook Bay ambient measurements (maximum level in each frequency bin for the trials in Figure 3).

3.1.2 FREE-WHEELING

The rotating turbine, when not generating, yields very little increase from ambient noise levels outside of three discrete frequency regions. These increases occur at approximately 105 Hz, at a related harmonic around 210 Hz, and at 2.8 kHz. There is also some increase between 105 Hz and 210 Hz, however it is less consistent and is generally weaker than both of those regions.

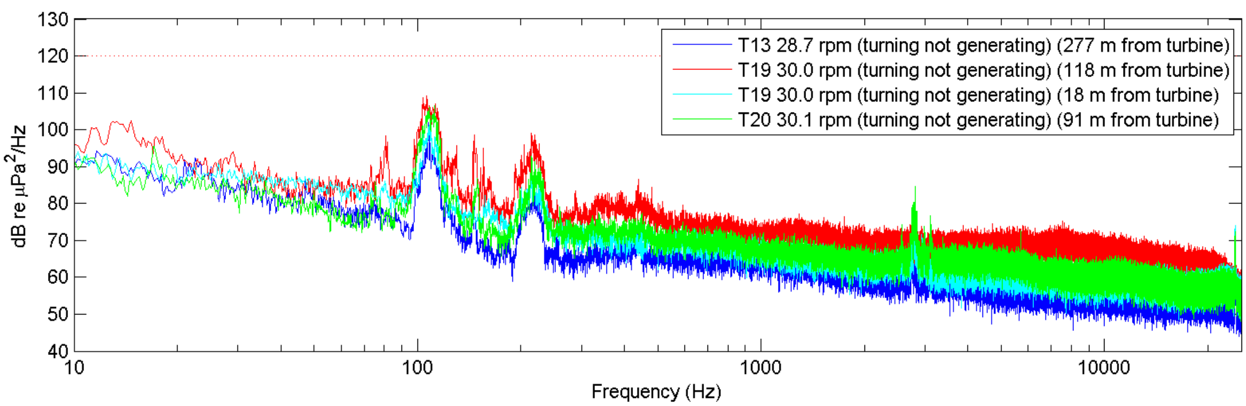

Figure 6: Power spectral density for the free-wheeling turbine (not generating) at various ranges from the turbine.

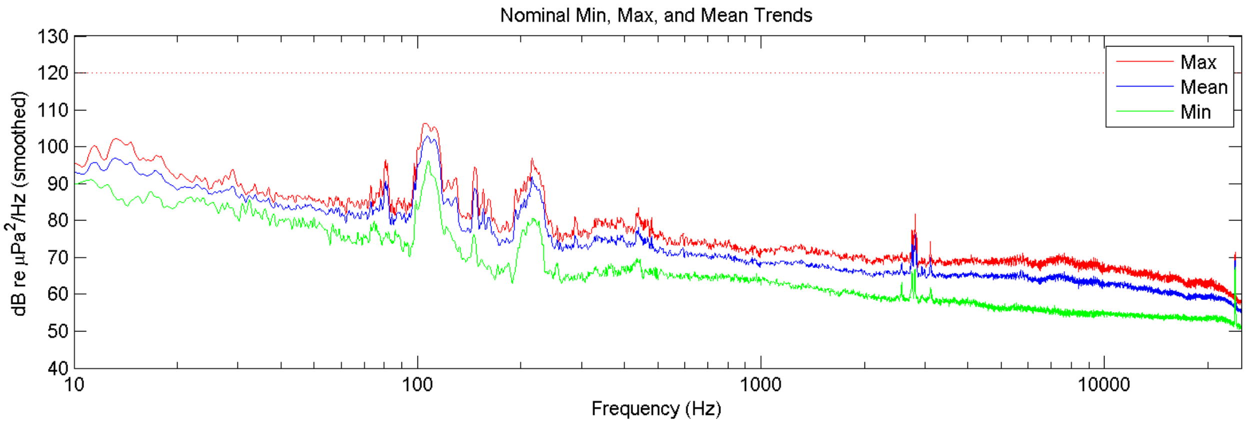

Figure 7: Nominal minimum, maximum, and mean power spectral density when the turbine is free-wheeling. The data has been smoothed to highlight the features of the data, which leads to values 1-3 dB lower than actual values. Smoothing is for presentation in this figure only; values used in reporting levels are true levels without smoothing.

The increase at approximately 2.8 kHz appears as four to five closely-spaced peaks as shown in Figure 8. The strongest and most consistent response includes two to three peaks around 2.8 kHz followed by an additional weaker peak on each side approximately 300 Hz apart.

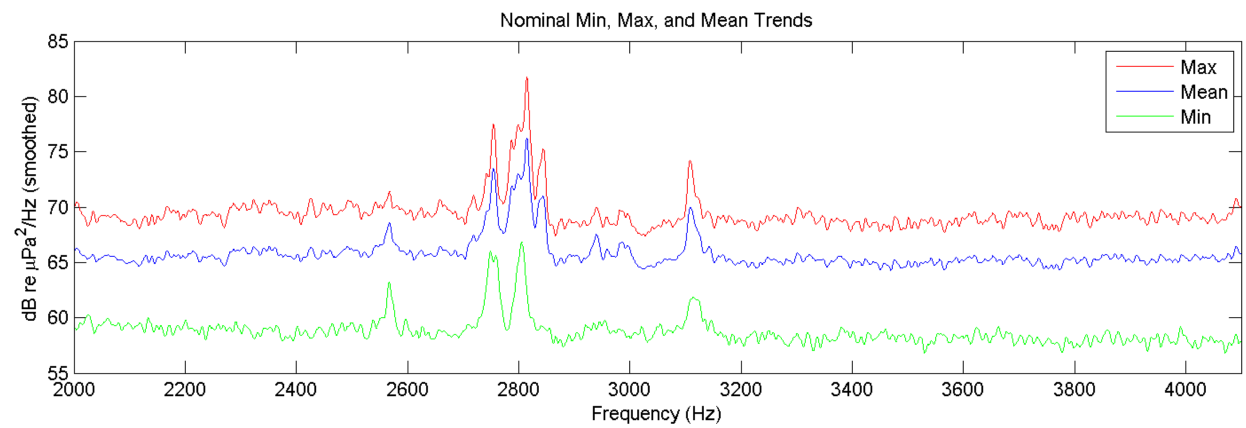

Figure 8: Narrowband view of the data from Figure 7 around the 2.8 kHz noise source.

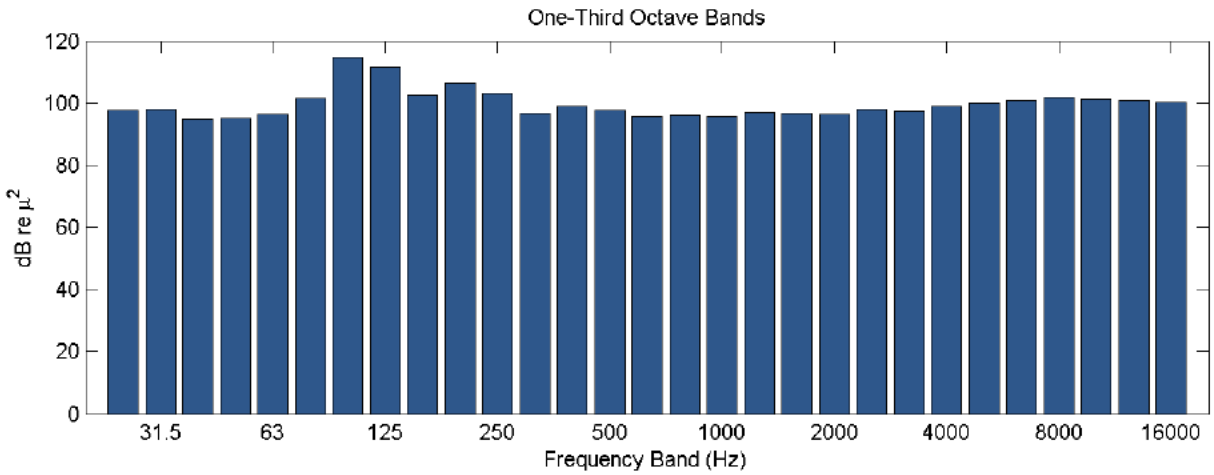

Figure 9: One-third octave spectrum data for TidGen® device free-wheeling measurements (maximum level in each frequency bin for the trials in Figure 6).

Table 2 lists the maximum levels at the frequencies with measured increases in sound level as a function of range and turbine RPM. Figure 10 shows the maximum levels as a function of range. The range independence for the ranges measured in this test demonstrates that the source of the radiated noise is not exhibiting point source behavior with geometric transmission loss. These noise sources likely represent structural noise radiation which, given the size of structure, put these measurements within the near field of the structure. Therefore, it would not be appropriate to apply a geometric spreading factor (*e.g.*, $10\log(r)$ or $20\log(r)$ for cylindrical or spherical spreading) to scale the level based on range from the TidGen® device. As a result, it is also unlikely that multiple units will result in a coherent addition of the sound field.

Table 2: Maximum levels at key frequencies as a function of range and RPM when free-wheeling.

			Maximum Level (dB re μPa²/Hz)		
Trial	**Range (m)**	**RPM**	**105 Hz**	**210 Hz**	**2.8 kHz**
Ambient	N/A	0	74	68	61
13	277	29	102	83	77
19	18	30	101	89	74
19	118	30	110	99	74
20	91	30	107	90	85

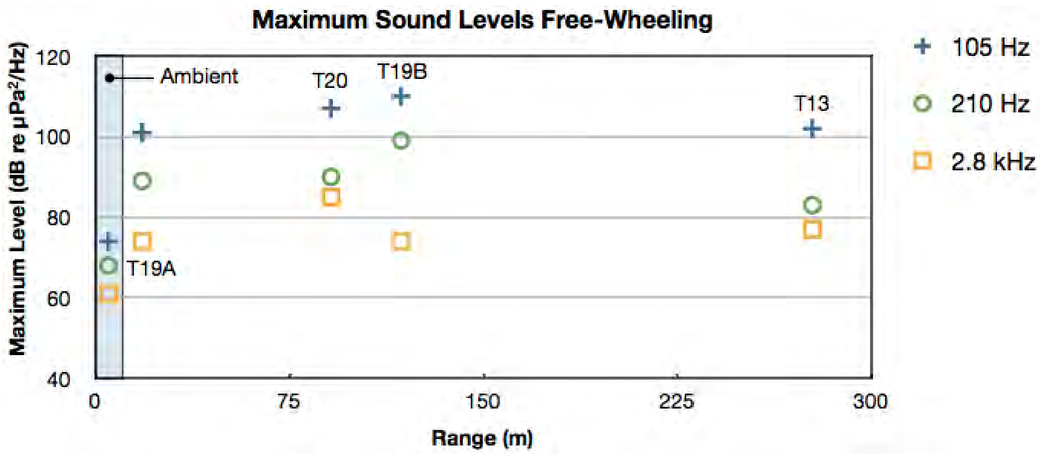

Figure 10: Maximum levels while free-wheeling as a function of range for the noise at approximately 105 Hz, 210 HZ, and 2.8 kHz. Measured levels do not reflect being in the far-field of the source with geometric spreading.

3.1.3 GENERATING

Noise levels while rotating and generating show some similarities and some significant differences as compared to when the generator is rotating only. These features include

- A much broader, but weaker peak around 105 Hz (~6 dB lower).
- A much weaker noise level around 210 Hz.
- Stronger noise levels around 2.8 kHz.
- A new tone at 5 kHz with apparent harmonics at 10 kHz, 15 kHz, and 20 kHz.

In general noise levels below 100 Hz appear to be slightly higher as compared to when the generator is free-wheeling. There are two peaks below 100 Hz that were seen in two measurements; however, they were not present in the other three measurements. The peaks were not associated with the two closest measurements, the two with the highest RPM values, or the two with the highest power generation. These factors suggest they are not related to the TidGen® Power System directly and are transients from either the noise measurement system or some other source. However, in if they do represent an intermittent noise attributable to the power system, all noise levels fell under the 120 dB re $\mu Pa^2/Hz$ threshold.

Perhaps more significantly, the low frequency peaks (between 100 and 300 Hz) associated with the rotation of turbine, and the levels in that frequency range in general are approximately 6 dB lower when the turbine is loaded and generating as compared to when the turbine is free-wheeling.

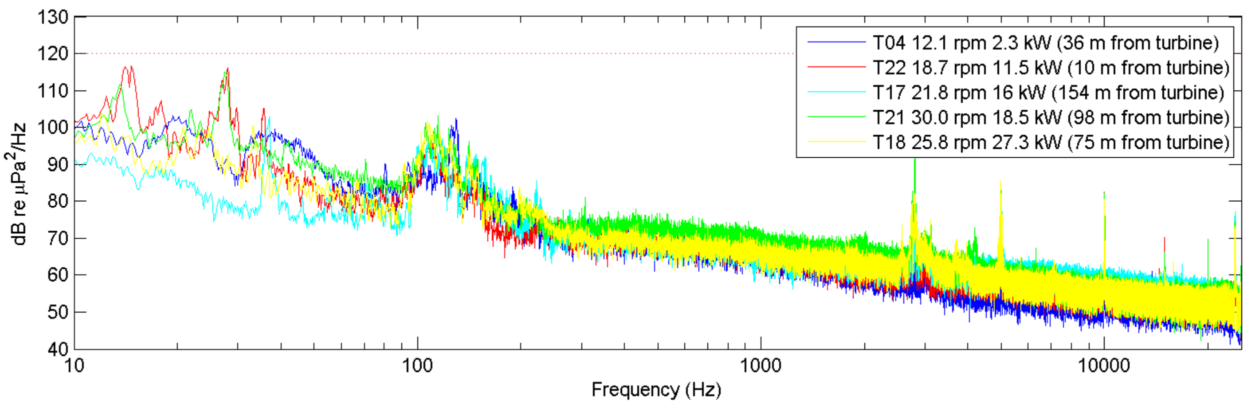

Figure 11: Power spectral density for the generating turbine at various ranges from the turbine.

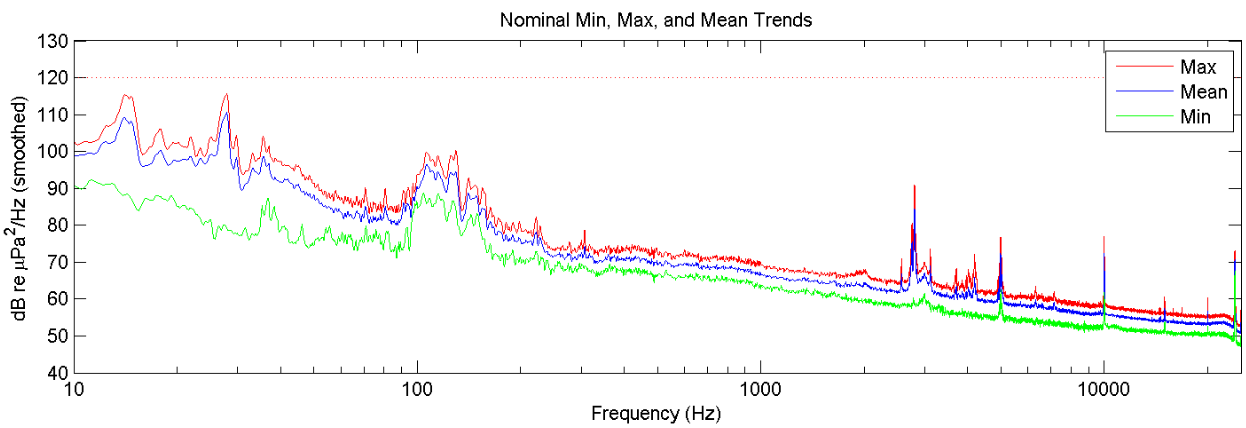

Figure 12: Nominal minimum, maximum, and mean power spectral density for the turbine when generating. The data has been smoothed to highlight the features of the data, which leads to values 1-3 dB lower than actual values. Smoothing is for presentation in this figure only; values used in reporting levels are true levels without smoothing.

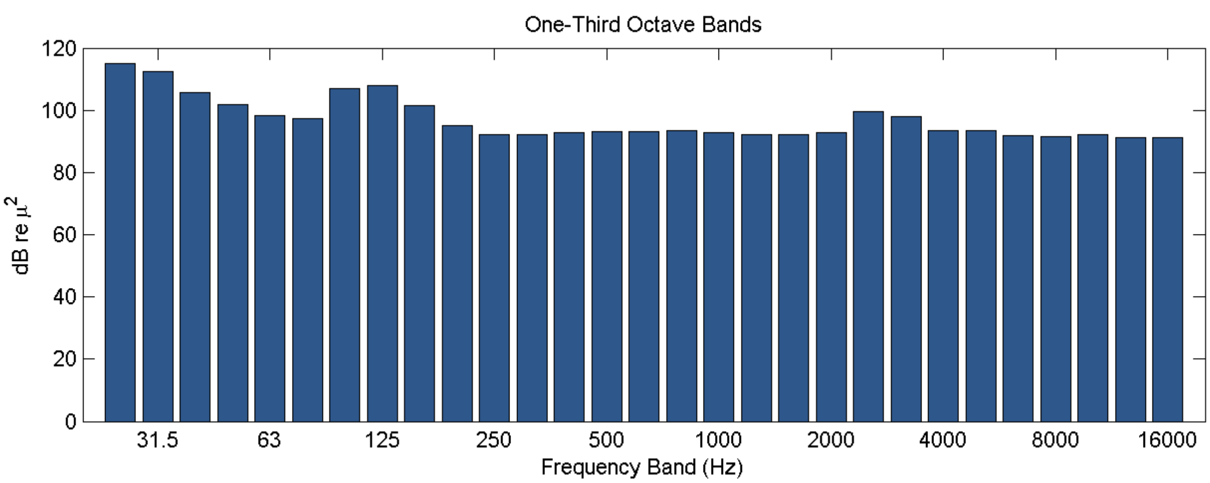

Figure 13: One-third octave spectrum data for TidGen® measurements while generating (maximum level in each frequency bin for the trials in Figure 11).

Table 3: Maximum levels at key frequencies as a function of range and RPM and power when generating.

				Maximum Level (dB re µPa²/Hz)						
Trial	Range (m)	RPM	Power (kW)	105 Hz	210 Hz	2.8 kHz	5 kHz	10 kHz	15 kHz	20 kHz
Ambient	N/A	0	0	74	68	61	61	58	55	56
4	36	12.1	2.3	90	75	62	80	70	62	60
22	10	18.7	11.5	95	74	74	80	82	70	63
17	154	21.8	16	98	77	70	78	82	61	58
21	98	30	18.5	101	80	92	84	75	66	70
18	75	25.8	27.3	101	81	82	86	81	61	58

Table 3 lists the maximum levels at the frequencies with measured increases in sound level as a function of range, turbine RPM, and power output. Figure 14 through Figure 16 show the maximum levels as a function of range, power output, and rotation speed respectively. The strongest correlation is as a function of turbine rotation speed, particularly for the frequency region around 105 Hz with the highest overall sound levels.

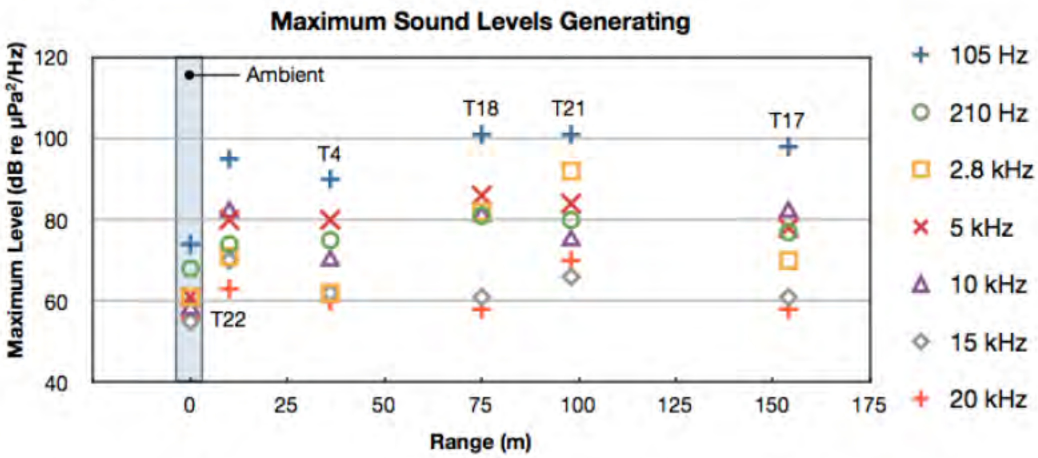

Figure 14: Maximum levels while generating as a function of range (with ambient reference).

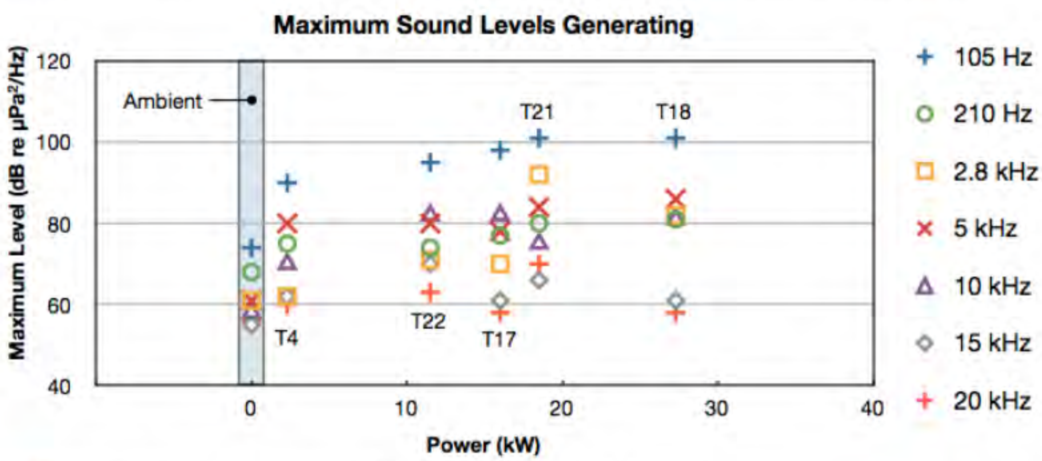

Figure 15: Maximum levels vs. power output (with ambient reference).

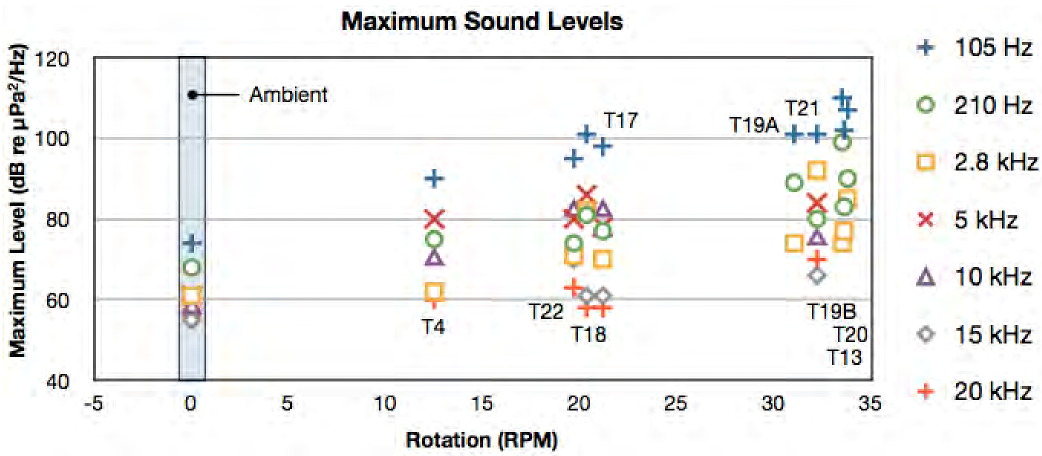

Figure 16: Maximum levels vs. turbine rotation both freewheeling and generating (and ambient).

3.2 WESTERN PASSAGE

Figure 17 shows an example drift pattern in Western Passage. The four red circles with white Xs represent the boundary of the area where turbine units are expected to be deployed. The blue circle with white X is the nominal center of the region for reference. The data from this trial (trial 23, April 3, < 0.5m/s flow going out) showed the least noise from surface action and was used to determine the ambient background sound levels.

Ambient measurements in Western Passage were similar to those in Cobscook Bay when the generator was not rotating. Although slightly lower overall, and particularly below 100 Hz, the Western Passage results in this section represent the data with the least interference from surface action across all of the measurements in both Western Passage and Cobscook Bay. The lower levels may be more representative of the variability in conditions.

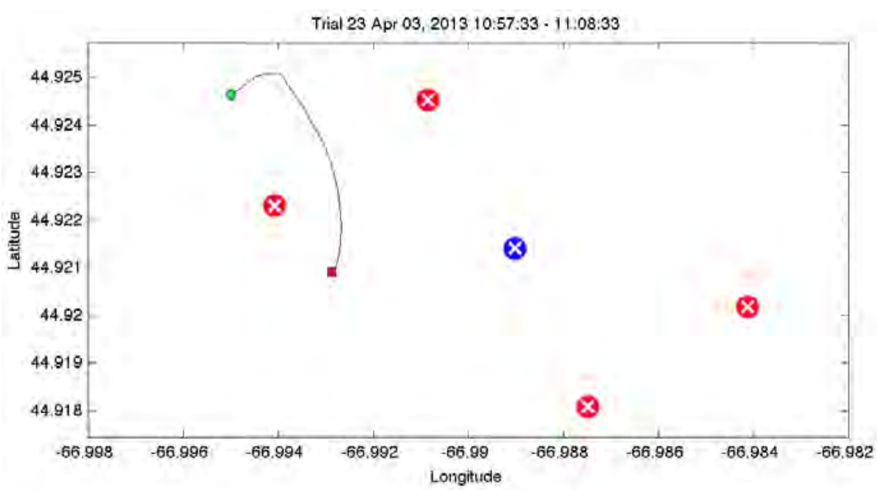

Figure 17: Example drift pattern in Western Passage. The four red circles with white Xs represent the boundary of the area of possible turbine deployment. The blue circle with white X is the nominal center of the region for reference.

3.2.1 Ambient

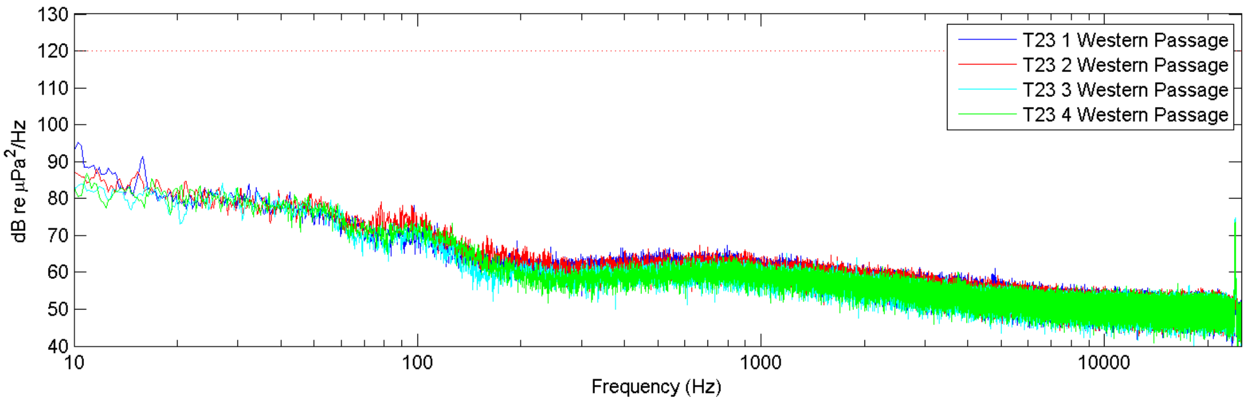

Figure 18: Power spectral density for ambient data in Western Passage.

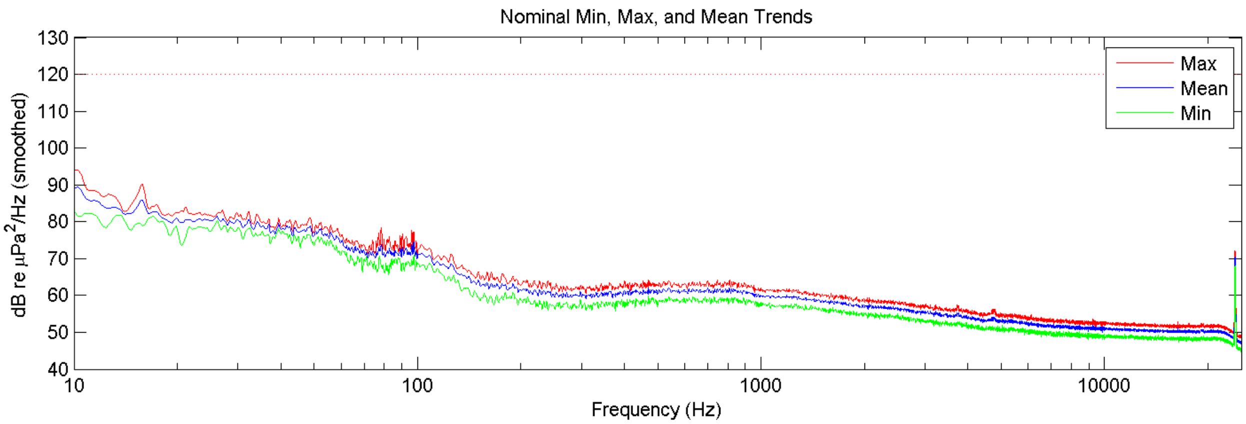

Figure 19: Nominal minimum, maximum, and mean power spectral density for ambient data Western Passage. The data has been smoothed to highlight the features of the data, which leads to values 1-3 dB lower than actual values. Smoothing is for presentation in this figure only; values used in reporting levels are true levels without smoothing.

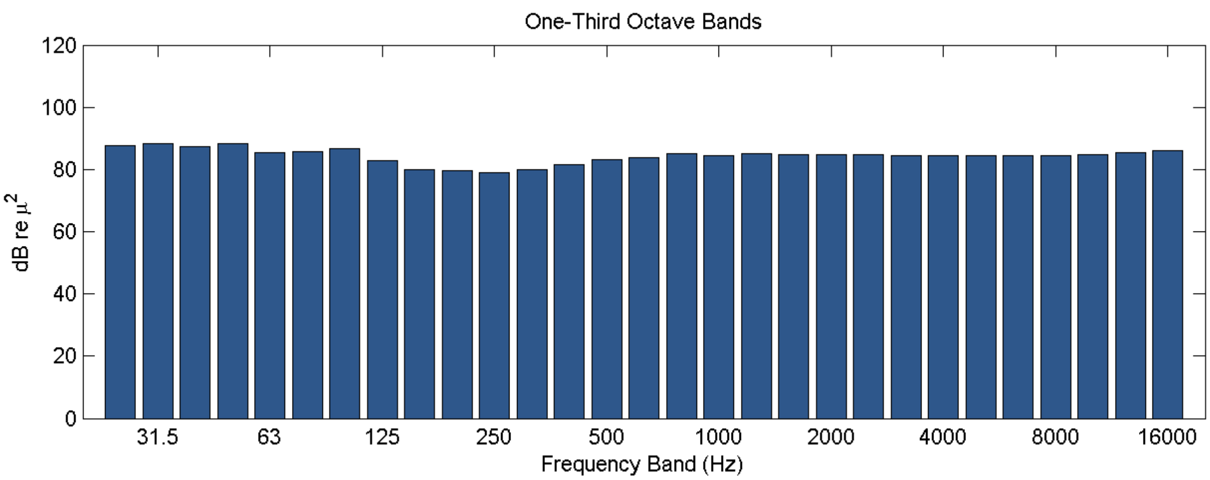

Figure 20: One-third octave spectrum data Western Passage ambient measurements (maximum level in each frequency bin for the trials in Figure 18).

3.3 Broadband Noise Levels

Table 4 shows the **total rms** noise levels integrated from 20 to 20000 Hz for the spectral levels shown in sections 3.1.1, 3.1.2, 3.1.3, and 3.2.1. For each category (*e.g.,* ambient Cobscook data, section 3.1.1) the table shows the minimum, maximum, and average power levels for the trials associated with that category (*e.g.,* the data shown in Figure 3). These values are limited to the 20 and 20000 Hz band based on discussions by a panel of experts during the *Instrumentation for Monitoring around Marine Renewable Energy Devices* workshop, held June 25-26, 2013 in Seattle, WA. The reasoning for the high pass filtering at 20 Hz is that a) it is very difficult to be sure there is no measurement system noise below 20 Hz and b) in shallow water the very low frequency energy does not propagate. In fact, the data in Figures 2 and 3 indicate artifacts that are not turbine related below 30 Hz. The reasoning behind the low pass filtering at 20 kHz is that a) noise attenuates fairly rapidly due to absorption at the higher frequencies and b) this allows for more readily available digital data acquisition systems to be used.

Based on the data in Figure 11, it is clear that a significant contributor to the maximum levels seen in Table 4 when the system is generating power are the two trials that show a large response at just below 30 Hz. This response is only seen in two of the five trials where the turbine is generating. This suggests it may not be related to the power system and is ambient noise similar to what is seen in near 20 Hz in two of the ambient data sets. What this implies is that the minimum level column of Table 4 is most likely the best representation of the total rms noise levels radiation from the turbine generator, the loudest of which is 111 dB re μPa^2 .

Table 4: Broadband noise levels between 20 and 20000 Hz.

	Level (dB re μPa^2)		
Category	**Min**	**Max**	**Mean**
Ambient (Western Passage)	99	100	99
Ambient (Cobscook)	104	107	106
Free-wheeling	108	119	113
Generating	111	119	115

4.0 Summary of Findings

4.1 Cobscook Bay

Maximums sound levels measured in the region around the TidGen® Power System appear to be driven primarily by the rotation speed of the turbine, particularly for the lower frequency noise components that generate the highest sound levels over ambient conditions.

Sound levels when the turbine is freewheeling are generally higher by as much as 10 dB re μPa^2/Hz for these lower frequency components. There are additional higher frequency components that appear to be only present when the system is generating power. These higher frequency tones are as much as tens of dB below the lower frequency components, but they do contribute enough to the integrated levels to raise the total rms values by perhaps a few dB.

4.2 Western Passage

Measurements in Western Passage showed ambient noise levels that were largely comparable with those from Cobscook Bay beyond the kiloHertz range, but are measurably lower for most of the sub-kiloHertz range and particularly tens of Hertz. Levels below 100 Hz may have been slightly higher in Cobscook Bay, however, this may have been influenced as much by varying surface conditions between locations and times.

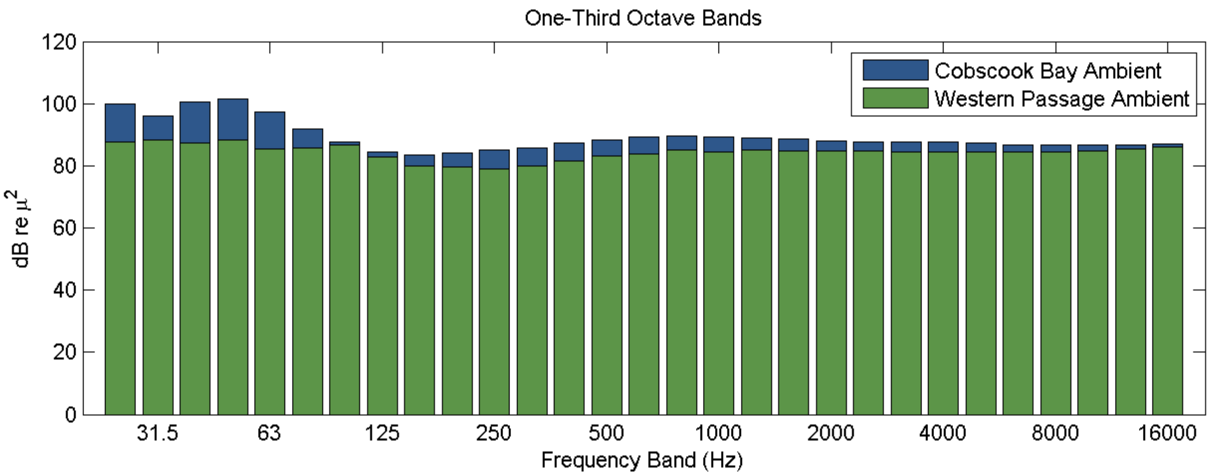

Figure 21: One-third octave band comparison for Western Passage and Cobscook Bay ambient measurements.

5.0 APPENDIX A

5.1 SAMPLE RAW DATA

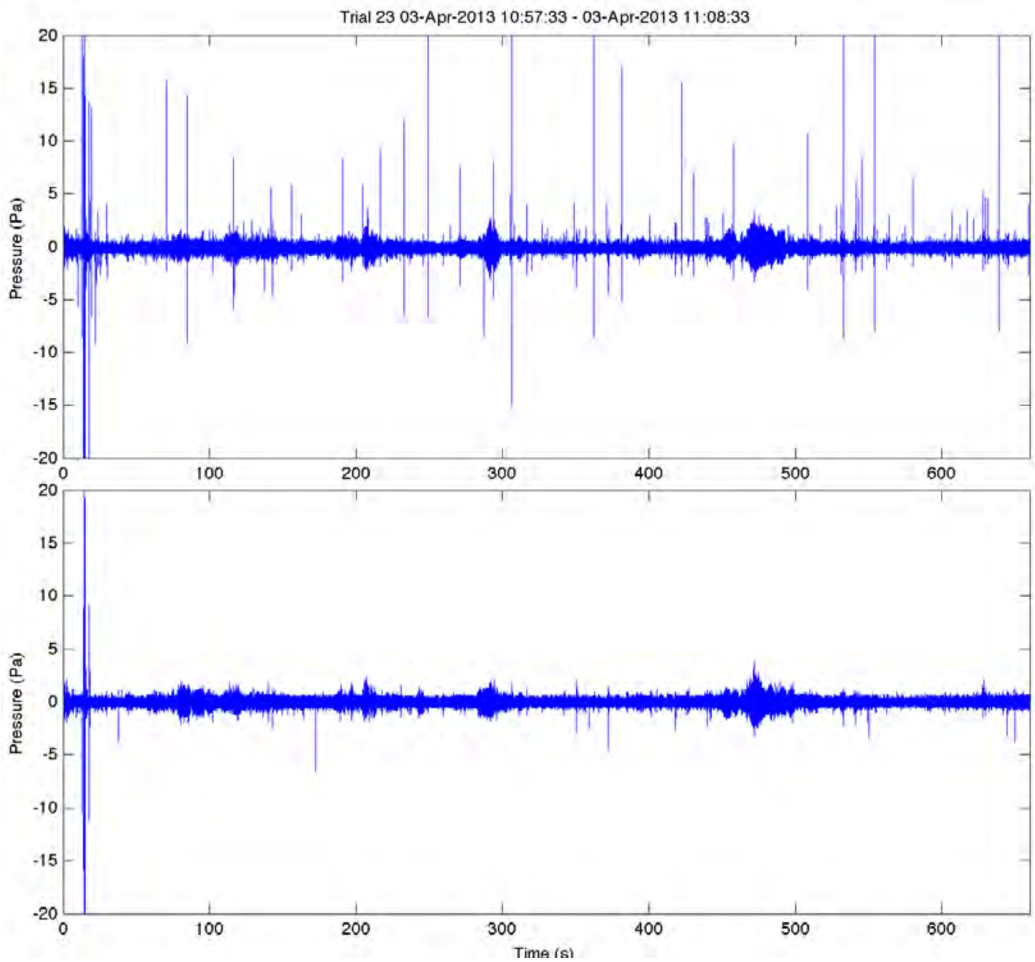

Figure 22: Time series data for the top and bottom channels of the DNMS. The large response at approximately 10 seconds is noise associated with deployment of the DNMS from the boat. The additional very short, often large impulses at intermittent times are due to rapid changes in hydrostatic pressure caused by surface roughness. In this example (trial23) there are periods of time, particularly for the bottom channel, where the measurement was not affected and data in this window could be extracted for analysis.

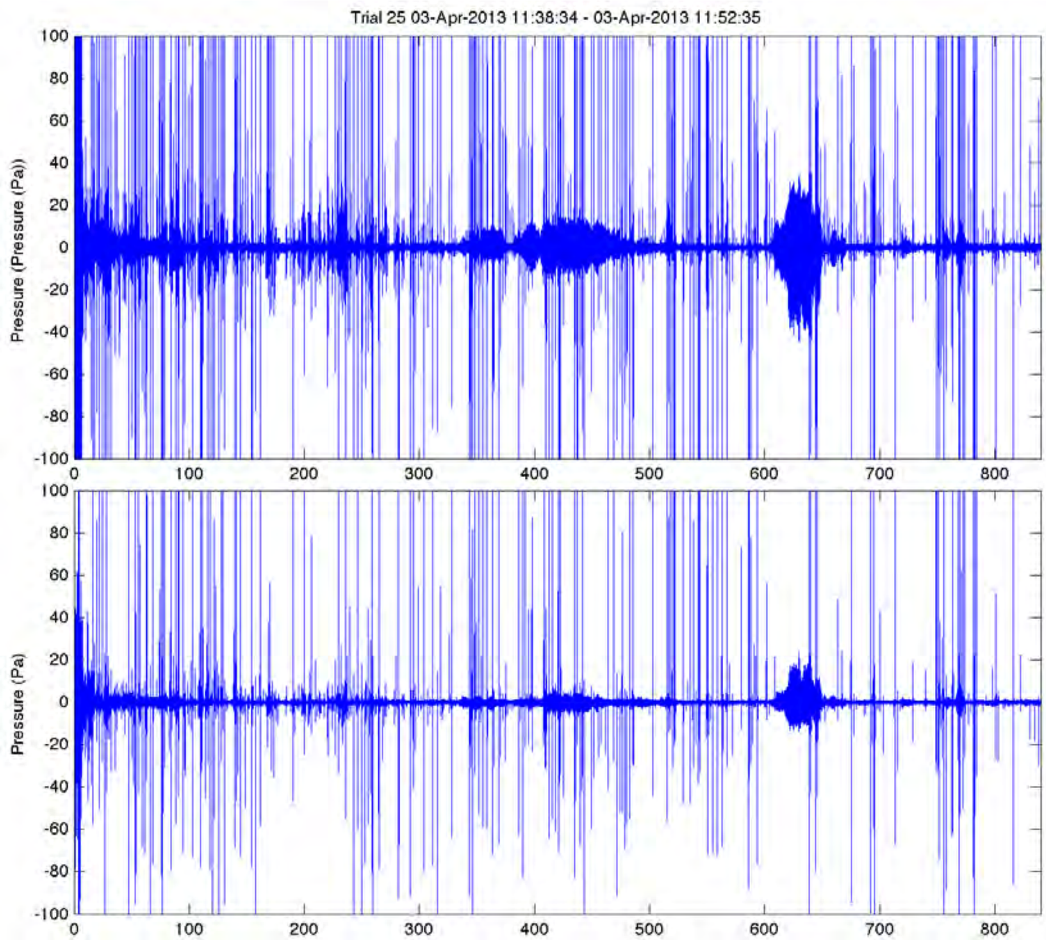

Figure 23: Time series data, similar to the previous figure, for a trial where the effects of surface roughness dominated the data set (trial 25). Although there are a few very small windows of opportunity in the data that can be extracted for analysis, the impulses are generally too close in time to define a suitable window of data.

Attachment B: DNMS Observation Measurement Log

OBSERVATIONAL MEASUREMENT LOG

Date: ________________

Time: ________________ (24 hr clock)

Measurement Process (circle) Drift Tethered Bottom Sensor

Sea Conditions (circle): Calm < 1ft < 1.5ft < 2ft > 3ft

Weather (circle) Sun Cloudy Rain Windy

Wind Speed _____________(knots or mph) and coming from _______________

Tide (circle): HIGH LOW COMING IN GOING OUT

Water Temp (°C) ______________________ measured at a depth of _______________

Water Velocity _____________________

Observations (Boats/Marine Life): ____

____

____

____

____

Attachment C: ORPC Accelerometer Logging

Accelerometer Logging / SSI
April 2nd/3rd

Accelerometer Channels Used

Channel #	Location	Orientation	Notes
0	Port Generator	Vertical, Perp. to flow	Gen. y-axis
1	Port Generator	Horizontal, perp. to flow	Gen. x-axis
8	Starboard Generator	Horizontal, parallel to flow	Gen. z-axis
7	Port Inner	Horizontal, Perp. to flow	
14	Starboard Inner	Horizontal, Parallel to flow	

Accelerometer Logging

File #	Start time	Channel	DNMS Deployment #	Generator Status at start	Notes
1	11:34	0	3	OFF	AKS & GSS during last 2 minutes of file
2	11:48	1	4	ON	
3	12:11	8	5	ON	
4	12:39	0	6	ON	
5	12:58	1	7	ON	
6	13:13	0		OFF	Freewheel
7	13:18	0	8	OFF	Freewheel
8	13:38	8	9	OFF	Freewheel
9	14:02	1	10	ON	
10	14:24	14	11	ON	While TT over Starboard end of TGU
11	14:33	7		ON	No Boat, Ch 7 over port side.
12	14:42	8	12	ON	Switched to Freewheel during file
13	15:06	0	13	OFF	Freewheel
14	15:28	0	14	ON	
15	16:18	0	15	ON	Stalled during logging due to slowing tides
16	8:02	0	16	ON	New Day, April 3rd
17	8:21	1	17	ON	
18	8:40	8	18	ON	
19	9:04	0	19	OFF	Freewheel
20	9:26	1	20	OFF	Freewheel
21	10:10	8	22	ON	

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Appendix C

Review of video recordings of June 13, 2013, MER Associates, July 23, 2013

Interim Report, Subtidal and intertidal benthic survey, Upper Cobscook Bay, Maine, August 7-8, 2013, MER Associates, February 17, 2014

ORPC Biofouling Inspection Report (TGU), October 5, 2013

ORPC Biofouling Inspection Report (BSF), August 27, 2013

Review of video recordings of June 13, 2013
ORPC Maine
Cobscook Bay

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July 23, 2013

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Introduction

ORPC Maine, a subsidiary of Ocean Renewable Power Company Maine (collectively, ORPC) conducted an inspection of the power and data cable route associated with its Cobscook Bay Tidal Energy Project (CBTEP) on June 13, 2013. The inspection was conducted using two techniques: 1) a diver-held camera and housing that covered the entire cable route running from the nearshore area (previously Station 1) in Gove Cove on Seward Neck in Lubec, Maine to the TidGen Turbine Generator Unit (TGU) deployment area and 2) a remote drop-camera video of five transects running across the cable route in the vicinity of Stations 2, 4, 6, 8 and 10, as shown in Figure 1. The inspections included video recordings to document the condition of the cable as well as the benthic habitat along the cable route. This report summarizes observations made in the field as well as during the review and provides comments on the video recording methods used.

Methods

A video transect line was deployed along the bottom by ORPC on June 10, 2013 using their Tide Tracker vessel and a Hemisphere VS101 GPS positioning unit. The transect line was made up of four (4) 900 ft lines and one (1) 400 ft line for a total of 4,000 ft. The transect line was marked at 300-ft intervals with orange tape bearing the distance and was held in place by weights dropped at specific distances as shown in Table 1 (see also Attachment I) following a course shown in Figures 1 and 2. The original baseline survey transect line was marked in meters rather than feet and station locations consequently do not correspond exactly; additionally, the baseline survey and diver transect line following the 'As Built' cable route are offset from one another.

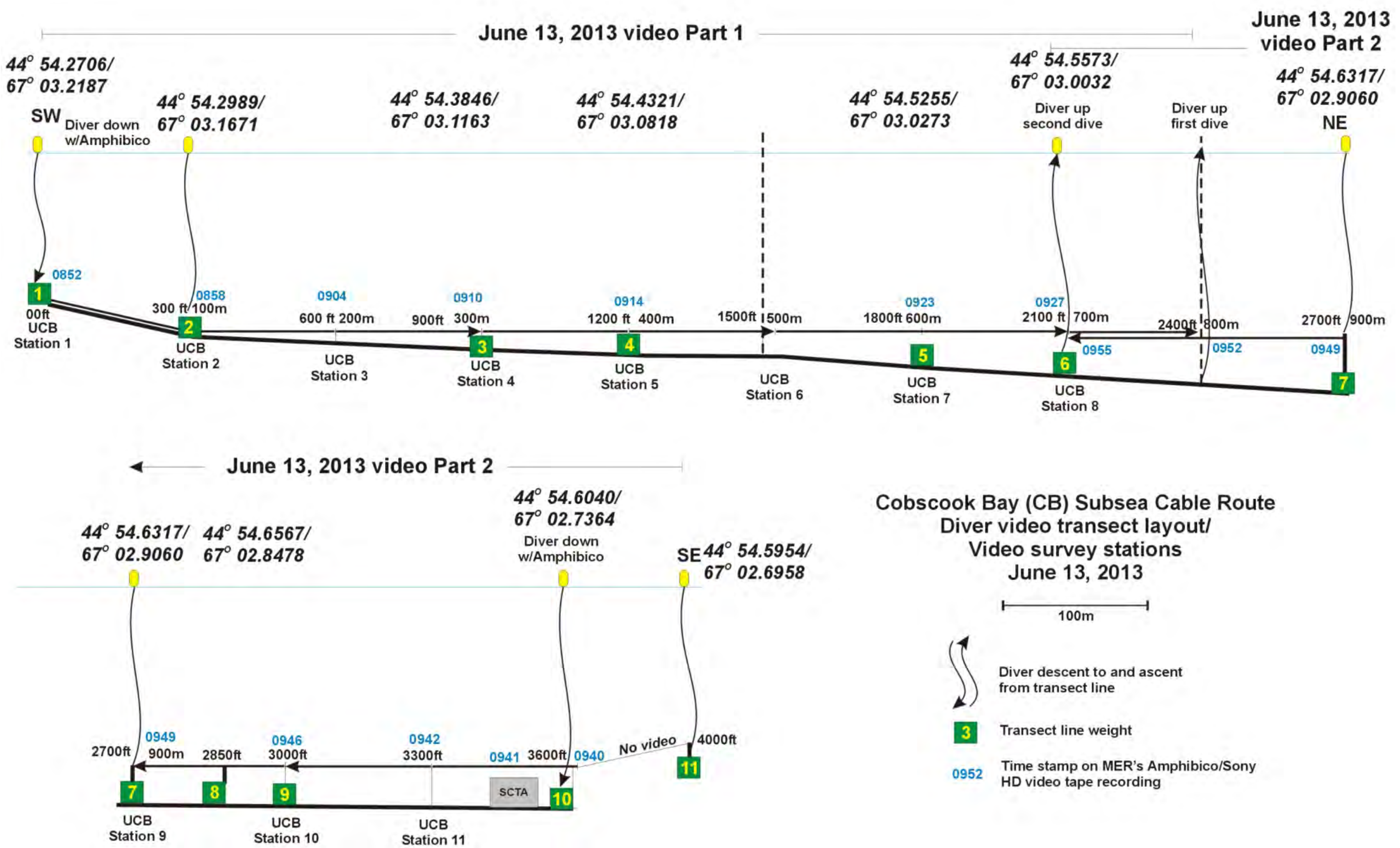
Table 1. Video transect line distances, weight locations (Lat/Long) and depths in meters (Source: ORPC)

Distance (ft)	Latitude	Longitude	Depth (m)
0	44°54.2706	67°03.2187	1.0
300	44°54.2989	67°03.1671	4.0
900	44°54.3846	67°03.1163	11.9
1200	44°54.4321	67°03.0818	14.5
1800	44°54.5255	67°03.0273	21.8
2100	44°54.5573	67°03.0032	25.9
2700	44°54.6317	67°02.9060	24.5
2850	44°54.6511	67°02.8659	24.9
3000	44°54.6567	67°02.8478	24.7
3600	44°54.6040	67°02.7364	25.1
4000	44°54.5954	67°02.6958	25.3

Video recordings were made by Brayden's Future, Inc. SCUBA divers using MER's Amphibico VHHCEL57/Sony HDR-HC9 high definition digital video camera and Amphibico VLDIG3AL 35W/50W switchable underwater arc lamp lighting package and recorded on Sony HD tapes. The tethered drop camera videos were recorded by MER using a SeaViewer Sea-Drop 650 Series real-time color camera system attached to a heavily weighted stainless steel frame equipped with an Amphibico VLDIG3AL 35W/50W switchable underwater arc lamp. The camera video feed was connected to a SeaViewer SeaTrak unit that embeds GPS (WGS84) and date/time data (GMT) directly on the video recording; the video was recorded on-board the support boat using a SONY GV-D800 NTSC digital video recorder.

Figure 1. June 13, 2013 diver and drop camera video survey transects (Source: ORPC; MER)

Figure 2. June 13, 2013 diver survey video route and weight locations (Source: ORPC)



Results:

Table 2, below, summarizes the sediment composition and predominant species and their relative abundance based on the review of the diver-carried camera video recordings. Relative abundance is A – abundant, C – common, O - occasional, R – rare.

Table 2. Video survey times, distances and observed sediment types and species/relative abundance

Station	Start time	Interim time	Distance on transect (ft)	Sediment Type	Species/Abundance
1-2	8:52:45	8:58:42	0'-300'	Sand/light relic shells/ light cobble	Urchins (A), mermaid hair (C), worm tubes (O), burrowing anemones (R), waved whelk (R), hermit crab (R), silver spotted anemone (R), northern red anemone (R), small burrows (R),
2-3	8:58:42	9:04:12	300'-600'	gravel/sand; cobble at end	Urchins (A), mermaid hair (C), sea peach (O), northern red anemone (O), sea scallop (O), worm tubes (O), Blood star fish (R), burrowing anemone (R), Stimpson whelk (R), green crab (R), lobster (R), small burrows (R), palmate sponge (R), star fish (R), purple sun star (R), fig sponge (R), sea lettuce (R), orange tunicate (R), large northern sea cucumber (R)
3-4	9:04:12	9:09:49	600'-900'	cobble	Urchins (A), northern red anemone (C), mermaid hair (C), large northern sea cucumber (O), sea peach (O), sea scallop (O), star fish (O), blood star fish (R), spiny sun star (R),
4-5	9:09:49	9:14:24	900'-1200'	cobble	Northern red anemone (A), sea scallop (A), urchins (A), sea peach (C), blood star fish (C), Large northern sea cucumber (O), star fish (O), purple sun star (R), sea potato (R), mermaid hair (R), hermit crab (R).
5-7	9:14:24	9:23:41	1200'-1800'	gravel/cobble/ heavy relic shells	Sea scallop (A), Urchins (A), Northern red anemone (A), Large Northern sea cucumber (A), blood star fish (C), sea potato (C), hermit crab (O), star fish (O), blue mussel (R), sea peach (R), Stimpson's whelk (R), sculpin (R).
7-8	9:23:41	9:27:15	1800'-2100'	gravel/sand/ heavy relic shells/ becoming rock/ clay/rock	Sea potato (A), northern red anemone (A), urchins (A), Large northern sea cucumber (C), blue mussel (C), star fish (O), hermit crab (R), sea scallop (R), Fig sponge (R).
8-diver up	9:27:15	9:30:58	2100'-2400'	heavy relic shells	Northern red anemone (A), Large northern sea cucumber (A), urchin (C), sea potato (C), blood star fish (C), hermit crab (O), star fish (R), Spiny sun star (R), sea squirt (R), sea scallop (R),
SCTA-11	9:40:06	9:42:21	3600'-3300'	cobble/relic shells	Northern red anemone (A), Large northern sea cucumber (A), sea potato (A), urchin (A), sea scallop (C), blood star fish (C), hermit crab (O), star fish (O), rock crab (R),
11-10	9:42:21	9:45:53	3300'-3000'	heavy relic shells	Urchin (A), Large northern cucumber (A), hermit crab (C), sea potato (C), star fish (C), blue mussel (O), sea scallop (R), Stimpson's whelk (R), green crab (R).
10-9	9:45:53	9:49:09	3000'-2700'	heavy relic shells	Large northern cucumber (A), urchin (A), sea potato (C), star fish (O), hermit crab (O), Northern red anemone (R).
9-8	9:49:09	9:52:56	2700'-2400'	heavy relic shells	Large northern cucumber (A), sea potato (A), star fish (C), urchins (C), northern red anemone (O), hermit crab (R), sea scallop (R), spiny sun star (R), sea peach (R).
8-diver up	9:52:56	9:55:40	2400'-2100'	heavy relic shells	Large northern sea cucumber (A), northern red sea anemone (A), sea potato (C), urchin (C), star fish (O), sea scallop (R), blood star fish (R), finger sponge (R), sculpin (R), mermaid hair (R), unid. Fish (R)

Table 3, below, summarizes the sediment composition and predominant species and their relative abundance based on the review of the drop camera video recordings (times are GMT, +4 local time). Relative abundance is A – abundant, C – common, O - occasional, R – rare.

Table 3. Drop camera video survey times, transect number and observed sediment types and species/relative abundance

Start time	End time	Transect #	Sediment Type	Species/Abundance
13:38:04	13:53:02	T 10	Relic shell (mussel), cobble/rocks and some clay	Urchins (A), northern red anemone (C), northern sea cucumber (C), sea potato (C), sea star (C), hermit crab (C), sea peach (O), waved whelk(O), mussels (O), crumb of bread (O), scallop (R), blood star (R), barnacles (R), sculpins (R), bulbous sponge (R), palmate sponge (R), unid. crab (R), unid. sponge (R), unid. weed
14:08:24	14:15:06	T 8	Cobble/clay/relic shell interspersed with barren patches early in video, followed by relic shell/cobble/stones/boulders.	Urchins (A), northern red anemone (C), northern sea cucumber (C), sea potato (C), sea star (C), sea peach (O), crumb of bread sponge (R), scallop (R), blood star (R), Jonah crab (R)
14:24:06	14:29:54	T 6	Clay/cobble/rocks and relic shell	Urchins (A), northern red anemone (C), sea potato (C), scallop (C), sea star (C), northern sea cucumber (O), blood star (R), unid. whelk (R)
14:39:08	14:46:34	T 4	Cobble/rock transitioning to sand	Urchins (A), northern red anemone (C), sea peach (C), sea star (C), scallop (C), northern sea cucumber (C), crumb of bread sponge (C), mermaid's hair (R)
14:55:22	15:06:40	T 2	Sand/cobble/rock softening to sand and silt	Urchins (A), burrowing anemone (C/A), northern sea cucumber (O), scallop (O), sea peach (O), hermit crab (R), mermaid's hair (R), unid. fish (R)

Relative abundance: abundant (A) seen throughout segment; common (C) seen frequently throughout segment; occasional (O) seen infrequently, but throughout segment; rare (R) seen one to a few times during the video segment.

Discussion

Diver video recording

The diver video recording quality is good throughout. The dive began at the shoreward end of the cable route and proceeded between 2,100 and 2,400 feet (Diver video Part 1) until the change in tide at which point the diver ascended and resumed recording from the approximate 3,600 foot mark back toward the 2,100 foot mark (Diver video Part 2). The transect line is marked with distance markers (orange tape making 300-ft intervals) and this time the diver was nearly consistently able to show the marker and distance quite clearly allowing distance along the transect line to be known during review.

The bottom in the shallower area between 0' to 600' covering Stations 1 and 3 consists of sand with light relic shell and cobble. Green sea urchins, *Strongylocentrotus droebachiensis*, are abundant and worm tubes of unidentified polychaetes are occasionally seen; sea peaches, *Halocynthia pyriformis*, blood sea stars, *Henricia* sp., and northern red anemones, *Urticina felina*, are common to occasional; sea scallops, *Placopecten magellanicus*, are occasional and burrowing anemones, *Cerianthus borealis*, are rare to occasional.

Between 600' and 1,200', covering from Stations 3 to Station 5, the bottom consists primarily of cobble. Urchins remain abundant and northern red anemones are common; the large northern sea cucumber, *Cucumaria frondosa*, occasionally seen, as are scallops, sea peaches and sea stars, *Asterias* spp. Purple sun star, *Solaster endeca*, sea potato, *Boltenia ovifera*, and hermit crab, *Pagurus* sp., are only rarely seen. The bottom transitions from cobble to relic mussel shell between 1,200' and 1,800', then to rock at 2,100'. Urchins continue to be abundant throughout; northern red anemones and sea potatoes also become abundant with increasing depth. Scallops are abundant initially but decrease in abundance with depth. Sea cucumbers are common to abundant and blue mussels, *Mytilus edulis*, are common; additional species include fig sponge, *Suberites ficus*, Stimpson's whelk, *Colus stimpsoni*, and one sculpin, *Myoxocephalus* sp., all seen only rarely; also seen only rarely are blue mussels, hermit crabs and sea peaches.

Over the relic mussel shell that covers the deeper portion of the route between 2,100' to 3,600' northern red anemones, sea cucumbers, urchins and sea potatoes are generally abundant throughout, although some patchiness is seen where these become common or occasional. Blue mussels, hermit crabs, sea stars, spiny sunstar, *Solaster papposus*, green crab, *Carcinus maenas*, finger sponge, *Haliclona oculata*, and blood stars are only rarely seen at depth.

Direct comparison between the July 2013 diver video survey and the July 2011 baseline survey is not possible due to the offset between the two. Nevertheless, the July 2013 observations are generally consistent with those of the original baseline video survey of July 2011, when sea urchins, sea peaches, sea cucumbers and scallops were observed as abundant to common in the shallower sections and sea potatoes, northern red anemones, urchins and sea stars were the predominant organisms in the deeper sections (refer to Table 4). The northern sea cucumber appears more abundant in deeper water than previously observed and northern red anemones also appear to be abundant where they were previously only common. Sea scallops appear to be more abundant between Stations 4 and 6; an increase in relative abundance of sea cucumbers and sea scallops is consistent with a reduction in dragging activity for these commercially important species in the immediate vicinity of the cable route.

Table 4. July 2011 Upper Cobscook Bay baseline video transect and benthic sampling station coordinates, sediment type, and predominant organism(s)

UCB	Latitude	Longitude	Sediment	Predominant organism(s)/relative abundance*
Station 1 (T1)	44 54.264	-67 3.217	sand, clay, relic shell	sea urchins (A), sea cucumbers (C), waved whelk (C)
Station 2 (T1)	44 54.300	-67 3.160	sand, clay, relic shell, shell hash	sea urchins (A), sea cucumbers (C), waved whelk (C), sea peaches (C)
Station 3 (T1)	44 54.347	-67 3.128	gravel, shell hash, sand, hard-pan clay	sea urchins (A), sea peaches (A), sea cucumbers (C), sea scallops (C)
Station 4 (T1)	44 54.396	-67 3.094	cobble, sand, mussel shell hash, rocks, clay base	sea urchins (A), sea peaches (A), sea cucumbers (C), sea scallops (C)
Station 5 (T1)	44 54.444	-67 3.060	cobble, gravel, sand, mussel shell hash	sea urchins (A), sea stars (C), sea scallops (C), sea potatoes (C/A), sea peaches (C)
Station 6 (T1)	44 54.493	-67 3.027	cobble, gravel, relic mussel shell	sea scallops (C/A), sea cucumbers (C), anemones (C); hermit crab (R); lobster (R),
Station 7 (T1)	44 54.541	-67 2.994	relic mussel shells, cobble	sea scallops (C/A), sea cucumbers (C), anemones (C)
Station 8 (T1)	44 54.590	-67 2.960	relic mussel shell, cobble, stones, boulders	sea potatoes (A), sea cucumbers (C), anemones (C)
Station 9 (T2)	44 54.620	-67 2.870	cobble, relic mussel shell, shell hash	sea potatoes (A), sea cucumbers (C), sea urchins (C), sea scallops (O)
Station 10 (T2)	44 54.601	-67 2.809	cobble, relic mussel shell, shell hash	sea potatoes (A), sea stars (C), sea cucumbers (C), sea urchins (C), sea scallops (O)
Station 11 (T2)	44 54.580	-67 2.740	cobble, relic mussel shell, shell hash	sea potatoes (A), anemones (C/A), sea stars (C), sea cucumbers (C), sea urchins (C), sea scallops (O)

Relative abundance: abundant (A) seen throughout segment; common (C) seen frequently throughout segment; occasional (O) seen infrequently, but throughout segment; rare (R) seen one to a few times during the video segment.

As in previous monitoring events, at certain locations the video transect is offset from the *As built* cable route as well as the original baseline survey route. However, the exposed transmission and data cables are seen for several meters in the shallower area and only briefly and partially buried in the deeper section. As before, where the cable is visible on the surface, the cable is seen firmly stapled to the bottom and there continues to be little, if any, evidence of scouring or disturbance to the bottom caused by the cable(s). Also as previously reported, epifauna, including green sea urchins, northern red anemones, sea peaches and sea scallops are seen adjacent to, and in some cases attached to, the cable(s). Based on these observations, it does not appear that the cables are causing any discernible adverse impacts to the substrate habitat or the associated epifauna.

Drop camera video

The first segment of the drop camera video was recorded in the vicinity of Station 10 northwest of shore cable termination anchor (SCTA). The camera drop for the first video segment transect began south of the *As Built* route and diver video transect line but the support boat was carried very close to the cable route by the current when the camera finally reached bottom. The bottom throughout the area is relic mussel shell with occasional cobble and rocks and some clay. Urchins are abundant and sea potatoes are common and locally abundant. Red northern anemones, sea cucumbers, sea stars and hermit crabs are common; waved whelks, mussels and crumb of bread sponge, *Halichondria panicea*, are occasionally seen. Blood sea stars, barnacles, *Balanus* sp., palmate sponge, *Isodictya* sp., are rare along with an unidentified sponge and crab. The drop camera video transect crossed the diver video transect at four points and the exposed cable was seen at 13:44:28 at 44° 54.629/67° 2.811 with no apparent evidence of disturbance to fauna.

The second segment of the drop camera video was recorded in the vicinity of Station 8. The video recording began east of the cable route and ended to the west. The bottom consists predominantly of cobble and relic shell with occasional stones and boulders. Urchins remain abundant and the predominant species with red northern anemones, sea cucumbers, sea potatoes commonly seen. Sea peaches are occasional with crumb of bread sponge, sea scallops, blood stars and Jonah crab, *Cancer borealis*, only rarely seen. The diver transect line was crossed at 14:13:56 at 44° 54.576/67° 3.047, but the cable was not seen and is presumed buried in the area.

The third segment of the drop camera video was recorded in the vicinity of Station 6; similar to the previous transect, the video recording began southeast of the cable route and ended on the northwest side of the cable route. The bottom consists of cobble and clay with rocks and relic mussel shells. Urchins are again abundant with red northern anemones, sea potatoes and scallops commonly seen. Sea cucumbers are occasional with blood sea stars and whelks seen only rarely. The dual transmission and data cables were crossed at 14:26:26 at 44° 54.485/67° 3.051 with no indications of disturbance to the bottom or resident fauna. The diver transect line was crossed at 14:27:22 at 44° 54.491/67° 3.075.

The fourth segment of the drop camera video was recorded in the vicinity of Station 4 beginning just southeast of the cable route and ending on the southwest side; the close proximity of the video starting point to the cable route was due to very strong current over the relatively shallow area at the intended starting point approximately 100m upcurrent (southeast) of the cable route; the swift current and consequent high speed of travel across the bottom made review of the initial portion of the recording very difficult. The diver transect line was crossed near the start of the video at 14:39:44 but the cable is not seen and is presumed buried in the area. The bottom consists of cobble and clay with rocks, transitioning to sand at the northwest end of the transect. Urchins are abundant with red northern anemones, sea peaches, sea stars, scallops, sea cucumbers and crumb of bread sponge commonly seen; mermaid's hair seaweed, *Desmarestia* sp, is rare.

The fifth and final segment was recorded in the vicinity of Station 2 beginning southeast of and ending to the west of the cable route. The bottom is initially cobble with interstitial sand and occasional bedrock outcrops but transitions to sand, softening to sand and silt but transitions back to cobble and sand toward the end in shallow water. Urchins remain abundant with cerianthid burrowing anemones also abundant (in softer sediment) to common. Sea peaches, scallops and sea cucumbers are occasionally seen; hermit crabs and mermaid's hair seaweed are rare; one unidentified fish was seen. The diver transect line was crossed at 15:01:04 at 44° 54.306/67° 3.162.

The fauna observed along the drop camera video segments are consistent with the diver recorded video in the same general vicinity. Relative abundance is also generally similar although some variations exist between the reviews of the diver recording and that of the drop camera.

Diver held and drop camera video comparison

As on previous occasions, the quality of the video recorded with the MER camera and light package is very good and allows clear observation of the seafloor composition and epibenthic community. The diver transect line is marked with distance markers (orange tape making 300-ft intervals) and the diver was able to show most of the distance markers with the exception of those missed while following the cables rather than the transect line. Consistency in showing the marks simplifies both the determination of progress along the transect line and the video review process.

The drop camera video recording was conducted simultaneously with the diver video recordings to determine the feasibility of using it as an alternative method of assessing the benthic habitat and associated epifauna. The 36-foot F/V Lady H operated by Capt. Butch Harris was used as the surface platform for the video recordings; the boat is equipped with a hydraulic hauler and davit to facilitate lowering and hauling of the video camera frame.

The video recordings were begun in the vicinity of Station 10 to the northeast of the SCTA immediately after the start of the incoming tide; ORPC had specifically requested filming be done in the area only on the incoming tide to avoid possible entanglement with the TidGen (TGU).

The combination of the incoming tidal current with an opposing wind out of the northeast made maneuvering of the boat difficult when crossing the current. Acceleration of the boat to maintain course caused the camera frame to be raised high off the bottom. Deceleration to allow the camera frame to ride at an appropriate distance off of the bottom resulted in a northwest drift as a combination of the current and wind forces. To complete the transect, the boat was repositioned several times and allowed to drift with periodic engagement of the engine; this resulted in a “zig-zag” course across the cable route area and periodic “flying” of the camera frame off the bottom.

The course along the remaining transects (T8, T6, T4, and T2) was generally parallel to the current direction. Drift with the current was periodically adjusted by engine engagement to allow for reasonable speed along the bottom for video recording as well as to maintain course to cross the cable route. Transect 4 was the exception due to the shallow depth at the intended start point that resulted in very fast current and excessive speed of the camera across the bottom at the start of the video recording; however, acceptable speed was reached once greater depths were reached and current velocity slowed. Visibility along Transect 2 at the shallow end of the cable route was reduced by elevated turbidity resulting from wave action caused by the northeast wind.

The high current velocities along the cable route, particularly in the deeper area in the vicinity of the TGU, present substantial challenges for remote video recording. The slack water period during which video recordings can be made unaffected by the current is very short. As mentioned previously, on this occasion recording in the vicinity of the TGU was delayed until the current had shifted to incoming to avoid any possible entanglement with the TGU; if the recording could be started at slack water, sufficient time may be available to complete the transect before the current becomes excessively fast.

Changing the timing and sequence of the transects may also improve boat maneuverability and video quality. The current velocity in the shallower areas is generally less than in the deeper area, particularly on either side of slack water. Therefore, beginning the transect sequence in the shallower area of the cable route toward the latter part of the ebb tide (perhaps an hour before low water) and moving into progressively deeper and stronger current areas as slack water approaches, doing the transect closest to the TGU immediately before through immediately after slack water, would likely improve both boat maneuverability and video quality. Any transects in shallower water could be completed during the initial stage of the flood tide.

Conclusions/recommendations

The diver recorded video quality is very good and offers a clear view of the benthic habitat and associated flora and fauna. The diver also clearly showed the distance markers rather consistently which substantially improves the reviewers' ability to determine distance traveled and location along the transect. The drop camera video quality was generally good although the current velocity and consequent speed of the camera frame along the bottom made the review process challenging along certain transects. The quality and usefulness of the drop camera videos can likely be improved by making changes to the timing and sequence in which the transects are recorded to avoid high current periods.

The faunal community observed along the diver recorded video and drop camera video segments are consistent for the same general vicinity covered by both and are also generally similar to the faunal community distribution observed during the baseline survey of July 2011. Relative abundance is also generally similar although some variations exist between the diver recording and that of the drop camera due to the different areas covered. Based on observations of the exposed cable(s) there continues to be little, if any, evidence of scouring or disturbance to the bottom or the associated faunal community.

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ATTACHMENT 1

ORPC Benthic Dive Log
June 10, 2013
(Source: ORPC)

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BENTHIC DIVE LOG

6/10/13

There was 4000 feet of rope on the rear deck of the Tide Tracker.

Line has:

Black markings every 50’

Orange tape is used every 300’ and labeled with the number of feet it is (300’, 600’, 900’, 1200’, etc.).

There are 4 – 900’ sections of rope. A final length of 400’ of rope gave us 4000’ total.

Weights were added at 900’ intervals. For this deployment we added one on the first dogleg and two on the corner.

6/10/13 @ 0733 Low water

Kicked first weight (0000 feet) off as close to the beach as we could get it.

0000’ is at:	44 54.2706 N 67 03.2187 W	1 meter depth
0300’ is at:	44 54.2989 N 67 03.1671 W	4 meter depth
0900’ is at:	44 54.3846 N 67 03.1163 W	11.9 meters depth
1200’ is at	44 54.4321 N 67 03.0818 W	14.5 meters depth
1800’ is at	44 54.5255 N 67 03.0273 W	21.8 Meters depth
2100’ is at:	44 54.5573 N 67 03.0032 W	25.9 Meters depth
2700’ is at:	44 54.6317 N 67 02.9060 W	24.5 Meters depth
2850’ is at:	44 54.6511 N 67 02.8659 W	24.9 Meters depth
3000’ is at:	44 54.6567 N 67 02.8478 W	24.7 Meters depth
3600’ is at:	44 54.6040 N 67 02.7364 W	25.1 Meters depth
4000’ is at:	44 54.5954 N 67 02.6958 W	25.3 Meters depth

Benthic line was entangled in the chassis and was cut for retrieval.

Interim Report

Subtidal and intertidal benthic survey
Upper Cobscook Bay, Maine
August 7-8, 2013

Prepared for

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February 17, 2014

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Introduction

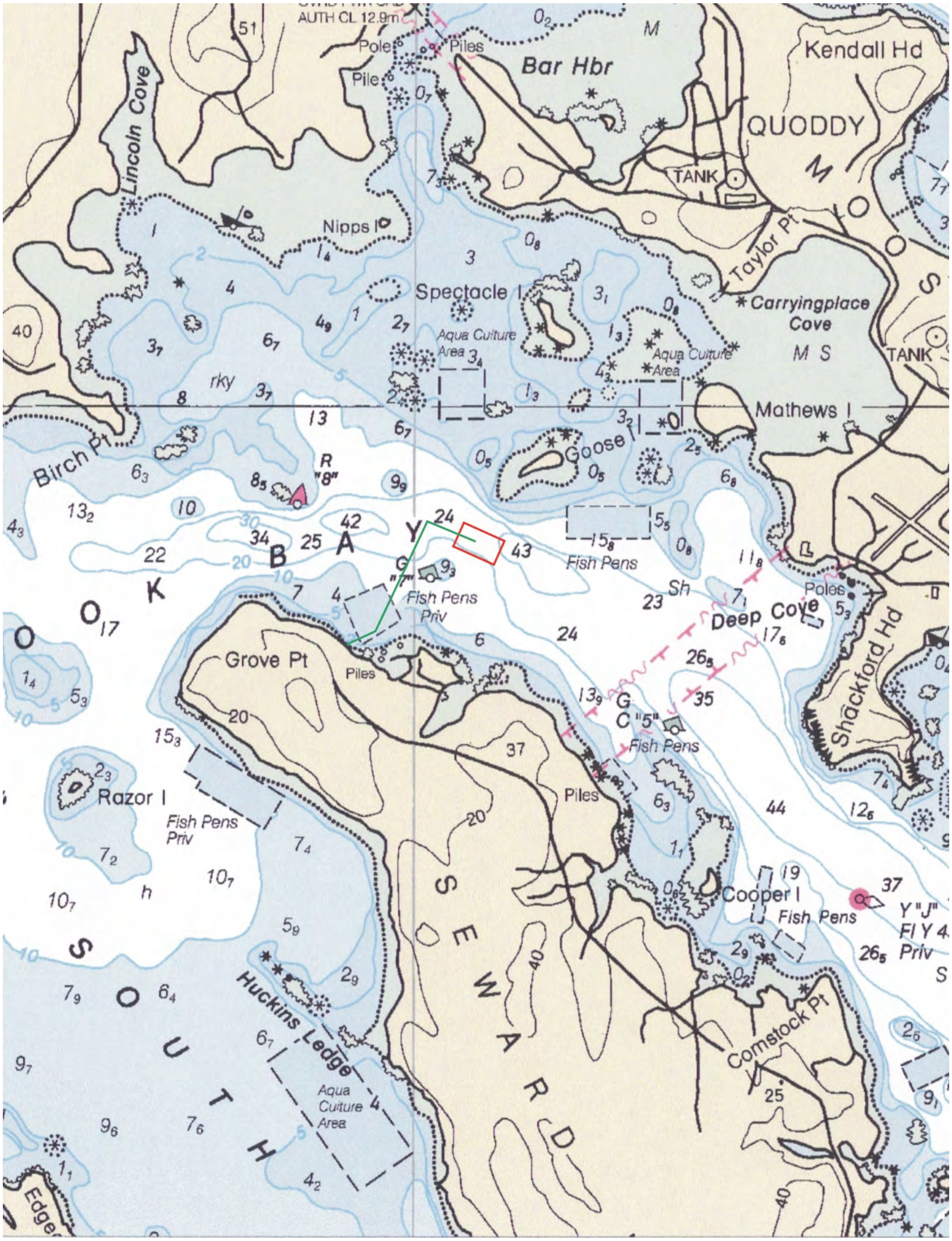
ORPC Maine, a subsidiary of Ocean Renewable Power Company Maine (collectively, ORPC) conducted both subtidal and intertidal monitoring of the power and data cable route associated with its Cobscook Bay Tidal Energy Project (CBTEP) on August 7 and 8, 2013 in a section of Upper Cobscook Bay (UCB) in the vicinity of Gove Point, North Lubec, Maine in an area shown in Figures 1 and 2. MER Assessment Corporation (MER) was requested to assist with habitat characterizations of the deployment areas (shown in red in Figures 1 and 2) and the subsea cable routes (shown in green in Figures 1 and 2).

MER conducted the subtidal habitats portion of the survey in collaboration with Brayden's Future, LLC divers on August 7, 2013, during a period of two daylight-hour slack tides (one low tide and one high tide) with average amplitude tides of 0.0m LW and 5.6m HW (0.0 ft. LW to 18.4 ft. HW). As previously reported, Upper Cobscook Bay is characterized by large amplitude tides and very strong tidal currents and the selected deployment area is subject to some of the strongest tidal currents in the region, indeed in the world. These strong currents present constraints on both the timing and duration of survey events (extremely short slack water period). Sampling was consequently conducted immediately before, during and after slack water (high tide or low tide) and the sampling stations sequenced to take advantage of slower current velocities in certain sections of the cable route during specific periods around slack water.

Benthic sampling was conducted *in situ* by the divers. The transects layout and benthic sampling stations for the Upper Cobscook Bay deployment area and subsea cable route are shown in Figures 3. No video recordings were made during the sampling event since video recording of the entire subtidal cable route had been recently completed on June 13, 2013.

The intertidal habitat characterization was completed during the afternoon of August 7, 2013 (LW 0.7m @ 1816) and the morning of August 8, 2013 (LW -0.2m @ 0639). This report serves as a summary of the interim results of the subtidal surveys; a complete, detailed report that includes the intertidal epifauna and benthic infauna analyses will follow once sample processing is completed and full results are available.

Figure 1. Site location map of Upper Cobscook Bay Deployment Area



Source: SeaClear II

Figure 2. Upper Cobscook Bay subsea cable route and subtidal/intertidal sampling station locations

Part I. Subtidal benthic sampling

Methods

Benthic sampling transect line deployment

A benthic sampling transect line was deployed along the bottom by ORPC on August 6, 2013 using their vessel Tide Tracker and a Hemisphere VS101 GPS positioning unit. The transect line was made up of four (4) 900 ft lines and one (1) 400 ft line for a total of 4,000 ft. The transect line was marked at approximately 330-ft (100m) intervals along the surface with buoys bearing the sampling station number; the coordinates for each sampling station are shown in Table 1 (see also Attachment I) following a course shown in Figures 2 and 3.

Table 1. Benthic sampling station location coordinates (Lat/Long) (Source: ORPC)

Distance (ft)	Latitude	Longitude
Station 1	44°54.264	67°03.217
Station 2	44°54.300	67°03.180
Station 3	44°54.349	67°03.135
Station 4	44°54.401	67°03.107
Station 5	44°54.448	67°03.077
Station 6	44°54.499	67°03.043
Station 7	44°54.546	67°03.012
Station 8	44°54.596	67°02.978
Station 9	44°54.643	67°02.867
Station 10	44°54.622	67°02.796
Station 11	44°54.605	67°02.727

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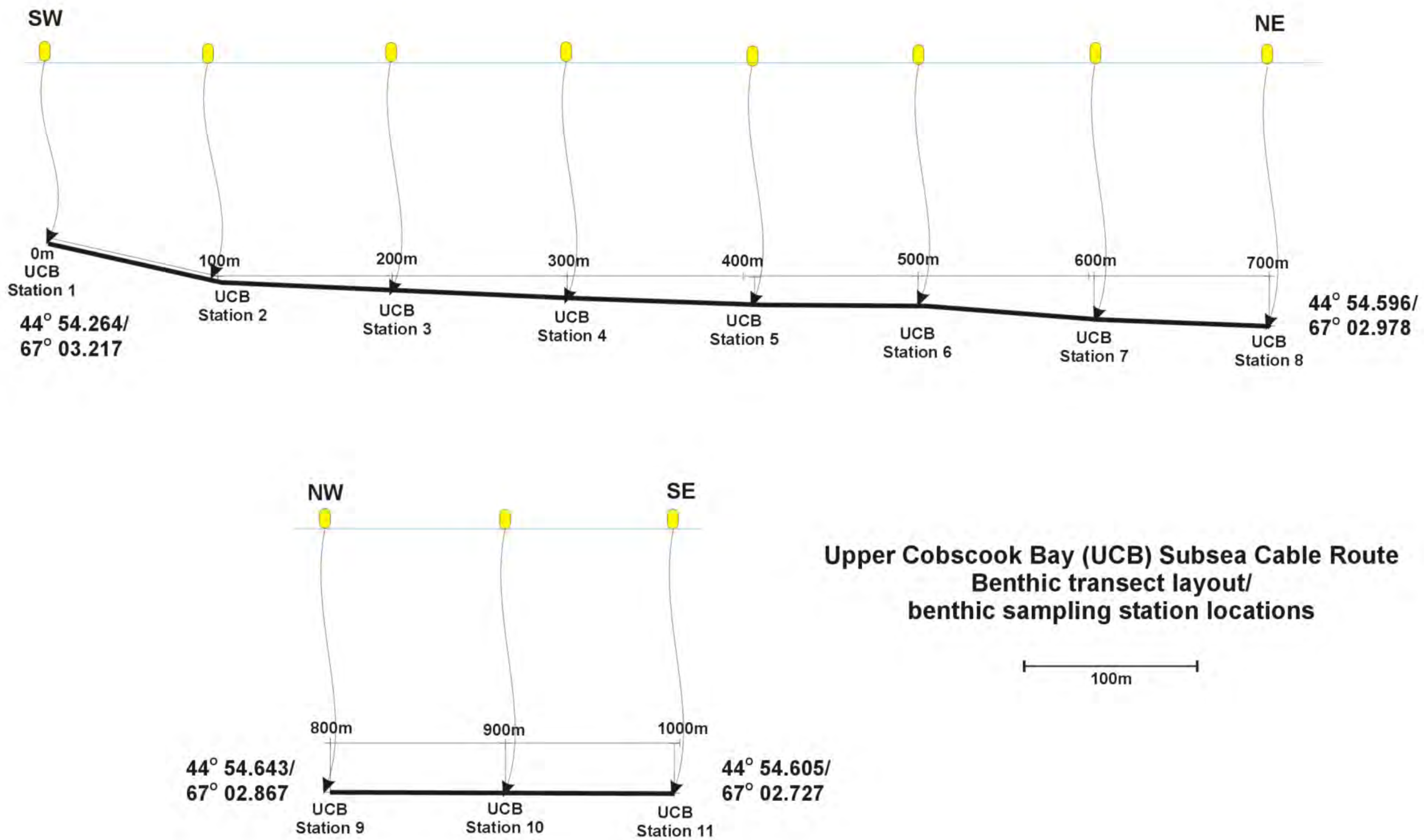
Figure 3. Benthic sampling transects Upper Cobscook Bay, 08/07/13



Subtidal benthic infauna sample processing

Benthic infauna samples were collected in triplicate at eleven (11) stations along the transect lines (33 samples). Sediment cores were taken using 4 in. diameter PVC pipe coring devices that were inserted to a depth of 10 cm or full resistance. The contents of the cores were washed through a U.S. Standard No. 35 sieve (500µm mesh). All material retained on the screen was transferred into plastic sample jars and the jars filled with 10% buffered formalin. Several drops of a 1% Rose Bengal staining solution were added to each sample to assist in the sorting of organisms. After 5-10 days of fixing, the formalin solution was decanted from the sample jars through a 500µm mesh sieve and the formalin volume replaced with 70% ethanol to insure preservation of the organisms' integrity, particularly the bivalves and other calcareous forms.

During processing, organisms are sorted from the sediment under lighted magnification lenses and/or binocular dissecting microscopes. Organisms collected from the samples are identified to the lowest practical taxonomic level and enumerated under a stereoscopic dissecting scope to 63x power. Data resulting from the sample processing are entered into an Excel® spreadsheet developed by MER that calculates statistics for abundance, taxa richness, and relative diversity (Shannon-Weiner Index, J'). Standard operation procedures for the collection and processing of benthic infauna samples are attached as Appendix I.

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Results

Subtidal benthic infauna analysis results

The results of the subtidal benthic infauna analyses for each station, based on the three replicates taken at each station, are summarized below in Table 2 and include total organisms found in the sample, abundance as organisms/0.1m^2, taxa richness (at species and family levels), and relative diversity (Shannon-Wiener). Detailed information on infauna composition at each station by replicate is included in Appendix II. Photos of the sediment composition at each station are included in Appendix III.

Table 2. Summary of benthic infauna analysis for subtidal samples collected at Cobscook Bay

	Total organisms			Abundance (#/0.1m^2)		Species Richness			Species Rel. Div.		Family Richness			Family Rel. Div.	
Station	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.
CB-1	1025	341.7	1128.2	4218	171940	57	39.0	8.0	0.817	0.002	41	30.3	6.2	0.755	0.002
CB-2	468	156.0	1112.0	1926	170382	42	26.7	32.9	0.765	0.000	34	22.0	28.7	0.771	0.000
CB-3	667	222.3	957.6	2745	145931	54	33.3	5.6	0.720	0.000	43	28.7	6.9	0.706	0.001
CB-4	539	179.7	189.6	2218	28888	50	30.0	28.7	0.619	0.002	40	25.7	13.6	0.617	0.002
CB-5	1743	581	33317	7172	5077428	58	37.3	6.2	0.571	0.001	50	33.7	4.2	0.572	0.001
CB-6	1824	608	15555	7505	2370516	55	36.7	16.9	0.580	0.006	48	31.7	10.9	0.531	0.005
CB-7*	2557	852	176304	10522	26868693	75	45.0	211	0.598	0.002	55	36.0	104	0.557	0.003
CB-8	1486	495	294	6115	44738	52	34.7	10.9	0.584	0.002	43	30.3	10.9	0.571	0.001
CB-9	414	138	6565	1703	1000449	38	20.0	24.7	0.678	0.019	33	17.7	27.6	0.671	0.017
CB-10	1357	452	7777	5584	1185292	56	36.0	12.7	0.655	0.008	50	31.3	16.2	0.601	0.011
CB-11	441	147	914	1815	139293	36	23.7	11.6	0.677	0.002	33	21.7	11.6	0.617	0.008

*** Based on 100% of Reps 1 and 2 70% of Rep 3**

Part II Intertidal Cable Crossing Area Sampling

Methods

Sampling and sample processing

Sampling of the intertidal cable crossing area was conducted on August 7, 2013 between 1415 and 1830 (HW 1202 18.4 ft/5.61m; LW 1816 0.7 ft/0.021m) and between 0530 and 0900 on August 8, 2013 (LW 0639 -0.2 ft/-0.006m; HW 1239 18.7 FT/5.70M - NOAA Tide Prediction Station for Eastport, Maine).

Sampling was conducted at three levels within the intertidal zone: 1) upper intertidal (H), 2) mid-intertidal (M), and 3) lower intertidal (L). Three subsets with three replicates each were sampled within each level, thus nine (9) samples were collected within each level for a total of twenty-seven (27) and labeled as shown in Figures 4. A panoramic overview photo and photos of the various intertidal sampling levels of the UCB intertidal cable crossing area are shown in Figures 5-8.

Within each subset of each sampling level a 0.25m^2 (0.5m/side) ½-inch PVC pipe frame was randomly tossed "behind the back" to avoid visual bias of the area to be sampled. Prior to sampling, a pre-sampling photo was taken of all sampling stations with frame and station label in place. Where present, all flora (rockweeds) within the frame were removed by cutting down to the base of the holdfast with either scissors or a knife and the collected material placed in a pre-labeled plastic bag. On hard substrate, following removal of the rockweed, all organisms within the frame were removed either by picking with forceps or scraping with a narrow paint scrapper or knife (barnacles were counted *in situ*). In softer sediment where coring was allowed, core samples were collected using 10cm (4 in.) diameter PVC pipe coring devices and samples processed as described above under Subtidal Benthic Infauna Sampling. All removed material, picked, scraped, or sieved, was placed in one or more pre-labeled 1000ml Nalgene container and 10% buffered formalin added to cover the organisms. Following collection of all flora and fauna, a post-sampling photo was taken of each station with frame and station label in place. Processing of core samples is the same as described above for the subtidal benthic core samples.

Figure 4. Intertidal sampling scheme and station labeling

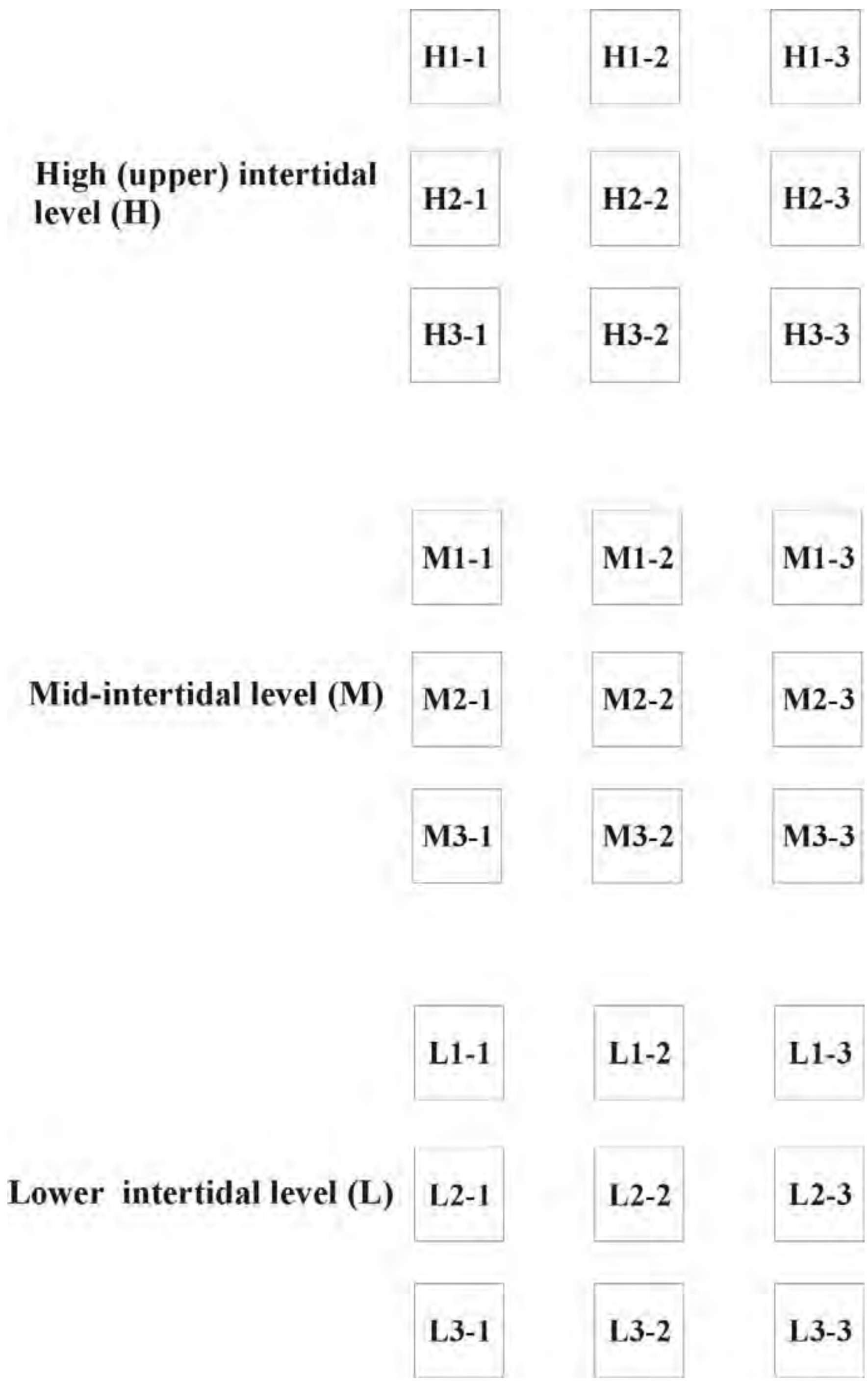

Figure 5. Panoramic view of intertidal cable crossing area

Figure 6. Upper (H) intertidal sampling level

Figure 7. Middle (M) intertidal sampling level

Figure 8. Lower (L) intertidal sampling level

At the completion of on-site sampling, wet-weight of all rockweed samples (including associated fauna, *e.g.* periwinkles) was measured using a Mettler Toledo BD601scale (600g ± 0.01g / SN 09031AB) tared for an 8 inch aluminum pie pan; some samples required multiple partial weighing. Following weight measurement and recording, the rockweed was placed in an 80cm by 46cm by 29cm fish tote partially filled with freshwater and swirled and agitated to remove all associated organisms. The rockweed was then removed and discarded and the contents of the fish tote poured through a 500µm mesh screen; material retained on the screen was then transferred to the Nalgene container corresponding to the station and replicate. All collected material was placed in one or more pre-labeled 1000ml Nalgene container and 10% buffered formalin added to cover the organisms.

Once at the lab, each sample was poured onto a 500µm mesh screen and rinsed. All large organisms, *e.g.* mussels and snails, were removed, identified, enumerated, and transferred back into the Nalgene container with 70% ethanol (ETOH) for archiving. The remaining small organisms were transferred into smaller Nalgene containers for subsequent microscopic identification and enumeration. Organisms collected from the samples will be identified to the lowest practical taxonomic level and enumerated under an Olympus SZ-60 stereoscopic dissecting scope to 63x power. Data resulting from the sample processing will be entered into an Excel® spreadsheet developed by MER that calculates statistics for abundance, taxa richness, and relative diversity (Shannon-Weiner Relative Diversity Index, J'). Standard operation procedures for the collection and processing of intertidal benthic infauna samples is the same as that for the subtidal benthic infauna samples (refer to Appendix I).

Results

Intertidal sampling

The upper (high) intertidal area (H) is composed of loose rocks overlying pebbles and coarse sand/fine gravel (see Figure 6). The rocks, cobble and pebbles at this upper level of the intertidal area appear subject to shifting, either from currents or waves affecting the area. No flora was observed in any of the three sub-sampling levels (H1, H2, and H3) within this area and the only fauna observed were unidentified amphipods sheltered within the rockweed "wrack" (H1) and cobble and coarse sand (H2, H3).

The mid-intertidal area (M) consists of a shallow layer of rocks, pebbles, and very coarse sand over a sticky marine clay base. The clay appears to provide some sediment stability within this level compared to the upper level, thus allowing it to support flora and fauna, albeit still limited and patchy (see Figure 7). The flora is rockweeds, *Fucus* spp. which occurs in small quantities, primarily as geminating plants. Epifauna observed during field sampling include barnacles, *Balanus balanoides*, common periwinkle, *Littorina littorea*, and green crabs, *Carcinus mae*nas.

The lower intertidal area (L) has a sediment composition similar to that of the mid-level area, but with slightly more softer silt, *i.e.* mud layer, as is evident from the post-sampling photographs (refer to Appendix IV). Flora is rockweeds, primarily *Fucus* spp. with some *Ascophyllum nodosum* present at all sublevels. Epifauna observed at this lower level include barnacles, *Balanus balanoides*, common periwinkle, *Littorina littorea*, green crabs, *Carcinus mae*nas, common limpet, *Tectura (Acmea) testudinalis*, blue mussels, *Mytilus edulis*, one soft shell clam, *Mya arenaria*, and unidentified amphipods.

Benthic infauna cores were taken using the same methods for collection and preservation described above for the subtidal benthic cores. These will be processed and analyzed using the same methods described above for the subtidal benthic cores and the final results will be reported in the final report along with the subtidal benthic infauna results.

A summary of observations of the intertidal habitat and associated flora and fauna is included in Table 3, below. Table 4, below, summarizes the *Fucus* spp. and *Ascophyllum nodosum* biomass data for the rockweed collected from the intertidal samples. Pre- and post-sampling photos of each intertidal sampling station are included here as Appendix IV.

Results of the epibenthic *in situ* identification and counts of fixed organisms and the identification and counts of organisms collected from the ¼m^2 frames are reported in Table 5. Identification and counts results of organisms collected in the benthic cores taken from within the frames where sediment composition allowed core samples to be collected are shown in Table 6.

Table 3. Upper Cobscook Bay intertidal habitat and epifauna community

Tide level	Photo #	Sediment type	Latitude/Longitude	Common name	Scientific name	Relative abundance
Upper (H)	**Append. III H-1-1 through H-3-3**	**Loose stone over gravel**	**44 54.226N/67 03.261W**	**Flora**		
				No flora	None	None
				Fauna		
				Amphipods	Unidentified	abundant (H1, H3); rare (H2)

Tide level	Photo #	Sediment type	Latitude/Longitude	Common name	Scientific name	Relative abundance
Mid (M)	**Append. III M-1-1 through M-3-3**	**Stone, gravel, coarse sand over "sticky" clay base**	**44 54.234N/67 03.255W**	**Flora**		
				Rockweed	*Fucus* spp.	rare (M1, M2, M3)
				Fauna		
				Common periwinkle	*Littorina littorea*	common (M2, M3), absent (M1)
				Barnacle	*Balanus balanoides*	comm./abundant (M1, M2)
				Green crab	*Carcinus maenas*	rare adjacent (M3)
				Amphipods	*Unidentified (small)*	common (M1)

Tide level	Photo #	Sediment type	Latitude/Longitude	Common name	Scientific name	Relative abundance
Lower (L)	**Append. III L-1-1 through L-3-3**	**Stone, gravel, clay, silt**	**44 54.243N/67 03.239W**	**Flora**		
				Rockweed	*Fucus* spp.	common/abundant (L1, L2), rare (L3)
					Ascophyllum nodosum	common (L2), occasional (L1, L3)
				Fauna		
				Common periwinkle	*Littorina littorea*	common (L1, L2, L3)
				Blue mussel	*Mytilus edulis*	rare (small) (L1, L2)
				Soft-shell clam	*Mya arenaria*	rare (L3)
				Limpet	*Tectura (Acmea) testudinalis*	rare (L3)
				Common barnacle	*Balanus balanoides*	abundant (L1, L2), occasional (L3)
				Amphipods	Unidentified	occasional (L2)
				Green crab	*Carcinus maenas*	common/occasional (L1, L2)

Table 4. UCB Gove Point *Fucus/Ascophyllum* biomass measurements

Station/Rep	Biomass (kg)	Comments
H-1-1	0.000	No flora
H-1-2	0.000	No flora
H-1-3	0.000	No flora
Mean	**0.000**	
S.D.	**0.000**	
Variance	**0.000**	
H-2-1	0.000	No flora
H-2-2	0.000	No flora
H-2-3	0.000	No flora
Mean	**0.000**	
S.D.	**0.000**	
Variance	**0.000**	
H-3-1	0.000	No flora
H-3-2	0.000	No flora
H-3-3	0.000	No flora
Mean	**0.000**	
S.D.	**0.000**	
Variance	**0.000**	
M-1-1	0.000	No flora
M-1-2	0.006	*Fucus* sp. (germinating)
M-1-3	0.000	No flora
Mean	**0.002**	
S.D.	**0.000**	
Variance	**0.000**	
M-2-1	0.000	No flora
M-2-2	0.003	*Fucus* sp. (germinating)
M-2-3	0.000	No flora
Mean	**0.001**	
S.D.	**0.000**	
Variance	**0.000**	

Station/Rep	Biomass (kg)	Comments
M-3-1	0.001	*Fucus* sp. (germinating)
M-3-2	0.000	No flora
M-3-3	0.000	No flora
Mean	**0.000**	
S.D.	**0.000**	
Variance	**0.000**	
L-1-1	1.397	*Fucus* spp.
L-1-2	0.147	*Fucus* spp.
L-1-3	0.057/2.586	*Fucus* spp./*Ascophyllum nodosum*
Mean	**1.400**	
S.D.	**1.250**	
Variance	**1.560**	
L-2-1	2.210/0.317	*Fucus* spp./*Ascophyllum nodosum*
L-2-2	1.149	*Fucus* spp.
L-2-3	0.375	*Fucus* spp.
Mean	**1.240**	
S.D.	**1.250**	
Variance	**1.550**	
L-3-1	0.162/410	*Fucus* spp./*Ascophyllum nodosum*
L-3-2	0.428	*Fucus* spp.
L-3-3	0.000	No flora
Mean	**0.330**	
S.D.	**0.300**	
Variance	**0.090**	

Table 5. Summary of intertidal epibenthic fauna analysis Cobscook Bay (Refer to Appendix V)

	Total organisms			Abundance (#/m^2)		Species Richness			Species Rel. Div.		Family Richness			Family Rel. Div.	
Station	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.
CB-H-1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
CB-H-2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
CB-H-3	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
CB-M-1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
CB-M-2	61	20.3	76.2	81.3	1220	2	1.7	0.2	0.284	0.050	2	1.7	0.2	0.284	0.050
CB-M-3	429	143	7223	572	120363	3	2.3	0.2	0.395	0.034	3	2.3	0.2	0.395	0.034
CB-L-1	1768	589	109414	2357	1750627	11	7.3	2.9	0.496	0.008	9	6.0	2.7	0.478	0.010
CB-L-2	2448	816	351213	3264	5619403	11	8.3	1.6	0.498	0.033	9	6.3	1.6	0.451	0.020
CB-L-3	583	194	7298	773	116761	10	6.3	0.9	0.591	0.001	8	4.7	1.6	0.448	0.025

Table 6. Summary of intertidal benthic infauna analysis for cores taken at Cobscook Bay (Refer to Appendix VI)

	Total organisms			Abundance (#/m^2)		Species Richness			Species Rel. Div.		Family Richness			Family Rel. Div.	
Station	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.	Total	Mean	Var.	Mean	Var.
CB-H-1	224	74.7	8188	922	1247775	3	1.7	1.6	0.202	0.053	3	1.7	1.6	0.202	0.053
CB-H-2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
CB-H-3	79	26.3	168	325	25637	6	3.3	1.6	0.498	0.050	6	3.3	1.6	0.498	0.050
CB-M-1	120	40	2049	494	312215	5	2.3	0.2	0.481	0.086	5	2.3	0.2	0.481	0.086
CB-M-2	215	71.7	1788	885	272523	4	2.7	0.2	0.662	0.029	4	2.7	0.2	0.662	0.029
CB-M-3	199	66.3	1103	819	168079	3	3	0.0	0.614	0.009	3	3	0.0	0.614	0.009
CB-L-1	774	258	9386	3185	1430417	4	4	0.0	0.505	0.017	4	4	0.0	0.505	0.017
CB-L-2	999	333	7506	4110	1143907	11	5.7	6.2	0.405	0.019	9	5	2.7	0.418	0.017
CB-L-3	534	178	3433	2197	523135	8	4	0.7	0.193	0.003	8	4	0.4	0.193	0.003

Discussion

As was previously found, with the exception of the softer, nearshore bottom, the sediment composition over much of the sampling area made collection of accurate benthic cores difficult to near impossible with some samples being "scooped" into the corer by hand by the diver. The benthic infauna data from these cores therefore need to be treated as semi-quantitative and generally characterizing the benthic infauna community rather than strictly quantitative.

The benthic infauna samples collected along the shallower portion of the subtidal cable route (Station 1-5) at the Upper Cobscook Bay site contain 113 species representing 81 families with polychaetes representing 51.6% of the organisms found. The families most represented, in rank order, are Sepulidae (*Spirorbis* sp.), Spionidae, Paraonidae, Cirratulidae, Terebellidae, Ampharetidae, Syllidae, Lumbrineridae and Opheliidae, together representing, 47% of all organisms, all families normally found in clean environments with sandy to coarse sediments. Other polychaete families represented include Capitellidae, Phyllodocidae, Polynoidea, Sigalionidae, Nephtyidae, Hesionidae, Nereidae, Scalibregmidae, Maldanidae, Eunicidae, Dorveillidae, Cossuridae, Pectinaridae, Flabelligeridae, Sabellidae and Orbiniidae. Mollusks, representing 18.3% of all organisms, are dominated by *Anomia* sp., found attached to rocks and shells, representing 13% of the organisms. Crustaceans account for 9.0% of all organisms and are dominated by barnacles and amphipods. Together these represent 87.3% of the 4,442 organisms identified from the 5 stations.

The benthic infauna samples collected along the deeper portion of the subtidal cable route (Station 6-11) at the Upper Cobscook Bay site contain 104 species representing 74 families with mollusks representing 52.9% of the organisms and being dominated by *Mytilus edulis* (36.2%) and *Anomia* sp. (12.4%). Polychaetes represent only 11.6% of the organisms found. The families most represented, in rank order, are Sepulidae (*Spirorbis* sp.), Polynoidea, Eunicidae, Sigalionidae, Capitellidae, Terebellidae, Syllidae, Ampharetidae, and Cirratulidae. Other polychaete families represented include Phyllodocidae, Spionidae, Paraonidae, Opheliidae, Nereidae, Pectinaridae, Sabellidae and Orbiniidae. Crustaceans account for only 3.5% of all organisms; entoprocts represent 25.6% of the population. Together these represent 91.7% of the 8,079 organisms identified from the 6 stations.

Combined, the shallow and deep sampling locations contain 12,521 organisms representing 143 species and 102 families; this is somewhat greater than the 127 species and 90 families found in the 2011 baseline samples as well as the 131 species representing 78 families found in a similar study in Deep Cove in Lower Cobscook Bay in 2009. All of these sampling events are indicative of the biological and functional diversity for which Cobscook Bay and the region is renowned.

The intertidal area remains essentially unchanged other than a reduction in *Fucus* spp. and *Ascophyllum nodosum* in the Middle level and the decrease in number of blue mussels, *Mytilus edulis* in the Lower level where they were found to be abundant during the July 2011 baseline survey. This reduction in mussels, most of which were rather small in 2011, may be related to the increased presence of the green crab, *Carcinus maenas*, which was commonly to occasionally found in the Lower level (L1 and L2; none in L3) in this recent survey but absent in 2011. *C. maenas* has been implicated in a near complete elimination of small soft-shell clams, *Mya arenaria*, in several coastal areas of Maine during the 2013 summer season, especially Casco Bay (pers. obs.); *C. maenas* is known to prey on mussels as its preferred diet (Ropes, 1968).

The intertidal grid sample results again showed the upper, high intertidal area (H) area being essentially barren of organisms except where the seaweed wrack provides shelter to small amphipods (see benthic core results below). The mid-intertidal (M) and lower-intertidal levels (L) offer habitat for isopods, *Idotea* spp., primarily associated with rockweeds, which are the most numerous species at 2,972 individuals representing 56.2% of all organisms found. The common barnacle, *Balanus* sp., ranks second at 1,124 individuals counted representing 21.3% of all organisms found. Other species found, in rank order, are the smooth periwinkle (9.6%), *Littorina obtusata*, common periwinkle (7.1%), *L. littorea*, and rough periwinkle (2.1%), *L. saxatilis*; common amphipods, *Gammarus* sp, represent 147 organisms or 2.8% of the organisms found. Together these species represent 5,239 or 99.1% of the 5,289 organisms found. Other organisms found in very small numbers include Cumaceans, *Diastylis quadrispinosa*, the green crab, *Carcinus maenas*, the limpet, *Tectura (Acmea) testudinalis*, mud snail, *Ilyanassa* sp., blue mussel, *Mytilus edulis*, and oligochaetes.

Compared to the 2011 samples results, the mid-level (M) shows a reduction in both number of species and abundance, but this reduction appears related to the reduced amount of rockweed cover, (which provides both habitat as well as protection from desiccation) in 2013 within the level; the reduced amount of rockweed may or may not be related to the installation of the cable since rockweed cover is naturally patchy in the intertidal as shown in Figures 5 and 6. Results for the lower intertidal level (L) are very similar to those of the 2011 sampling event with number of species higher in 2013, although the dominant species remain the same, and abundance being very similar.

The intertidal benthic cores are dominated by oligochaetes representing 2,298 or 79.1% of the 3,144 organisms found in the samples; these are found primarily in the lower intertidal level with some in the middle intertidal level. The isopod, *Idotea* sp., is found in the lower level (associated with rockweeds) and represents 9.4% of the benthic cores population. Amphipods, *Talochestia* sp., found in the upper (H) area associated with wrack weed, and *Gammarus* spp. found in the lower level, represent 7.1% and 6.0% of the population, respectively. Together, these species represent 3,008 or 95.7% of the organisms found in the benthic cores taken in the intertidal area.

The results of the intertidal benthic infauna core samples show strong similarity between the 2011 and 2013 samples, the number of species being the same and the dominant taxa being oligochaetes and nematodes in the mid-level. In the lower level (L) the number of species is higher in 2013 compared to 2011, but the population is again dominated by oligochaetes and nematodes. The 2011 lower level benthic core samples also contained blue mussels, *Mytilus edulis*, which were absent in 2013. Again, as mentioned above, the lack of small mussels may be related to the increase in green crabs observed at the site. The 2013 samples contained isopods and amphipods not seen in 2011. These latter differences are likely attributable to normal seasonal and inter-annual differences.

Conclusions

Based on the results of the subtidal samples, it appears that the sediment composition at the sampling stations has not changed substantially since the initial baseline survey of 2011. Some changes between the baseline and the most recent sampling may be due to relocation of the sampling station to the "As-built" cable location from the initially planned route. As we stated in our preliminary report of September 2013, in general, based on the reviews of video recorded over the entire subsea cable route that indicate little if any disturbance to the bottom, little change in the benthic infauna was anticipated other than slight differences resulting from timing of the sampling (August 2013 versus July 2011). Indeed, the number of species and families represented in the 2013 samples exceed those found in July 2011, with nearly all of the species and families found in the baseline still being represented. However, the number of organisms found in 2013 is much greater than the number found during the baseline in 2011. The exact reason for this is not clear, although some of the increase may be attributable to an increased amount of material collected by the samplers, slight differences in the sediment composition between the 2013 and 2011 sampling locations and the slight difference in timing of the sampling between August 2013 and July 2011. Additionally, prior to being permitted for the project, the area was had been dragged for scallops and urchins; however, dragging is currently prohibited within the project permitted area. The reduction or complete elimination of dragging-related disturbance may also be contributing to the greater abundance. Regardless of the cause, the very high abundance indicates a healthy and highly productive benthic community with no discernible continuing effects from either the installation or operation of the cable.

Similarly, the intertidal area remains essentially unchanged other than a reduction in *Fucus* spp. and *Ascophyllum nodosum* in the middle level (M) and the decrease in number of blue mussels, *Mytilus edulis*, in the lower level (L) where they were found to be abundant during the July 2011 baseline survey. This reduction in mussels may be related to the increased presence of the green crab, *Carcinus maenas*, in the area.

Taken together, the subtidal and intertidal results indicate negligible, if any, continuing effects related to the installation and operation of the cable. Indeed, the restrictions imposed on dragging within the subtidal area as a result of the installations and the resulting reduced disturbance to the bottom may be having beneficial effects by stabilizing the habitat and consequently the associated benthic community.

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Appendix I

MER Assessment Corporation Standard Operating Procedures (SOP)s for benthic sampling and processing

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MER Assessment Corporation
Standard Operating Procedure (SOP) 001-D
Benthic core collection by Diver
Revision 0, 9 January 2006

1. Once the diver has selected the location for replicate, *e.g.* 5m Rep #2, all three cores marked #2 are removed from the vinyl-clad wire sampler carrier basket and placed open end down onto the sea floor;
2. Once aligned, all three samplers are pushed into the sediment to either full depth or full resistance, whichever is reached first.
3. Once inserted, the diver slides a gloved hand along the side of the PVC corer until he reaches the bottom at which point the corer is tipped within the sediment to allow the gloved hand to be inserted under the corer, thus maintaining the contents in the corer. With hand in place, the corer is removed from the sediment and the tethered end cap placed over the open end of the corer.
4. The corer is always maintained in the upright position (permanently fixed cap up) and placed back into the vinyl-clad wire carrier.
5. The sequence is continued until all samples at all replicate locations are collected and placed in the carriers.
6. When only sediment chemistry sampling is required, consisting of simply three corers, one taken at each of the replicate locations, the diver can easily return the carrier to the surface himself. If, on the other hand, full sampling is carried out requiring a total of nine (9) cores, the carrier baskets are clipped either into the thimble at the end of the transect line along with the tag line, or into the loop tied into the transect line;
7. The carriers are then gently hauled to the surface as the transect line is retrieved off the bottom.

Note: Except in extremely soft, nearly flocculent, bottom conditions it is difficult to obtain a full 10-15 cm sediment core due to water pressure build up within the corer as it is inserted into the bottom, even if slightly vented and inserted slowly, and due to friction of the soft sediment against the inner wall of the PVC corer. It is more common to obtain 5-6 cm of sediment. On hard-packed or coarse bottom types, direct, vertical insertion of the corers is virtually impossible, and a slightly oblique angle toward the bottom is taken to insure collection of at least the top 4-5 cm of bottom surface material; in gravel conditions coring is essentially impossible and surface scrapings of the top 3-4 cm of bottom material. It should be noted that the DEP has now recognized the difficulty posed by such coarse bottom conditions and, in conjunction with the DMR is now reviewing all sites to determine which site might be exempted from sediment chemistry measurements; to date at least three sites have received such exemption.

Revision 0
Date: 9 January 2006

MER Assessment Corporation
Standard Operating Procedure (SOP) 001-R
Benthic core collection by Remote PONAR Drop
Revision 0, 9 January 2006

1. Prior to deployment the swivel shackle connecting the Ponar sampler to the retrieval line must be verified to be straight and not cocked, which would result in improper, oblique contact with the bottom, and the sample securing screens verified as being securely in place.
2. In soft bottom conditions, when properly deployed in a near vertical drop through the water column onto the bottom, the Ponar sampler collects a complete bottom sample that reaches fully to the covering screens. In such case, as many as three full cores can be recovered from the single sample collection, the ideal situation since the full triplicate set comes from a single location.
3. a) If the sampling calls only for redox and sulfide measurement, a 4 in. diameter core imprint is made on the sediment surface and half the circle is scooped out to a depth of approx. 2 cm with a plastic spoon and placed in a 125 ml mixing container for redox measurement and extraction of the sulfide subsample;
   b) If additional sediment chemistry analyses are required, the second half of the circle is partly collected for metal analysis and placed in a pre-labeled *Whirl-Pak*® and the other portion scooped out to a depth of 2 cm for TOC/TON analyses placed in a pre-labeled *Whirl-Pak*® (refer to MER LW-728 (LB-12 Chain of Custody and Labeling techniques Page 34/208);
   c) If additional full cores are required for benthic infauna and granulometry, two corers are set on the sediment surface within the Ponar, either two on one side and one on either side, thus leaving one area open in addition to the area already sampled for sediment chemistry.
4. The plastic corers are inserted into the bottom at a slight oblique angle due to the curve of the Ponar clam shell walls; a gloved hand is inserted into the open slot and slip under the first corer and sediment pushed up into the corer as fully as possible and the corer removed with hand in place.
5. The same procedure is repeated for the other corer, excepting that the gloved hand must be inserted under the center support bar of the Ponar making removal of the corer somewhat more difficult.
6. As with diver collected cores, the corers are always maintained in the upright position to avoid sloughing or mixing of the sediment core.

Note 1: In hard-packed bottoms it is sometimes difficult to collect sufficient material to allow collection of a single core imprint and two full cores; it is therefore sometimes necessary to make repeated drops in order to secure sufficient material for full sample collection. Although re-sampling the same hole previously sampled is to be avoided (and is rather unlikely), every effort is made during repeated sampling of a replicate location to maintain the boat as close to station as possible based on GPS position or a weighted tag line making the location, or both.

MER Assessment Corporation
Standard Operating Procedure (SOP) 003
Benthic Sample Tracking, Sorting, and Identification
Revision 0, 9 January 2006

Sample Tracking

1. All sample containers carry the following identification label:

Project: ______________________	Sample I.D. No. _______________
Sampling Date: ________________	Site: ________________________
Station: ______________________	Rep. No. _____________________
Preservative: __________________	Transfer Date: ________________

One ***external*** label will appear on the exterior of the sample container and a second ***internal*** label will be placed inside the container along with the sample.

2. In the initial sorting process, the container into which sorted organisms are placed will carry both an ***external*** and ***internal*** label identical to the one appearing on the original sample container. Any subsequent containers will likewise carry these labels. ***The internal label will remain with the sample at all times.***

3. If the project calls for separation of taxa, in the identification process, each vial or container representing a specific taxonomic group will contain the following label:

Project: ______________________	Sample I.D. No. _______________
Sampling Date: ________________	Site: ________________________
Station: ______________________	Rep. No. _____________________
Taxon: ____	

All vials from a specific sample will be maintained together and placed in a container(s) bearing external and internal labels identical to those of the original sample container.

Benthic Collection

Samples are taken with a PVC pipe coring devices, which are inserted to a depth of 10 cm or full resistance whichever is greater. The contents of the cores are then washed through a U.S. Standard No. 35 sieve (500µ mesh), all material retained on the screen is transferred into pre-labeled plastic sample jars, and filled with 10% buffered formalin. Several drops of a 1% Rose Bengal staining solution are added to each sample to assist in the sorting of organisms. After 5 days of fixing in 10% Formalin, the formalin solution is decanted from the sample jars through a 1 mm mesh sieve and the formalin volume replaced with 70% ethanol to insure preservation of the organisms' integrity, particularly the bivalves and other calcareous forms. If a loss of stain occurs after transfer to 70% ETOH, samples will be re-stained prior to sorting.

Sample sorting

1. To ensure complete picking/sorting, samples are to be picked and scanned until no organisms have been found after two or three scans, depending on the amount of detritus. Samples are magnified to aid the sorting process.

2. To prevent confusion and/or mixing of samples, only ***one (1)*** sample will be open at any given time. Samples are also processed by site.

3. All material from the original sample will be retained in the original container and archived for one year after the sampling date unless other arrangements are made.

Identification

1. Organisms present in sorted samples, are identified to the lowest practical taxonomic level. All samples are examined using a binocular microscope.

2. To prevent confusion and/or mixing of samples, only ***one (1)*** sample will be open at any given time. Samples are also processed by site.

3. All organisms are returned to sample container and archived for future reference.

4. A minimum of 10% of the total samples collected, sorted and identified during a specific project will be checked for thoroughness of picking/sorting, and accuracy of enumeration and identification by the person responsible for QA/QC. If an error exceeds 5%, additional samples will be checked until an accuracy level of 95% is achieved

Revision 0
Date: 9 January 2006

Appendix II

Detailed benthic infauna data for subtidal core samples collected at Cobscook Bay (CB)

Station 1

	Sta 1-1		Sta 1-2		Sta 1-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		4		5		6
Eteone spp.	4		5		5	
Phyllodoce sp.					1	
Sigalionidae		6		3		1
Pholoe minuta	6		3		1	
Nephtyidae		0		3		6
Aglaophamus neotenus			1		3	
Nephtys sp.			2		3	
Syllidae		1		6		2
Exogone spp.	1		6		2	
Nereidae		5		2		2
Nereis spp.	5		2		2	
ORDER Capitellida						
Capitellidae		1		2		2
Capitella capitata	1					
Mediomastus ambiseta			2		2	
Scalibregmidae		1		0		1
Scalibregma inflatum	1				1	
Maldanidae		0		0		5
Praxillella praetermisa					5	
Opheliidae		28		20		13
Ophelina acuminata	28		20		13	
ORDER Spionida						
Spionidae		79		141		74
Polydora spp.	38		92		39	
Prionospio steenstrupi	15		15		18	
Marenzelleria (Scolecolepedis) viridis	1		2		2	
Spio setosa	25		31		15	
Spiophanes bombyx			1			
Paraonidae		24		36		19
Aricidea catherinae	6		5		5	
Aricidea suecica	18		31		14	
ORDER Eunicida						
Lumbrineridae		6		7		10
Lumbrineris spp.	6		6		8	
Ninoe nigripes			1		2	
ORDER Ariciida						
Orbiniidae		14		3		13
Scoloplos sp.	14		3		13	
ORDER Cirratulida						
Cirratulidae		25		29		10
Tharyx spp.	25		29		10	

Station 1 (continued)

	Sta 1-1		Sta 1-2		Sta 1-3	
	Species	**Family**	**Species**	**Family**	**Species**	**Family**
Cossuridae		1		4		1
Cossura longicirrata	1		4		1	
ORDER Terebellida						
Pectinaridae		1		0		0
Pectinaria (Cistena) gouldii	1					
Ampharetidae		49		21		22
Ampharete sp.	35		13		15	
Asabellides oculata					1	
Melinna cristata	1					
Anobothrus gracilis	13		8		6	
Terebellidae		3		5		10
Amphitrite sp.			1			
Polycirrus sp.			2			
Terebellides stroemi	3		2		10	
ORDER Sabellida						
Sabellidae		0		0		2
Fabricia sabella					1	
Psuedopotamilla (Potamilla) neglecta					1	
CLASS CLITELLA		12		38		19
Oligochaeta	12		38		19	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Ampeliscidae		13		0		1
Ampelisca spp.	13				1	
Corophiidae		2		1		1
Corophium spp.	2		1		1	
Gammaridae		0		0		2
Gammarus sp.					2	
Lysianassidae		1		0		0
Anonyx sp.	1					
Photidae		5		1		4
Photis spp.	5		1		4	
Order Cumacea						
Diastylidae		25		3		19
Diastylis quadrispinosa	25		3		19	
Leuconidae		1		1		3
Eudorella truncatula	1		1		3	

Station 1 (continued)

	Sta 1-1		Sta 1-2		Sta 1-3	
	Species	Family	Species	Family	Species	Family
MOLLUSCA						
Class Gastropoda						
Order Archaeogastropoda						
Acmaeidae		1		0		10
Tectura (Acmea) testudinalis	1				10	
Class Bivalvia						
Order Protobranchia						
Nuculidae		27		36		9
Nucula proxima	27		36		9	
Order Heterodontida						
Astartidae		0		1		0
Astarte sp.			1			
Carditidae		0		0		1
Cyclocardia (Cardita) borealis					1	
Thyasiridae		2		0		0
Thyasira gouldii	2					
Solenidae		8		3		2
Ensis directus	8		3		2	
Myidae		0		1		0
Mya truncata			1			
Order Eudesmodontia						
Thraciidae		1		0		0
Thracia sp.	1					
Lyonsiidae		1		0		1
Lyonsia hyalina					1	
Lyonsia arenosa	1					
CNIDARIA						
Class Anthozoa						
Order Actiniaria						
Edwardsiidae		0		1		1
Edwardsia elegans			1		1	
ENTROPROCTA		0		0		24
Class Ectoprocta					24	
PHORONIDA		0		0		1
Phoronidae						
Phoronis architecta					1	
RHYNCHOCOELA		2		1		0
Unid. Nemertea	2		1			
ASCHELMINTHES						
Class Nematoda		1		4		0
Unid.	1		4			

Station 1 (continued)

SPECIES Station 1	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	350	378	297	1025	341.7	1128.2
Abundance (organisms/0.1 m²)	4320.8	4666.4	3666.5	12653.6	4217.9	171940.0
Species richness (No. species)	37	37	43	57	39.0	8.0
Rel. Div. by sp.	0.839	0.754	0.857	2.450	0.817	0.002
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	350	378	297	1025	341.7	1128.2
Abundance (organisms/0.1 m²)	4320.8	4666.4	3666.5	12653.6	4217.9	171940.0
Family richness (No. Families)	31	27	33	41	30.3	6.2
Rel. Div. by Family	0.772	0.688	0.804	2.264	0.755	0.002

Station 2

	Sta 2-1		Sta 2-2		Sta 2-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		0		1		1
Eteone spp.			1		1	
Polynoidae		0		1		0
Harmothoe sp.			1			
Sigalionidae		2		5		2
Pholoe minuta	2		5		2	
Nephtyidae		1		5		3
Aglaophamus neotenus	1		1		1	
Nephtys sp.			4		2	
Hesionidae		0		1		0
Microphthalmus aberrans			1			
ORDER Capitellida						
Capitellidae		0		1		0
Mediomastus ambiseta			1			
Opheliidae		6		5		4
Ophelina acuminata	6		5		4	
ORDER Spionida						
Spionidae		14		17		13
Polydora spp.	1		3		4	
Prionospio steenstrupi	11		12		8	
Spio setosa	2		2		1	
Paraonidae		6		7		6
Aricidea catherinae					3	
Aricidea suecica	6		7		3	
ORDER Eunicida						
Lumbrineridae		13		20		22
Lumbrineris spp.	13		20		22	
ORDER Ariciida						
Orbiniidae		4		1		3
Scoloplos sp.	4		1		3	
ORDER Cirratulida						
Cirratulidae		1		1		2
Tharyx spp.	1		1		2	
Cossuridae		0		1		1
Cossura longicirrata			1		1	

Station 2 (continued)

	Sta 2-1		Sta 2-2		Sta 2-3	
	Species	Family	Species	Family	Species	Family
ORDER Terebellida						
Ampharetidae		4		5		8
Ampharete sp.	3		1		8	
Asabellides oculata	1					
Anobothrus gracilis			4			
Terebellidae		32		49		56
Terebellides stroemi	32		49		56	
ORDER Flabelligerida						
Flabelligeridae		0		1		0
Pherusa spp.			1			
ORDER Sabellida						
Sabellidae		0		0		3
Psuedopotamilla (Potamilla) neglecta					3	
CLASS CLITELLA		0		6		0
Oligochaeta			6			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Ampeliscidae		3		5		2
Ampelisca spp.	3		5		2	
Photidae		0		6		3
Photis spp.			6		3	
Podoceridae		0		0		1
Dulichia porrecta					1	
Order Cumacea						
Diastylidae		17		27		24
Diastylis quadrispinosa	17		27		24	
Leuconidae		0		1		0
Eudorella truncatula			1			
CLASS OSTRACODA						
OSTRACODA		0		1		0
Unid.			1			
MOLLUSCA						
Class Bivalvia						
Order Protobranchia						
Nuculidae		2		8		18
Nucula delphinodonta	1		4		5	
Nucula proxima	1		4		13	
Nuculanidae		1		1		1
Yoldia sp.	1		1		1	

Station 2 (continued)

	Sta 2-1		Sta 2-2		Sta 2-3	
	Species	Family	Species	Family	Species	Family
Order Pteroconchida						
Mytilidae		0		1		1
Modiolus modiolus					1	
Mytilus edulis			1			
Order Heterodontida						
Astartidae		0		1		0
Astarte sp.			1			
Thyasiridae		2		0		0
Thyasira gouldii	2					
Tellinidae		0		1		0
Macoma sp.			1			
Solenidae		1		0		0
Ensis directus	1					
Myidae		0		1		0
Mya arenaria			1			
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		0		0		1
Boltenia ovifera					1	
ASCHELMINTHES						
Class Nematoda		0		4		0
Unid.			4			

SPECIES Station 2	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	109	184	175	468	156.0	1118.0
Abundance (organisms/0.1 m²)	1345.6	2271.5	2160.4	5777.5	1925.8	170382.1
Species richness (No. species)	20	34	26	42	26.7	32.9
Rel. Div. by sp.	0.780	0.768	0.748	2.3	0.765	0.000
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	109	184	175	468	156.0	1118.0
Abundance (organisms/0.1 m²)	1345.6	2271.5	2160.4	5777.5	1925.8	170382.1
Family richness (No. Families)	16	29	21	34	22.0	28.7
Rel. Div. by Family	0.801	0.765	0.748	2.3	0.771	0.000

Station 3

	Sta 3-1		Sta 3-2		Sta 3-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		1		0		0
Eteone spp.	1					
Sigalionidae		2		3		3
Pholoe minuta	2		3		3	
Syllidae		8		23		13
Exogone spp.	6		19		12	
Syllis cornuta	2		4			
Sphaerosyllis erinaceus					1	
Hesionidae		1		0		0
Microphthalmus aberrans	1					
Nereidae		1		0		0
Nereis spp.	1					
ORDER Capitellida						
Maldanidae		2		2		4
Praxillella praetermisa	2		2		4	
Opheliidae		2		3		3
Ophelina acuminata	2		3		3	
ORDER Spionida						
Spionidae		15		20		30
Polydora spp.	5		8		14	
Prionospio steenstrupi	4		5		6	
Marenzelleria (Scolecolepedis) viridis	2					
Spio setosa	4		7		10	
Paraonidae		68		91		83
Aricidea catherinae					1	
Aricidea suecica	68		91		82	
ORDER Eunicida						
Lumbrineridae		0		1		0
Lumbrineris spp.			1			
ORDER Ariciida						
Orbiniidae		2		2		0
Scoloplos sp.	2		2			
ORDER Cirratulida						
Cirratulidae		21		20		11
Tharyx spp.	21		20		11	

Station 3 (continued)

	Sta 3-1		Sta 3-2		Sta 3-3	
	Species	Family	Species	Family	Species	Family
ORDER Terebellida						
Ampharetidae		1		4		0
Ampharete sp.			2			
Melinna cristata	1		2			
Terebellidae		3		0		0
Amphitrite sp.	1					
Terebellides stroemi	2					
ORDER Sabellida						
Sabellidae		0		0		1
Euchone elegans					1	
Serpulidae		10		20		2
Filograna implexa			1			
Spirorbis spp.	10		19		2	
CLASS CLITELLA		5		10		0
Oligochaeta	5		10			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Aoridae		11		18		5
Unciola sp.	11		18		5	
Ampeliscidae		1		1		1
Ampelisca spp.	1		1		1	
Corophiidae		0		0		1
Corophium spp.					1	
Lysianassidae		2		3		1
Anonyx sp.	2		3		1	
Order Cumacea						
Diastylidae		0		2		1
Diastylis quadrispinosa			2		1	
Order Tanaidae						
Tanaidae		10		3		10
Tanais sp.	10		3		10	
Order Isopoda						
Idoteidae		0		0		1
Edotea spp.					1	
CLASS MAXILLOPODA						
Order Harpacticoida		1		0		1
Harpacticidae						
Harpacticus sp.	1				1	
Order Thoracica						
Balanidae		0		2		0
Balanus sp.			2			

Station 3 (continued)

	Sta 3-1		Sta 3-2		Sta 3-3	
	Species	Family	Species	Family	Species	Family
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		0		0		2
Stenosemus (Ischnochiton) albus					2	
Class Gastropoda						
Order Archaeogastropoda						
Trochidae		0		0		2
Margarites spp.					2	
Acmaeidae		0		0		3
Tectura (Acmea) testudinalis					3	
Class Bivalvia						
Order Protobranchia						
Nuculidae		0		1		1
Nucula proxima			1		1	
Order Pteroconchida						
Mytilidae		1		1		2
Crenella glandula	1					
Musculus sp. (niger)			1		2	
Mytilus edulis						
Order Heterodontida						
Astartidae		1		1		1
Astarte sp.	1		1		1	
Carditidae		1		0		1
Cyclocardia (Cardita) borealis	1				1	
Cardiidae		0		3		0
Cerastoderma pinnulatum			3			
Tellinidae		0		1		0
Macoma sp.			1			
Myidae		1		0		1
Mya arenaria					1	
Mya truncata	1					
Order Eudesmodontia						
Lyonsiidae		0		0		1
Lyonsia arenosa					1	
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		1		0		2
Boltenia ovifera	1				2	
Mogulidae		1		0		1
Molgula sp.	1				1	

Station 3 (continued)

	Sta 3-1		Sta 3-2		Sta 3-3	
	Species	Family	Species	Family	Species	Family
CNIDARIA						
Class Anthozoa						
Order Ceriantharia		1		1		1
Cerianthidae						
Cerianthus borealis	1		1		1	
ENTROPROCTA		19		30		6
Class Ectoprocta	19		30		6	
RHYNCHOCOELA		1		0		0
Unid. Nemertea	1					
ASCHELMINTHES						
Class Nematoda		4		0		8
Unid.	4				8	

SPECIES Station 3	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	198	266	203	667	222.3	957.6
Abundance (organisms/0.1 m²)	2444.3	3283.8	2506.0	8234.1	2744.7	145930.5
Species richness (No. species)	35	30	35	54	33.3	5.6
Rel. Div. by sp.	0.729	0.726	0.706	2.2	0.720	0.000
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	198	266	203	667	222.3	957.6
Abundance (organisms/0.1 m²)	2444.3	3283.8	2506.0	8234.1	2744.7	145930.5
Family richness (No. Families)	30	25	31	43	28.7	6.9
Rel. Div. by Family	0.723	0.722	0.673	2.1	0.706	0.001

Station 4

	Sta 4-1		Sta 4-2		Sta 4-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Polynoidae		1		2		1
Harmothoe sp.	1		2		1	
Sigalionidae		1		3		1
Pholoe minuta	1		3		1	
Syllidae		12		8		6
Exogone spp.	7		7		6	
Paraprionosyllis longicirrata	1					
Syllis cornuta	2		1			
Sphaerosyllis erinaceus	2					
ORDER Capitellida						
Opheliidae		1		0		0
Ophelina acuminata	1					
ORDER Spionida						
Spionidae		4		0		13
Polydora spp.	1				6	
Marenzelleria (Scolecolepedis) viridis					2	
Spio setosa	3				5	
Paraonidae		14		11		7
Aricidea catherinae	2				1	
Aricidea suecica	10		7		6	
Paraonis sp.			4			
Tauberia gracilis	2					
ORDER Eunicida						
Dorvilleidae		2		0		0
Protodorvillea kefersteini	2					
ORDER Cirratulida						
Cirratulidae		14		8		3
Tharyx spp.	14		8		3	
ORDER Terebellida						
Ampharetidae		0		0		1
Ampharete sp.					1	
Terebellidae		1		0		0
Terebellides stroemi	1					
ORDER Sabellida						
Serpulidae		106		102		4
Filograna implexa						
Spirorbis spp.	106		102		4	

Station 4 (continued)

	Sta 4-1		Sta 4-2		Sta 4-3	
	Species	**Family**	**Species**	**Family**	**Species**	**Family**
CLASS CLITELLA		4		10		10
Oligochaeta	4		10		10	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Aoridae		1		0		0
Unciola sp.	1					
Ampeliscidae		3		1		0
Ampelisca spp.	3		1			
Corophiidae		0		1		3
Corophium spp.			1		2	
Erichthonius sp.					1	
Lysianassidae		1		2		1
Anonyx sp.	1		2		1	
Photidae		1		0		0
Photis spp.	1					
Order Tanaidae						
Tanaidae		6		3		1
Tanais sp.	6		3		1	
Order Isopoda						
Munnidae		0		0		1
Munna fabricii					1	
Order Decapoda						
Paguroidae		0		1		0
Pagurus sp.			1			
CLASS MAXILLOPODA						
Order Harpacticoida		6		4		4
Harpacticidae						
Harpacticus sp.	6		4		4	
Order Thoracica						
Balanidae		0		0		69
Balanus sp.					69	
ECHINODERMATA						
Class Stelleroidea						
Order Spinulosida						
Echinasteridae		1		0		0
Henricia sanguinolenta	1					
Order Ophiurida						
Ophiuridae		1		0		0
Ophiura sp.	1					
Ophiactidae		2		4		2
Ophiopholis sp.	2		4		2	

Station 4 (continued)

	Sta 4-1		Sta 4-2		Sta 4-3	
	Species	Family	Species	Family	Species	Family
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		2		3		2
Stenosemus (Ischnochiton) albus	2		3		1	
Tonicella (Ischnochiton) rubra					1	
Class Bivalvia						
Order Protobranchia						
Nuculidae		0		0		1
Nucula proxima					1	
Order Pteroconchida						
Mytilidae		1		1		1
Musculus sp. (niger)	1		1		1	
Anomiidae		1		1		1
Anomia sp	1		1		1	
Order Heterodontida						
Astartidae		1		1		0
Astarte sp.	1		1			
Carditidae		0		4		3
Cyclocardia (Cardita) borealis			4		3	
Cardiidae		1		0		0
Cerastoderma pinnulatum	1					
Order Eudesmodontia						
Lyonsiidae		1		1		0
Lyonsia arenosa	1		1			
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		0		0		1
Boltenia ovifera					1	
Mogulidae		1		0		0
Molgula sp.	1					
CNIDARIA						
Class Hydrozoa						
Order Athecata						
Tubulariidae		4		0		0
Tubularia sp.	4					
Class Anthozoa						
Order Actiniaria						
Actinidae		0		0		1
Urticina (Tealia) felina					1	

Station 4 (continued)

	Sta 4-1		Sta 4-2		Sta 4-3	
	Species	Family	Species	Family	Species	Family
ENTROPROCTA		0		0		28
Class Ectoprocta					28	
RHYNCHOCOELA		3		1		2
Unid. Nemertea	3		1		2	
ASCHELMINTHES						
Class Nematoda		2		0		1
Unid.	2				1	

SPECIES Station 4	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	199	172	168	539	179.7	189.6
Abundance (organisms/0.1 m²)	2456.7	2123.3	2074.0	6654.0	2218.0	28888.1
Species richness (No. species)	36	23	31	50	30.0	28.7
Rel. Div. by sp.	0.606	0.578	0.674	1.9	0.619	0.002
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	199	172	168	539	179.7	189.6
Abundance (organisms/0.1 m²)	2456.7	2123.3	2074.0	6654.0	2218.0	28888.1
Family richness (No. Families)	30	21	26	40	25.7	13.6
Rel. Div. by Family	0.598	0.576	0.675	1.8	0.617	0.002

Station 5

	Sta 5-1		Sta 5-2		Sta 5-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		0		0		1
Eteone spp.					1	
Polynoidae		0		4		2
Harmothoe sp.			4		2	
Sigalionidae		0		2		0
Pholoe minuta			2			
Syllidae		7		10		4
Exogone spp.	6		10		2	
Syllis cornuta	1				2	
Nereidae		1		1		0
Nereis spp.	1		1			
ORDER Spionida						
Spionidae		0		1		3
Polydora spp.					1	
Marenzelleria (Scolecolepedis) viridis					1	
Spio setosa			1		1	
Paraonidae		2		2		2
Aricidea suecica	2					
Paraonis sp.			2		2	
ORDER Eunicida						
Eunicidae		8		8		11
Onuphis (Nothria) conchylega	8		8		11	
Dorvilleidae		2		1		2
Protodorvillea kefersteini	2		1		2	
ORDER Cirratulida						
Cirratulidae		5		3		1
Tharyx spp.	5		3		1	
ORDER Terebellida						
Ampharetidae		0		0		2
Asabellides oculata					2	
Terebellidae		2		2		2
Polycirrus sp.	2		2		2	
ORDER Flabelligerida						
Flabelligeridae		1		0		0
Pherusa spp.	1					
ORDER Sabellida						
Sabellidae		0		1		0
Potamilla reinformis			1			
Serpulidae		83		146		104
Spirorbis spp.	83		146		104	
CLASS CLITELLA		4		8		3
Oligochaeta	4		8		3	

Station 5 (continued)

	Sta 5-1		Sta 5-2		Sta 5-3	
	Species	Family	Species	Family	Species	Family
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Ampithoidae		0		1		0
Ampithoe sp.			1			
Corophiidae		3		2		6
Corophium spp.			2		1	
Erichthonius sp.	3				5	
Order Tanaidae						
Tanaidae		2		4		1
Tanais sp.	2		4		1	
Order Isopoda						
Ligididae		1		0		0
Ligia oceanica	1					
CLASS MAXILLOPODA						
Order Cyclopoidea		1		0		0
Unid	1					
Order Harpacticoida		1		0		0
Harpacticidae						
Harpacticus sp.	1					
Order Thoracica						
Balanidae		0		3		2
Balanus sp.			3		2	
CLASS OSTRACODA						
OSTRACODA		0		0		1
Unid.					1	
CLASS PANTOPODA						
ORDER						
Ammotheidae		0		6		1
Achelia sp.			6		1	
Phoxichilidiidae		7		1		0
Phoxichilidium femoratum	7		1			
ECHINODERMATA						
Class Stelleroidea						
Order Foripultida						
Asteridae		0		1		0
Asterias sp.			1			
Order Ophiurida						
Ophiuridae		0		1		0
Ophiura sp.			1			
Ophiactidae		0		0		2
Ophiopholis sp.					2	

Station 5 (continued)

	Sta 5-1		Sta 5-2		Sta 5-3	
	Species	Family	Species	Family	Species	Family
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		1		2		8
Stenosemus (Ischnochiton) albus	1		2		8	
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		1		1		0
Puncturella noachina	1		1			
Class Bivalvia						
Order Protobranchia						
Nuculidae		1		0		0
Nucula proxima	1					
Order Pteroconchida						
Mytilidae		17		31		48
Crenella glandula	9		4		8	
Modiolus modiolus	6		5		5	
Mytilus edulis	2		22		35	
Pectinidae		0		1		0
Placopecten magellanicus			1			
Anomiidae		92		252		171
Anomia sp	92		252		171	
Order Heterodontida						
Astartidae		2		1		3
Astarte sp.	2		1		3	
Carditidae		5		0		4
Cyclocardia (Cardita) borealis	5				4	
Cardiidae		1		0		1
Cerastoderma pinnulatum	1				1	
Tellinidae		0		3		4
Macoma sp.			3		4	
Myidae		1		0		0
Mya arenaria	1					
Hiatellidae		0		4		2
Hiatella arctica					2	
Hiatella striata			4			
Order Eudesmodontia						
Lyonsiidae		0		0		1
Lyonsia arenosa					1	
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		1		1		1
Boltenia ovifera	1		1		1	

Station 5 (continued)

	Sta 5-1		Sta 5-2		Sta 5-3	
	Species	Family	Species	Family	Species	Family
Mogulidae		0		2		0
Molgula sp.			2			
CNIDARIA						
Class Hydrozoa						
Order Athecata						
Tubulariidae		4		4		6
Tubularia sp.	4		4		6	
ENTROPROCTA		82		236		196
Class Ectoprocta	82		236		196	
ECHIUROIDEA		1		23		4
Thalassema	1		23		4	
Unid.						
RHYNCHOCOELA		4		8		4
Unid. Nemertea	4		8		4	
ASCHELMINTHES						
Class Nematoda		3		14		2
Unid.	3		14		2	

SPECIES Station 5	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	346	791	606	1743	581.0	33316.7
Abundance (organisms/0.1 m²)	4271.4	9764.9	7481.1	21517.3	7172.4	5077427.5
Species richness (No. species)	34	38	40	58	37.3	6.2
Rel. Div. by sp.	0.623	0.540	0.551	1.7	0.571	0.001
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	346	791	606	1743	581.0	33316.7
Abundance (organisms/0.1 m²)	4271.4	9764.9	7481.1	21517.3	7172.4	5077427.5
Family richness (No. Families)	31	36	34	50	33.7	4.2
Rel. Div. by Family	0.623	0.539	0.555	1.7	0.572	0.001

Station 6

	Sta 6-1		Sta 6-2		Sta 6-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		0		3		4
Eteone spp.			1		2	
Paranaitis speciosa			1			
Phyllodoce sp.			1		2	
Polynoidae		16		7		2
Harmothoe sp.	16		7		2	
Sigalionidae		1		10		3
Pholoe minuta	1		10		3	
Syllidae		0		2		3
Exogone spp.			2		3	
Nereidae		1		1		1
Nereis spp.	1		1		1	
ORDER Capitellida						
Capitellidae		0		2		2
Mediomastus ambiseta			2		2	
Opheliidae		0		2		0
Ophelina acuminata			2			
ORDER Spionida						
Spionidae		0		1		0
Polydora spp.			1			
ORDER Eunicida						
Eunicidae		12		3		4
Onuphis (Nothria) conchylega	12		3		4	
ORDER Ariciida						
Orbiniidae		0		0		1
Naineris quadricuspida					1	
ORDER Terebellida						
Ampharetidae		0		1		0
Ampharete sp.			1			
Terebellidae		1		3		3
Amphitrite sp.			3		1	
Polycirrus sp.	1				2	
ORDER Sabellida						
Serpulidae		34		6		16
Spirorbis spp.	34		6		16	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		7		19		6
Corophium spp.	7		19		6	

Station 6 (continued)

	Sta 6-1		Sta 6-2		Sta 6-3	
	Species	Family	Species	Family	Species	Family
Photidae		5		2		3
Gammaropsis sp.						
Photis spp.	5		2		3	
Pleustidae		2		0		0
Stenopleustes sp.	2					
Stenothoidae		2		2		0
Metopella angusta	2		2			
Order Tanaidae						
Tanaidae		0		0		1
Tanais sp.					1	
Order Caprellidea						
Caprellidae		0		0		3
Caprella spp.					3	
CLASS MAXILLOPODA						
SUB CLASS COPEPODS		0		0		0
Order Thoracica						
Balanidae		10		0		4
Balanus sp.	10				4	
CLASS PANTOPODA						
ORDER						
Ammotheidae		1		2		0
Achelia sp.	1		2			
ECHINODERMATA						
Class Stelleroidea						
Order Ophiurida						
Ophiuridae		16		5		0
Ophiura sp.	16		5			
Ophiactidae		0		18		3
Ophiopholis sp.			18		3	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		2		0		0
Stenosemus (Ischnochiton) albus	2					
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		0		1		0
Puncturella noachina			1			
Trochidae		1		0		0
Margarites spp.	1					

Station 6 (continued)

	Sta 6-1		Sta 6-2		Sta 6-3	
	Species	Family	Species	Family	Species	Family
Order Nudibranchia						
Dotonidae		0		2		0
Doto coronata			2			
Class Bivalvia						
Order Protobranchia						
Nuculidae		0		1		0
Nucula proxima			1			
Order Pteroconchida						
Mytilidae		142		428		332
Crenella glandula	7		10		6	
Modiolus modiolus	33		30		24	
Musculus sp. (niger)	4		2			
Mytilus edulis	98		386		302	
Anomiidae		112		58		57
Anomia sp	112		58		57	
Order Heterodontida						
Astartidae		0		2		0
Astarte sp.			2			
Carditidae		0		0		2
Cyclocardia (Cardita) borealis					2	
Cardiidae		0		1		1
Cerastoderma pinnulatum			1		1	
Tellinidae		0		4		3
Macoma sp.			4		3	
Myidae		0		1		1
Mya arenaria			1		1	
Hiatellidae		7		62		39
Hiatella arctica	6		55		35	
Hiatella striata	1		7		4	
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		2		5		3
Boltenia ovifera	2		5		3	
Mogulidae		1		2		1
Molgula sp.	1		2		1	
PORIFERA						
Class Calcarea						
Homocoelidae		1		0		0
Leucosolenia sp.	1					

Station 6 (continued)

	Sta 6-1		Sta 6-2		Sta 6-3	
	Species	Family	Species	Family	Species	Family
CNIDARIA						
Class Anthozoa						
Order Actiniaria						
Actinidae		1		0		0
Urticina (Tealia) felina	1					
Metridiidae		0		0		1
Metridium senile					1	
Order Ceriantharia		0		1		1
Cerianthidae						
Cerianthus borealis			1		1	
ENTROPROCTA		46		39		173
Class Ectoprocta	46		39		173	
ECHIUROIDEA		1		1		4
Thalassema sp.	1		1		4	
RHYNCHOCOELA		1		4		0
Unid. Nemertea	1		4			
PLATYHELMINTHES		3		1		1
Unid.	3		1		1	
ASCHELMINTHES						
Class Nematoda		3		4		8
Unid.	3		4		8	
BRACHIOPODA						
Class Articulata						
Order Terebratulida						
Cancellothyrididae		1		0		0
Terebratulina septentrionalis	1					

SPECIES Station 6	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	432	706	686	1824	608.0	15554.7
Abundance (organisms/0.1 m²)	5333.0	8715.6	8468.7	22517.3	7505.8	2370516.0
Species richness (No. species)	32	42	36	55	36.7	16.9
Rel. Div. by sp.	0.686	0.525	0.528	1.739	0.580	0.006
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	432	706	686	1824	608.0	15554.7
Abundance (organisms/0.1 m²)	5333.0	8715.6	8468.7	22517.3	7505.8	2370516.0
Family richness (No. Families)	28	36	31	48	31.7	10.9
Rel. Div. by Family	0.628	0.472	0.494	1.594	0.531	0.005

Station 7

	Sta 7-1		Sta 7-2		Sta 7-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		0		1		0
Eteone spp.			1			
Polynoidae		8		20		23
Harmothoe sp.	7		17		23	
Lepidonotus squamatus	1		3			
Sigalionidae		1		18		0
Pholoe minuta	1		18			
Syllidae		4		12		6
Exogone spp.			4		1	
Syllides longicirrata			1			
Syllis cornuta	4		6		5	
Syllis gracilis			1			
Hesionidae		0		0		1
Microphthalmus aberrans					1	
ORDER Capitellida						
Capitellidae		0		12		3
Capitella capitata			9			
Mediomastus ambiseta			3		3	
ORDER Spionida						
Spionidae		1		2		0
Prionospio steenstrupi			2			
Spio setosa	1					
Paraonidae		0		1		1
Aricidea suecica			1		1	
ORDER Eunicida						
Eunicidae		2		4		1
Onuphis (Nothria) conchylega	2		4		1	
ORDER Ariciida						
Orbiniidae		1		3		3
Naineris quadricuspida	1		3		3	
ORDER Cirratulida						
Cirratulidae		1		6		12
Cirratulus cirratus			2			
Tharyx spp.	1		4		12	
ORDER Terebellida						
Pectinaridae		0		1		0
Cistena granulata			1			
Ampharetidae		0		11		14
Asabellides oculata			6		9	
Melinna cristata			5		5	

Station 7 (continued)

	Sta 7-1		Sta 7-2		Sta 7-3	
	Species	Family	Species	Family	Species	Family
Terebellidae		5		16		10
Amphitrite sp.			5		3	
Polycirrus sp.	5		9		3	
Terebellides stroemi			2		4	
ORDER Sabellida						
Sabellidae		0		1		3
Myxicola infundibulum			1		3	
Serpulidae		10		66		163
Filograna implexa			1			
Spirorbis spp.	10		65		163	
CLASS CLITELLA		0		2		0
Oligochaeta			2			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		3		4		8
Corophium spp.	3		4		7	
Erichthonius sp.					1	
Photidae		1		0		0
Photis spp.	1					
Pleustidae		1		22		8
Pleusymtes glaber	1					
Stenopleustes sp.			22		8	
Stenothoidae		0		2		25
Metopella angusta			2			
Stenothoe minuta					25	
Order Tanaidae						
Tanaidae		0		0		1
Tanais sp.					1	
CLASS MAXILLOPODA						
SUB CLASS COPEPODS		0		0		0
Order Thoracica						
Balanidae		1		5		13
Balanus sp.	1		5		13	
CLASS PANTOPODA						
ORDER						
Ammotheidae		0		2		1
Achelia sp.			2		1	

Station 7 (continued)

	Sta 7-1		Sta 7-2		Sta 7-3	
	Species	Family	Species	Family	Species	Family
ECHINODERMATA						
Class Holothuroidea						
Order Apodida						
Chiridotidae		0		0		1
Chiridota laevis					1	
Class Stelleroidea						
Order Foripultida						
Asteridae		0		2		0
Asterias sp.			2			
Order Ophiurida						
Ophiuridae		0		0		3
Ophiura sp.					3	
Ophiactidae		0		11		7
Ophiopholis sp.			11		7	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		0		3		3
Stenosemus (Ischnochiton) albus			3		3	
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		0		1		0
Puncturella noachina			1			
Trochidae		0		0		1
Margarites spp.					1	
Order Mesogastropoda						
Hydrobiidae		0		0		4
Hydrobia minuta					4	
Order Neogastropoda						
Buccinidae		0		0		3
Buccinum undatum					3	
Class Bivalvia						
Order Protobranchia						
Nuculidae		0		7		6
Nucula delphinodonta					1	
Nucula proxima			7		5	
Order Pteroconchida						
Mytilidae		154		710		349
Crenella glandula			9		18	
Modiolus modiolus	11		106		251	
Musculus sp. (niger)					5	
Mytilus edulis	143		595		75	
Pectinidae		0		1		0
Placopecten magellanicus			1			

Station 7 (continued)

	Sta 7-1		Sta 7-2		Sta 7-3	
	Species	Family	Species	Family	Species	Family
Anomiidae		52		76		95
Anomia sp	52		76		95	
Order Heterodontida						
Astartidae		0		1		1
Astarte sp.			1		1	
Carditidae		0		1		0
Cyclocardia (Cardita) borealis			1			
Cardiidae		0		2		1
Cerastoderma pinnulatum			2		1	
Tellinidae		0		1		0
Macoma sp.			1			
Myidae		0		1		0
Mya arenaria			1			
Hiatellidae		10		21		26
Hiatella arctica	6		7		1	
Hiatella striata	4		14		25	
CHORDATA						
Class Ascidiacea						
Order Enterogona						
Cionidae		0		1		1
Ciona intestinalis			1		1	
Order Pleurogona						
Pyuridae		4		3		2
Boltenia echinata					1	
Boltenia ovifera	4		3		1	
Mogulidae		0		3		4
Molgula sp.			3		4	
CNIDARIA						
Class Hydrozoa						
Order Athecata						
Tubulariidae		0		1		3
Tubularia sp.			1		3	
Class Anthozoa						
Order Actiniaria						
Actinidae		9		44		22
Urticina (Tealia) felina	9		44		22	
Metridiidae		2		2		1
Metridium senile	2		2		1	
ENTROPROCTA		29		206		96
Class Ectoprocta	29		206		96	

Station 7 (continued)

	Sta 7-1		Sta 7-2		Sta 7-3	
	Species	Family	Species	Family	Species	Family
ECHIUROIDEA		0		2		0
Thalassema sp.			2			
RHYNCHOCOELA		1		3		0
Unid. Nemertea	1		3			
PLATYHELMINTHES		0		1		5
Unid.			1		5	
ASCHELMINTHES						
Class Nematoda		0		4		7
Unid.			4		7	
BRACHIOPODA						
Class Articulata						
Order Terebratulida						
Cancellothyrididae		1		0		0
Terebratulina septentrionalis	1					

SPECIES Station 7	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	301	1319	937	2557	852.3	176304.9
Abundance (organisms/0.1 m²)	3715.845	16283.1	11567.3	31566.2	10522.1	26868693.2
Species richness (No. species)	25	59	51	75	45.0	210.7
Rel. Div. by sp.	0.599	0.537	0.657	1.8	0.598	0.002
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	301	1319	937	2557	852.3	176304.9
Abundance (organisms/0.1 m²)	3715.8	16283.1	11567.3	31566.2	10522.1	26868693.2
Family richness (No. Families)	22	46	40	55	36.0	104.0
Rel. Div. by Family	0.571	0.489	0.611	1.7	0.557	0.003

Station 8

	Sta 8-1		Sta 8-2		Sta 8-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		0		1		0
Phyllodoce sp.			1			
Polynoidae		8		7		7
Harmothoe sp.	2		5		7	
Lepidonotus squamatus	6		2			
Sigalionidae		2		0		2
Pholoe minuta	2				2	
Syllidae		2		1		1
Exogone spp.			1			
Syllis cornuta					1	
Sphaerosyllis erinaceus	2					
ORDER Capitellida						
Capitellidae		8		1		6
Capitella capitata	3		1			
Mediomastus ambiseta	5				6	
ORDER Spionida						
Spionidae		0		0		1
Polydora spp.					1	
Paraonidae		1		0		0
Aricidea catherinae	1					
ORDER Eunicida						
Eunicidae		8		4		2
Onuphis (Nothria) conchylega	8		4		2	
ORDER Cirratulida						
Cirratulidae		1		0		2
Tharyx spp.	1				2	
ORDER Terebellida						
Ampharetidae		1		0		1
Asabellides oculata	1				1	
Terebellidae		3		0		0
Polycirrus sp.	3					
ORDER Sabellida						
Serpulidae		44		28		42
Spirorbis spp.	44		28		42	
CLASS CLITELLA		0		0		1
Oligochaeta					1	

Station 8 (continued)

	Sta 8-1		Sta 8-2		Sta 8-3	
	Species	Family	Species	Family	Species	Family
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		10		40		16
Corophium spp.	9		3		7	
Erichthonius sp.	1		37		9	
Pleustidae		1		1		4
Stenopleustes sp.	1		1		4	
Stenothoidae		1		1		0
Metopella angusta	1		1			
Order Cumacea						
Diastylidae		0		0		1
Diastylis quadrispinosa					1	
Order Tanaidae						
Tanaidae		2		0		8
Tanais sp.	2				8	
Order Caprellidea						
Caprellidae		0		2		4
Caprella spp.			2		4	
CLASS MAXILLOPODA						
SUB CLASS COPEPODS		0		0		0
Order Harpacticoida		0		0		2
Harpacticidae						
Harpacticus sp.					2	
Order Thoracica						
Balanidae		0		0		7
Balanus sp.					7	
CLASS PANTOPODA						
ORDER						
Ammotheidae		1		1		5
Achelia sp.	1		1		5	
ECHINODERMATA						
Class Holothuroidea						
Order Dendrochirotida						
Cucumariidae		0		2		1
Cucumaria frondosa			2		1	
Class Echinoidea						
Order Echinoida						
Strongylocentrotidae		1		1		0
Strongylocentrotus droebachiensis	1		1			
Class Stelleroidea						
Order Foripultida						
Asteridae		1		1		2
Asterias sp.	1		1		2	

Station 8 (continued)

	Sta 8-1		Sta 8-2		Sta 8-3	
	Species	Family	Species	Family	Species	Family
Order Ophiurida						
Ophiactidae		12		9		5
Ophiopholis sp.	12		9		5	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		5		3		2
Stenosemus (Ischnochiton) albus	5		3		2	
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		1		1		0
Puncturella noachina	1		1			
Order Nudibranchia						
Dotonidae		0		4		0
Doto coronata			4			
Class Bivalvia						
Order Pteroconchida						
Mytilidae		56		26		66
Crenella glandula	26		3		22	
Modiolus modiolus	20		19		37	
Mytilus edulis	10		4		7	
Anomiidae		106		68		46
Anomia sp	106		68		46	
Order Heterodontida						
Astartidae		0		0		1
Astarte sp.					1	
Tellinidae		2		1		1
Macoma sp.	2		1		1	
Hiatellidae		6		0		11
Hiatella arctica	3				11	
Hiatella striata	3					
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Pyuridae		1		11		0
Boltenia echinata	1					
Boltenia ovifera			11			
Mogulidae		0		2		1
Molgula sp.			2		1	

Station 8 (continued)

	Sta 8-1		Sta 8-2		Sta 8-3	
	Species	Family	Species	Family	Species	Family
Class Anthozoa						
Order Actiniaria						
Actinidae		1		0		2
Urticina (Tealia) felina	1				2	
Order Ceriantharia		1		0		0
Cerianthidae						
Cerianthus borealis	1					
ENTROPROCTA		181		268		240
Class Ectoprocta	181		268		240	
ECHIUROIDEA		7		1		17
Thalassema sp.	7		1		17	
RHYNCHOCOELA		2		0		1
Unid. Nemertea	2				1	
PLATYHELMINTHES		0		0		5
Unid.					5	
ASCHELMINTHES						
Class Nematoda		3		3		6
Unid.	3		3		6	

SPECIES Station 8	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	479	488	519	1486	495.3	293.6
Abundance (organisms/0.1 m²)	5913.3	6024.4	6407.1	18344.7	6114.9	44737.6
Species richness (No. species)	37	30	37	52	34.7	10.9
Rel. Div. by sp.	0.610	0.520	0.620	1.8	0.584	0.002
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	479	488	519	1486	495.3	293.6
Abundance (organisms/0.1 m²)	5913.3	6024.4	6407.1	18344.7	6114.9	44737.6
Family richness (No. Families)	31	26	34	43	30.3	10.9
Rel. Div. by Family	0.596	0.521	0.596	1.7	0.571	0.001

Station 9

	Sta 9-1		Sta 9-2		Sta 9-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Polynoidae		0		2		0
Harmothoe sp.			2			
Sphaerodoridae		0		0		1
Ephesiella (Sphaerodoropsis) minuta					1	
Syllidae		0		1		2
Exogone spp.			1		1	
Sphaerosyllis erinaceus					1	
ORDER Capitellida						
Capitellidae		0		1		0
Capitella capitata			1			
ORDER Spionida						
Paraonidae		0		0		2
Aricidea suecica					2	
ORDER Eunicida						
Eunicidae		5		1		0
Onuphis (Nothria) conchylega	5		1			
ORDER Terebellida						
Ampharetidae		0		1		0
Asabellides oculata			1			
ORDER Sabellida						
Serpulidae		3		4		0
Spirorbis spp.	3		4			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		4		6		0
Corophium spp.	1					
Erichthonius sp.	3		6			
Dexaminidae		0		1		0
Dexamine thea			1			
Pleustidae		4		3		1
Stenopleustes sp.	4		3		1	
Stenothoidae		0		1		0
Metopella angusta			1			
Order Tanaidae						
Tanaidae		0		3		2
Tanais sp.			3		2	

Station 9 (continued)

	Sta 9-1		Sta 9-2		Sta 9-3	
	Species	Family	Species	Family	Species	Family
CLASS PANTOPODA						
ORDER						
Ammotheidae		0		2		2
Achelia sp.			2		2	
Nymphonidae		0		2		0
Nymphon sp.			2			
ECHINODERMATA						
Class Stelleroidea						
Order Ophiurida						
Ophiuridae		0		2		0
Ophiura sp.			2			
Ophiactidae		0		1		2
Ophiopholis sp.			1		2	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		1		2		0
Stenosemus (Ischnochiton) albus	1		2			
Class Gastropoda						
Order Neogastropoda						
Buccinidae		1		0		0
Buccinum undatum	1					
Order Nudibranchia						
Dotonidae		0		1		1
Doto coronata			1		1	
Class Bivalvia						
Order Pteroconchida						
Mytilidae		19		24		11
Crenella glandula			11		10	
Modiolus modiolus	15		11			
Mytilus edulis	4		2		1	
Anomiidae		27		68		1
Anomia sp	27		68		1	
Order Heterodontida						
Astartidae		0		1		1
Astarte sp.			1		1	
Myidae		0		0		1
Mya arenaria					1	
Hiatellidae		3		1		0
Hiatella arctica	2		1			
Hiatella striata	1					

Station 9 (continued)

	Sta 9-1		Sta 9-2		Sta 9-3	
	Species	Family	Species	Family	Species	Family
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Mogulidae		1		0		0
Molgula sp.	1					
CNIDARIA						
Class Anthozoa						
Order Actiniaria						
Actinidae		2		0		0
Urticina (Tealia) felina	2					
Metridiidae		1		0		0
Metridium senile	1					
Order Ceriantharia		0		1		1
Cerianthidae						
Cerianthus borealis			1		1	
ENTROPROCTA		85		93		0
Class Ectoprocta	85		93			
ECHIUROIDEA		0		0		2
Thalassema sp.					2	
RHYNCHOCOELA		0		1		0
Unid. Nemertea			1			
ASCHELMINTHES						
Class Nematoda		0		4		1
Unid.			4		1	

SPECIES Station 9	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	156	227	31	414	138.0	6564.7
Abundance (organisms/0.1 m²)	1925.8	2802.3	382.7	5110.8	1703.6	1000448.8
Species richness (No. species)	16	27	17	38	20.0	24.7
Rel. Div. by sp.	0.583	0.579	0.871	2.0	0.678	0.019
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	156	227	31	414	138.0	6564.7
Abundance (organisms/0.1 m²)	1925.8	2802.3	382.7	5110.8	1703.6	1000448.8
Family richness (No. Families)	13	25	15	33	17.7	27.6
Rel. Div. by Family	0.595	0.563	0.855	2.0	0.671	0.017

Station 10

	Sta 10-1		Sta 10-2		Sta 10-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		3		0		0
Phyllodoce sp.	3					
Polynoidae		10		10		13
Harmothoe sp.	9		9		10	
Lepidonotus squamatus	1		1		3	
Sigalionidae		7		2		2
Pholoe minuta	7		2		2	
Syllidae		1		0		1
Exogone spp.					1	
Sphaerosyllis erinaceus	1					
Nereidae		0		1		0
Nereis spp.			1			
ORDER Capitellida						
Capitellidae		0		0		11
Mediomastus ambiseta					11	
Opheliidae		0		0		1
Ophelina acuminata					1	
ORDER Eunicida						
Eunicidae		3		4		2
Onuphis (Nothria) conchylega	3		4		2	
ORDER Ariciida						
Orbiniidae		1		0		0
Naineris quadricuspida	1					
ORDER Cirratulida						
Cirratulidae		0		1		3
Tharyx spp.			1		3	
ORDER Terebellida						
Ampharetidae		0		4		6
Asabellides oculata			4		6	
Terebellidae		1		2		1
Polycirrus sp.	1		2		1	
ORDER Sabellida						
Sabellidae		1		1		0
Psuedopotamilla (Potamilla) neglecta	1		1			
Serpulidae		10		4		4
Spirorbis spp.	10		4		4	

Station 10 (continued)

	Sta 10-1		Sta 10-2		Sta 10-3	
	Species	Family	Species	Family	Species	Family
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		9		8		9
Corophium spp.	9		3		2	
Erichthonius sp.			5		7	
Photidae		1		0		0
Gammaropsis sp.	1					
Pleustidae		11		2		6
Stenopleustes sp.	11		2		6	
Stenothoidae		1		1		0
Metopella angusta	1		1			
Order Isopoda						
Munnidae		1		0		0
Munna fabricii	1					
Order Caprellidea						
Caprellidae		0		0		2
Caprella spp.					2	
Order Decapoda						
Cancridea		0		0		1
Cancer borealis					1	
CLASS MAXILLOPODA						
SUB CLASS COPEPODS		0		0		0
Order Thoracica						
Balanidae		25		2		0
Balanus sp.	25		2			
CLASS PANTOPODA						
ORDER						
Ammotheidae		5		1		0
Achelia sp.	5		1			
ECHINODERMATA						
Class Holothuroidea						
Order Dendrochirotida						
Cucumariidae		0		1		0
Cucumaria frondosa			1			
Class Echinoidea						
Order Echinoida						
Strongylocentrotidae		0		1		0
Strongylocentrotus droebachiensis			1			
Class Stelleroidea						
Order Foripultida						
Asteridae		1		0		0
Asterias sp.	1					

Station 10 (continued)

	Sta 10-1		Sta 10-2		Sta 10-3	
	Species	Family	Species	Family	Species	Family
Order Ophiurida						
Ophiactidae		30		2		4
Ophiopholis sp.	30		2		4	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		0		1		2
Stenosemus (Ischnochiton) albus			1		2	
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		0		0		1
Puncturella noachina					1	
Trochidae		2		0		0
Margarites spp.	2					
Acmaeidae		0		0		1
Tectura (Acmea) testudinalis					1	
Order Nudibranchia						
Dendrontidae		1		0		0
Dendronotus frondosus	1					
Class Bivalvia						
Order Pteroconchida						
Mytilidae		79		240		218
Crenella glandula	3		5		8	
Modiolus modiolus	64		31		123	
Mytilus edulis	12		204		87	
Anomiidae		54		62		49
Anomia sp	54		62		49	
Order Heterodontida						
Astartidae		1		0		0
Astarte sp.	1					
Carditidae		2		0		0
Cyclocardia (Cardita) borealis	2					
Cardiidae		1		0		1
Cerastoderma pinnulatum	1				1	
Tellinidae		0		1		2
Macoma sp.			1		2	
Hiatellidae		15		26		22
Hiatella arctica	7		24		15	
Hiatella striata	8		2		7	
CHORDATA						
Class Ascidiacea						
Order Enterogona						
Cionidae		1		0		0
Ciona intestinalis	1					

Station 10 (continued)

	Sta 10-1		Sta 10-2		Sta 10-3	
	Species	Family	Species	Family	Species	Family
Order Pleurogona						
Pyuridae		4		0		0
Boltenia ovifera	4					
Mogulidae		2		0		3
Molgula sp.	2				3	
CNIDARIA						
Class Hydrozoa						
Order Athecata						
Tubulariidae		1		5		5
Tubularia sp.	1		5		5	
Class Anthozoa						
Order Actiniaria						
Actinidae		3		1		0
Urticina (Tealia) felina	3		1			
Metridiidae		2		1		0
Metridium senile	2		1			
ENTROPROCTA		21		120		146
Class Ectoprocta	21		120		146	
ECHIUROIDEA		3		0		2
Thalassema sp.	3				2	
RHYNCHOCOELA		1		1		4
Unid. Nemertea	1		1		4	
PLATYHELMINTHES		2		0		0
Unid.	2					
ASCHELMINTHES						
Class Nematoda		12		1		1
Unid.	12		1		1	

SPECIES Station 10	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	328	506	523	1357	452.3	7777.6
Abundance (organisms/0.1 m²)	4049.2	6246.6	6456.4	16752.2	5584.1	1185291.9
Species richness (No. species)	41	33	34	56	36.0	12.7
Rel. Div. by sp.	0.774	0.554	0.637	2.0	0.655	0.008
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	328	506	523	1357	452.3	7777.6
Abundance (organisms/0.1 m²)	4049.2	6246.6	6456.4	16752.2	5584.1	1185291.9
Family richness (No. Families)	37	28	29	50	31.3	16.2
Rel. Div. by Family	0.746	0.503	0.553	1.8	0.601	0.011

Station 11

	Sta 11-1		Sta 11-2		Sta 11-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Polynoidae		1		1		0
Harmothoe sp.	1		1			
Sphaerodoridae		1		0		0
Ephesiella (Sphaerodoropsis) minuta	1					
ORDER Capitellida						
Capitellidae		1		0		0
Mediomastus ambiseta	1					
ORDER Spionida						
Spionidae		1		0		0
Marenzelleria (Scolecolepedis) viridis	1					
ORDER Eunicida						
Eunicidae		4		5		2
Onuphis (Nothria) conchylega	4		5		2	
ORDER Terebellida						
Terebellidae		0		1		0
Amphitrite sp.			1			
ORDER Sabellida						
Serpulidae		3		7		2
Spirorbis spp.	3		7		2	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Corophiidae		7		5		3
Erichthonius sp.	7		5		3	
Oedicerotidae		0		1		0
Monoculodes spp.			1			
Pleustidae		9		2		1
Stenopleustes sp.	9		2		1	
Stenothoidae		1		2		0
Metopella angusta	1		2			
Order Isopoda						
Ligididae		1		0		0
Ligia oceanica	1					
Order Caprellidea						
Caprellidae		1		0		0
Caprella spp.	1					

Station 11 (continued)

	Sta 11-1		Sta 11-2		Sta 11-3	
	Species	**Family**	**Species**	**Family**	**Species**	**Family**
CLASS MAXILLOPODA						
SUB CLASS COPEPODS		0		0		0
Order Thoracica						
Balanidae		1		17		4
Balanus sp.	1		17		4	
CLASS PANTOPODA						
ORDER						
Ammotheidae		1		1		1
Achelia sp.	1		1		1	
Nymphonidae		1		0		0
Nymphon sp.	1					
ECHINODERMATA						
Class Echinoidea						
Order Echinoida						
Strongylocentrotidae		1		0		2
Strongylocentrotus droebachiensis	1				2	
Class Stelleroidea						
Order Ophiurida						
Ophiuridae		0		0		1
Ophiura sp.					1	
Ophiactidae		0		2		1
Ophiopholis sp.			2		1	
MOLLUSCA						
Class Polyplacophora						
Order Neoloricata						
Ischnochitonidae		1		2		1
Stenosemus (Ischnochiton) albus	1		2		1	
Class Gastropoda						
Order Archaeogastropoda						
Fissurellidae		1		0		0
Puncturella noachina	1					
Order Neogastropoda						
Buccinidae		0		1		2
Buccinum undatum					2	
Colus sp.			1			
Order Nudibranchia						
Dotonidae		4		1		0
Doto coronata	4		1			
Class Bivalvia						
Order Pteroconchida						
Mytilidae		33		29		12
Crenella glandula	1		4		1	
Modiolus modiolus	23		21		9	
Mytilus edulis	9		4		2	

Station 11 (continued)

	Sta 11-1		Sta 11-2		Sta 11-3	
	Species	Family	Species	Family	Species	Family
Anomiidae		19		30		21
Anomia sp	19		30		21	
Order Heterodontida						
Cardiidae		0		1		0
Cerastoderma pinnulatum			1			
Hiatellidae		3		2		1
Hiatella arctica	3		2		1	
CHORDATA						
Class Ascidiacea						
Order Pleurogona						
Mogulidae		1		0		2
Molgula sp.	1				2	
CNIDARIA						
Class Hydrozoa						
Order Athecata						
Tubulariidae		1		1		1
Tubularia sp.	1		1		1	
Class Anthozoa						
Order Actiniaria						
Actinidae		1		3		0
Urticina (Tealia) felina	1		3			
Metridiidae		0		1		0
Metridium senile			1			
ENTROPROCTA		39		72		59
Class Ectoprocta	39		72		59	
ASCHELMINTHES						
Class Nematoda		0		1		0
Unid.			1			

SPECIES Station 11	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**137**	**188**	**116**	**441**	**147.0**	**914.0**
Abundance (organisms/0.1 m²)	**1691.3**	**2320.9**	**1432.0**	**5444.1**	**1814.7**	**139292.7**
Species richness (No. species)	**27**	**25**	**19**	**36**	**23.7**	**11.6**
Rel. Div. by sp.	**0.736**	**0.680**	**0.615**	**2.0**	**0.677**	**0.002**
FAMILY	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**137**	**188**	**116**	**441**	**147.0**	**914.0**
Abundance (organisms/0.1 m²)	**1691.3**	**2320.9**	**1432.0**	**5444.1**	**1814.7**	**139292.7**
Family richness (No. Families)	**25**	**23**	**17**	**33**	**21.7**	**11.6**
Rel. Div. by Family	**0.700**	**0.659**	**0.492**	**1.9**	**0.617**	**0.008**

Appendix III

Upper Cobscook Bay subtidal granulometry samples

ORPC UCB Station 1-1

ORPC UCB Station 1-2

ORPC UCB Station 1-3

ORPC UCB Station 2-1

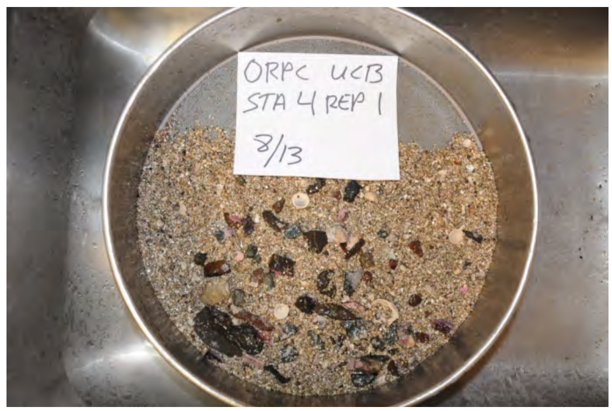
ORPC UCB Station 2-2

ORPC UCB Station 2-3

ORPC UCB Station 3-1

ORPC UCB Station 3-2

ORPC UCB Station 3-3



ORPC UCB Station 4-1

ORPC UCB Station 4-2

ORPC UCB Station 4-3

ORPC UCB Station 5-1

ORPC UCB Station 5-2 (part 1 of 2)

ORPC UCB Station 5-2 (part 2 of 2)

ORPC UCB Station 5-3 (part 1 of 2)

ORPC UCB Station 5-3 (part 2 of 2)

ORPC UCB Station 6-1

ORPC UCB Station 6-2

ORPC UCB Station 6-3

ORPC UCB Station 7-1

ORPC UCB Station 7-2

ORPC UCB Station 7-3

ORPC UCB Station 8-1

ORPC UCB Station 8-2

ORPC UCB Station 8-3

ORPC UCB Station 9-1

ORPC UCB Station 9-2

ORPC UCB Station 9-3

ORPC UCB Station 10-1

ORPC UCB Station 10-2

ORPC UCB Station 10-3

ORPC UCB Station 11-1

ORPC UCB Station 11-2

ORPC UCB Station 11-3

Appendix IV

Pre- and post-sampling photographs of stations at Upper Cobscook Bay intertidal cable crossing area

H-1-1 before sampling

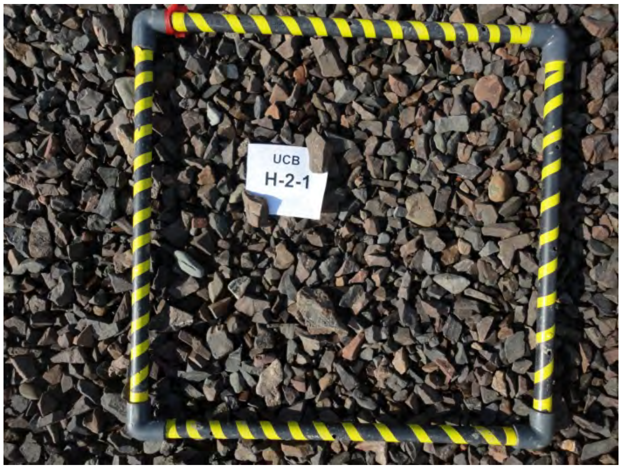
H-1-1 after sampling

H-1-2 before sampling

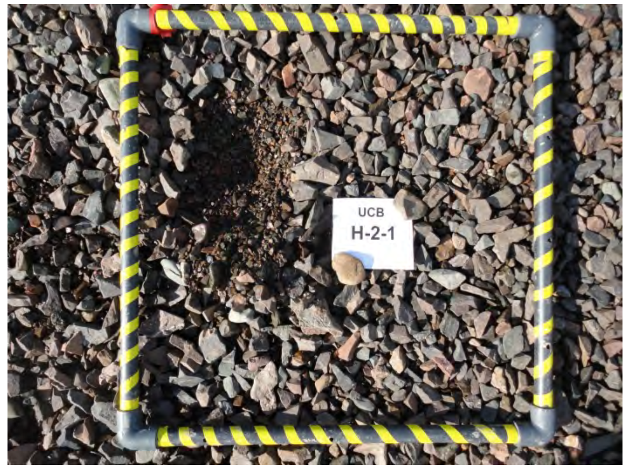
H-1-2 after sampling

H-1-3 before sampling

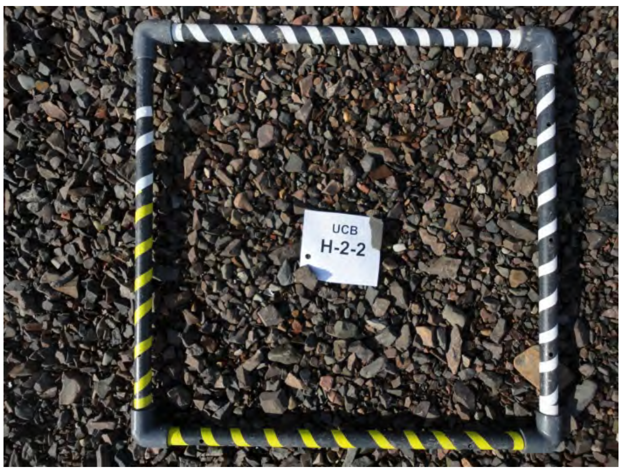
H-1-3 after sampling



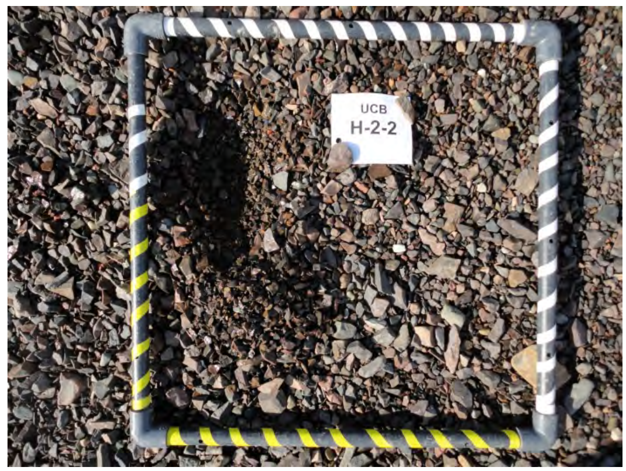
H-2-1 before sampling



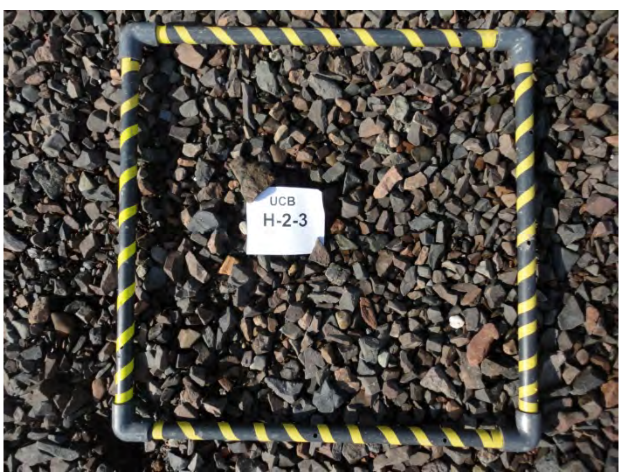
H-2-1 after sampling



H-2-2 before sampling



H-2-2 after sampling



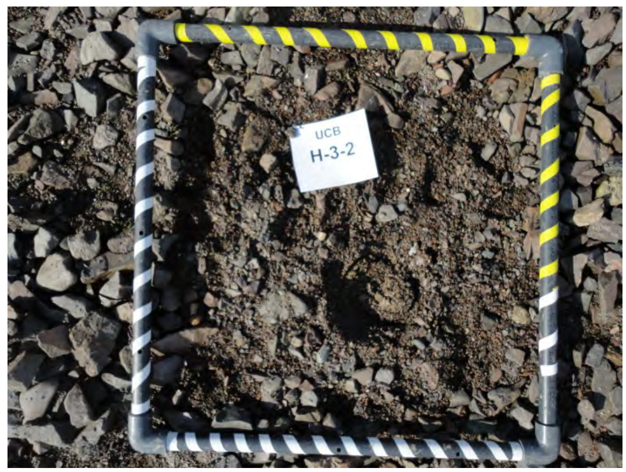
H-2-3 before sampling

H-2-3 after sampling

H-3-1 before sampling

H-3-1 after sampling

H-3-2 before sampling



H-3-2 after sampling

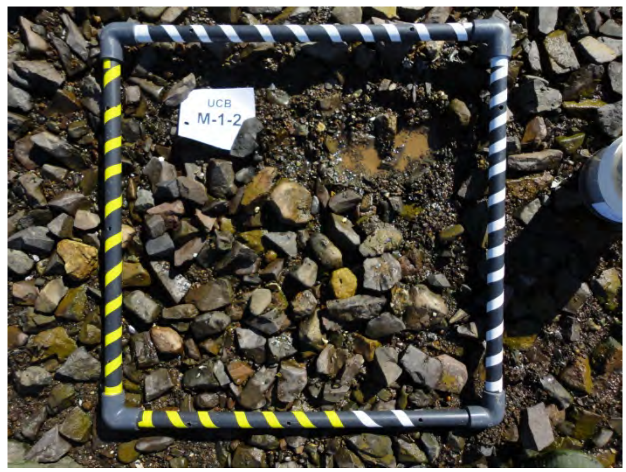
H-3-3 before sampling

H-3-3 after sampling

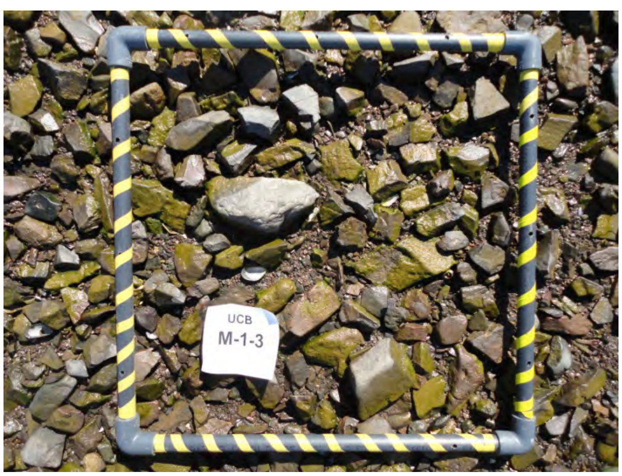
M-1-1 before sampling

M-1-1 after sampling

M-1-2 before sampling



M-1-2 after sampling



M-1-3 before sampling

M-1-3 after sampling

M-2-1 before sampling

M-2-1 after sampling

M-2-2 before sampling

M-2-2 after sampling

M-2-3 before sampling

M-2-3 after sampling

M-3-1 before sampling

M-3-1 after sampling

M-3-2 before sampling

M-3-2 after sampling

M-3-3 before sampling

M-3-3 after sampling

L-1-1 before sampling

L-1-1 after sampling

L-1-2 before sampling

L-1-2 after sampling

L-1-3 before sampling

L-1-3 after sampling

L-2-1 before sampling

L-2-1 after sampling

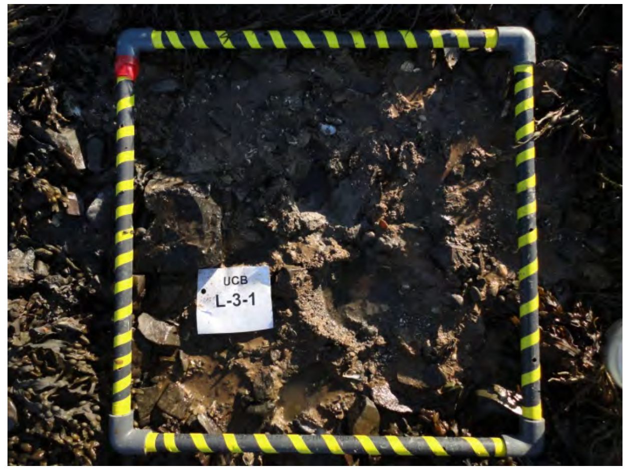
L-2-2 before sampling

L-2-2 after sampling

L-2-3 before sampling

L-2-3 after sampling

L-3-1 before sampling

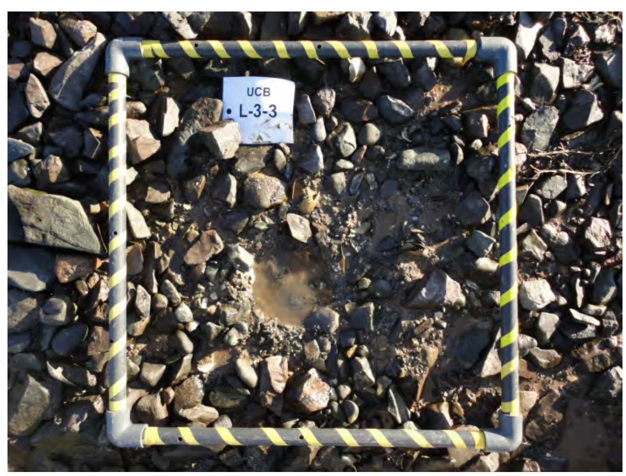


L-3-1 after sampling

L-3-2 before sampling

L-3-2 after sampling

L-3-3 before sampling



L-3-3 after sampling

Appendix V
Detailed epibenthic fauna data for intertidal scrape samples collected at the Upper Cobscook Bay (UCB) site

H-1, H-2, H-3, M-1 SAMPLES: NO EPIBENTHIC INFAUNA IDENTIFIED

	M 2-1		M 2-2		M 2-3	
	Species	**Family**	**Species**	**Family**	**Species**	**Family**
ARTHROPODA						
CLASS MAXILLOPODA						
Order Thoracica						
Balanidae		28		1		0
Balanus sp.	28		1			
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		4		17		11
Littorina littorea	4		17		11	

SPECIES M-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**32**	**18**	**11**	**61**	**20.3**	**76.2**
Abundance (organisms/0.1 m²)	**128.0**	**72.0**	**44.0**		**81.3**	**1219.6**
Species richness (No. species)	**2**	**2**	**1**	**2**	**1.7**	**0.2**
Rel. Div. by sp.	**0.544**	**0.310**	**0.000**		**0.284**	**0.050**
FAMILY M-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**32**	**18**	**11**	**61**	**20.3**	**76.2**
Abundance (organisms/0.1 m²)	**128.0**	**72.0**	**44.0**		**81.3**	**1219.6**
Family richness (No. Families)	**2**	**2**	**1**	**2**	**1.7**	**0.2**
Rel. Div. by Family	**0.544**	**0.310**	**0.000**		**0.284**	**0.050**

	M 3-1		M 3-2		M 3-3	
	Species	Family	Species	Family	Species	Family
ARTHROPODA						
CLASS MALCOSTRACA						
Order Isopoda						
Idoteidae		0		0		1
Idotea sp.					1	
CLASS MAXILLOPODA						
Order Thoracica						
Balanidae		35		123		244
Balanus sp.	35		123		244	
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		6		12		8
Littorina littorea	6		12		8	

SPECIES M-3	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	41	135	253	429	143.0	7522.7
Abundance (organisms/0.1 m²)	164.0	540.0	1012.0		572.0	120362.7
Species richness (No. species)	2	2	3	3	2.3	0.2
Rel. Div. by sp.	0.601	0.433	0.151		0.395	0.034
FAMILY M-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	41	135	253	429	143.0	7522.7
Abundance (organisms/0.1 m²)	164.0	540.0	1012.0		572.0	120362.7
Family richness (No. Families)	2	2	3	3	2.3	0.2
Rel. Div. by Family	0.601	0.433	0.151		0.395	0.034

	L 1-1		L 1-2		L 1-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		0		2		2
Oligochaeta			2		2	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		3		5		3
Gammarus sp.	3		5		3	
Order Cumacea						
Diastylidae		0		0		1
Diastylis quadrispinosa					1	
Order Isopoda						
Idoteidae		228		120		420
Idotea sp.	228		120		420	
Order Decapoda						
Portunidae		0		0		7
Carcinus maenas					7	
CLASS MAXILLOPODA						
Order Thoracica						
Balanidae		689		3		0
Balanus sp.	689		3			
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		80		59		141
Littorina littorea	41		28		19	
Littorina obtusata	39		24		122	
Littorina saxatilis			7			
Order Neogastropoda						
Nassaridae		0		0		2
Ilyanassa sp.					2	
Class Bivalvia						
Order Pteroconchida						
Mytilidae		0		1		2
Mytilus edulis			1		2	

SPECIES L-1	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	1000	190	578	1768	589.3	109414.2
Abundance (organisms/0.1 m²)	4000.0	760.0	2312.0		2357.3	1750627.6
Species richness (No. species)	5	8	9	11	7.3	2.9
Rel. Div. by sp.	0.540	0.573	0.375		0.496	0.008
FAMILY L-1	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	1000	190	578	1768	589.3	109414.2
Abundance (organisms/0.1 m²)	4000.0	760.0	2312.0		2357.3	1750627.6
Family richness (No. Families)	4	6	8	9	6.0	2.7
Rel. Div. by Family	0.587	0.497	0.350		0.478	0.010

	L 2-1		L 2-2		L 2-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		7		1		0
Oligochaeta	7		1			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		97		10		11
Gammarus sp.	97		10		11	
Order Isopoda						
Idoteidae		1195		663		23
Idotea sp.	1195		663		23	
Order Decapoda						
Portunidae		0		0		1
Carcinus maenas					1	
CLASS MAXILLOPODA						
Order Thoracica						
Balanidae		0		1		0
Balanus sp.			1			
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		228		162		41
Littorina littorea	49		38		29	
Littorina obtusata	153		112		8	
Littorina saxatilis	26		12		4	

Order Neogastropoda						
Nassaridae		0		2		1
Ilyanassa sp.			2		1	
Class Bivalvia						
Order Pteroconchida						
Mytilidae		2		1		1
Mytilus edulis	2		1		1	
ASCHELMINTHES						
Class Nematoda		0		1		0
Unid.			1			

SPECIES L-2	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	1529	841	78	2448	816.0	351212.7
Abundance (organisms/0.1 m²)	6116.0	3364.0	312.0		3264.0	5619402.7
Species richness (No. species)	7	10	8	11	8.3	1.6
Rel. Div. by sp.	0.417	0.328	0.749		0.498	0.033
FAMILY L-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	1529	841	78	2448	816.0	351212.7
Abundance (organisms/0.1 m²)	6116.0	3364.0	312.0		3264.0	5619402.7
Family richness (No. Families)	5	8	6	9	6.3	1.6
Rel. Div. by Family	0.425	0.290	0.637		0.451	0.020

	L 3-1		L 3-2		L 3-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		8		1		0
Oligochaeta	8		1			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		12		6		0
Gammarus sp.	12		6			
Order Cumacea						
Diastylidae		0		0		0
Diastylis quadrispinosa						
Order Isopoda						
Idoteidae		125		194		3
Idotea sp.	125		194		3	

MOLLUSCA						
Class Gastropoda						
Order Archaeogastropoda						
Acmaeidae		0		0		2
Tectura (Acmea) testudinalis					2	
Order Mesogastropoda						
Littoridae		63		87		77
Littorina littorea	33		39		41	
Littorina obtusata	27		21		1	
Littorina saxatilis	3		27		35	
Order Neogastropoda						
Nassaridae		0		1		0
Ilyanassa sp.			1			
Class Bivalvia						
Order Pteroconchida						
Mytilidae		3		0		0
Mytilus edulis	3					
Order Heterodontida						
Myidae						
Mya arenaria	1	0		0		0

SPECIES L-3	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	212	289	82	583	194.0	7297.6
Abundance (organisms/0.1 m²)	848.0	1156.0	328.0		773.0	116760.9
Species richness (No. species)	8	7	5	10	6.7	1.6
Rel. Div. by sp.	0.618	0.550	0.606		0.591	0.001
FAMILY L-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	212	289	82	583	194.0	7297.6
Abundance (organisms/0.1 m²)	848.0	1156.0	328.0		773.0	116760.9
Family richness (No. Families)	6	5	3	8	4.7	1.6
Rel. Div. by Family	0.633	0.465	0.246		0.448	0.025

Appendix VI
Detailed intertidal benthic infauna core samples collected at the Upper Cobscook Bay (UCB) site

H-2 SAMPLES: NO BENTHIC INFAUNA CORES TAKEN

	H 1-1		H 1-2		H 1-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
CLASS CLITELLA		2		3		0
Oligochaeta	2		3			
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Talitridae		200		18		0
Talochestia sp.	200		18			
PLATYHELMINTHES		0		1		0
Unid.			1			

SPECIES H-1	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	202	22	0	224	74.7	8187.6
Abundance (organisms/0.1 m²)	2493.7	271.6	0.0		921.8	1247775.5
Species richness (No. species)	2	3	0	3	1.7	1.6
Rel. Div. by sp.	0.080	0.525	0.000		0.202	0.053
FAMILY H-1	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	202	22	0	224	74.7	8187.6
Abundance (organisms/0.1 m²)	2493.7	271.6	0.0		921.8	1247775.5
Family richness (No. Families)	2	3	0	3	1.7	1.6
Rel. Div. by Family	0.080	0.525	0.000		0.202	0.053

	H 3-1		H 3-2		H 3-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		31		32		6
Oligochaeta	31		32		6	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Talitridae		1		2		2
Talochestia sp.	1		2		2	
Order Isopoda						
Idoteidae		0		1		0
Idotea sp.			1			
CLASS Archnoidae						
Order Acarina						
Halacaridae		1		0		0
Halacarus sp.	1					
PLATYHELMINTHES		2		0		0
Unid.	2					
ASCHELMINTHES						
Class Nematoda		1		0		0
Unid.	1					

SPECIES H-3	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	36	35	8	79	26.3	168.2
Abundance (organisms/0.1 m²)	444.4	432.1	98.8		325.1	25636.9
Species richness (No. species)	5	3	2	6	3.3	1.6
Rel. Div. by sp.	0.365	0.316	0.811		0.498	0.050
FAMILY H-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	36	35	8	79	26.3	168.2
Abundance (organisms/0.1 m²)	444.4	432.1	98.8		325.1	25636.9
Family richness (No. Families)	5	3	2	6	3.3	1.6
Rel. Div. by Family	0.365	0.316	0.811		0.498	0.050

	M 1-1		M 1-2		M 1-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		103		6		6
Oligochaeta	103		6		6	
ARTHROPODA						
CLASS MALCOSTRACA						
Talitridae		1		0		0
Talochestia sp.	1					
Order Isopoda						
Idoteidae		0		0		1
Idotea sp.					1	
Order Caprellidea						
Caprellidae		0		1		0
Caprella spp.			1			
ASCHELMINTHES						
Class Nematoda		0		0		2
Unid.					2	

SPECIES M-1	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	104	7	9	120	40.0	2048.7
Abundance (organisms/0.1 m²)	1283.9	86.4	111.1		493.8	312214.8
Species richness (No. species)	2	2	3	5	2.3	0.2
Rel. Div. by sp.	0.078	0.592	0.773		0.481	0.086
FAMILY M-1	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	104	7	9	120	40.0	2048.7
Abundance (organisms/0.1 m²)	1283.9	86.4	111.1		493.8	312214.8
Family richness (No. Families)	2	2	3	5	2.3	0.2
Rel. Div. by Family	0.078	0.592	0.773		0.481	0.086

	M 2-1		M 2-2		M 2-3	
	Species	**Family**	**Species**	**Family**	**Species**	**Family**
ANNELIDA						
CLASS POLYCHAETA						
ORDER Spionida						
Spionidae		1		0		0
Spio setosa	1					
CLASS CLITELLA		81		74		1
Oligochaeta	81		74		1	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Isopoda						
Idoteidae		0		0		9
Idotea sp.					9	
ASCHELMINTHES						
Class Nematoda		16		31		2
Unid.	16		31		2	

SPECIES M-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**98**	**105**	**12**	**215**	**71.7**	**1788.2**
Abundance (organisms/0.1 m²)	**1209.8**	**1296.2**	**148.1**		**884.7**	**272523.3**
Species richness (No. species)	**3**	**2**	**3**	**4**	**2.7**	**0.2**
Rel. Div. by sp.	**0.455**	**0.875**	**0.657**		**0.662**	**0.029**
FAMILY M-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**98**	**105**	**12**	**215**	**71.7**	**1788.2**
Abundance (organisms/0.1 m²)	**1209.8**	**1296.2**	**148.1**		**884.7**	**272523.3**
Family richness (No. Families)	**3**	**2**	**3**	**4**	**2.7**	**0.2**
Rel. Div. by Family	**0.455**	**0.875**	**0.657**		**0.662**	**0.029**

	M 3-1		M 3-2		M 3-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		83		27		37
Oligochaeta	83		27		37	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Isopoda						
Idoteidae		1		1		9
Idotea sp.	1		1		9	
ASCHELMINTHES						
Class Nematoda		28		6		7
Unid.	28		6		7	

SPECIES M-3	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	112	34	53	199	66.3	1102.9
Abundance (organisms/0.1 m²)	1382.6	419.7	654.3		818.9	168079.2
Species richness (No. species)	3	3	3	3	3.0	0.0
Rel. Div. by sp.	0.556	0.540	0.746		0.614	0.009
FAMILY M-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	112	34	53	199	66.3	1102.9
Abundance (organisms/0.1 m²)	1382.6	419.7	654.3		818.9	168079.2
Family richness (No. Families)	3	3	3	3	3.0	0.0
Rel. Div. by Family	0.556	0.540	0.746		0.614	0.009

	L 1-1		L 1-2		L 1-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS CLITELLA		291		41		167
Oligochaeta	291		41		167	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		13		16		1
Gammarus sp.	13		16		1	
Order Isopoda						
Idoteidae		81		127		19

Idotea sp.	81		127		19	
ASCHELMINTHES						
Class Nematoda		10		4		4
Unid.	10		4		4	

SPECIES L-1	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**395**	**188**	**191**	774	**258.0**	**9386.0**
Abundance (organisms/0.1 m²)	**4876.3**	**2320.9**	**2357.9**		**3185.0**	**1430417.2**
Species richness (No. species)	**4**	**4**	**4**	**4**	**4.0**	**0.0**
Rel. Div. by sp.	**0.545**	**0.641**	**0.329**		**0.505**	**0.017**

FAMILY L-1	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**395**	**188**	**191**	774	**258.0**	**9386.0**
Abundance (organisms/0.1 m²)	**4876.3**	**2320.9**	**2357.9**		**3185.0**	**1430417.2**
Family richness (No. Families)	**4**	**4**	**4**	**4**	**4.0**	**0.0**
Rel. Div. by Family	**0.545**	**0.641**	**0.329**		**0.505**	**0.017**

	L 2-1		L 2-2		L 2-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
Nereidae		0		1		0
Nereis spp.			1			
ORDER Capitellida						
Capitellidae		2		0		0
Capitella capitata	2					
CLASS CLITELLA		347		269		190
Oligochaeta	347		269		190	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		87		22		37
Gammarus sp.	87		22		37	
Order Cumacea						
Diastylidae		0		2		0
Diastylis quadrispinosa			2			
Order Isopoda						
Idoteidae		6		12		16
Idotea sp.	6		12		16	
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		3		0		0
Littorina littorea	2					
Littorina saxatilis	1					
Class Bivalvia						
Order Heterodontida						
Myidae		2		0		0
Mya arenaria	1					
Mya truncata	1					
ASCHELMINTHES						
Class Nematoda		3		0		0
Unid.	3					

SPECIES L-2	Rep 1	Rep 2	Rep 3	Total	Mean	Var.
Total organisms	450	306	243	999	333.0	7506.0
Abundance (organisms/0.1 m²)	5555.3	3777.6	2999.8		4110.9	1143907.1
Species richness (No. species)	9	5	3	11	5.7	6.2
Rel. Div. by sp.	0.318	0.299	0.599		0.405	0.019
FAMILY L-2	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	450	306	243	999	333.0	7506.0
Abundance (organisms/0.1 m²)	5555.3	3777.6	2999.8		4110.9	1143907.1
Family richness (No. Families)	7	5	3	9	5.0	2.7
Rel. Div. by Family	0.355	0.299	0.599		0.418	0.017

	L 3-1		L 3-2		L 3-3	
	Species	Family	Species	Family	Species	Family
ANNELIDA						
CLASS POLYCHAETA						
ORDER Phyllodocida						
Phyllodocidae		1		0		0
Eteone spp.	1					
CLASS CLITELLA		96		184		221
Oligochaeta	96		184		221	
ARTHROPODA						
CLASS MALCOSTRACA						
Order Amphipoda						
Gammaridae		0		5		9
Gammarus sp.			5		9	
Order Cumacea						
Diastylidae		2		0		0
Diastylis quadrispinosa	2					
Order Isopoda						
Idoteidae		1		0		12
Idotea sp.	1				12	
MOLLUSCA						
Class Gastropoda						
Order Mesogastropoda						
Littoridae		0		0		1
Littorina littorea						

Littorina saxatilis					1	
Order Neogastropoda						
Buccinidae		0		1		0
Buccinum undatum			1			
ASCHELMINTHES						
Class Nematoda		1		0		0
Unid.	1					

SPECIES L-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**101**	**190**	**243**	**534**	**178.0**	**3432.7**
Abundance (organisms/0.1 m²)	**1246.8**	**2345.6**	**2999.8**		**2197.4**	**523135.1**
Species richness (No. species)	**5**	**3**	**4**	**8**	**4.0**	**0.7**
Rel. Div. by sp.	**0.163**	**0.141**	**0.274**		**0.193**	**0.003**
FAMILY L-3	**Rep 1**	**Rep 2**	**Rep 3**	**Total**	**Mean**	**Var.**
Total organisms	**101**	**190**	**243**	**534**	**178.0**	**3432.7**
Abundance (organisms/0.1 m²)	**1246.8**	**2345.6**	**2999.8**		**2197.4**	**523135.1**
Family richness (No. Families)	**5**	**3**	**4**	**8**	**4.0**	**0.7**
Rel. Div. by Family	**0.163**	**0.141**	**0.274**		**0.193**	**0.003**

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Summary

ORPC performed a biofouling assessment during the afternoon of July 15, 2013 while the TidGen® Turbine Generator Unit (TGU) was berthed at the end of the Morrison Landing Pier as well as the same evening following its relocation to the boat ramp. The TidGen® was assessed for percent coverage of biofouling on distinct structural components and biological samples were taken from representative locations. Additionally ORPC evaluated the effectiveness of a test patch of antifouling paint.

The preliminary assessment indicates minor biofouling of the overall TGU. The most significant growth has occurred on the generator, sacrificial anodes, and bearing mounts, and on mounting brackets with flat surfaces and complex geometry. Additionally, the evaluation of the applied anti-fouling paint determined that it was not effective in reducing marine growth on the generator.

As further inspections were performed, effects of biofouling continued to be monitored. This report also contains observations of biofouling on internal components, which were revealed as components of the TGU were disassembled.

Assessment

1. Visual inspection to estimate percentage cover of TGU with plant and/or animal life.

Immediately after retrieval, all regions of biofouling occurrence were photographed for future reference. Additionally, each major component of the TGU was assessed for the percent of surface covered with plant or animal life. The plant and animal species were identified, and the growth was described in terms of plant size, color, strength of adherence, etc. Table 1 describes the location of growth, type of growth and approximate percentage of cover.

Table 1. Biofouling description for TidGen components

Component	Approximate % Cover	Description of Growth
Generator (Figure 1)	75	Predominantly tubularian hydroids and lesser barnacles and filamentous algae
Bracelet Anodes (Figure 2)	95	Barnacles
Disc Anodes (Figure 3)	95	Barnacles and algae, growth on flat surface, rounded edge, and in between stacked discs
Long and Short Flush Mount Anodes (Figure 4)	95	Barnacles, >1cm thick
Chassis (Figure 5)	Flat structures – 25 Tubular structures - 5	Flat surfaces – barnacles and algal growth Tubular surfaces – minor algal growth
Foils (Figure 6)	10-15	Tubularian hydroids and barnacles
Bearing Mounts and top of Pedestals (Figure 7)	50-75	Tubularian hydroids, barnacles and filamentous algae
Mounting brackets to BSF Figure 8)	75	Barnacles, mussels (lower half and behind tubular) and tubularian hydroids

Figures 1 through 8 are photographs showing the locations where biofouling was documented.

Figure 1: Generator

Figure 2: Bracelet anode

Figure 3: Stacked torque coupling disc anodes

Figure 4: Long and short flush mount anodes

Figure 5: Overall Chassis

Figure 6: Foil

Figure 7: Bearing Mounts

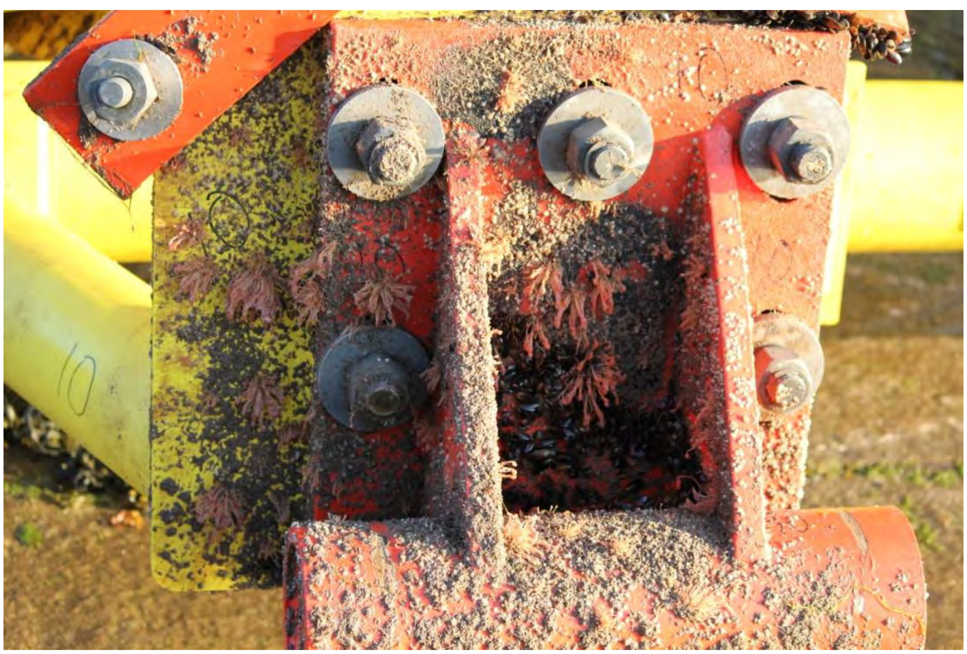


Figure 8: Mounting bracket to BSF

The biofouling inspection identified the presence of the following species:

Plants
Filamentous Algae
Mermaid's Hair

Animals
Barnacles
Blue mussels
Tubularian hydroids

2. Sampling of Species

ORPC collected three biologic samples of representative marine growth on the TGU. Samples were removed from the structure with a plastic card to prevent damage and stored in plastic sample jars. Samples were labeled and preserved with Formalin. This of samples collected is documented in Table 2.

Table 2. Summary of biologic sampling

Sample #	**Date/Time**	**Location**	**Species**
S1	7/15/2013 14:10	Generator frame	Tubularian hydroids
S2	7/15/2013 19:30	Mounting bracket to BSF	Mussels
S3	7/15/2013 19:30	Mounting bracket to BSF	Barnacles

3. Visual inspection of corrosion after removal of growth.

ORPC performed a visual inspection of corrosion to the host surface in two sections of dense growth, a sacrificial anode and a section of the mounting bracket to the bottom support frame. The following procedures were followed for the inspection:

a. Sections were chosen that were both accessible and have been largely affected by biofouling.
b. Several square inches of plant or animal life were removed by scrapping with a plastic card to expose the surface underneath.
c. The exposed surface was inspected and photographed for corrosion. This surface was compared to a nearby region that has not been affected by biofouling. A detailed description of the appearance was recorded, including notes on discoloration or peeling of paint, exposure of metal underneath, and extent of region affected.

A description of the corrosion after removal of the marine growth is summarized in Table 3.

Table 3. Summary of Corrosion

Component of TGU	Approximate % Cover	Description of Corrosion after growth removal
Bracelet Anode (Figure9)	90% barnacle	Small cavities forming underneath growth, as anticipated. Refer to complete Anode Inspection for results of anode-specific inspection.
Mounting bracket to BSF Figure 10)	60% barnacle, 10% filamentous algae, 5% tubularian hydroid	No corrosive effects to surface. Slight residue left underneath barnacles, to be removed during power washing.

Areas inspected were photographed and are shown in Figures 9 and 10.

Figure 9: Bracelet anode before and after growth removal

Figure 10: Mounting bracket to BSF before and after growth removal

4. Effectiveness of Anti-Fouling Paint.

On 2/13/2013, Nanomyte TC-4001M Metal Coat anti-fouling paint was applied to a section of the generator. The coating test application area is approximately 17.3 inches wide by 21.3 inches high (masking tape included) located on the TidGen ® Generator Back Lower Quadrant. The top of the Test area block is about 5.5 inches down from the Generator Back structural rib, and the sides of the block are adjacent to the edge of the E-case struts to the Generator. Refer to Figure 11. Test Area 1, 2, 3, 4 are approximately 6.0 in wide x 8.0 in high. Area 5 is approximately 3.3 in x 3.3 in.

The Amerlock Yellow Coating at Areas 1, 2, 3, 4 were first sanded with 220 grit paper, wiped with a tack clock, and then wiped with a clean lint-free cloth. The area 5 surface was neither sanded, nor wiped.

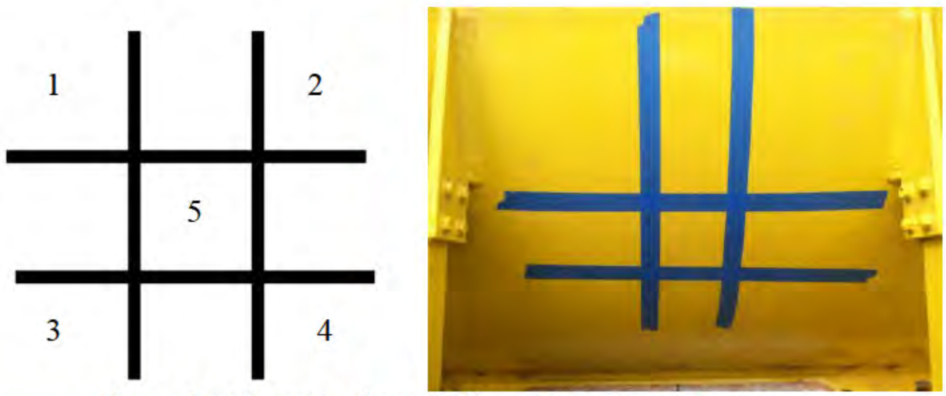


Figure 11: Diagram of anti-fouling paint upon application.

Figure 12: Area treated with anti-fouling tape upon inspection.

Following retrieval ORPC evaluated the area which was applied with anti-fouling paint (Figure 12). A description of each section is provided in Table 4 below:

Table 4. Evaluation of anti-fouling paint

Section 1 *Sanded and wiped* Description of growth: 40% Hydroid, 5% barnacle, 20% algae; Hydroids clustered on outer edge	Not treated	**Section 2** *Sanded and wiped* Description of growth: 25% Hydroid, 5% barnacle, 15% algae; Hydroids clustered on outer edge
Not Treated	**Section 5** *NOT sanded or wiped* Description of growth: 35% Hydroid, 25% barnacles, 35% algae; Barnacles clustered on upper tape line	Not Treated
Section 3 *Sanded and wiped* Description of growth: 5% Hydroid, 30% barnacle, 60% algae; Barnacles clustered on upper tape line	Not Treated	**Section 4** *Sanded and wiped* Description of growth: 15% hydroid, 20% barnacles, 70% algae; barnacles clustered on upper tape line

ORPC's evaluation of the applied anti-fouling paint has determined that it was not effective in reducing marine growth on the generator as applied. Conversations with the material supplier strongly suggest that the coating was not applied in a proper fashion. Any results from this test are therefore inconclusive.

5. Further observations of biofouling

As additional inspections were performed, components of the TGU were made accessible that could not be inspected as part of the initial biofouling report, performed July 15, 2013. Minor biofouling has been observed on the Prevco housing, Prevco connector locker rings and inside the "doghouse."

On the Prevco housing, several hydroids and barnacles are affixed to the face of the housing unit. Effects of biofouling can also be seen on the doghouse lid, with some growth of filamentous algae.

Figure 13: Face of Prevco Housing and doghouse cover

On the Prevco connector locker rings, barnacles have covered approximately 90% of the plastic surface. This does not affect the performance of the locker rings. However, this will compromise the ability of locker ring identification, as they are distinguished by painted designs which are now covered by biofouling. In the future, the locker rings may be painted with various colors of anti-biofouling paint to ensure identification is visible.

Figure 14: Prevco connector locker rings.

Inside the doghouse well, several hydroids and patches of filamentous algae have collected.

Figure 15: Inside of doghouse well

These regions are protected from flow, and thus susceptible to biofouling. This report shows that biofouling is minimal on these internal components, but should be monitored in the future due to the potential of excessive growth in these protected conditions.

Additional Information:
<u>Prevco Locking Rings</u>

- **Supplier:** Subconn®
- **Part:** Locking Sleeve
- **Material:** "Delrin" – Polyoxymethylene (POM) – a.k.a. acetal, polyacetal, polyformaldehyde
- **Description:** injection molded synthetic polymer providing high stiffness, low friction, dimensional stability. Has a high abrasion resistance.
- **Sensitivities:** mineral acids and chlorine, alkaline attack, hot water

<u>Observed Biofouling:</u>
The Prevco Locking Rings showed growth of predominantly barnacles - hard fouling creatures.
Barnacles

- Exclusively marine, tend to live in shallow and tidal waters (100m/300ft or less), typically in erosive settings.
- Attach themselves to hard substrates; shells grow directly onto the substrate.
- Are suspension feeders, reach into the water column with modified feathery legs to draw plankton and detritus into shell for consumption.

- Competitors: limpets and mussels.

Biofouling of the Bottom Support Frame:
2013 Inspection, in conjunction with the 7/10/2013 Scouring Assessment

INTRODUCTION

On July 10, 2013, two divers recorded footage of the TidGen® Bottom Support Frame (BSF) for an assessment of scouring around each of the 10 piles. The procedure for this inspection can be found in document "D10-0175 TidGen Scour Measurement Procedure.docx" and the results of the assessment can be found under "TGU001 Pile Height Measurement Inspections" on the server: O:\Maine\TidGen Inspection. The footage from the scouring inspection has been used for the following qualitative report of biofouling on the BSF.

PROCEDURE

Dive footage from 7/10/2013 Pile Scouring Assessment (location: O:\Maine\TidGen Videos\2013 Videos\7 10 13 scour videos) was analyzed for incidents of biofouling on the BSF. Screenshots were taking from the videos of all piles, all anodes visible in the footage, and other locations showing significant signs of biofouling. Videos were analyzed in QuickTime Play, and snapshots were taken using Microsoft Snipping Tool. This report is broken into three segments: Pile Observations, Frame Observations and Anode observations.

Component Labels

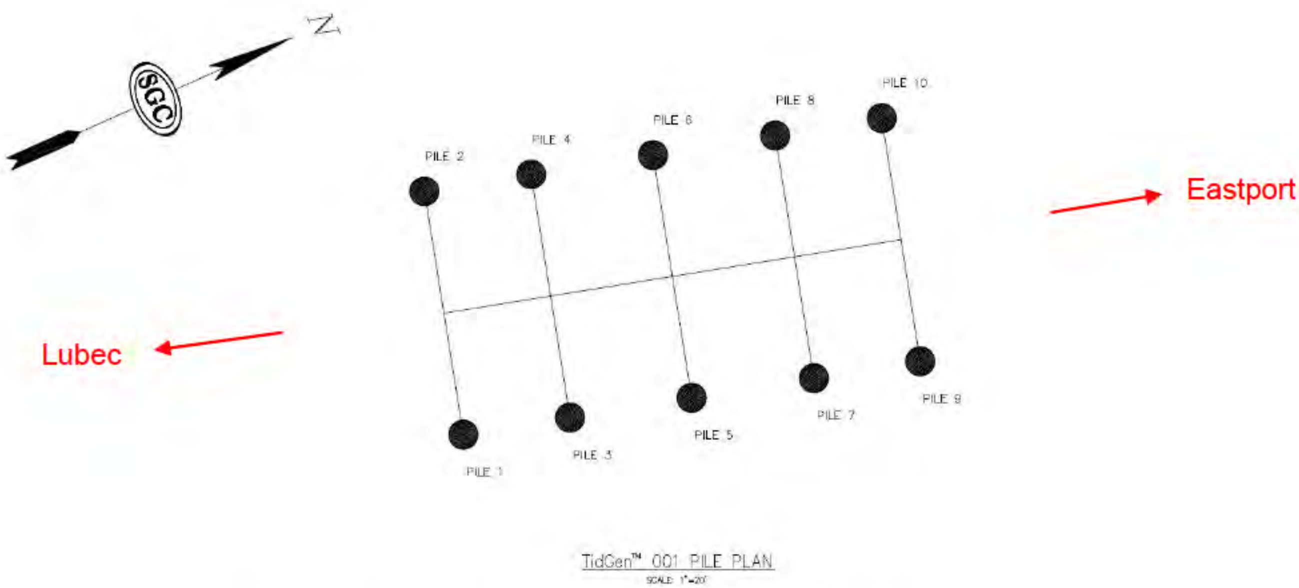


Figure 1. Pile Labels, with Lubec/Eastport Orientation.

Anode Locations are based on the corresponding pile locations. Each anode has been given a two digit name, consisting of the pile numbers it is between. Only anodes with available footage have been given identifiers.

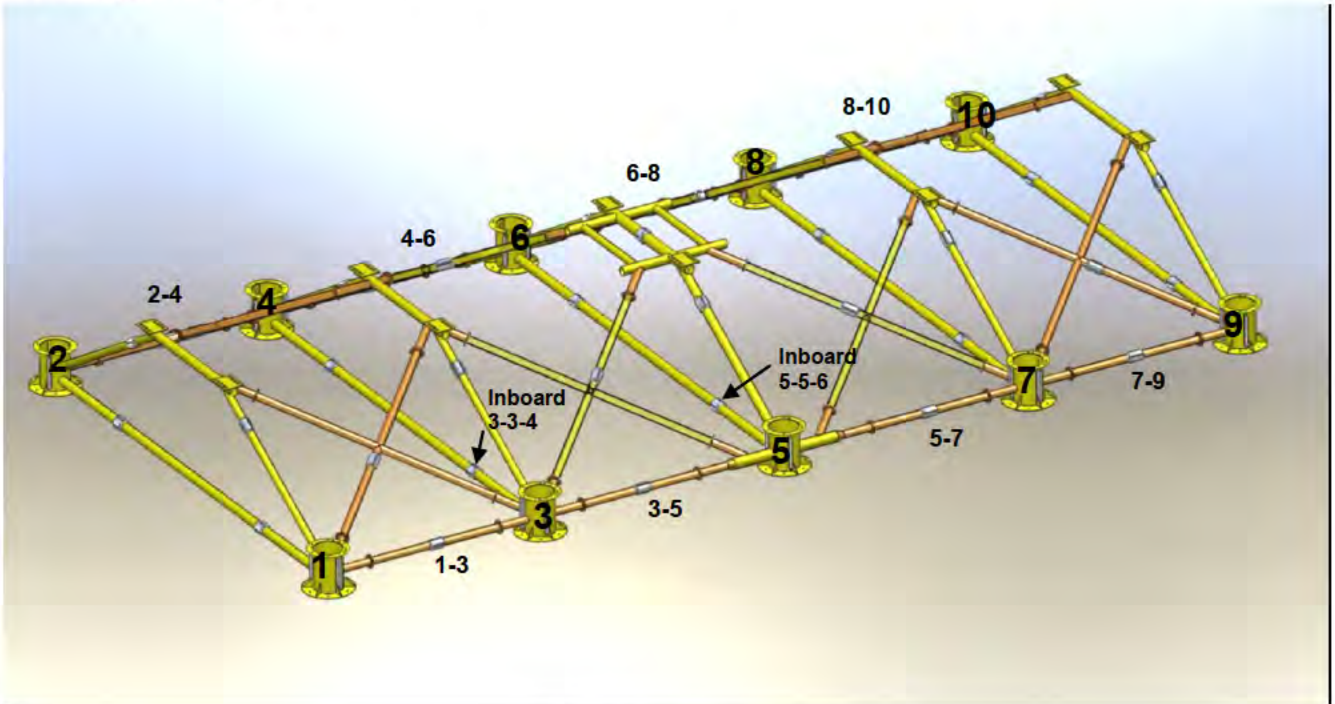


Figure 2. Anode Labels.

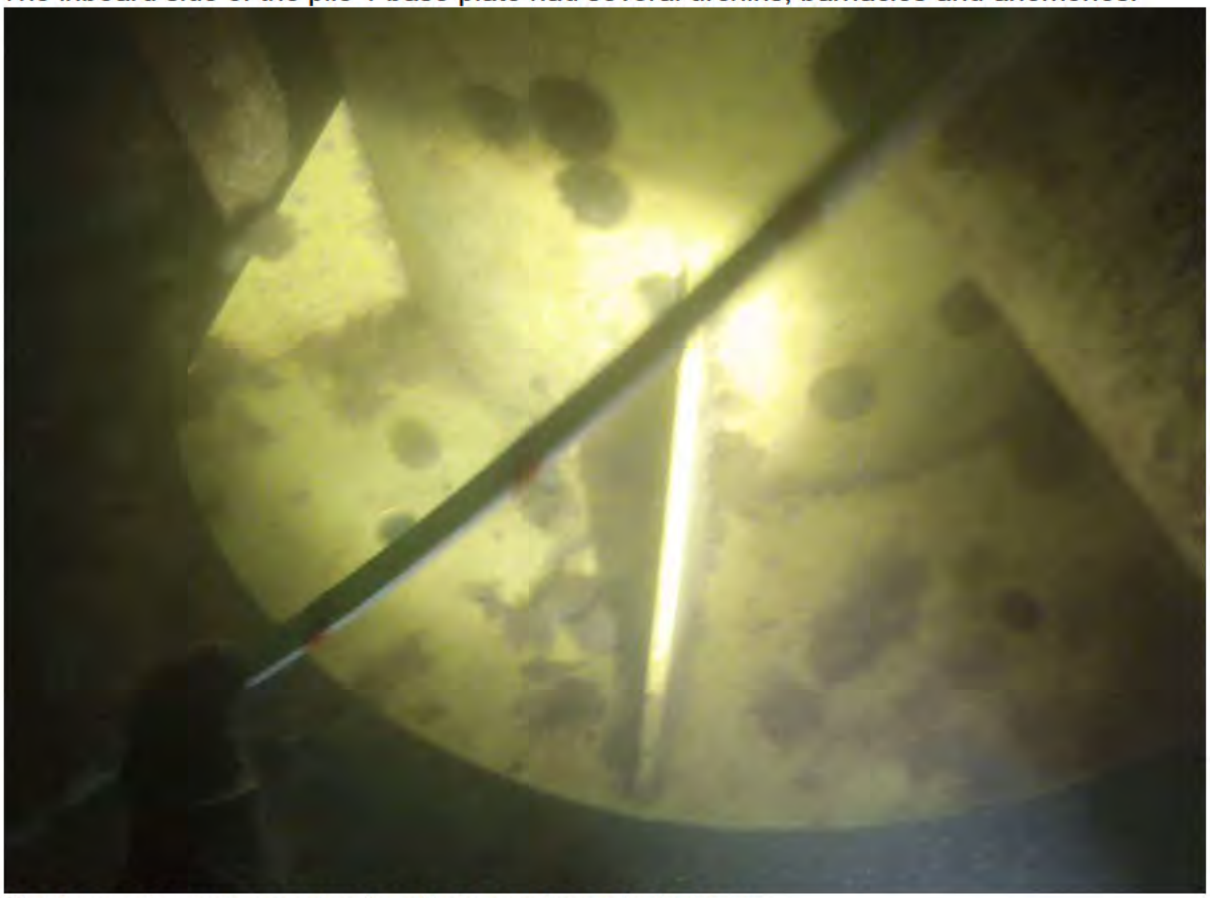
OBSERVATIONS

<u>Pile and Frame Observations:</u>

Pile 1:

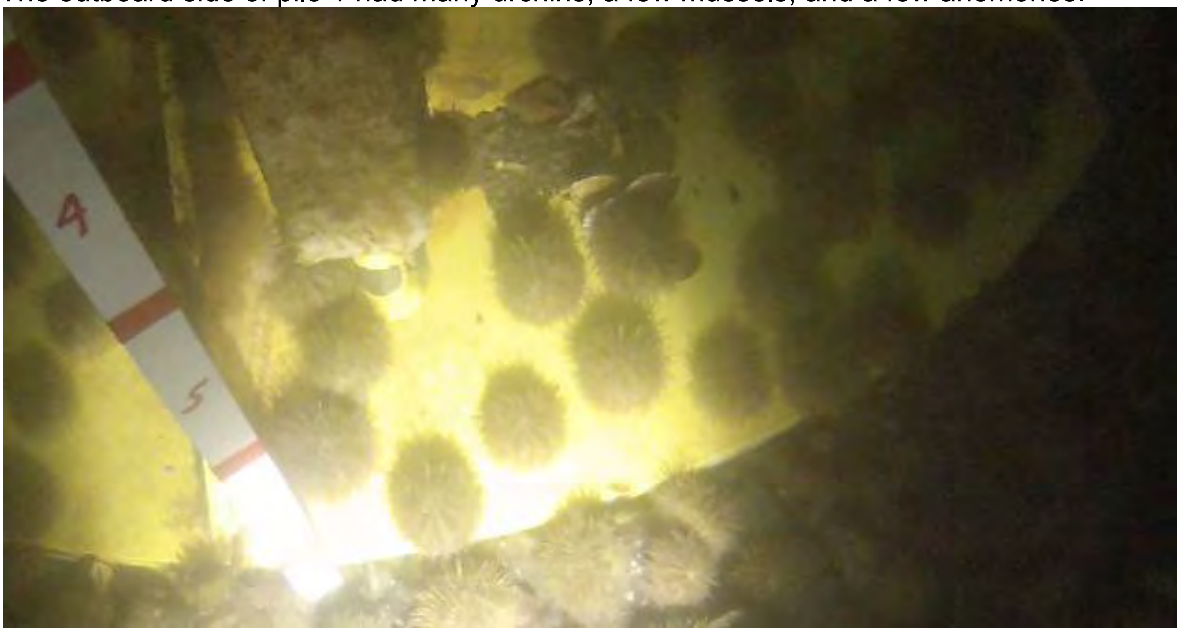
(Footage: Camera A, video GOPR0001)
The red paint upper section on pile 1 had approximately 90% barnacle coverage. Pictures show before and after diver scraped at barnacles with yard stick.

The inboard side of the pile 1 base plate had several urchins, barnacles and anemones.



The barnacles grew predominantly in crevices of pile base.

The outboard side of pile 1 had many urchins, a few mussels, and a few anemones.



(Footage: Camera A, video GOPR0001)
Hinge near pile 1 shows that urchins congregate around hinges, perhaps because they provide protection on one side.

Very thick growth on frame between piles 1 and 2. Growth increases dramatically as diver swims from 1 to 2. Near pile 1, frame shows some urchin growth, and many barnacles. Closer to pile 2, frame shows very thick mussel growth.

In this image, the diver is scraping at the mussels with his measuring stick.

After scraping the mussels off:

Pile 2:

(Footage: Camera D, video GOPR0001)
Pile 2 has very minimal growth.

The base plates show some urchin and barnacle growth.

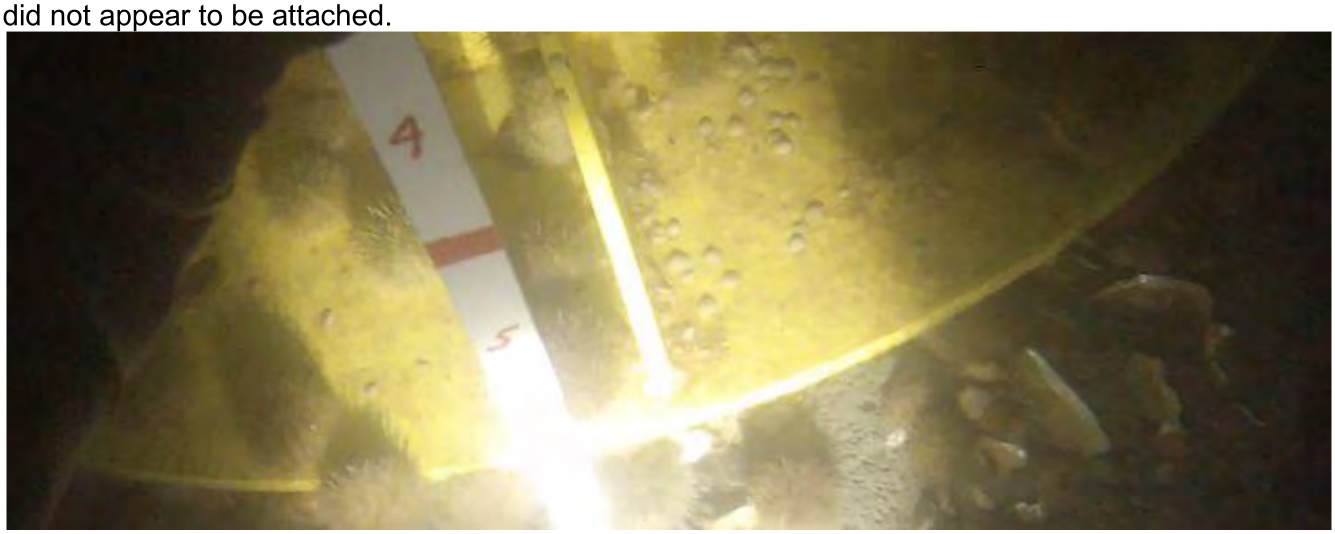
There are a few pieces of line and metal strewn about the base plate.

Pile 3:

(Footage: Camera A, video GOPR0001)

The red paint upper portion of pile 3 had several urchins and many small barnacles. The diver easily removed the urchins with his yard sick, with no signs of paint chip underneath.

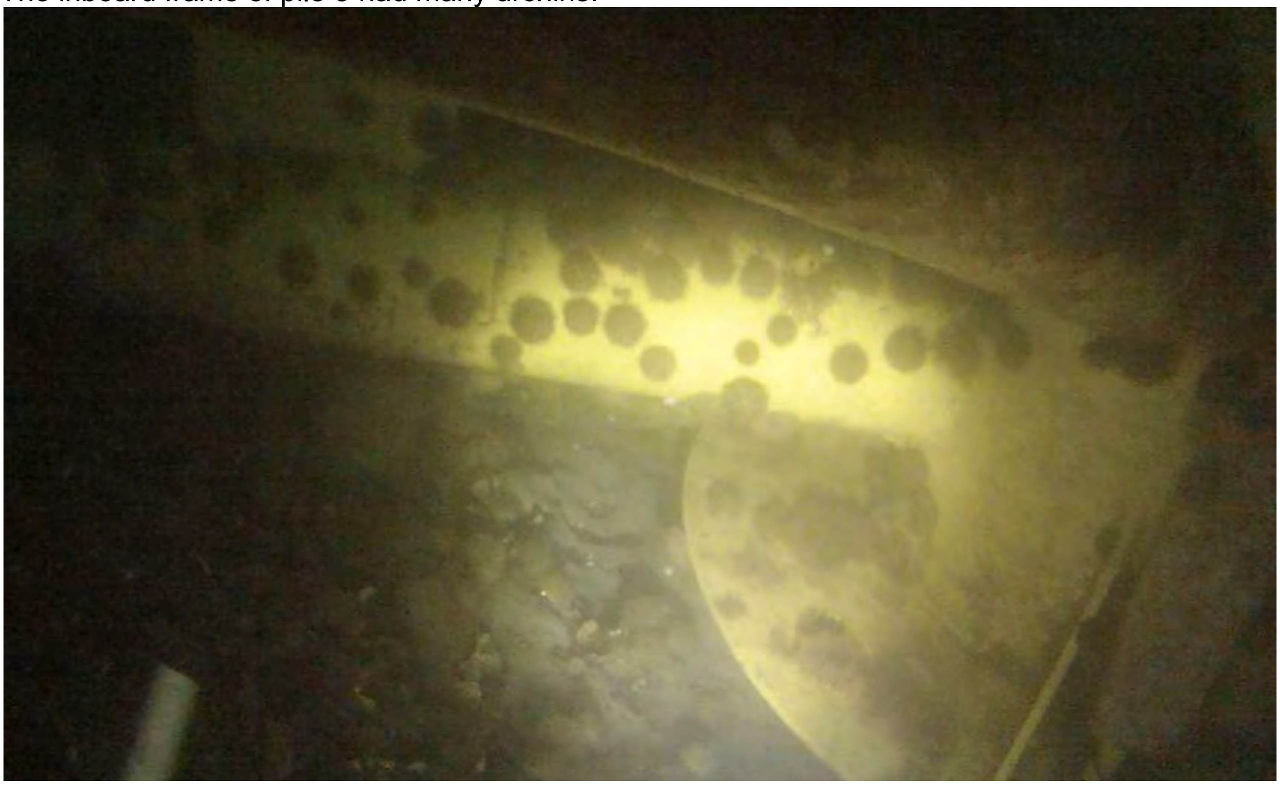
Pile 3 overall showed minimal growth. Several urchins were attached, and several barnacles are visible but there was overall very little additional growth One large piece of kelp was on the frame, but did not appear to be attached.



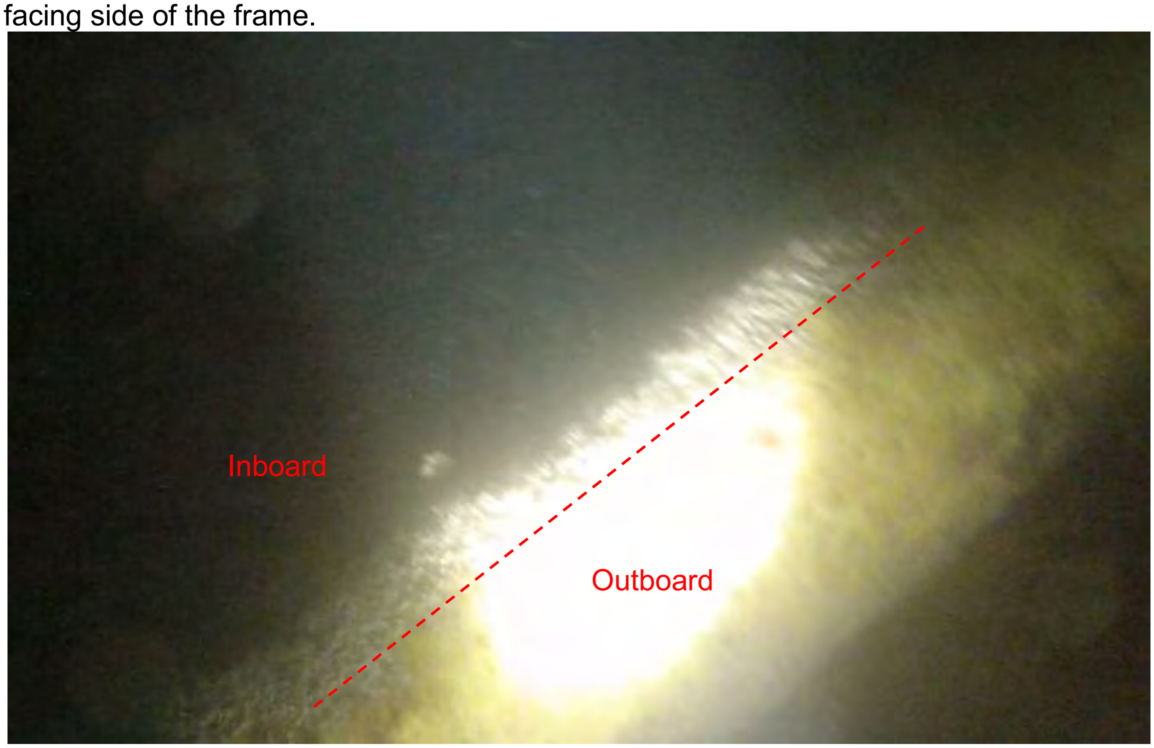
The white paint above pile 3 has patches of dense mussel growth.

At the base of pile 3, a gray substrate is visible. There is significantly less growth on this substrate than the surrounding seafloor. Likewise, there is minimal growth on the base of this pile.

The inboard frame of pile 3 had many urchins.



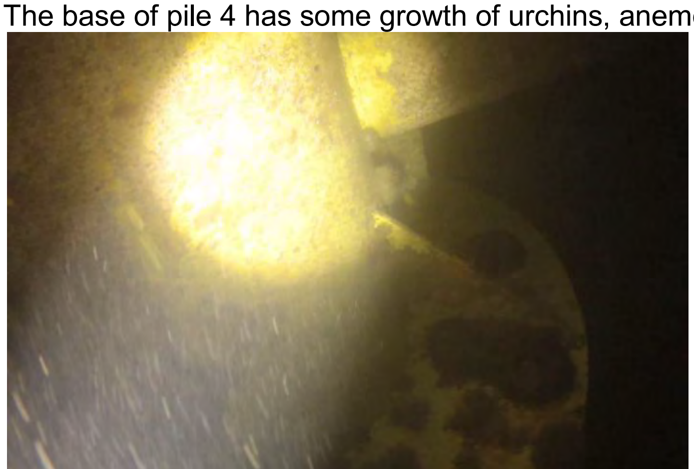
Between piles 1 and 3, there is some dense barnacle and mussel growth, but only on the inboard facing side of the frame.



Pile 4:

(Footage: Camera D, video GOPR0001)
The main shaft on pile 4 has significant barnacle growth. This image shows the growth before in one region where the diver scraped barnacles off with his measuring stick.

The base of pile 4 has some growth of urchins, anemones and barnacles.

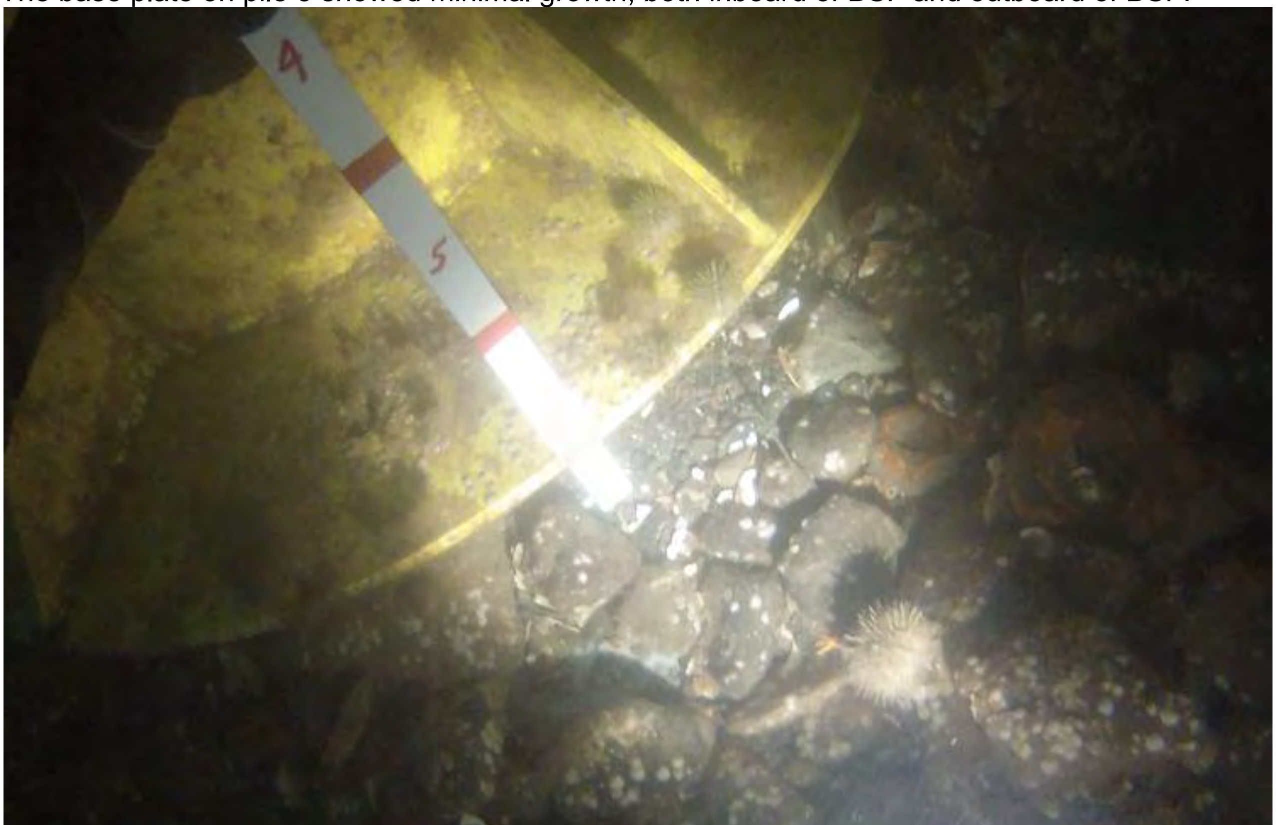


Pile 5:

(Footage: Camera A, video GOPR0001)
Several urchins adhered to pile walls.

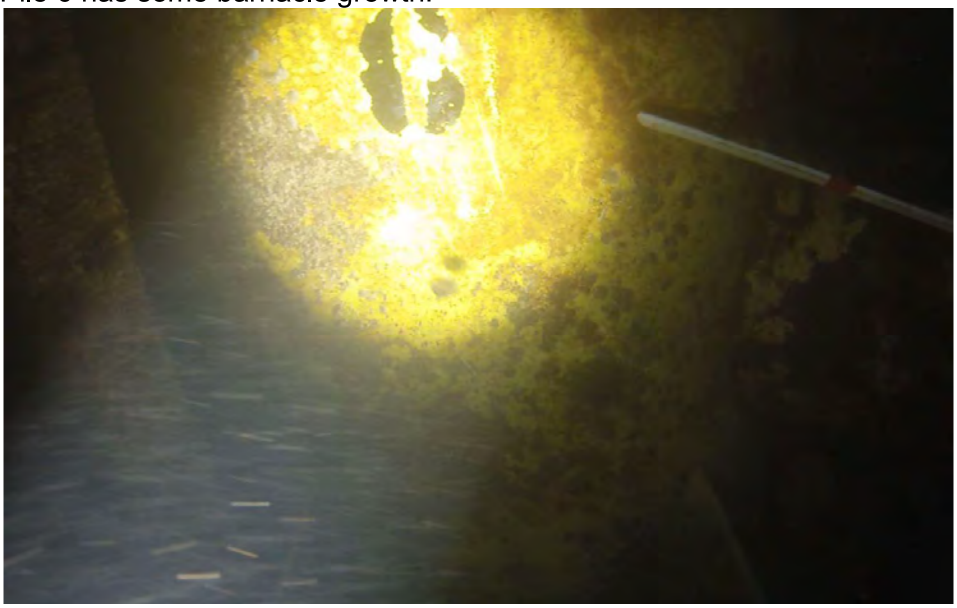
One fish observed laying on pile 5; swam away when diver approached with measuring stick.

The base plate on pile 5 showed minimal growth, both inboard of BSF and outboard of BSF.

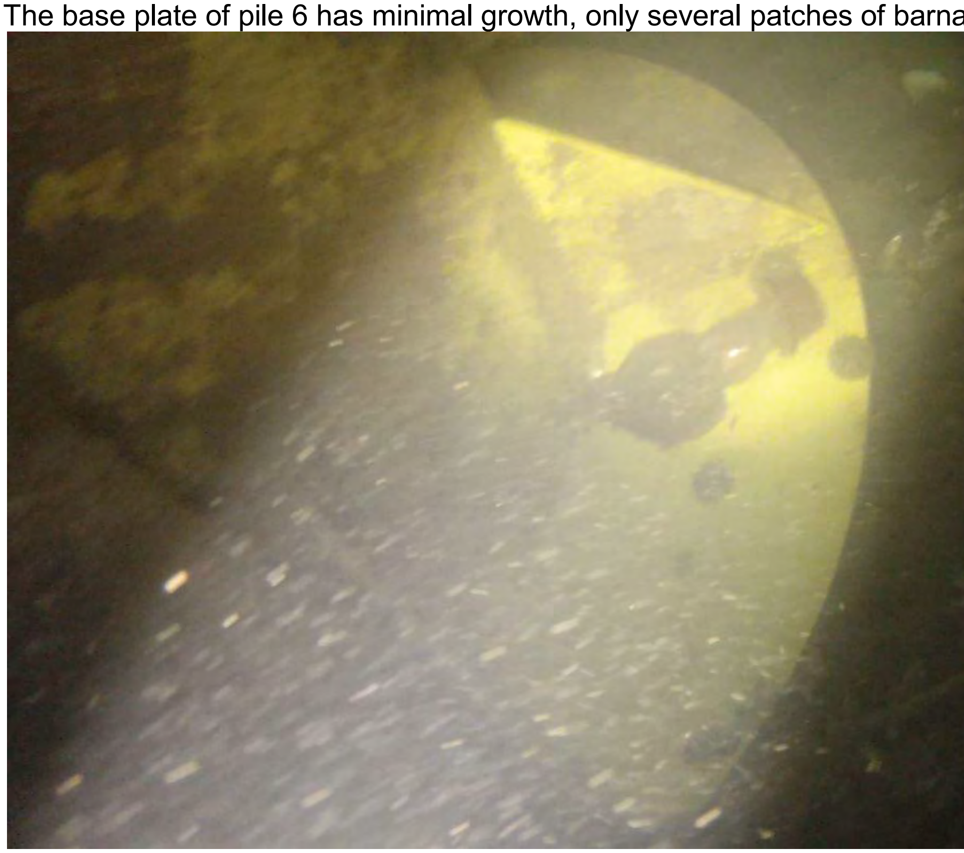


Pile 6:

(Footage: Camera D, video GOPR0001)
Pile 6 has some barnacle growth.



The base plate of pile 6 has minimal growth, only several patches of barnacles.



One lobster was observed near pile 6.

Pile 7:

(Footage: Camera A, video GOPR0001)
The base plates on pile 7 show minimal mussel buildup. There are several urchins present, with approximately 40% algae/grass coverage.

Two anemones are observed on the red paint, upper pile segment. Several large barnacles are present.

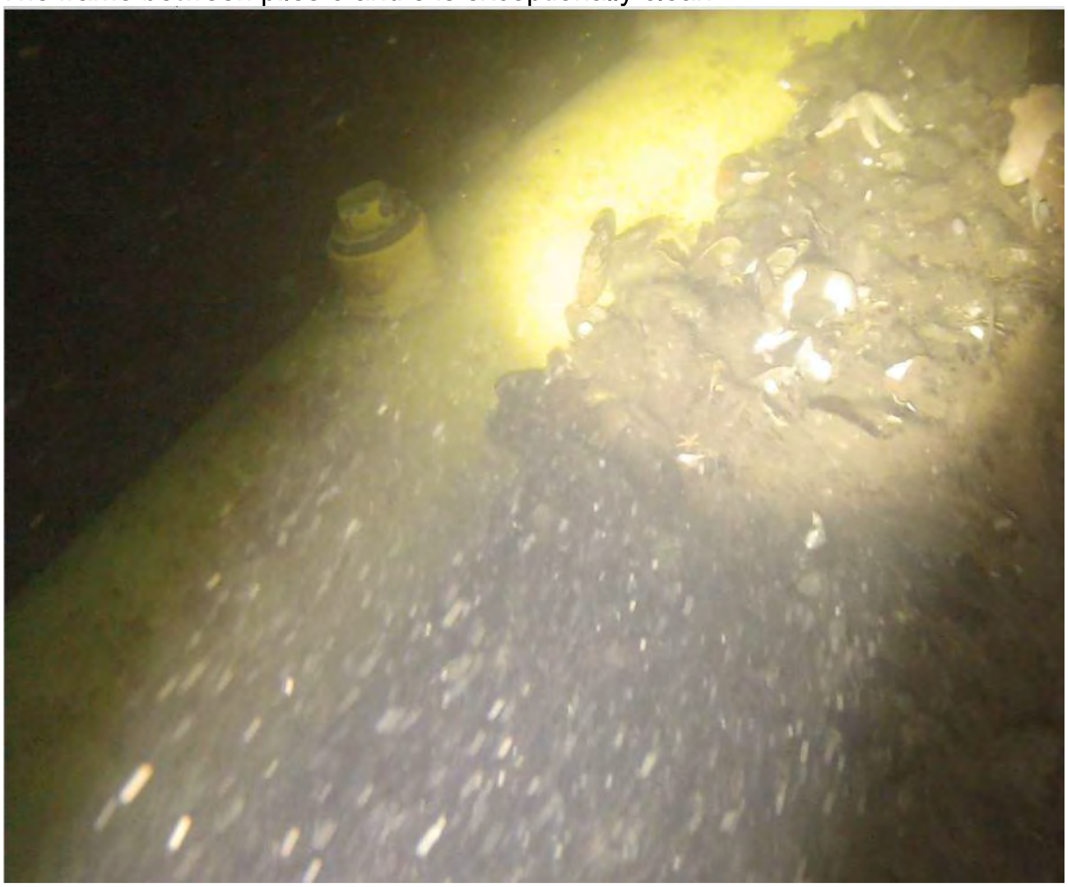
Dense patch of mussels observed on frame between pile 7 and pile 9.

Pile 8:

Pile 8 had thick barnacle growth, relative to piles 2 and 6.

The base of pile 8 has some mermaid's hair, barnacles and urchins.

The frame between piles 6 and 8 is exceptionally clean.



Pile 9:

(Footage: Camera A, video GOPR0001)
BSF between pile 7 and 9 densely covered (80% visible surface) in mussels. Base of pile 9 has heavy fouling of mussels, urchins, and sea stars. Seen on flat horizontal surface on base and rounded walls of pile. Accumulation on base plates of pile is approximately 4 inches thick with 100% coverage on "exterior" edge (eastport side) and much thinner with only 60% coverage on "interior" edge (towards pile 7).

Top of pile has large, dense patches of mussels (100% mussel, surrounded by 0% mussel).

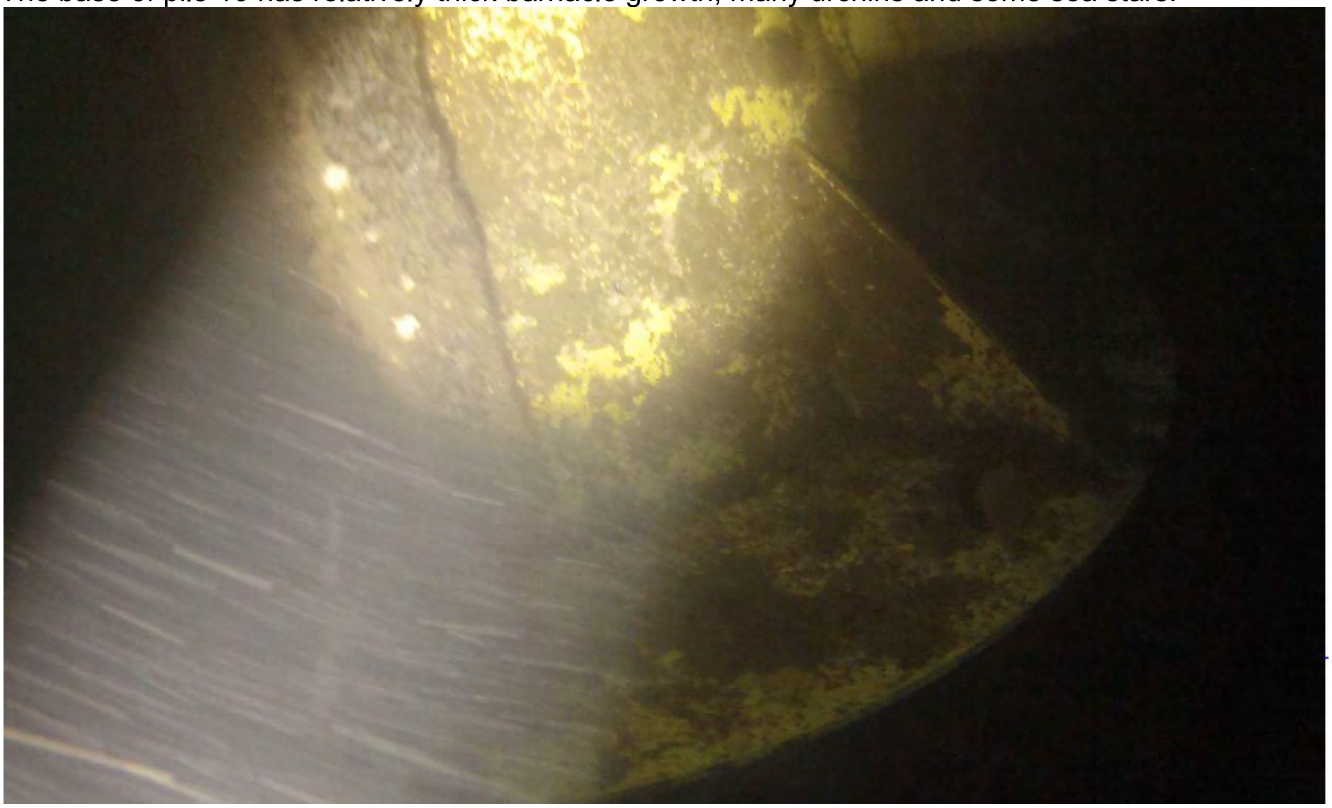
Between pile 9 and pile 10, buildup of mussels can be seen above conduit.

One region of fire hose between pile 9 and 10 is sagging off of BSF.

Pile 10:

(Footage: Camera A, video GOPR0001)
Pile 10 has heavy mussel growth, and dense barnacle growth.

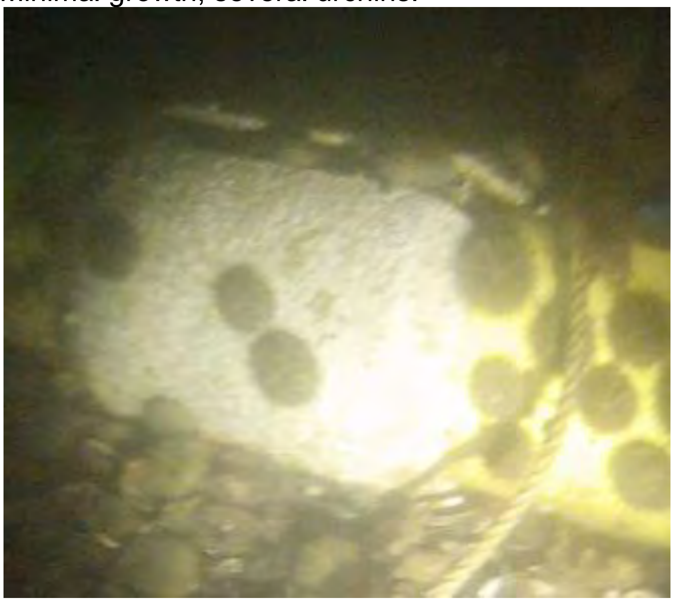
The base of pile 10 has relatively thick barnacle growth, many urchins and some sea stars.



Anode Observations:

Anode 1-1-2:

(Footage: Camera A, video GP010001)
Minimal growth, several urchins.



Anode 2-2-1:

(Footage: Camera A, video GP010001)
This anode has very thick mussel coverage (up to 6 inches thick). There is an urchin growing between the halves of the bracelet.

Anode 1-3

No footage.

Inboard Anode 3-3-4:

(Footage: Camera A, video GOPR0001)
Very minimal growth.

Anode 3-5:

(Footage: Camera A, video GOPR0001)
Shows 100% coverage in mussels. Large strand of kelp is draped over the top.

Anode 5-7:

(Footage: Camera A, video GOPR0001)
Covered in 100% mussels. Diver scraped anode with measuring stick and mussels did not remove easily.

Inboard Anode 5-5-6:

(Footage: Camera A, video GOPR0001)
Anode has minimal mussel growth.

Anode 7-9:

(Footage: Camera A, video GOPR0001)
Densely covered (100% visible surface) in mussel growth.

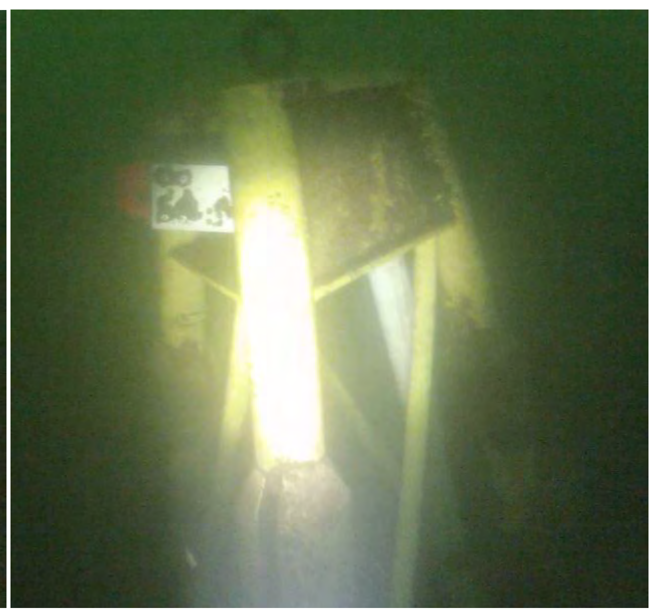
<u>Biofouling on Simrad Tower</u>

Some stretches of the fire hose cable housing have twists.

One staple appears to have a shallow hold on the substrate.

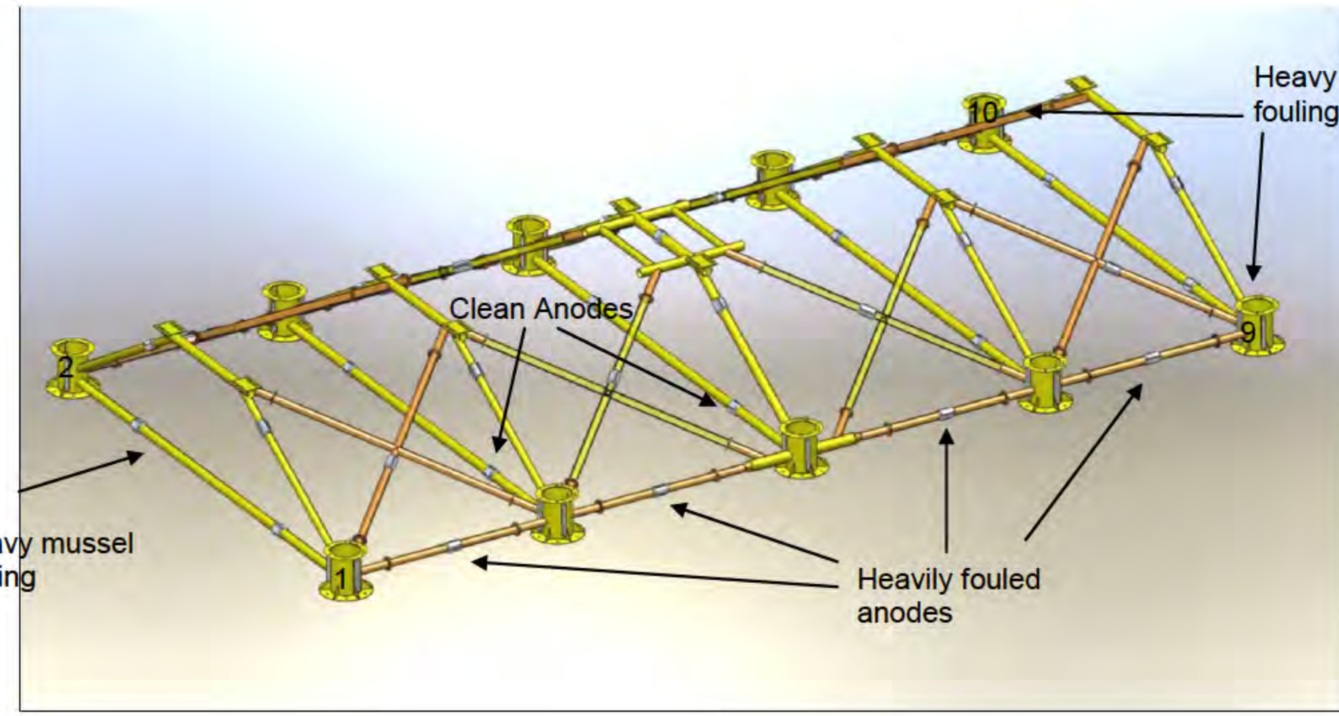
Anodes have some algae and mermaid hair growth, but no signs of mussels or barnacles.

Overall, the simrad tower has minimal growth.



CONCLUSIONS

- Overall, the BSF is heavily fouled
- Overall, fouling does not seem to inhibit functionality of BSF
- Fouling may interfere with conduits and fire hoses
- Anodes on outermost frame members have dense barnacle growth.
- Anodes that are inboard are relatively clean.
- Piles 9 and 10 have significantly more biofouling than other piles.
- The stretches of frame between piles 1 and 2 and between piles 9 and 10 have very dense barnacle growth, favoring the side closer to piles 2 and 10.



Observed Species:

- Mussels (black)
- Urchins (rock boring)
- Sea stars
- Barnacles
- Algae
- Mermaid's hair
- Hydroids

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Appendix D

Fisheries and Marine Life Interaction Monitoring, Bi-Annual Report, University of Maine, School of Marine Sciences, September 2013

2013 Annual Report: Maine Department of Marine Resources Special License Number ME 2013-02-03, University of Maine, School of Marine Sciences, January 6, 2014

Fisheries and Marine Life Interaction Monitoring

Bi-Annual Report

September 2013

University of Maine, School of Marine Sciences
Haley Viehman, Garrett Staines, Gayle Zydlewski

Contents

1.0 Introduction: Study Context and Purpose 2
2.0 Fisheries Monitoring (downlooking hydroacoustics) 2
    2.1 Methods........ 3
    2.2 Results 7
3.0 Marine life interaction monitoring (side-looking hydroacoustics)........ 12
    3.1 Methods........ 12
    3.2 Results 20
4.0 Summary 25
    4.1 Fisheries monitoring (down-looking hydroacoustics)........ 25
    4.2 Marine life interaction monitoring (side-looking hydroacoustics) 27
5.0 References 29
Appendix 1: Fish Community Assessment in Cobscook Bay, Maine 30

1.0 Introduction: Study Context and Purpose

Ocean Renewable Power Company, LLC (ORPC) deployed a TidGen® Power System in outer Cobscook Bay, Maine, as the first stage of the Cobscook Bay Tidal Energy Project (CBTEP) (Figure 1). This installation requires monitoring to assess potential effects of the TidGen® Power System on the marine environment. ORPC's marine life monitoring plan has two parts: 1) Fisheries Monitoring and 2) Marine Life Interaction Monitoring.

Figure 1. Cobscook Bay Tidal Energy Project location map and TidGen® device drawing (CBTEP Fisheries and Marine Life Interaction Plan, 2012). The yellow icon represents the location of the TidGen® device. The grey icons represent potential TGU locations to complete an array in the future.

2.0 Fisheries Monitoring (downlooking hydroacoustics)

The Fisheries Monitoring Plan is a continuation of research started by the University of Maine's School of Marine Science researchers in 2009. The study was designed to capture annual, seasonal, tidal, and spatial variability of fish presence in the area of interest (near the TidGen® deployment site). The design involves down-looking hydroacoustic surveys during several months of the year, and examines the relative density and vertical distribution of fish at the project site and a control site. Pre-deployment data were collected in 2010, 2011, and early 2012, and post-deployment data were collected from August 2012 through September 2013 (August 2012 through June 2013 are reported here). Data from the project site were compared to the control site to quantify changes in fish presence, density, and vertical distribution that may be associated with the installation of the TidGen® power system. ORPC plans to conduct surveys through the year 2017.

2.1 Methods

2.1.1 Study design

Down-looking hydroacoustic surveys were conducted from an anchored research vessel for one 24-hour period several times per year at a project site (CB1) and a control site (CB2) (Table 1, Figure 2). During the time when the complete TidGen® (bottom support structure and the dynamic turbine) was in the water (from here on referenced as "deployment"), three sites were sampled: two at the project location (CB1a, beside the turbine, and CB1b, in line with the turbine) and one at the same control site (CB2) (Figure 2). Sampling locations at the project sites in 2012 varied geographically because of construction activities and related safety concerns around the TidGen®. January and March 2012 were pre-deployment surveys, so only CB1 and CB2 were sampled. In January, CB1 was only sampled for 12 hours due to unsafe weather conditions. There was no November 2012 survey because the dynamic part of the TidGen® was removed for maintenance at the time.

The down-looking surveys were carried out using a single-beam Simrad ES60 commercial fisheries echosounder, with a wide-angle (31° half-power beam angle), dual-frequency (38 and 200 kHz) circular transducer. The transducer was mounted over the side of the research vessel 1.8 meters below the surface, and ensonified an approximately conical volume of water extending to the sea floor. Current speed was measured every half-hour of each survey using a Marsh-McBirney flow meter (May 2011 to May 2012) or a Workhorse Sentinal Acoustic Doppler Current Profiler (ADCP) (June 2011 onward). A 300 kHz ADCP was used in 2011 and 2012, and a 600 kHz ADCP was used in 2013. Every 30 minutes, the ADCP operated for 1 minute, recording mean current speed in 1 m depth bins from 3 m below the surface to the sea floor.

Table 1. Months sampled for Fisheries Monitoring Plan (down-looking hydroacoustics). 1 and 2 indicate sampling at CB1 and CB2, respectively; 1a, 1b, and 2 indicate sampling at CB1a (beside), CB1b (in-line), and CB2 (control), respectively. Light gray indicates presence of TidGen® bottom frame only; dark gray indicates presence of complete TidGen®.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2010					1, 2			1, 2	1, 2	1, 2	1, 2	
2011			1, 2		1, 2	1,2		1, 2	1, 2		1, 2	
2012	1, 2		1, 2		1a, 1b, 2	2		1a, 1b, 2	1a, 1b, 2			
2013			1a, 1b, 2		2	2						

Figure 2. Fisheries Monitoring Plan study area and down-looking hydroacoustic survey locations for 2010-2013. CB1 and CB2 are indicated by dashed ovals. CB1a and CB1b are indicated by small round points. CB1 current directions are averages provided by Ocean Renewable Power Company.

The single-beam transducer was used to obtain an index of fish density, which allowed us to examine changes in fish density over time. This relative measure was also used to assess vertical distribution of fish throughout the water column.

Comparisons of fish density and vertical distribution were made among the control site and project site(s) and among different months at each site. Sampling before and after turbine deployment at the project as well as at a control site improves the ability to distinguish changes that may be related to the presence of the turbine from changes due to annual, seasonal, daily, and tidal variation. These methods are consistent with a before-after-control-impact (BACI) study design.

2.1.2 Data processing

Hydroacoustic data were processed using Echoview® software (5.3, Myriax Pty. Ltd., Hobart, Australia), and statistical analyses were carried out in R (2.15.2, R Core Team, Vienna, Austria). The data collected at the 200 kHz frequency were used in analyses. Processing included scrutinizing the data and manually removing areas of noise (e.g., from electrical interference, a passing boat's depth sounder, high boat motion, or interference from the ADCP). Hydroacoustic interference from entrained air was common in the upper 10 m of the water column, so the top 10 m of the water column were excluded from analyses. Weak hydroacoustic signals, such as plankton, krill, and fish larvae, were excluded by eliminating backscatter with target strength (TS) less than -60 dB. Most fish have TS between -60 dB and -20 dB but TS varies greatly with fish anatomy and orientation (Simmonds and MacLennan 2005). This variability, combined with the TS uncertainty inherent in single beam systems, means that some fish with TS higher than -60 dB were likely excluded from analyses (Simmonds and MacLennan 2005).

In March and June of 2013, some weak background noise from electrical interference could not be eliminated using the -60 dB threshold. Echoview's background subtraction tool (based on the algorithm developed by de Robertis and Higginbottom, 2007) was used to remove this interference.

Because flowing tides were the focus of this study, hydroacoustic data during slack tides were not included in analyses. Slack tides were defined as the hour centered at the time of low or high water. The time of low and high tide was determined using the depth of the bottom line detected in Echoview. Thirty minutes to either side of these time points was then removed from the hydroacoustic dataset.

Fish density was represented on a relative scale using volume backscattering strength, S_v, which is a measure of the sound scattered by a unit volume of water and is assumed proportional to density (Simmonds and MacLennan 2005). S_v is expressed in the logarithmic domain as decibels, dB re 1 m^{-1}. The vertical distribution of fish throughout the water column was examined using the area backscatter coefficient, s_a, which is the summation of volume backscatter over a given depth range and is also proportional to fish density (Simmonds and MacLennan 2005). s_a is expressed in the linear domain ($m^2 \cdot m^{-2}$) and is additive.

The inspected and cleaned hydroacoustic data were divided into 30-minute time segments, which were large enough to minimize autocorrelation but maintain variation in density that occurred over the course of each survey. Echoview was used to calculate the mean S_v of the entire water column for each 30-min interval. Then, for each interval, s_a was calculated for 1-m layers of water. Layers were measured upward from the sea floor, rather than downward from the surface, because the turbine is installed at a fixed distance above the bottom (the top of the turbine is 9.6 m above the sea floor). By calculating the proportion of total water column s_a contributed by each 1-m layer of water, the vertical distribution of fish was constructed for each 30-min interval.

2.1.2 Statistical analyses

To examine annual, seasonal, tidal, and spatial variability of fish density in the area of interest, comparisons of water column fish density index (S_V) were made using permutation ANOVAs (R package *lmPerm*; Wheeler 2010), followed by nonparametric Tukey-type multiple comparisons to determine significant differences (R package *nparcomp*; Konietschke 2012). Five questions were asked:

1) Inter-annual variability: was fish density constant across years? We tested the effect of year on fish density in outer Cobscook Bay, combining data for all sites.
2) Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? We tested the effect of site on mean water column S_V for surveys in which CB1a and CB1b were both sampled (May, August and September 2012, and March 2013). If CB1a and CB1b have similar fish densities, they may be grouped for comparison to CB1 surveys carried out in previous years.
3) Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? To validate the utility of CB2 as a control site, differences between the project site (CB1) and control site (CB2) were evaluated using month and site as factors.
4) Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? The effect of month on fish density was tested, combining data for CB1 and CB2.

5) Did deployment of the TidGen® affect fish density at the project site (CB1)? Results from the tests in (2) were used to compare differences before and after device deployment.

The vertical distribution of fish was compared between sites within each survey, with the goal of detecting differences potentially related to the presence of the turbine. To test the similarity of two distributions, one was fit to the other with linear regression. Similar vertical distributions were indicated by a significant fit (significance level of 0.05) and a positive slope. Negative slope or insignificant fit indicated dissimilar distributions. If distributions at the project and controls sites were similar before the turbine was installed, differences afterward may indicate an effect of the turbine on how fish use the water column (e.g., avoidance of the depths spanned by the turbine). Differences between CB1a and CB1b may also indicate behaviors altered by the turbine's presence.

2.2 Results

2.2.1 Relative fish density

1) Inter-annual variability: was fish density constant across years? Fish density (mean water column S_v) changed significantly each year. Density was significantly higher in 2010 and 2012 than 2011 and 2013 (Figure 3). Because of these differences, years were analyzed separately in subsequent statistical analyses.

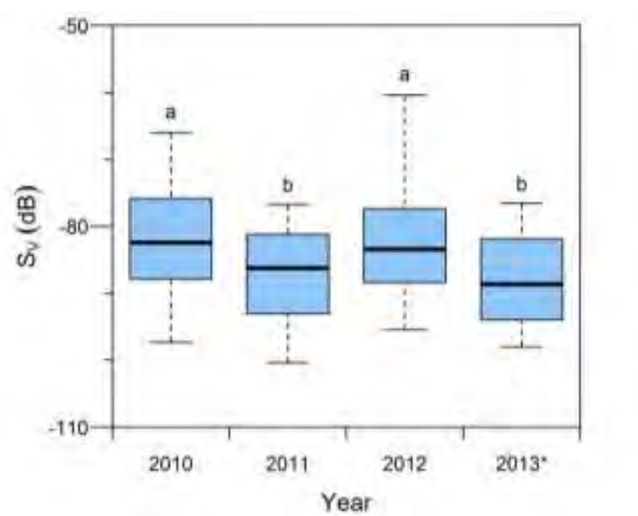


Figure 3. Water column S_v for all years sampled (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles. Significantly different groups are indicated by letters a and b. (*) In 2013, only March, May, and June have been analyzed.

2) Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? There were no differences in fish density (total water column S_v) between CB1a and CB1b (Figure 4). As such, we grouped these two sites as CB1 in further analyses of water column S_v.

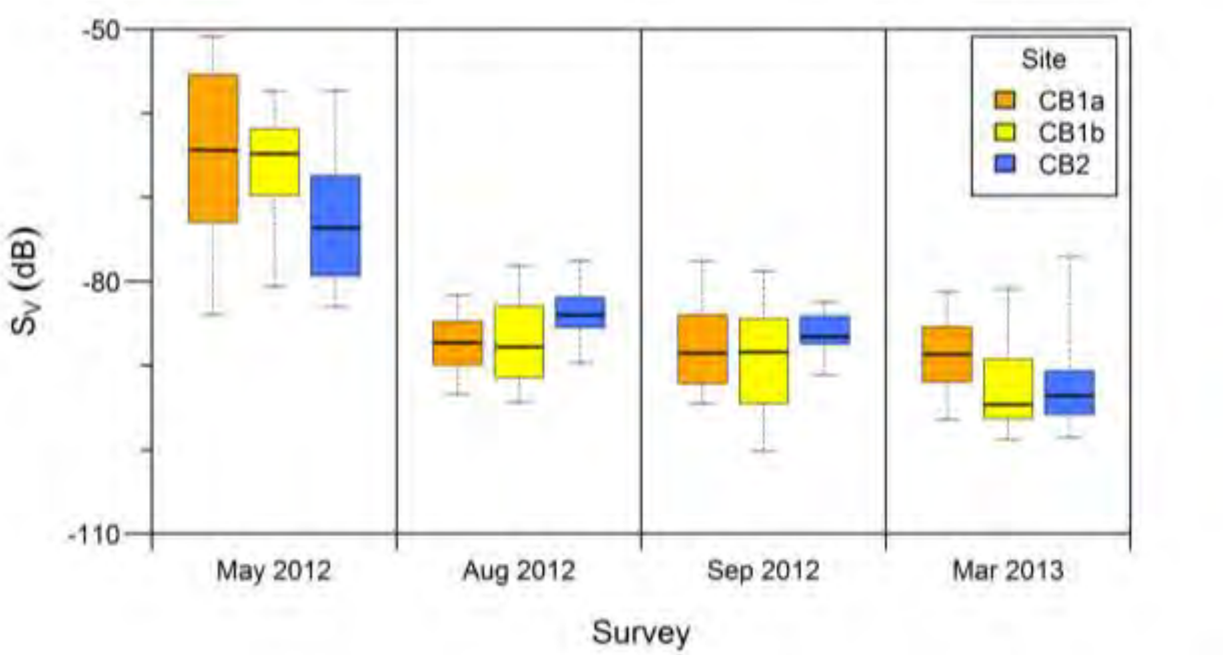


Figure 4. Water column S_v at CB1a, CB1b, and CB2 surveys in 2012 and 2013. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles.

3) Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? In each year, fish density varied significantly with month (Figure 5). Site had a significant effect on fish density in 2011, meaning density was greater at CB2 when data from all surveys were grouped together. However, within surveys (months), densities at CB1 and CB2 were not significantly different. The interaction of site and month significantly affected fish density in 2010 and 2012, indicating that site had a different effect on density in the different months. Multiple comparisons showed that fish density was significantly different at CB1 and CB2 in September 2010 and in March and August of 2012, but that there was no effect of site in the other surveys. Interaction effects could not be tested in 2013 since CB1 was only sampled in only one of three months.

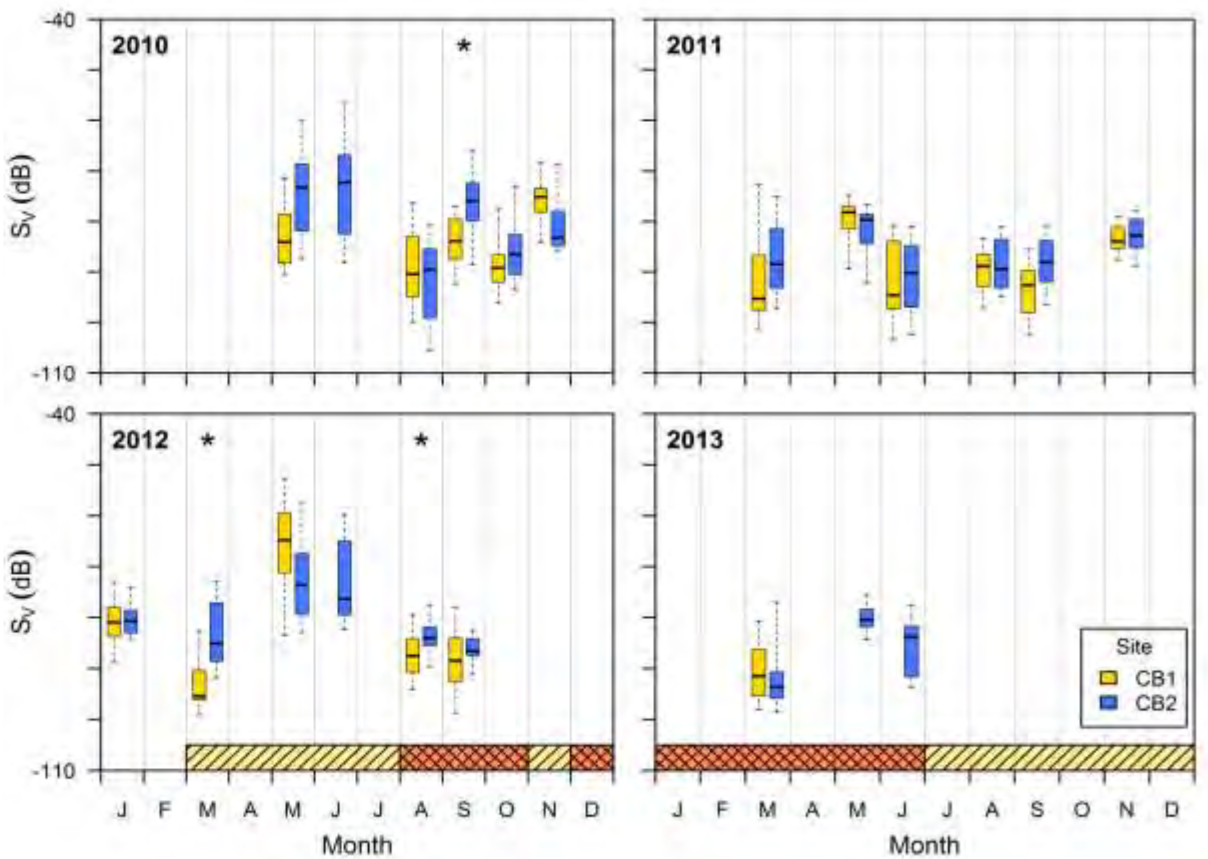


Figure 5. Water column S_v at CB1 (which includes CB1a and CB1b data) and CB2. Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5th and 95th percentiles. Asterisks indicate significant differences between CB1 and CB2. † indicates surveys when only ebb tide data were sampled; ‡ indicates surveys when only daytime was sampled. Yellow hatched box indicates surveys when the TidGen® bottom frame was present on the seafloor; red hatched boxes indicate when the TidGen® turbine was also present. The turbine was braked (present but not spinning) starting mid-April until it was removed in July.

4) Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? Results of multiple comparisons indicated highest fish densities in May and June, followed by November (Figure 6).

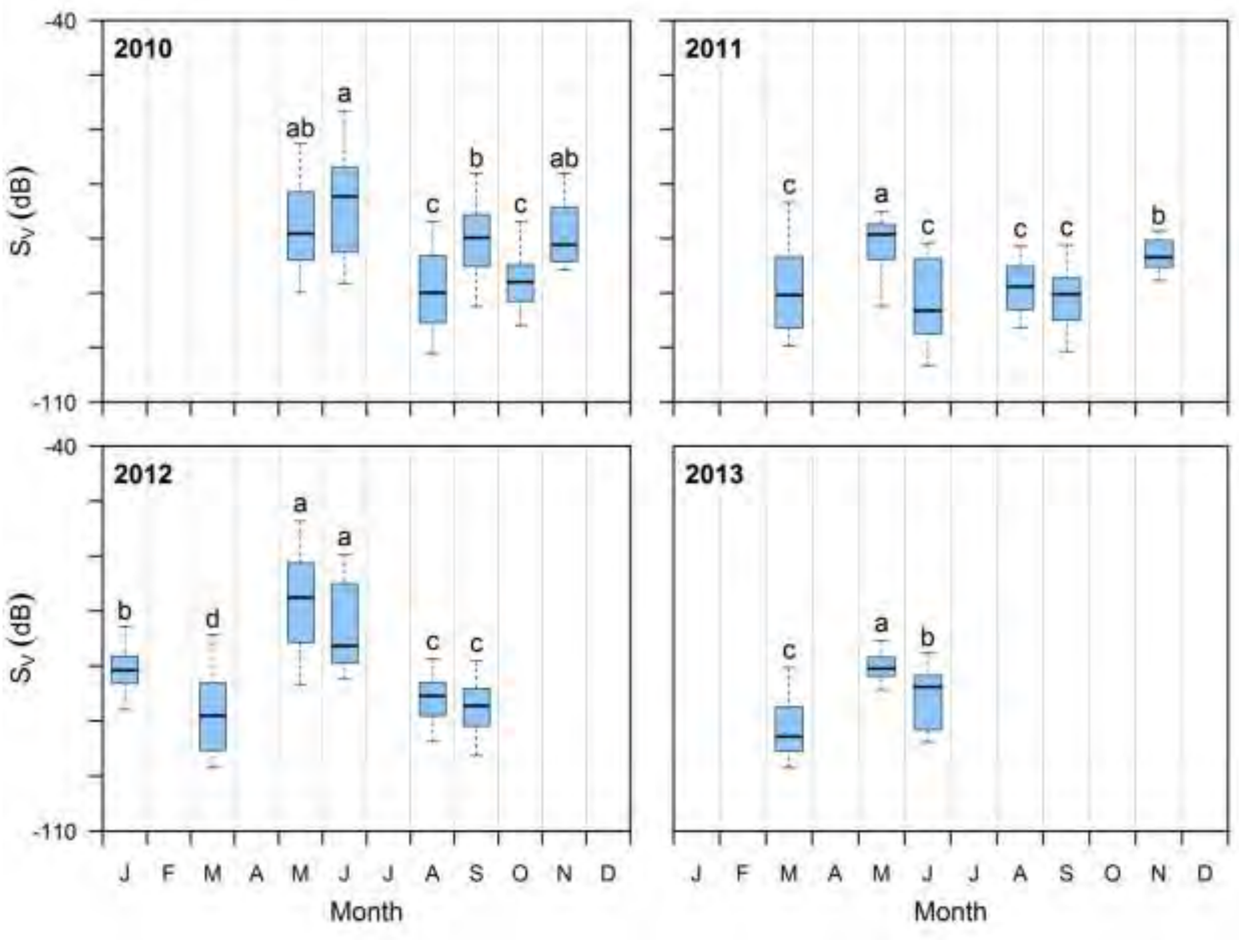


Figure 6. Water column S_v for all surveys (CB1 and CB2 data pooled together). Bold horizontal line indicates the median, boxes span the interquartile range, and whiskers extend to the 5^{th} and 95^{th} percentiles. Significantly different groups within each year are indicated by letters a through d (group a is the highest, d is the lowest).

5) Did deployment of the TidGen® affect fish density at the project site (CB1)? A significant difference between CB1 and CB2 was found only in the August 2012 survey, when CB2 had a higher density index (water column S_v) than CB1 (Figure 5). A similar difference was seen in March 2012, when the turbine's bottom support frame was deployed.

2.2.2 Vertical Distribution

Significant differences were only found between sites CB1 and CB2 in May 2011, CB1 and CB2 in March 2012, CB1a and CB2 in May 2012, CB1b and CB2 in May 2012, and CB1a and CB1b in March 2013 (Figure 7).

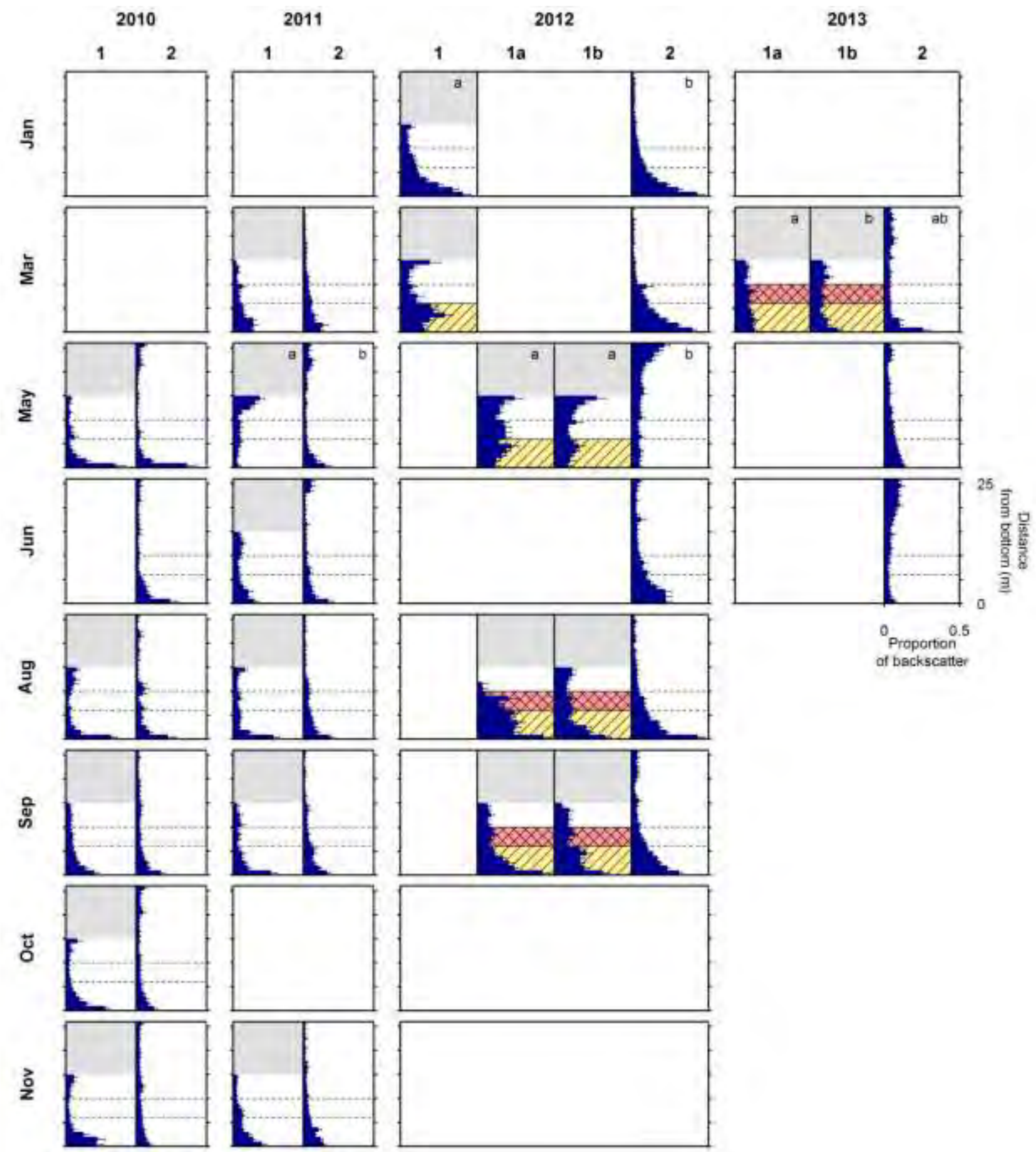


Figure 7. Mean proportion of S_a contributed by each layer of the water column. All layers analyzed are shown for each site (0-15 m above the bottom at CB1, 0-26 m above the bottom at CB2). Whiskers are one standard error. Depth of turbine is indicated by horizontal dashed lines. Yellow hatched areas indicate

when the bottom support frame was deployed at the project site; red hatched areas indicate when the turbine was also present. Significantly different distributions between sites are indicated by letters "a" and "b" in the upper right of the graph.

3.0 Marine life interaction monitoring (side-looking hydroacoustics)

The Marine Life Interaction Monitoring Plan uses side-looking hydroacoustics collected by ORPC at the TidGen® project site to assess the interaction of marine life (fish, mammals, and diving birds) with the TidGen® device. This monitoring focuses on the behavior of marine life (primarily fish) as they approach or depart from the region of the turbine, to document variation in behavioral responses related to the TidGen® unit. ORPC plans to collect side-looking hydroacoustic data for three years after the deployment of the TidGen® Power System.

3.1 Methods

3.1.1 Study design

ORPC has mounted a Simrad EK60 split beam echosounder (200 kHz, 7° half-power beam width) to a steel frame located 44.5 m from the southern edge of the TidGen® (Figure 8). This frame holds the transducer 3.4 m above the sea floor, with the transducer angled 9.6° above the horizontal with a heading of 23.3°. The echosounder samples an approximately conical volume of water extending for 100 m, directly seaward (southeast) of the TidGen® device (Figure 8). The actual sampled volume used in data analysis does not include the entire beam. The sampled volume extends to the far edge of the turbine (78.1 m), not beyond because after that point, interference from sound reflection off the water's surface becomes too great to reliably detect fish. The sampled volume is upstream of the device during the flood tide (examining approach behaviors) and downstream of the device during the ebb tide (examining departure behaviors). The echosounder is powered and controlled via undersea cables from the ORPC shore station in Lubec, where data files are stored on a server and collected periodically by the University.

When operational, the echosounder records data continuously. Continuous data collection at a sample rate of 4 to 6 pings per second allows each fish or other marine animal that passes through the beam to be detected several times, recording information on the echo strength and 3D location of targets within the beam (Figure 9). These data are used to track fish movement during their approach to the turbine (flood tide) as well as during their departure (ebb tide) on a fine spatio-temporal scale. The sampled volume is divided into three zones: the turbine zone (red hatched area, Figure 8a), where fish would be likely to encounter the moving turbine; above the turbine zone (A, Figure 8a); and beside the turbine zone (B, Figure 8a). Fish numbers and movement in each zone provide indicators of turbine avoidance. The total sampling volume to 78.1 m range (for a 7° hydroacoustic cone) is 1,866 m³, and of this, 607m³ (33%) are within the turbine zone, 345 m³ (18%) are beside the turbine zone, and 914 m³ (49%) are above the turbine zone.

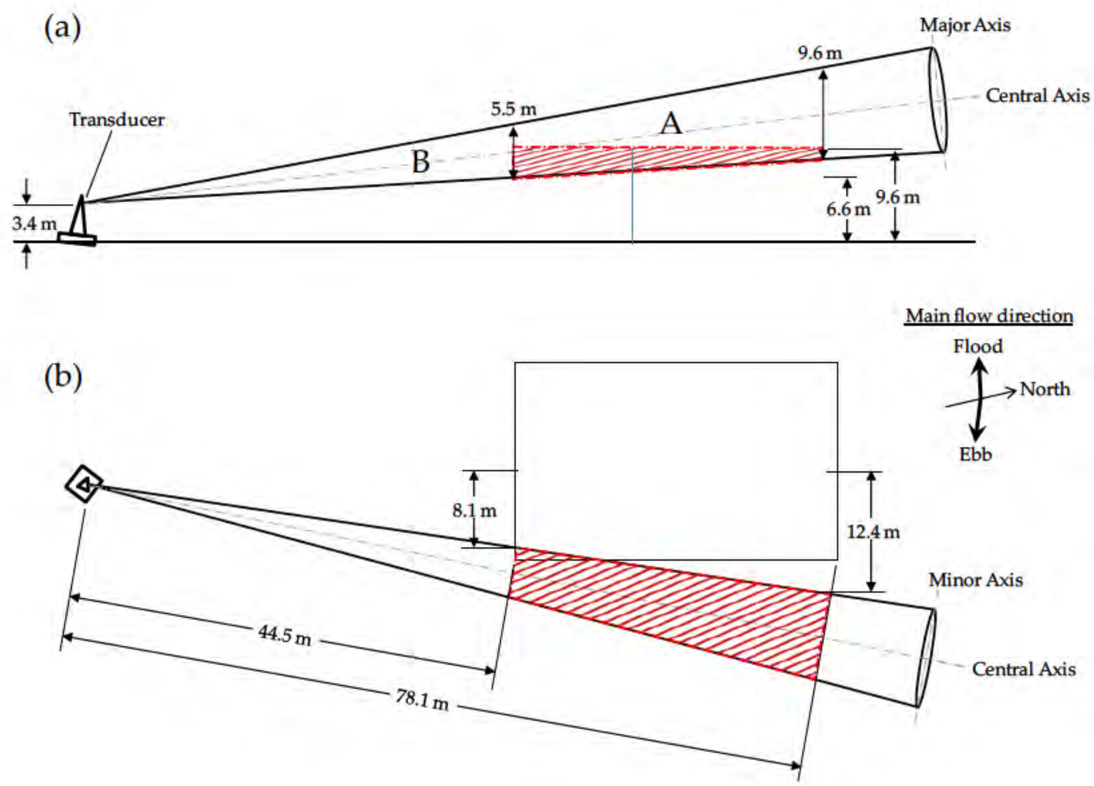


Figure 8. Marine Life Interaction Monitoring Plan setup. TidGen® device and Simrad EK60 support structure shown from (a) the seaward side and (b) above. Hydroacoustic beam represented as 7° cone (half-power beam width) in solid black lines. Red hatched area indicates sampled volume within the turbine zone, A indicates the volume sampled above the turbine, and B indicates the volume sampled beside the turbine. Current directions shown are project site averages provided by ORPC.

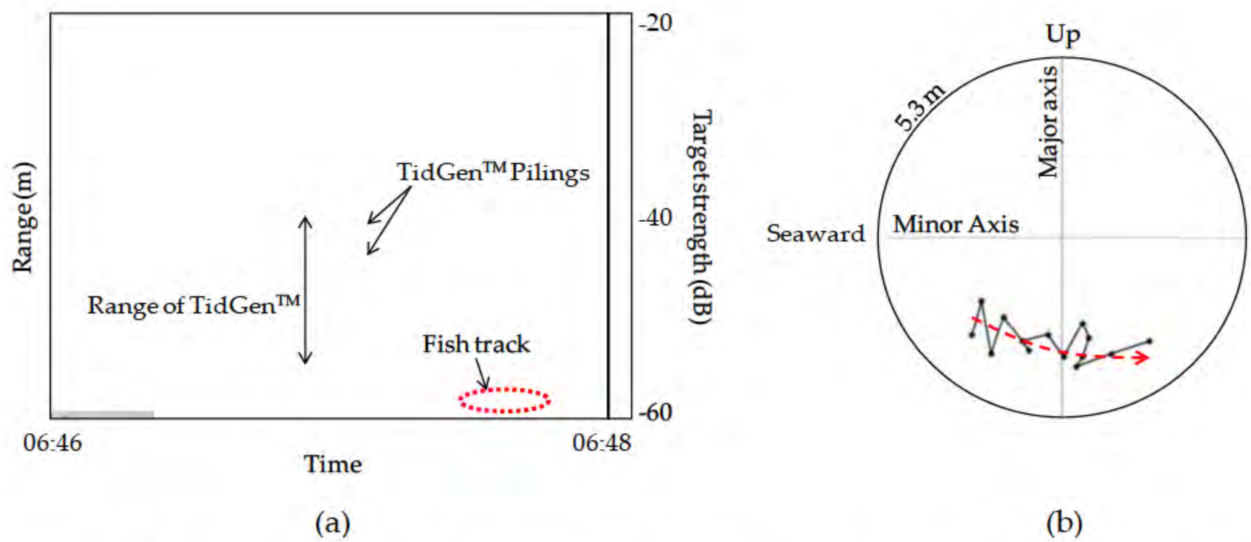


Figure 9. (a) Sample of side-looking hydroacoustic data from 9/30/2012 during the flood tide. (b) Fish in red dashed oval in (a) tracked through beam cross section. Outer circle represents 3.5° off-axis, or 5.3 m at this range. Each dot is a single detection of the fish. Red dashed arrow indicates direction of movement.

ORPC also collected current speed, direction (intermittently; see section 3.1.2), turbine movement in rotations per minute (RPM), and turbine operation state (generating or not).

3.1.2 Data Availability

Data collection began on August 29, 2012. Data could not be collected while the turbine was generating power due to electrical interference between the data and power transmission cables running together along the seabed to the shore station. Therefore, hydroacoustic data have been collected only for periods of time when the turbine was not rotating (either during slack tides when the current was too weak, or when the brake was applied), or when it was free-spinning (rotating but not generating power). Gaps also exist in the dataset whenever the turbine or hydroacoustic system was being repaired or adjusted, during periods of turbine deployment or removal, and whenever divers were present near the echosounder.

Collection of current speed and direction data by sensors mounted on the TidGen® Power System frame has been intermittent. For times when data are available, current direction is not useful for fish behavior analysis due to the placement of ORPC's flow meters, which are oriented to collect information in the plane parallel to the TidGen®. At times, ORPC has collected current speed and direction information with an Acoustic

Doppler Current Profiler (ADCP) placed approximately 4.6 m from the turbine, between the turbine and hydroacoustic transducer. This ADCP would operate for various lengths of time (spanning days), obtaining current speed and direction readings every second. When ADCP deployment overlaps with hydroacoustic data collection, the information may be used to analyze fish swimming direction and speed in relation to the current.

Given these constraints to data collection and availability, three subsets of the data collected since August 2012 were analyzed for this report (Table 2). The first two subsets spanned March 19th to 21st and April 18th to April 20th, when ORPC ceased normal power generation to allow continuous hydroacoustic data collection with the turbine free-spinning. These dates were chosen because there were nearly two complete tidal cycles during each day and night. While a free-spinning turbine does not have the same hydraulic signature as one generating power, these data should provide a better idea of fish behavior around an operating turbine than data collected while the turbine is held stationary by its brake. Current speed and RPM (range 8.22-16.73) data were available for these time segments. More free-spinning data collection periods had been planned for May, June, July, and August 2013; however, unforeseen circumstances caused turbine operation to cease in April 2013, just after the free-spinning data presented here were collected. The turbine brake was then applied and the turbine held motionless until it was removed in July 2013.

Hydroacoustic data collection continued after the turbine brake was applied, so a third time period was selected from these data for comparison to the free-spinning datasets from March and April. This 'braked' dataset spans April 26th to April 28th. These dates were chosen for comparison because they were the closest data available to the April free-spinning period that had similar timing of tides (e.g., nearly two complete cycles during each day and night). Current speed data were not available for this time, however, and were instead estimated using previous current speed data (see section 3.1.3).

Table 2. Summary of data subset analyzed to date.

Data subset	Tidal stage	Start Date	Start time	End time	Mean current speed ($m \cdot s^{-1}$)	Duration (hrs)	Mean turbine rotation speed (rpm)*
March Free-spinning	Ebb	3/19/13	17:00	22:20	0.82	5.33	11.80
	Flood	3/19/13	23:15	4:50	0.91	5.58	12.95
	Ebb	3/20/13	5:50	10:40	0.86	4.83	13.52
	Flood	3/20/13	11:40	17:20	0.93	5.67	13.28
	Ebb	3/20/13	18:20	23:20	0.81	5.00	11.95
	Flood	3/21/13	0:20	5:30	0.99	5.17	15.05
	Ebb	3/21/13	6:30	11:40	0.86	5.17	8.22
	Flood	3/21/13	12:40	18:30	0.95	5.83	–
	Ebb	3/21/13	19:30	0:30	0.85	5.00	–
	Flood	3/22/13	1:30	7:00	1.01	5.50	–
	Ebb	3/22/13	8:00	13:00	0.95	5.00	–
April Free-spinning	Ebb	4/18/13	5:00	10:20	0.94	5.33	15.82
	Flood	4/18/13	11:20	16:40	1.02	5.33	16.24
	Ebb	4/18/13	17:40	22:40	0.84	5.00	–
	Flood	4/18/13	23:40	4:50	1.03	5.17	16.24
	Ebb	4/19/13	5:50	11:15	0.91	5.42	15.24
	Flood	4/19/13	12:15	17:30	1.01	5.25	16.22
	Ebb	4/19/13	18:30	23:40	0.86	5.17	14.51
	Flood	4/20/13	0:40	6:00	1.01	5.33	16.73
April Braked	Flood	4/26/13	7:00	12:00	1.22*	5.00	0.00
	Ebb	4/26/13	13:00	18:20	1.24*	5.33	0.00
	Flood	4/26/13	19:20	0:15	1.22*	4.92	0.00
	Ebb	4/27/13	1:15	6:45	1.24*	5.50	0.00
	Flood	4/27/13	7:45	12:45	1.22*	5.00	0.00
	Ebb	4/27/13	13:45	19:05	1.24*	5.33	0.00
	Flood	4/27/13	20:05	1:55	1.22*	5.83	0.00
	Ebb	4/28/13	2:55	7:35	1.24*	4.67	0.00

* Turbine rotation speed while free-spinning is faster than rotation speed during normal operation.

3.1.3 Data processing and analysis

Echoview software (5.3, Myriax Pty. Ltd., Hobart, Australia) was used to process side-looking split beam hydroacoustic data. Processing in Echoview began with manually inspecting the data to identify and exclude unwanted noise (e.g., interference from depth sounders, entrained air from the surface, reflection from surface waves, reflection from fish schools), and setting a target strength threshold of -50 dB to exclude background noise, plankton, and other small objects from analyses. Target strength (TS) is a measure of the relative amount of acoustic energy reflected back toward the transducer by an object, compensating for transmission and signal losses and represented in decibels (dB re 1 m^2; Simmonds and MacLennan 2005). Though TS is dependent on several factors, including fish anatomy (e.g., swim bladder or none) and orientation relative to the transducer, it is generally proportional to fish size (Simmonds and MacLennan 2005). A threshold of -50 dB should eliminate most fish less than 8.7 cm in length (Lilja et al. 2004), assuming they have air-filled swim bladders (e.g., Atlantic herring). For fish lacking a gas-filled swimbladder, such as Atlantic mackerel, this threshold may eliminate larger fish to an unknown degree.

Echoes from single targets were then detected, excluding data collected beyond 78.1 m from the transducer (far edge of the turbine) due to frequent interference from the surface. Single target detection parameters (Table 3) were set liberally to allow a large number of single targets to be detected among the noise, though this also allowed more false detections to occur. Echoview's fish tracking module was then used to trace the paths of individual fish through the sampled volume. Fish track parameters (Table 4) were chosen to limit the effect of false single target detections on the number of detected fish. Fish track data (including time of detection, target strength, and direction of movement) were exported from Echoview to be further analyzed using MATLAB.

Table 3. Single target detection settings in Echoview.

Parameter	Value	Units
Target strength threshold	-50.00	dB
Pulse length determination level	6.00	dB
Minimum normalized pulse length	0.24	Unitless
Maximum normalized pulse length	10.00	Unitless
Beam compensation model	Simrad LOBE	
Maximum beam compensation	35	dB
Maximum standard deviation of minor-axis angles	1.000	Degrees
Maximum standard deviation of major-axis angles	1.000	Degrees

Table 4. 4D fish track detection settings in Echoview.

		Major Axis	Minor Axis	Range
Algorithm	Alpha	0.5	0.5	0.7
	Beta	0.1	0.2	0.1
	Exclusion distance (m)	2.25	2.25	0.2
	Missed ping expansion (%)	0	0	100
Weights	Major axis	0		
	Minor axis	0		
	Range	1		
	TS	0		
	Ping gap	0		
Track Acceptance	Min number single targets in track	5		
	Min number of pings in track (pings)	5		
	Max gap between single targets	8		

In MATLAB, fish tracks that had been contaminated by false single targets were removed based on track properties, including minor and major axis angle, tortuosity, and change in depth and range (Table 5). These settings helped eliminate fish tracks affected by noise from the turbine and other environmental factors. However, one effect of the turbine that could not be removed without drastically limiting the dataset was its apparent masking of weaker fish echoes within its range (i.e., between 44.5 and 78.1 m from the transducer; Figure 8). This masking is apparent in the distribution of fish track TS from beside the turbine and within the turbine's range (Figure 10). As weaker fish tracks were not detected in the range of the turbine, the numbers of fish detected on either side of the turbine were likely to be inflated with respect to numbers of fish detected within the turbine zone or above it, and included more of the weaker echoes (e.g., smaller fish).

Table 5. Fish track acceptance parameters used in MATLAB processing.

Fish track property	Value required for track acceptance
Minor axis angle	< 3.0°
Major axis angle	< 3.0°
Change in range	> 0.05 m
Change in depth	> 0.05 m
2D and 3D tortuosity	< 5.0

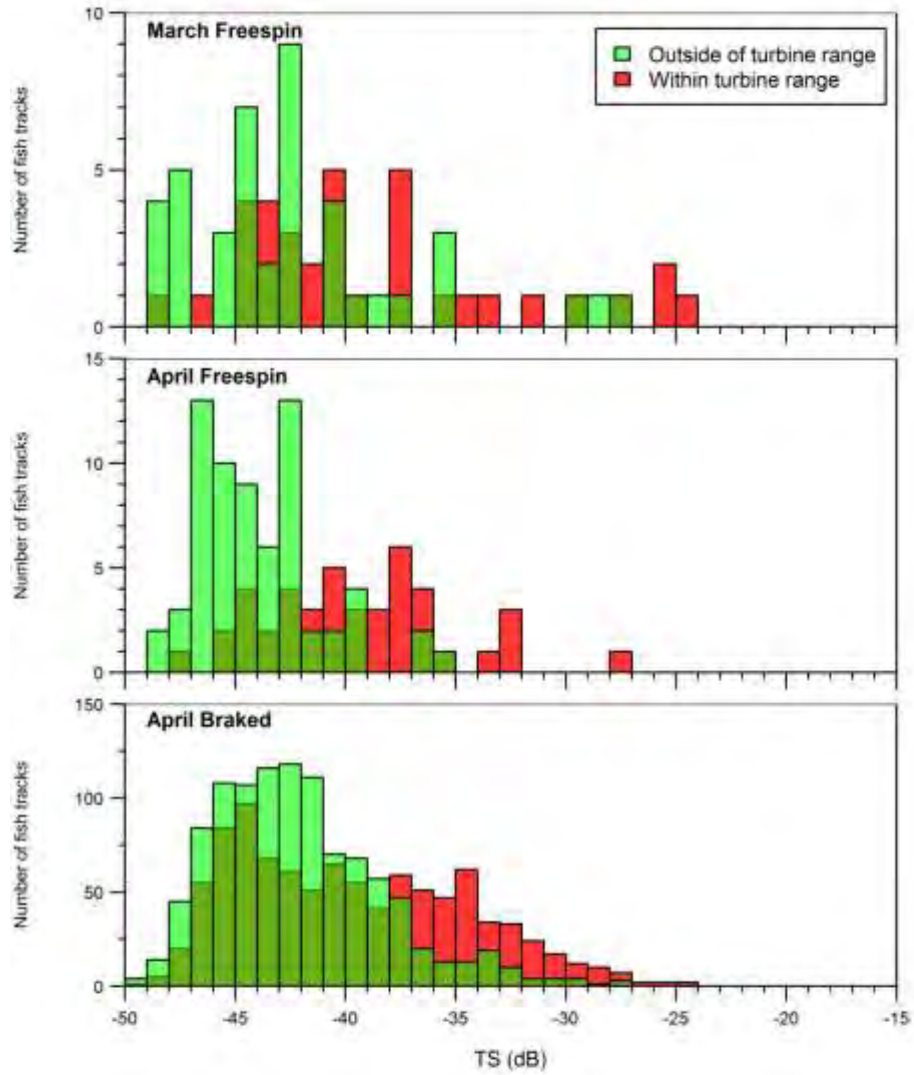


Figure 10. Target strength (TS) distribution from before the turbine range (< 44.5 m from transducer) and within the turbine range (> 44.5 m and ≤ 78.1 m from transducer).

Accepted fish tracks were grouped by tidal stage for analysis of target strength and direction of movement. Flood and ebb tide data were treated separately because a fish's approach to the turbine is sampled during the flood and its departure from the turbine is sampled during the ebb, and behaviors during each are assumed to differ (Viehman 2012; Viehman and Zydlewski accepted).

3.1.5 Fish density and location of tracks

The total number of fish tracks detected in the hydroacoustic data provided an estimate of the density of fish in the sampled volume over time. The location of each fish in the sampled volume was used to place it in one of the three zones near the turbine (Figure 8). Density of fish in a zone (in fish per cubic hectometer, hm^3)was calculated for each time span of interest (e.g., each ebb and flood tide) by dividing the total number of fish detected in the zone by the volume of water to pass through that zone. This volume was calculated by multiplying the area of the zone's vertical cross-section by the approximate linear distance of water to pass through it during the analysis period. The linear distance of water was determined using the mean current speed of each 10-minute time increment. Using 10-minute averages greatly reduced the effect of the noise in the ADCP current speed data. In this way, fish counts were normalized for varying sampling duration and current speed, allowing the direct comparison of densities from different datasets.

Current speed data were not available for the braked turbine dataset, so current speeds from the nearest free-spinning data (April 18-20) were used to obtain an approximation. Since free-spinning data were collected at neap tide (first quarter moon) and braked data were collected at spring tide (full moon), the mean flood tide current speed was multiplied by a factor of 1.2 and the mean ebb tide speed was multiplied by 1.4. These factors were determined using ADCP data collected during spring and neap tides in 2012. While this is a coarse approximation, some estimate was needed in order to make any comparisons between fish numbers obtained from the free-spinning data to those of the braked data.

3.1.6 Direction of movement

The direction of movement (heading, degrees from North; inclination, degrees from horizontal) of each fish was compared to the current direction at the time of fish detection (when data were available). Higher deviation from the water current direction within the turbine zone than in other zones may indicate avoidance behavior during approach (flood tides), or milling during departure (ebb tides).

3.2 Results

A total of 68 fish tracks were detected during the March free-spinning period, 87 were detected during the April free-spinning period, and 1,827 were detected during the April braked period (Figure 11). The number of flood and ebb tides sampled was too low to carry out statistical analyses of the differences between these sampling periods (5 tidal cycles in March, 4 in each April dataset). The large number of fish in the braked dataset in April compared to the other two datasets is unlikely related to turbine operation. To investigate this, the number of fish detected during the slack tides were also compared across datasets, and showed a similar pattern (Figure 12). As the turbine was not moving (and therefore assumed not to be a contributing factor) during the slack tides in either dataset, this comparison supports a natural increase in fish numbers between the free-spinning periods and the braked period. This would also be in line with results from down-looking hydroacoustic surveys (Section 2.2.1), which have shown a large increase in fish density between March and May.

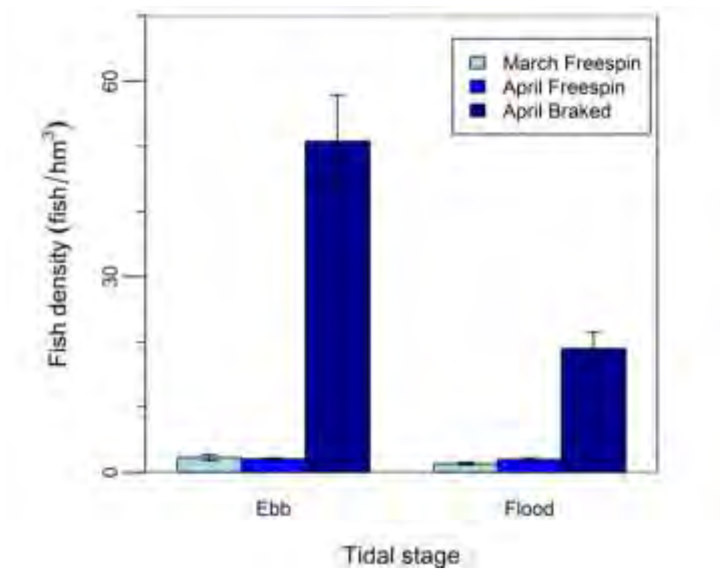


Figure 11. Mean fish density (fish/hm^3) of each tide of each dataset. Whiskers are one standard error.

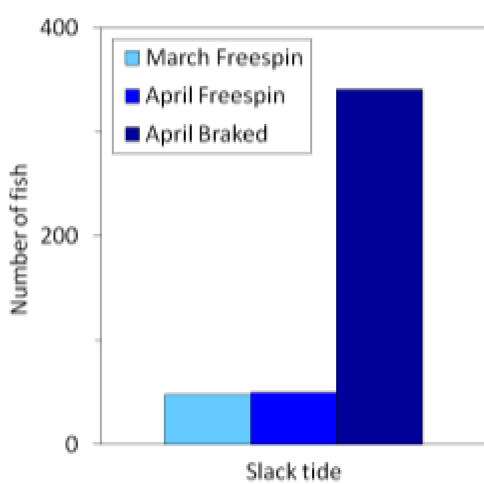
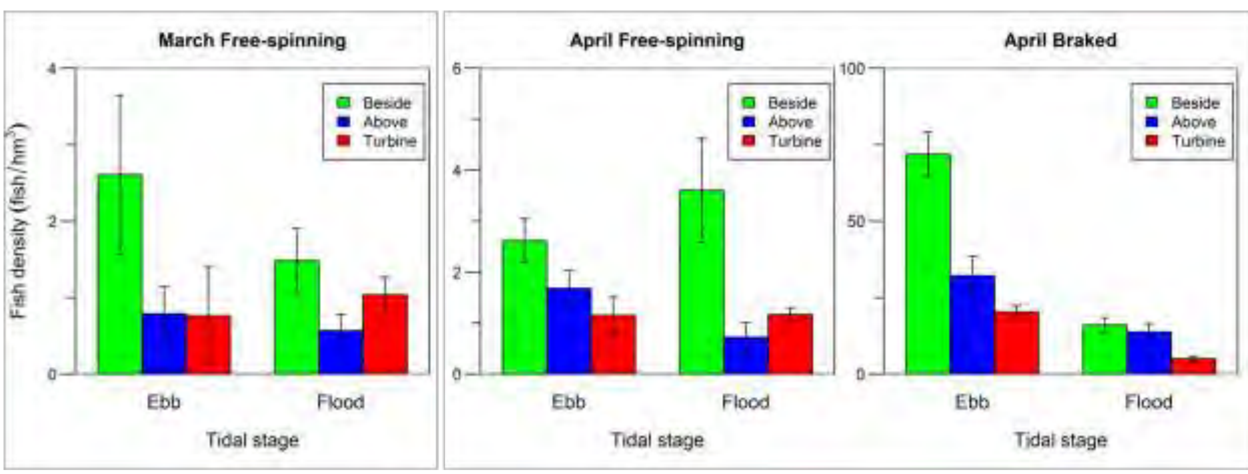


Figure 12. Number of fish detected during the slack tides in each dataset.

3.2.3 Fish density by zone

The mean density of fish in each sampling zone is shown in Figure 13. Density appears greatest beside the turbine and lowest in the turbine zone, though no tests for statistical significance have been carried out due to the low sample sizes (5 tides in March, 4 tides in each April dataset). This is unlikely to be entirely natural or a response to the turbine; rather, it is likely largely due to the masking of weaker fish echoes within the range of the turbine (see section 3.1.3). Though fish track filtering removed much of this effect, the target strength distributions of accepted fish tracks (Figure 10) show that the lower end of the TS spectrum (-50 dB to -41 dB) appear undersampled in the turbine range compared to beside the turbine.

In the braked dataset, more fish were detected during the ebb tide than during the flood tide. This could be explained by the natural movements of fish in the area (e.g., an outward movement of species at the time of the data collection), or may be related to fish sheltering in the lee of the device and its supporting structure. This behavior was previously observed within approximately 3 m of a test turbine (Viehman and Zydlewski, accepted) but more data are necessary before this behavior can be identified in these datasets, especially as the sampling volume of this study is approximately 10 m from the device. The low sample size and the few fish detected to date result in a high degree of variability that makes further comparison of fish counts not useful.



Total = 68 (1.10 fish/hm^3) *N = 5*

Total = 87 (1.66 fish/hm^3) *N = 4*

Total = 1,827 (27.09 fish/hm^3) *N = 4*

Figure 13. Mean fish density (fish/hm^3) in each zone (+/- 1 standard error).

3.2.4 Direction of movement

The distribution of the headings of fish in each sampling zone peaked at the predominant current direction, indicating fish moved primarily with the prevailing current (Figure 14). Due to the small sample size, statistical significance was not tested. The low number of fish detected in March and April free-spinning periods made interpretation of distributions unconstructive. However, in the braked dataset, enough fish were detected to make slight differences in each zone visible. During the flood tide (approach to the device), more fish were swimming in directions other than that of the main current. During the ebb (departure from the device), more fish swam with the current. The greater variation in fish direction during their approach indicates higher variability in behavior, though sample sizes were too low to draw any conclusions associated with avoidance. Additionally, some of this variation may be due to variable current direction, but this cannot be confirmed without current direction data.

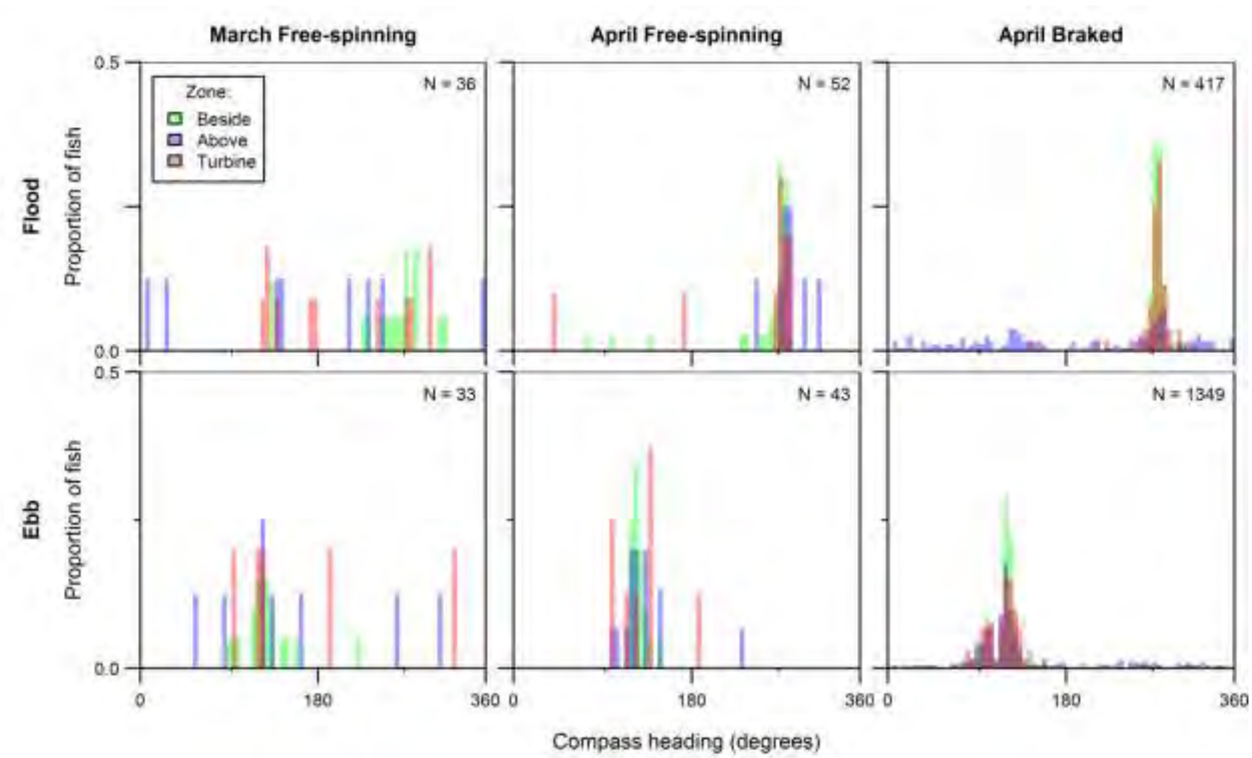


Figure 14. Distribution of fish headings during each dataset (0 = North). Values are scaled to number of fish detected in each zone.

The distribution of inclination angles of fish peaked between -10° and 0°, indicating that most fish were swimming horizontally or slightly downward (Figure 15). Again, the March and April free-spinning datasets did not yield enough fish to draw conclusions. In the braked dataset, variation in inclination angle appeared higher during the flood tide than the ebb tide, as indicated by the wider spread of the distribution. This increased variation could be linked to the fewer numbers of fish detected during the flood tide.

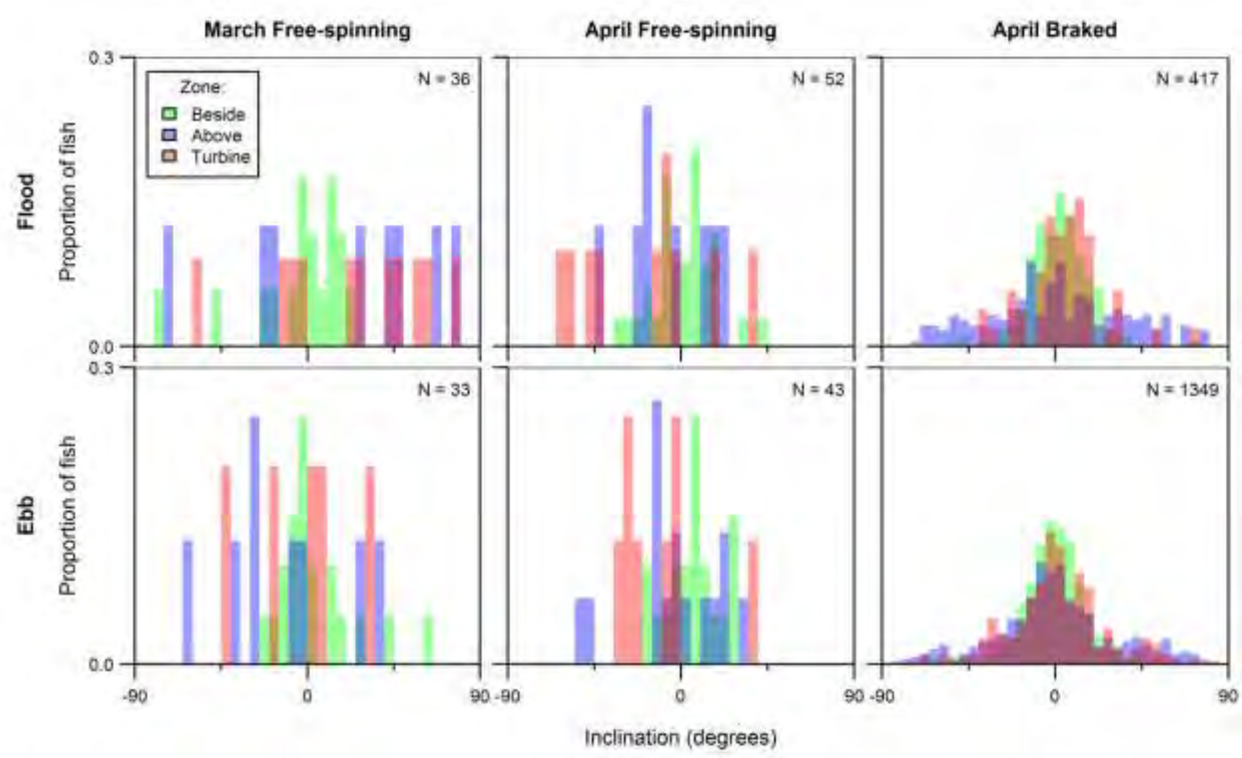


Figure 15. Distribution of fish inclination during each dataset (-90 = down, 0 = horizontal, 90 = up). Values are scaled to number of fish detected in each zone.

4.0 Summary

4.1 Fisheries monitoring (down-looking hydroacoustics)

Understanding the interactions between the environment and its biological constituents in tidally dynamic coastal regions is essential for informing tidal power development. Research and monitoring in these areas is limited because of the physical dynamics. Recent interest in tidal power extraction in Cobscook Bay provided the opportunity to develop an approach to assess such areas. The Bay's complicated bathymetry combines with a large tidal range to create high current speeds and flow patterns that vary greatly with location and tide (Brooks 2004, Huijie Xue, unpublished data). Multiple fish species pass through the strong currents of the outer bay to move between deeper ocean habitats and the extensive inshore habitats of the inner bays. Given the extreme variation in currents over time and space and the mixed seasonal and year-round fish community (Appendix 1), hydroacoustic measures of relative fish density were expected to vary widely in relation to season and location. Our hydroacoustic assessments demonstrate that while fish density is indeed variable, patterns are repeatable and will be useful in understanding the effects of devices.

4.1.1 Overall Fish Density

1. Inter-annual variability: was fish density constant across years? Differences in overall annual mean S_v with sites combined was discernible. The years 2010 and 2012 had higher fish density than 2011 and 2013. These differences display natural annual variation occurring within the years we have sampled. This highlights the importance of a useful control site in distinguishing changes in density due to turbine deployment from natural variation in fish density over time.

2. Beside vs. in-line with the turbine: were densities similar at the two project sites (CB1a and CB1b)? Both sites were similar and not statistically significantly different. The similarity between data collected at these two sites to date indicates that the inline site, CB1b, is representative of fish passage on a large lateral scale in the area of deployment. In addition, their similarity allowed us to combine them for analyses. It is important to note that the similarity between the inline and beside sites do not represent similarity of fish behavior in these locations. The beside site had little consistency in geographic location month to month and was often hundreds of meters away from the TidGen®, which could have resulted in similar data collected, not truly

reflecting fish distribution beside the turbine. Further data closer to the turbine for the "beside" monitoring is necessary.

3. Project site vs. control site: is fish density similar at CB1 and CB2, and is CB2 therefore a useful control site? The utility of the control site becomes apparent when examining the variation between the experimental site CB1 and the control site CB2 within each month sampled. These two sites typically had no significant differences with the exception of CB2 having significantly higher mean S_v in September 2010 and March and August 2012. With only these three exceptions to significant differences, we feel that the utility of the respective sites is valid. The difference in September 2010 could be linked to electrical noise in the hydroacoustic system during that year. The differences in March and August 2012 may be related to construction activities around the TidGen®: in March, the bottom support frame was being installed, and in August, the turbine was being deployed.

4. Seasonal variability: is there a consistent seasonal pattern to fish density in outer Cobscook Bay? Consistent monthly differences were found for all years, with peaks in density in May and June, followed by November. May of 2012 had much higher mean S_v than other years. This peak may have been related to elevated water temperatures, which affect the movements and growth of fish. For example, midwater trawls carried out near CB2 at this time found fully metamorphosed herring, while in other years the same trawls found larval herring or none at all (Vieser unpublished data). This early growth of herring would have caused a greater increase in mean S_v than normally seen. It is important to be able to distinguish this type of natural variation from turbine effects.

5. Did deployment of the TidGen® affect fish density at the project site (CB1)? The turbine was deployed during the August and September 2012 and March 2013 surveys. Only August 2013 had a significantly lower fish density at the project site than the control site. This may have been related to increased boat traffic and construction activities at the project site as the device was deployed. These activities included deploying and retrieving ADCPs, divers performing observation or maintenance on the device, or deployment and adjustment of the deployment area marker buoys. At times, there was also a large construction barge over the TidGen®. A similar difference between densities at the project and control sites was seen in March 2012, which was just after the bottom support frame was installed. This installation included pile

driving, divers, a large barge, and high boat traffic at the project site, all of which may have led to fish avoiding the area. Unfortunately, only three surveys were carried out while the turbine was operating. While there was no difference between project and control sites in the September 2012 and March 2013 surveys (carried out post-deployment and during normal turbine operation), this is not enough information to conclude that the turbine had negligible effect on fish density at the site.

4.1.2 Vertical Distribution

The vertical distribution of fish was rarely different among sites. Distributions showed that fish density generally increased toward the sea floor regardless of time of year. This trend of higher density near the bottom could possibly be related to the decrease in current speed in the boundary layer against the sea floor. Fish may be using this area as a refuge from faster current speeds found higher in the water. There are exceptions to this trend of fish density increasing toward the sea floor in May 2011 at CB1, May 2012 at all sites, and June 2013 at CB2, potentially related to the large numbers of larval and juvenile herring utilizing the upper layers of the water column at those times.

4.2 Marine life interaction monitoring (side-looking hydroacoustics)

The original goal of this monitoring was to collect data continuously during turbine operation (while generating power). A power-generating turbine has a different hydraulic and acoustic signature than a turbine that is free-spinning or braked. As such, fish response under these conditions may differ and it is important to collect fish response data while the turbine is generating power.

The dataset analyzed is limited to a few days of free-spinning and braked conditions. It is difficult to draw conclusions about fish behavior with so few fish detected during each tide, particularly during free-spinning periods. Down-looking hydroacoustic survey results indicate that fish densities are low in March compared to other months sampled, which is supported by the low numbers detected during the free-spinning periods in March and mid-April. The braked dataset in late April had many more fish than the earlier two datasets, perhaps linked to the springtime peak in density that was apparent in down-looking data. More data should be collected during times of the year when fish abundance is higher (e.g., May and June), which would provide datasets with higher sample sizes and allow quantitative statistical analyses. Higher sample sizes and statistical testing would lead to more constructive conclusions about effects of the TidGen® on fish behavior. This was originally planned, and will hopefully occur once the turbine has been re-deployed.

Available data allowed us to identify some key issues that should be addressed in the future.

1. Data should be collected while the turbine is generating power.
2. Current speed and direction data are necessary for accurate estimation of fish density and for analyses of fish movement through the beam. Without speed information, the volume of water sampled over time may be miscalculated. In this report, we estimated water speeds based on past data. This is unlikely to be accurate, but in this case even a large miscalculation in current speed would not account for the huge increase in fish density between the free-spinning datasets and the braked dataset. Current direction data is necessary for the identification of fish behaviors related to the turbine, as opposed to those related to current. This can be accomplished by adjusting or adding sensors on the TidGen® or more regularly deploying an ADCP near the TidGen®.
3. The turbine appears to be masking echoes from smaller fish within its range. This renders the TS distributions obtained incomplete, and excludes analyses of the behaviors of smaller size classes of fish. This could be solved by orienting the hydroacoustic beam further away from the device or focusing analyses on larger targets.
4. When more data are collected, more thorough analyses can be carried out. For now, the numbers of fish detected, their estimated densities, and their direction of movement are qualitative at best.

The fish community of Cobscook Bay is also being assessed by UMaine (preliminary results from 2013 are included in the Appendix 1). In the future, results from that study will be used to identify probable species represented by hydroacoustic targets. However, for now, the masking effect of the turbine on fish must be more carefully examined before target strength distributions will be useful.

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Appendix 1: Fish Community Assessment in Cobscook Bay, Maine

May and June Preliminary 2013 Report
University of Maine, School of Marine Sciences
Gayle Zydlewski, James McCleave, Jeffrey Vieser
30 August, 2013

Introduction

The first objective of this project is to use midwater trawling to provide species verification to accompany hydroacoustic assessment of pelagic fish abundance in Outer Cobscook Bay, near Eastport, Maine. The hydroacoustic assessment is being conducted independently. The hydroacoustic assessment and midwater trawling are parts of an overall project to assess the seasonal, daily, and tidal abundance and distribution of pelagic fishes in locations proposed for deployment of electricity generating tidal turbines.

The second objective of this project is to use midwater trawling, benthic trawling, intertidal seining, and intertidal fyke netting to characterize the fish community of the entire Cobscook Bay. This study provides a wider ecosystem perspective against which to consider deployment of arrays of electricity generating tidal turbines.

Methods

Midwater and benthic trawling was done with the commercial fishing vessel *Pandalus* (147YV), owned and operated by Stephen W. Brown. The midwater net mouth dimensions were: headrope, footrope and breastlines 40 feet. Mesh sizes were: belly, square and side panels 4 inch, tapers 2 inch, and extensions and codend 1 inch. The benthic net mouth dimensions were: headrope 45 feet, footrope 35 feet, no breastlines. Stretch mesh sizes were: net body 2 inch, codend 1 inch. Tows were nominally 20 minutes, but sometimes varied, especially to shorter times because towable distance was too short in inner Cobscook Bay (Figure 1, Tables 1, 2).

Two 100 foot x 6 foot seines with 0.25-inch diamond mesh were used to sample shallow intertidal habitats including cobble fields, mud flats, rockweed patches, and sea grass beds (Figure 1, Table 3). Two fyke nets with 30 foot wings, 4 foot tall square hoops, and 1.5-inch stretch mesh were used to sample larger rockweed covered rock piles (Table 4). Sampling of intertidal habitats was conducted mostly in daytime, with some night sampling.

Trawling and intertidal sampling were conducted during neap tides primarily in May and June 2013. Twenty midwater tows and 20 benthic tows were made over the two months, with eight tows of each type each month being at night in central and outer Cobscook Bay (Tables 1, 2). Seventy-five seine hauls were made over the two months, with 25 hauls being at night (Table 3). Twelve fyke net sets were made, with each set being two fyke nets nearby at the same location; six sets were at night (Table 4).

Results

In May and June, 2013, benthic trawling, pelagic trawling, and intertidal seining were quite successful in capturing a variety of fish species; fyke netting was less successful. More than 13,800 individual fish of 29 species have been caught (all gears and dates combined) (Table 5).[1] Atlantic herring (*Clupea harengus*) dominated the pelagic catch, and most were early juveniles. Winter flounder (*Pseudopleuronectes americanus*) juveniles dominated the catch in benthic trawls. Species richness was greatest among gears in the benthic trawls (20 species caught at least once) (Table 7).

Threespine stickleback (*Gasterosteus aculeatus*), mummichog (*Fundulus heteroclitus*), blackspotted stickleback (*Gasterosteus wheatlandi*), and Atlantic silverside (*Menidia menidia*) dominated the catches in intertidal seine tows, but in somewhat varying proportions in the two months of sampling (Table 8). Only five species represented by few individuals were caught in fyke nets (Table 9).

In both 2011 and 2012, four species comprised about 82% of the total catch. In 2012, these were, in rank order, threespine stickleback, Atlantic herring, Atlantic silverside, and winter flounder (Table 5), while in 2011, they were Atlantic herring, threespine stickleback, winter flounder, and rainbow smelt (*Osmerus mordax*). In 2013 to date the four most common species by abundance, Atlantic herring, winter flounder, threespine

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[1] Catch numbers in Tables 5-9 are provisional.

stickleback, and mummichog comprised more than 92% of the total catch. These numbers are not directly comparable however, as 2013 sampling is incomplete. However, in 2011 and 2012, upon completion of June netting, 3,132 and 10,072 individuals had been sampled, respectively. Sampling effort was lower in 2011 than 2012, which explains part of the differences among years.

Atlantic herring were abundant in both years, but those caught in May and June 2011 were mostly advanced larvae, while those caught in May and June 2012 were mostly juveniles. This may have been due to the mild winter of 2011-2012 and early warming in March 2012. In 2013 we again observed a return to conditions similar to 2011, where herring caught were predominantly advanced larvae.

One harbor seal entered a fyke net on June 28, 2012, and drowned; the incident was reported through the proper channels. Excluder bars were installed in the mouths of the fyke nets before August and September sampling periods following a design suggested by NOAA.

Discussion

Visual observation, hook and line recreational fishing, acoustic fish finder records, and local fishers' knowledge indicates the presence of large numbers of Atlantic herring throughout the water column in the study area. Though we are able to capture a limited number of individuals of this species, our gear is not ideal for the collection of a sample representing their true abundance. We also suspect that the ability of highly mobile fish to detect the presence of the trawls, through visual and other sensory clues, allows them to avoid it in most cases. When capture of these fishes did occur, it was primarily at night, when visual cues are restricted. Sampling effort at night with both midwater and benthic trawls was increased in 2012 and 2013 (n=4 per month) relative to 2011 (n=2 per month).

It is expected that larger benthic species, e.g., spiny dogfish (*Squalus acanthius*), succeeded in avoiding capture, though there is less anecdotal evidence to support their presence in the bay. However, three were caught in one benthic trawl in August of 2012. A number of other species are probably under sampled as well in various gears, e.g., adult river herring (alewife and blueback herring), skates and flatfish species (other than winter flounder).

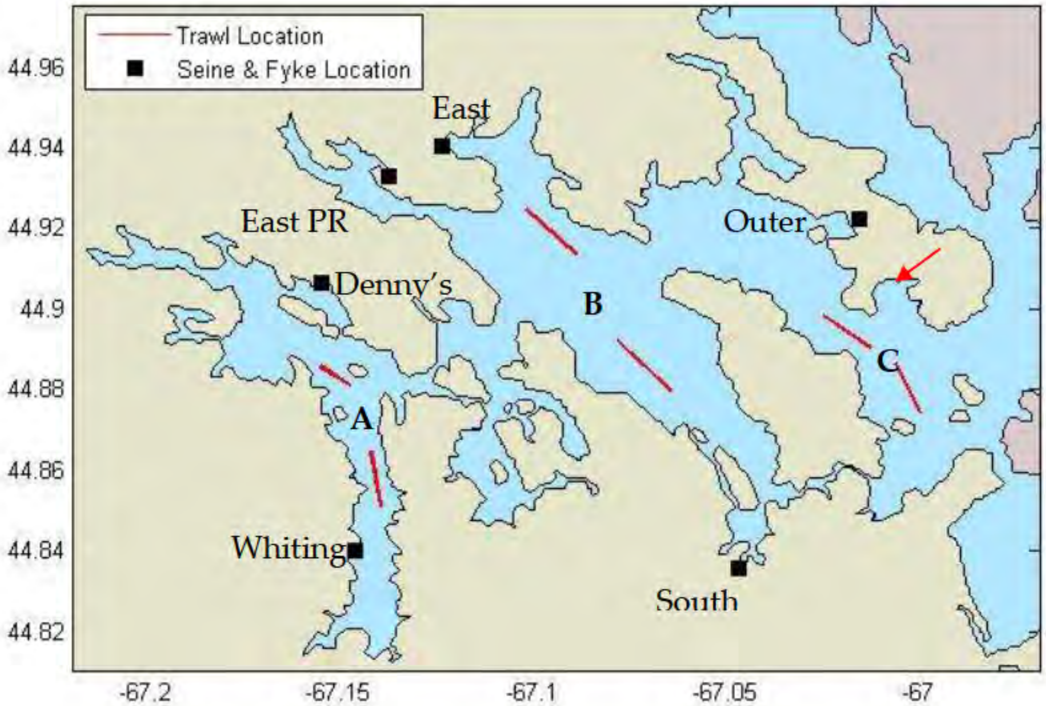

Figure 1. Map of Cobscook Bay and Western Passage of Passamaquoddy Bay showing mid-water and benthic trawl lines (red lines) fished in 2013, as well as regular seine and fyke net sampling locations (black dots), and one seining location specifically for sticklebacks (red arrow). Both benthic and pelagic trawls occurred in the same location. Uppercase letters indicate the center of each of the three sub-bays of Cobscook Bay (A = inner; B = central; C = outer). Smaller bays of each sub-bay are also named. PR is Pennamaquan River.

Table 1. Date and location of pelagic trawl samples in Cobscook Bay during May and June, 2013. Tide is the tidal stage when nets were fished. GPS Begin and GPS End are latitude (N) and longitude (W) where nets were deployed and retrieved, respectively. Tow is tow number. Begin and End are times (EDT) when the trawls were deployed and retrieved, respectively. Night samples are highlighted in gray.

Month	Day	Bay	GPS Begin	GPS End	Tide	Tow	Begin	End
May	6	Outer Bay	N44.8914 W67.012	N44.9038 W67.0327	Ebb	P801	8:31	8:56
	6	Outer Bay	N44.9041 W67.0321	N44.8881 W66.9997	Ebb	P802	9:08	9:35
	6	Outer Bay	N44.8886 W67.0132	N44.9057 W67.0366	Ebb	P810	21:40	22:10
	6	Outer Bay	N44.9039 W67.0335	N44.8894 W67.0049	Ebb	P811	22:23	22:50
	7	South Bay	N44.8937 W67.0778	N44.8809 W67.0647	Flood	P830	8:56	9:17
	7	East Bay	N44.9098 W67.091	N44.9216 W67.1005	High	P831	10:15	10:35
	8	Whiting Bay	N44.8682 W67.1454	N44.846 W67.1456	Flood	P841	9:55	10:17
	8	Denny's Bay	N44.8809 W67.1484	N44.8915 W67.1636	Flood	P842	11:15	11:35
	8	East Bay	N44.9101 W67.0915	N44.9245 W67.1041	Flood	P851	20:27	20:47
	8	South Bay	N44.8933 W67.0797	N44.8809 W67.0663	Flood	P852	21:41	22:01
June	2	Outer Bay	N44.8924 W67.0134	N44.9067 W67.0366	Flood	P901	6:10	6:30
	2	Outer Bay	N44.9052 W67.0372	N44.8917 W67.0193	Ebb	P902	7:07	7:27
	3	Outer Bay	N44.9041 W67.0343	N44.8921 W67.0149	Ebb	P911	20:50	21:10
	3	Outer Bay	N44.9005 W67.0271	N44.8815 W67.0037	Ebb	P912	21:40	22:00
	4	East Bay	N44.9113 W67.0916	N44.9235 W67.1025	Flood	P921	8:30	8:50
	4	South Bay	N44.8835 W67.0666	N44.8978 W67.0791	Ebb	P922	10:15	10:35
	5	Whiting Bay	N44.8727 W67.1455	N44.8523 W67.1433	High	P931	9:46	10:06
	5	Denny's Bay	N44.887 W67.1598	N44.8798 W67.1462	Ebb	P932	11:27	11:42
	5	East Bay	N44.9088 W67.0908	N44.9221 W67.1013	Flood	P941	21:05	21:25
	5	South Bay	N44.883 W67.0679	N44.8945 W67.0814	Ebb	P942	22:55	23:15

Table 2. Date and location of benthic trawl samples in Cobscook Bay during May and June, 2013. Tide is the tidal stage when nets were fished. GPS Begin and GPS End are latitude (N) and longitude (W) where nets were deployed and retrieved, respectively. Tow is tow number. Begin and End are times (EDT) when the trawls were deployed and retrieved, respectively. Night samples are highlighted in gray.

Month	Day	Bay	GPS Begin	GPS End	Tide	Tow	Begin	End
May	5	Outer Bay	N44.884 W67.007	N44.8674 W66.9936	High	B801	7:20	7:42
	5	Outer Bay	N44.8678 W66.9958	N44.8834 W67.0052	Ebb	B802	7:53	8:18
	6	Outer Bay	N44.8843 W67.0059	N44.8698 W66.996	Flood	B810	20:20	20:45
	6	Outer Bay	N44.8695 W66.9964	N44.8849 W67.0059	High	B811	21:00	21:27
	7	South Bay	N44.8817 W67.0667	N44.8937 W67.0679	Flood	B830	9:35	9:55
	7	East Bay	N44.9224 W67.1019	N44.91 W67.0903	Ebb	B831	10:49	11:10
	8	Whiting Bay	N44.8522 W67.1433	N44.8657 W67.1453	Flood	B841	10:35	10:55
	8	Denny's Bay	N44.8891 W67.1633	N44.8813 W67.1489	High	B842	11:50	12:07
	8	East Bay	N44.9228 W67.1026	N44.9112 W67.0921	Flood	B851	21:01	21:21
	8	South Bay	N44.8806 W67.0657	N44.8918 W67.0772	Flood	B852	22:15	22:35
June	2	Outer Bay	N44.8811 W67.0047	N44.8672 W66.9912	Ebb	B901	9:38	9:58
	2	Outer Bay	N44.8684 W66.9946	N44.8821 W67.0042	Ebb	B902	10:10	10:30
	3	Outer Bay	N44.882 W67.0045	N44.868 W66.9929	Ebb	B911	22:16	22:36
	3	Outer Bay	N44.8696 W66.9958	N44.8825 W67.0042	Ebb	B912	22:55	23:15
	4	East Bay	N44.9226 W67.1021	N44.9096 W67.0906	Ebb	B921	9:05	9:25
	4	South Bay	N44.8944 W67.0793	N44.8825 W67.0664	Ebb	B922	9:40	10:00
	5	Whiting Bay	N44.8525 W67.1431	N44.8673 W67.1439	Ebb	B931	10:19	10:39
	5	Denny's Bay	N44.8804 W67.147	N44.8884 W67.1605	Ebb	B932	10:53	11:13
	5	East Bay	N44.9217 W67.1014	N44.9099 W67.0911	High	B941	21:40	22:00
	5	South Bay	N44.8938 W67.0794	N44.8828 W67.0669	Ebb	B942	22:16	22:36

Table 3. Date and location of intertidal seine samples in Cobscook Bay during May and June, 2013. Tide is the tidal stage when nets were fished. Tow is tow number. Time is the time when each tow (EDT) began; each tow takes <10 minutes. Night samples are highlighted in gray.

Month	Day	Location	GPS	Tide	Habitat	Tow	Time
May	4	Denny's Bay	N44.9065 W67.1557	Ebb	Rockweed	S800	21:30
	4	Denny's Bay	N44.9065 W67.1557	Ebb	Cobble	S801	21:45
	4	Denny's Bay	N44.9065 W67.1557	Ebb	Grass	S802	22:00
	4	Denny's Bay	N44.9065 W67.1557	Ebb	Mudflat	S803	23:22
	5	Denny's Bay	N44.9065 W67.1557	Ebb	Cobble	S810	9:57
	5	Denny's Bay	N44.9065 W67.1557	Ebb	Cobble	S811	10:06
	5	Denny's Bay	N44.9065 W67.1557	Ebb	Grass	S812	10:23
	5	Denny's Bay	N44.9065 W67.1557	Ebb	Mudflat	S813	11:33
	5	East Bay	N44.9406 W67.1245	Ebb	Grass	S820	21:05
	5	East Bay	N44.9406 W67.1245	Ebb	Cobble	S821	21:20
	5	East Bay	N44.9406 W67.1245	Ebb	Cobble	S822	21:55
	5	East Bay	N44.9406 W67.1245	Ebb	Grass	S823	22:10
	5	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S824	23:00
	6	East Bay	N44.9406 W67.1245	Ebb	Grass	S830	9:50
	6	East Bay	N44.9406 W67.1245	Ebb	Cobble	S831	10:00
	6	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S832	10:29
	6	East Bay	N44.9406 W67.1245	Ebb	Cobble	S833	10:29
	6	Outer Bay	N44.9239 W67.0157	Ebb	Grass	S840	23:02
	6	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S841	23:30
	6	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S842	23:41
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Cobble	S851	10:45
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Cobble	S852	10:55
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Grass	S853	11:21
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Grass	S854	11:31
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Rockweed	S855	12:12
	7	Pennamaquan River	N44.9332 W67.138	Ebb	Rockweed	S856	12:25
	7	Outer Bay	N44.9239 W67.0157	Ebb	Grass	S861	10:58
	7	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S862	11:50
	7	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S863	12:05
	8	South Bay	N44.8357 W67.0482	Ebb	Cobble	S880	12:17
	8	South Bay	N44.8357 W67.0482	Ebb	Grass	S881	12:31
	8	South Bay	N44.8357 W67.0482	Ebb	Rockweed	S882	13:02
	9	Whiting Bay	N44.5041 W67.9423	Ebb	Rockweed	S891	14:10
	9	Whiting Bay	N44.5041 W67.9423	Ebb	Rockweed	S892	14:40
	9	Whiting Bay	N44.5041 W67.9423	Ebb	Mudflat	S893	15:39
	9	Whiting Bay	N44.5041 W67.9423	Ebb	Mudflat	S894	15:52
June	1	Denny's Bay	N44.9065 W67.1557	Ebb	Rockweed	S900	20:20
	1	Denny's Bay	N44.9065 W67.1557	Ebb	Cobble	S901	20:30
	1	Denny's Bay	N44.9065 W67.1557	Ebb	Grass	S902	20:55
	1	Denny's Bay	N44.9065 W67.1557	Ebb	Grass	S903	21:48

Month	Day	Location	GPS	Tide	Habitat	Tow	Time
	2	Denny's Bay	N44.9065 W67.1557	Ebb	Rockweed	S910	8:50
	2	Denny's Bay	N44.9065 W67.1557	Ebb	Cobble	S911	9:01
	2	Denny's Bay	N44.9065 W67.1557	Ebb	Grass	S912	9:13
	2	Denny's Bay	N44.9065 W67.1557	Ebb	Mudflat	S913	10:08
	2	Outer Bay	N44.9239 W67.0157	Ebb	Grass	S920	21:08
	2	Outer Bay	N44.9239 W67.0157	Ebb	Grass	S921	21:15
	2	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S922	21:47
	3	Outer Bay	N44.9239 W67.0157	Ebb	Grass	S931	9:25
	3	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S932	9:48
	3	Outer Bay	N44.9239 W67.0157	Ebb	Mudflat	S933	10:05
	3	East Bay	N44.9406 W67.1245	Ebb	Grass	S940	20:41
	3	East Bay	N44.9406 W67.1245	Ebb	Cobble	S941	20:53
	3	East Bay	N44.9406 W67.1245	Ebb	Grass	S942	21:35
	3	East Bay	N44.9406 W67.1245	Ebb	Cobble	S943	21:46
	3	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S944	22:35
	3	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S945	22:48
	4	East Bay	N44.9406 W67.1245	Ebb	Grass	S950	9:14
	4	East Bay	N44.9406 W67.1245	Ebb	Cobble	S951	9:23
	4	East Bay	N44.9406 W67.1245	Ebb	Grass	S952	10:00
	4	East Bay	N44.9406 W67.1245	Ebb	Cobble	S953	10:08
	4	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S954	10:44
	4	East Bay	N44.9406 W67.1245	Ebb	Rockweed	S955	11:04
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Cobble	S960	9:25
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Cobble	S961	9:32
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Grass	S962	9:47
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Grass	S963	10:02
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Rockweed	S964	10:45
	4	Pennamaquan River	N44.9332 W67.138	Ebb	Rockweed	S965	10:54
	5	South Bay	N44.8357 W67.0482	Ebb	Cobble	S971	10:50
	5	South Bay	N44.8357 W67.0482	Ebb	Grass	S972	11:00
	5	South Bay	N44.8357 W67.0482	Ebb	Rockweed	S973	11:30
	6	Whiting Bay	N44.5041 W67.9423	Ebb	Rockweed	S981	13:05
	6	Whiting Bay	N44.5041 W67.9423	Ebb	Rockweed	S982	13:51
	6	Whiting Bay	N44.5041 W67.9423	Ebb	Mudflat	S983	14:15
	6	Whiting Bay	N44.5041 W67.9423	Ebb	Mudflat	S984	14:37

Table 4. Date and location of intertidal fyke net samples in Cobscook Bay during May and June, 2013. Fyke is fyke set number; each set is composed of two fyke nets. Begin and End are the approximate times (EDT) when each set began and ended. Each fyke net was assumed to begin effective fishing at the time of high tide and to end effective fishing when the water level was low in the net. Samples partially or completely at night are highlighted in gray. CB is Cobscook Bay.

Month	Day	Location	GPS	Fyke	Begin	End
May	4	Denny's Bay	N44.9065 W67.1557	F800	20:00	23:59
	5	Denny's Bay	N44.9065 W67.1557	F810	9:02	11:53
	5	East Bay	N44.9406 W67.1245	F820	20:42	23:30
	6	East Bay	N44.9406 W67.1245	F830	9:30	11:43
	6	Outer Bay	N44.9239 W67.0157	F840	21:20	0:00
	7	Outer Bay	N44.9239 W67.0157	F850	9:47	13:20
June	1	Denny's Bay	N44.9065 W67.1557	F900	19:15	22:15
	2	Denny's Bay	N44.9065 W67.1557	F901	7:45	10:45
	2	Outer Bay	N44.9239 W67.0157	F903	19:02	22:30
	3	Outer Bay	N44.9239 W67.0157	F904	7:31	11:00
	3	East Bay	N44.9406 W67.1245	F905	20:30	23:00
	4	East Bay	N44.9406 W67.1245	F910	9:00	11:30

Table 5. Capture data, by month, all gear types combined, for sampling in Cobscook Bay in 2013. (*) The totals for 2011 and 2012 represent the catches for May and June only.

Month	**May**	**June**	**Total**	**2011**	**2012**
Species	**Number of Individuals**				
Atlantic herring, *Clupea harengus*	55	>6,153	>6,208	1,442	3,849
Winter flounder, *Pleuronectes americanus*	2,433	1,600	4,033	407	2,011
Threespine stickleback, *Gasterosteus aculeatus*	112	1,848	1,960	687	1,798
Mummichog, *Fundulus heteroclitus*	133	389	522	54	383
Longhorn sculpin, *Myoxocephalus octodecemspinosus*	140	123	263	40	173
Black spotted stickleback, *Gasterosteus wheatlandi*	62	148	210	152	458
Grubby, *Myoxocephalus aenaeus*	138	66	204	57	100
Atlantic silverside, *Menidia menidia*	79	26	105	13	122
Red hake, *Urophycis chuss*	23	52	75	2	13
Rainbow smelt, *Osmerus mordax*	9	58	67	252	149
Silver hake, *Merluccius bilinearis*	5	59	64	8	248
Atlantic tomcod, *Microgadus tomcod*	3	26	29	17	18
Windowpane, *Scophthalmus aquosus*	13	9	22	0	1
Snakeblenny, *Lumpenus lampretaeformis*	5	0	5	4	21
Alewife, *Alosa pseudoharengus*	5	0	5	1	734
Shorthorn sculpin, *Myoxocephalus scorpius*	0	4	4	9	3
Sea raven, *Hemitripterus americanus*	0	3	3	13	14
Atlantic snailfish, *Liparis atlanticus*	2	1	3	0	0
Radiated shanny, *Ulvaria subbifurcata*	2	1	3	1	1
Fourspine stickleback, *Apeltes quadracus*	2	0	2	1	0
Atlantic cod, *Gadus morhua*	2	0	2	13	11
American plaice, *Hippoglossoides platessoides*	1	1	2	0	0
Atlantic pollock, *Pollachius virens*	0	2	2	10	0
Winter skate, *Raja ocellatus*	1	1	2	2	2
Moustache sculpin, *Triglops murrayi*	0	2	2	0	0
Ocean pout, *Zoraces americanus*	0	2	2	0	0
Blueback herring, *Alosa aestivalis*	2	0	2	1	2
Cusk, *Brosme brosme*	1	0	1	0	0
Lumpfish, *Cyclopterus lumpus*	0	1	1	2	1
White hake, *Urophycis tenuis*	0	0	0	2	5
Rock gunnel, *Pholis gunnellus*	0	0	0	1	1
Ninespine stickleback, *Pungitius pungitius*	0	0	0	1	0
American sand lance, *Ammodytes americanus*	0	0	0	1	0
Atlantic halibut, *Hippoglossus hippoglossus*	0	0	0	0	7
Butterfish, *Peprilus triacanthius*	0	0	0	0	2
Smooth skate, *Malacoraja senta*	0	0	0	0	2
Little skate, *Raja erinacea*	0	0	0	0	1
Goosefish, *Lophius americanus*	0	0	0	0	1
Fourbeard rockling, *Enchelyopus cimbrius*	0	0	0	0	1
Total	**3228**	**>10,575**	**>13,803**	**3,192**	**10,132**

Table 6. Numbers of individuals caught by month in pelagic trawling in Cobscook Bay, 2013.

Species	May	June	Total
Atlantic herring	50	>6,150	>6,200
Threespine stickleback	6	46	52
Silver hake	0	4	4
Atlantic snailfish	1	1	2
Blackspotted stickleback	1	0	1
Windowpane flounder	1	0	1
Winter flounder	1	0	1
Lumpfish	0	1	1
Shorthorn sculpin	0	1	1
Total	**60**	**>6,203**	**>6,263**

Table 7. Numbers of individuals caught by month in benthic trawling in Cobscook Bay, 2013.

Species	May	June	Total
Winter flounder	2,442	1,600	4,042
Longhorn sculpin	140	123	263
Grubby	138	66	204
Red hake	23	52	75
Silver hake	5	55	60
Windowpane flounder	12	9	21
Rainbow smelt	7	5	12
Atlantic herring	2	3	5
Snakeblenny	5	0	5
Alewife	4	0	4
Radiated shanny	2	1	3
Sea raven	0	3	3
Shorthorn sculpin	0	3	3
Atlantic cod	2	0	2
American plaice	1	1	2
Winter skate	1	1	2
Moustache sculpin	0	2	2
Ocean pout	0	2	2
Cusk	1	0	1
Atlantic snailfish	1	0	1
Total	**2,786**	**1,926**	**4,712**

Table 8. Numbers of individuals caught by month in intertidal seining in Cobscook Bay, 2013.

Species	May	June	Total
Threespine stickleback	106	1,802	1,908
Mummichog	133	389	522
Blackspotted stickleback	61	148	209
Atlantic silverside	79	26	105
Rainbow smelt	2	50	52
Atlantic tomcod	1	22	23
Fourspine stickleback	2	0	2
Atlantic pollock	0	2	2
Total	**384**	**2,439**	**2,823**

Table 9. Numbers of individuals caught by month in fyke netting in Cobscook Bay, 2013.

Species	May	June	Total
Atlantic tomcod	2	4	6
Rainbow smelt	0	3	3
Atlantic herring	0	3	3
Blueback herring	2	0	2
Alewife	1	0	1
Total	**5**	**10**	**15**

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Introduction

The first objective of the project requiring the special license was to use midwater trawling to provide species verification to accompany acoustic assessment of pelagic fish abundance in Outer Cobscook Bay, near Eastport, Maine. The acoustic assessment was conducted independently of the special license. The acoustic assessment and midwater trawling are parts of an overall project to assess the seasonal, daily, and tidal abundance and distribution of pelagic fishes in locations proposed for deployment of electricity generating tidal turbines (marine hydrokinetic energy devices, MHK).

The second objective of the project requiring the special license was to use midwater trawling, benthic trawling, intertidal seining, and intertidal fyke netting to characterize the fish community of the entire Cobscook Bay. This study provides a wider ecosystem perspective against which to consider deployment of arrays of electricity generating tidal turbines.

Methods

Midwater and benthic trawling was done with the commercial fishing vessel *Pandalus* (147YV), owned and operated by Stephen W. Brown. The midwater net mouth dimensions were: headrope, footrope and breastlines 40 feet. Mesh sizes were: belly, square and side panels 4 inch, tapers 2 inch, and extensions and codend 1 inch. The benthic net mouth dimensions were: headrope 45 feet, footrope 35 feet, no breastlines. Stretch mesh sizes were: net body 2 inch, codend 1 inch. Tows were nominally 20 minutes, but sometimes varied, especially to shorter times because towable distance was too short in Inner Cobscook Bay (Figure 1, Tables 1, 2). Trawling was done both day and night in Outer Cobscook Bay and Central Cobscook Bay but only during day in Inner Cobscook Bay for safety reasons (Tables 1, 2).

Two 100 foot x 6 foot seines with 0.25-inch diamond mesh were used to sample shallow intertidal habitats including cobble fields, mud flats, rockweed patches, and sea grass beds (Figure 1, Table 3). Two fyke nets with 30 foot wings, 4 foot tall square hoops, and 1.5-inch stretch mesh were used to sample larger rockweed covered rock piles (Table 4). Excluder bars were present in the mouths of the fyke nets to prevent capture of marine mammals. Sampling of intertidal habitats was conducted both during day and during night (Tables 3, 4).

Trawling and intertidal sampling were conducted during neap tides primarily in May, June, August and September, 2013. Thirty nine midwater tows and 40 benthic tows were made over the four months, with 15 midwater tows and 16 benthic tows being at night in Central and Outer Cobscook Bays (Tables 1, 2). One hundred fifty four seine hauls were made over the four months, with 51 hauls being at night (Table 3). Twenty four fyke net sets were made, with each set being two fyke nets nearby at the same location; 11 sets were at night (Table 4). Eight additional seine hauls were made at a subset of locations in November, with 4 being at night (Table 3).

Results

Benthic trawling and intertidal seining were quite successful in capturing a variety of fish species, but midwater trawling and fyke netting were less successful. More than 27,000 individual fish of 41 species were caught (all gears and dates combined) (Table 5). Eight species were caught in 2013 that had not been caught previously: American eel, American plaice, Atlantic sea snail, cusk, moustache sculpin, ocean pout, smooth flounder, and white perch, each represented by 1-5 individuals (Table 5). Individuals of many species were primarily smaller (juvenile) specimens, but a few adult Atlantic herring were caught in pelagic trawls (Table 6). Threespine and blackspotted sticklebacks and mummichogs were caught as both adults and juveniles in seines (Table 8). Longhorn sculpin, grubby (Table7), and Atlantic tomcod (Tables 8, 9) were caught as adults and juveniles.

Atlantic herring dominated the pelagic catch, and most were early juveniles. Atlantic herring and winter flounder juveniles dominated the catch in benthic trawls, but species richness was greatest among gears in the benthic trawls (31 species caught at least once) (Table 7).

Threespine stickleback, Atlantic silverside, blackspotted stickleback, and alewife dominated the catches in intertidal seine tows, but in widely varying proportions in the four primary months of sampling (Table 8). For example, alewives were absent in May and June, but their juveniles dominated the catch in August. Threespine sticklebacks were much more abundant in June than in other months. Only six species represented by few individuals were caught in fyke nets (Table 9). However, fyke nets caught adult Atlantic tomcod, while seining captured the juveniles.

In 2011, 2012, and 2013 four species comprised about 82% of the total catch. In rank order these were:

2011	2012	2013
Atlantic herring	Threespine stickleback	Atlantic herring
Threespine stickleback	Atlantic herring	Winter flounder
Winter flounder	Atlantic silverside	Threespine stickleback
Rainbow smelt	Winter flounder	Alewife

The increase in proportion of threespine stickleback and Atlantic silverside in 2012 over 2011 is in part due to increased effort on intertidal seining in 2012. In 2013, the appearance of alewife in the top four species was due to the outmigration of large numbers of juveniles especially in August.

Atlantic herring were abundant in all years, but those caught in May and June 2011 and 2013 were mostly advanced larvae, while those caught in May and June 2012 were mostly already metamorphosed into juveniles. This was probably due to the mild winter of 2011-2012 and early warming in March 2012. Butterfish, a species with more southerly distribution, were more abundant in 2012 than 2011 or 2013, probably reflecting the same phenomenon. Of note, juvenile haddock were present (48 individuals caught) in 2011, absent in 2012, and more abundant in 2013 (343 caught).

No Atlantic salmon (*Salmo salar*), shortnose sturgeon (*Acipenser brevirostrum*), or Atlantic sturgeon (*A. oxyrhynchus*) were captured in any gear.

Discussion

Visual observation, hook and line recreational fishing, acoustic fish finder records, and local fishers' knowledge indicates the presence of large numbers of Atlantic herring and Atlantic mackerel throughout the water column in the study area, especially in August and September. The inability of our gear to capture these highly mobile pelagic species in proportion to their probable abundance is a problem. We suspect that the ability of highly mobile fish to detect the presence of the trawls, through visual and other sensory clues, allows them to avoid it in most cases. When capture did occur, it was primarily at night, when visual cues are restricted. Sampling effort at night with both midwater and benthic trawls was increased modestly in 2012 and 2013 compared with 2011.

It is expected that larger species, e.g., spiny dogfish, succeeded in avoiding capture, though there is less anecdotal evidence to support their presence in the bay. However, three were caught in one benthic trawl in 2012. A number of other species are probably under sampled as well in various gears, e.g., American eels, adult river herring (alewife and blueback herring), skates and flatfish species (other than winter flounder). Other species expected to be able to avoid the trawling gear used, e.g., striped bass (*Morone saxatilis*), have been rare or absent in recent years according to local knowledge.

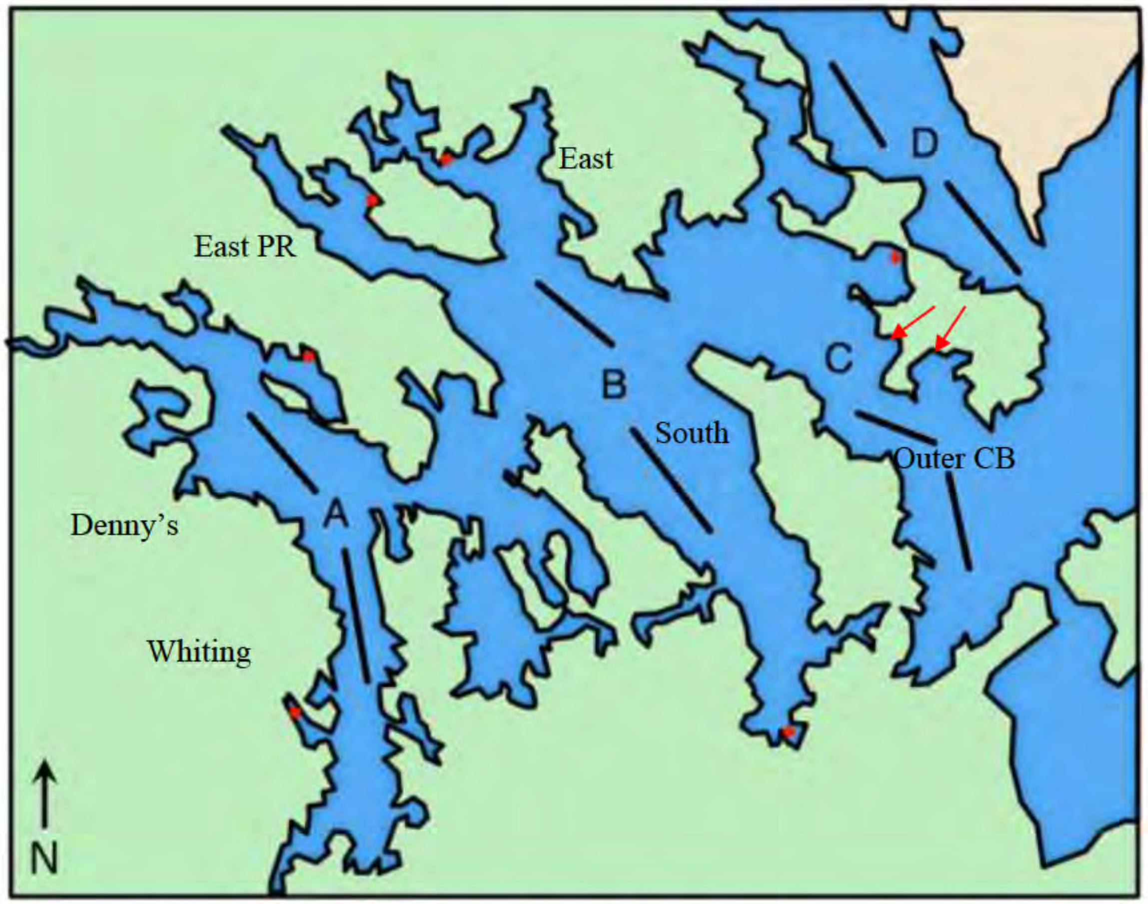

Figure 1. Map of Cobscook Bay and Western Passage of Passamaquoddy Bay showing mid-water and benthic trawl lines (black lines) fished in 2013 (Cobscook Bay only) and regular seine and fyke net sampling locations (red dots). Both benthic and pelagic trawls occurred in the same location. Uppercase letters indicate the center of each of the three sub-bays of Cobscook Bay (A = inner; B = central; C = outer) and Western Passage in Passamaquoddy Bay (D). Western Passage was sampled with some preliminary midwater trawling in 2011 but not later. Smaller bays of each sub-bay are also named. PR is Pennamaquan River.

Table 1. Date and location of pelagic trawl samples in Cobscook Bay during May, June, August, and September, 2013. Tide is the tidal stage when nets were fished. GPS positions where nets were deployed and retrieved are similar to those presented in the 2012 report and are not included here. Tow is tow number. Begin and end times (EDT) are when the trawls were deployed and retrieved, respectively. Night samples are highlighted in gray.

Month	Day	Bay	Tide	Tow	Begin time	End time
May	6	Outer Bay	Ebb	P801	8:31	8:56
May	6	Outer Bay	Ebb	P802	9:08	9:35
May	6	Outer Bay	Ebb	P810	21:40	22:10
May	6	Outer Bay	Ebb	P811	22:23	22:50
May	7	South Bay	Flood	P830	8:50	9:17
May	7	East Bay	High	P831	10:15	10:35
May	8	Whiting Bay	Ebb	P841	9:55	10:17
May	8	Dennys Bay	Flood	P842	11:15	11:35
May	8	East Bay	Flood	P851	20:27	20:47
May	8	South Bay	Flood	P852	21:41	22:01
June	2	Outer Bay	Flood	P901	6:10	6:30
June	2	Outer Bay	Ebb	P902	7:07	7:27
June	3	Outer Bay	Ebb	P911	20:50	21:10
June	3	Outer Bay	Ebb	P912	21:40	22:00
June	4	East Bay	Flood	P921	8:30	8:50
June	4	South Bay	Ebb	P922	10:15	10:35
June	5	Whiting Bay	High	P931	9:46	10:06
June	5	Dennys Bay	Ebb	P932	11:27	11:42
June	5	East Bay	Flood	P941	21:05	21:25
June	5	South Bay	Ebb	P942	22:55	23:15
August	4	Outer Bay	High	P1001	22:10	22:30
August	4	Outer Bay	High	P1002	22:45	23:05
August	5	Outer Bay	Flood	P1011	10:22	10:42
August	5	Outer Bay	Flood	P1012	10:58	11:18
August	6	South Bay	Flood	P1021	10:40	11:00
August	6	East Bay	Ebb	P1022	12:56	13:16
August	6	East Bay	Flood	P1031	21:50	22:10
August	7	Whiting Bay	Flood	P1041	11:13	11:33
August	7	Dennys Bay	High	P1042	12:56	13:16
September	1	Outer Bay	High	P1101	20:58	21:18
September	1	Outer Bay	High	P1102	21:35	21:55
September	2	Outer Bay	High	P1111	10:09	10:29
September	2	Outer Bay	High	P1112	10:43	11:03
September	3	South Bay	Flood	P1131	9:46	10:06
September	3	East Bay	Ebb	P1132	11:30	11:50
September	3	South Bay	Ebb	P1141	21:38	21:58
September	4	East Bay	Flood	P1142	20:05	20:25
September	4	Whiting Bay	Flood	P1151	10:58	11:18
September	4	Dennys Bay	Ebb	P1152	12:34	12:51

Table 2. Date and location of benthic trawl samples in Cobscook Bay during May, June, August, and September, 2012. Tide is the tidal stage when nets were fished. GPS positions where nets were deployed and retrieved are similar to those presented in the 2012 report and are not included here. Tow is tow number. Begin and end times (EDT) are when the trawls were deployed and retrieved, respectively. Night samples are highlighted in gray.

Month	Day	Bay	Tide	Tow	Begin time	End time
May	5	Outer Bay	High	B801	7:20	7:42
May	5	Outer Bay	Ebb	B802	7:53	8:18
May	6	Outer Bay	Flood	B810	20:20	20:45
May	6	Outer Bay	High	B811	21:00	21:27
May	7	South Bay	Flood	B830	9:35	9:55
May	7	East Bay	Ebb	B831	10:49	11:10
May	8	Whiting Bay	Flood	B841	10:35	10:55
May	8	Dennys Bay	High	B842	11:50	12:07
May	8	East Bay	Flood	B851	21:01	21:21
May	8	South Bay	Flood	B852	22:15	22:35
June	2	Outer Bay	Ebb	B901	9:38	9:58
June	2	Outer Bay	Ebb	B902	10:10	10:30
June	3	Outer Bay	Ebb	B911	22:16	22:36
June	3	Outer Bay	Ebb	B912	22:55	23:15
June	4	East Bay	Ebb	B921	9:05	9:25
June	4	South Bay	Ebb	B922	9:40	10:00
June	5	Whiting Bay	Ebb	B931	10:19	10:39
June	5	Dennys Bay	Ebb	B932	10:53	11:13
June	5	East Bay	High	B941	21:40	22:00
June	5	South Bay	Ebb	B942	22:16	22:36
August	4	Outer Bay	Flood	B1001	20:50	21:10
August	4	Outer Bay	Flood	B1002	21:30	21:50
August	5	Outer Bay	Ebb	B1011	11:35	11:55
August	5	Outer Bay	Ebb	B1012	12:08	12:28
August	6	South Bay	High	B1021	11:14	11:34
August	6	East Bay	High	B1022	12:18	12:38
August	6	East Bay	Flood	B1031	21:04	21:24
August	6	South Bay	Flood	B1032	22:23	22:43
August	7	Whiting Bay	Flood	B1041	11:49	12:09
August	7	Dennys Bay	Flood	B1042	12:25	12:40
September	1	Outer Bay	Flood	B1101	19:49	20:09
September	1	Outer Bay	Flood	B1102	20:23	20:43
September	2	Outer Bay	Flood	B1111	8:53	9:13
September	2	Outer Bay	Flood	B1112	9:33	9:53
September	3	South Bay	High	B1131	10:18	10:38
September	3	East Bay	Ebb	B1132	10:57	11:17
September	3	South Bay	Flood	B1141	22:14	22:34
September	4	East Bay	Flood	B1142	20:43	21:03
September	4	Whiting Bay	Flood	B1151	11:28	11:48
September	4	Dennys Bay	Ebb	B1152	12:05	12:22

Table 3. Date and location of regular intertidal seine samples in Cobscook Bay during May, June, August, and September, and additional seine samples at a subset of regular stations in November, 2013. Tide is the tidal stage when nets were fished. GPS positions and locales within bays where seines were deployed are similar to those presented in the 2012 report and are not included here. Tow is tow number. Time is the time (EDT) when each tow began; each tow takes <10 minutes. All tows were made on ebb tides. Night samples are highlighted in gray.

Month	Day	Bay	Locale	Habitat	Tow	Time
May	4	Dennys Bay	Youngs Cove	Rockweed	S800	21:30
May	4	Dennys Bay	Youngs Cove	Cobble	S801	21:45
May	4	Dennys Bay	Youngs Cove	Grass	S802	22:00
May	4	Dennys Bay	Youngs Cove	Mudflat	S803	23:22
May	5	Dennys Bay	Youngs Cove	Unknown	S810	9:57
May	5	Dennys Bay	Youngs Cove	Cobble	S811	10:06
May	5	Dennys Bay	Youngs Cove	Unknown	S812	10:23
May	5	Dennys Bay	Youngs Cove	Unknown	S813	11:33
May	5	East Bay	Sipp Bay	Unknown	S820	21:05
May	5	East Bay	Sipp Bay	Unknown	S821	21:20
May	5	East Bay	Sipp Bay	Unknown	S822	21:55
May	5	East Bay	Sipp Bay	Unknown	S823	22:10
May	5	East Bay	Sipp Bay	Unknown	S824	23:00
May	6	East Bay	Sipp Bay	Unknown	S830	9:50
May	6	East Bay	Sipp Bay	Unknown	S831	10:00
May	6	East Bay	Sipp Bay	Unknown	S832	10:29
May	6	East Bay	Sipp Bay	Unknown	S833	10:45
May	6	Outer Bay	Carrying Place Cove	Unknown	S840	23:02
May	6	Outer Bay	Carrying Place Cove	Unknown	S841	23:30
May	6	Outer Bay	Carrying Place Cove	Mudflat	S842	23:41
May	7	Pennamaquan River	Hersey Cove	Cobble	S851	10:45
May	7	Pennamaquan River	Hersey Cove	Cobble	S852	10:55
May	7	Pennamaquan River	Hersey Cove	Unknown	S853	11:23
May	7	Pennamaquan River	Hersey Cove	Unknown	S854	11:21
May	7	Pennamaquan River	Hersey Cove	Unknown	S855	12:12
May	7	Pennamaquan River	Hersey Cove	Unknown	S856	12:25
May	7	Outer Bay	Carrying Place Cove	Grass	S861	10:58
May	7	Outer Bay	Carrying Place Cove	Mudflat	S862	11:50
May	7	Outer Bay	Carrying Place Cove	Unknown	S863	12:05
May	8	South Bay	Case Cove	Unknown	S880	12:17
May	8	South Bay	Case Cove	Grass	S881	12:31
May	8	South Bay	Case Cove	Rockweed	S882	13:02
May	9	Whiting Bay	Burnt Cove	Rockweed	S891	14:10
May	9	Whiting Bay	Burnt Cove	Rockweed	S892	14:40
May	9	Whiting Bay	Burnt Cove	Unknown	S893	15:39
May	9	Whiting Bay	Burnt Cove	Unknown	S894	15:52
June	1	Dennys Bay	Youngs Cove	Rockweed	S900	20:20
June	1	Dennys Bay	Youngs Cove	Cobble	S901	20:30
June	1	Dennys Bay	Youngs Cove	Grass	S902	20:55
June	1	Dennys Bay	Youngs Cove	Grass	S903	21:48
June	2	Dennys Bay	Youngs Cove	Rockweed	S910	8:50

June	2	Dennys Bay	Youngs Cove	Cobble	S911	9:01
June	2	Dennys Bay	Youngs Cove	Grass	S912	9:13
June	2	Dennys Bay	Youngs Cove	Mudflat	S913	10:08
June	2	Outer Bay	Carrying Place Cove	Grass	S920	21:08
June	2	Outer Bay	Carrying Place Cove	Grass	S921	21:15
June	2	Outer Bay	Carrying Place Cove	Mudflat	S922	21:47
June	3	Outer Bay	Carrying Place Cove	Grass	S931	9:25
June	3	Outer Bay	Carrying Place Cove	Mudflat	S932	9:48
June	3	Outer Bay	Carrying Place Cove	Mudflat	S933	10:05
June	3	East Bay	Sipp Bay	Grass	S940	20:41
June	3	East Bay	Sipp Bay	Cobble	S941	20:53
June	3	East Bay	Sipp Bay	Grass	S942	21:35
June	3	East Bay	Sipp Bay	Cobble	S943	21:46
June	3	East Bay	Sipp Bay	Rockweed	S944	22:35
June	3	East Bay	Sipp Bay	Rockweed	S945	22:48
June	4	East Bay	Sipp Bay	Grass	S950	9:14
June	4	East Bay	Sipp Bay	Cobble	S951	9:23
June	4	East Bay	Sipp Bay	Grass	S952	10:00
June	4	East Bay	Sipp Bay	Unknown	S953	10:08
June	4	East Bay	Sipp Bay	Unknown	S954	10:44
June	4	East Bay	Sipp Bay	Unknown	S955	11:04
June	4	Pennamaquan River	Hersey Cove	Unknown	S960	9:25
June	4	Pennamaquan River	Hersey Cove	Unknown	S961	9:32
June	4	Pennamaquan River	Hersey Cove	Unknown	S962	9:47
June	4	Pennamaquan River	Hersey Cove	Grass	S963	10:02
June	4	Pennamaquan River	Hersey Cove	Unknown	S964	10:45
June	4	Pennamaquan River	Hersey Cove	Unknown	S965	10:54
June	5	South Bay	Case Cove	Cobble	S971	10:50
June	5	South Bay	Case Cove	Grass	S972	11:00
June	5	South Bay	Case Cove	Rockweed	S973	11:30
June	6	Whiting Bay	Burnt Cove	Rockweed	S981	13:05
June	6	Whiting Bay	Burnt Cove	Rockweed	S982	13:51
June	6	Whiting Bay	Burnt Cove	Unknown	S983	14:15
June	6	Whiting Bay	Burnt Cove	Mudflat	S984	14:37
August	3	Dennys Bay	Youngs Cove	Cobble	S1001	11:35
August	3	Dennys Bay	Youngs Cove	Unknown	S1002	11:52
August	3	Dennys Bay	Youngs Cove	Grass	S1003	12:06
August	3	Dennys Bay	Youngs Cove	Cobble	S1004	12:45
August	3	Dennys Bay	Youngs Cove	Unknown	S1005	13:06
August	3	Dennys Bay	Youngs Cove	Mudflat	S1006	13:30
August	4	Dennys Bay	Youngs Cove	Rockweed	S1011	0:06
August	4	Dennys Bay	Youngs Cove	Cobble	S1012	0:32
August	4	Dennys Bay	Youngs Cove	Grass	S1013	0:55
August	4	Dennys Bay	Youngs Cove	Mudflat	S1014	1:50
August	4	East Bay	Sipp Bay	Grass	S1021	11:00
August	4	East Bay	Sipp Bay	Cobble	S1022	11:17
August	4	East Bay	Sipp Bay	Grass	S1023	11:30
August	4	East Bay	Sipp Bay	Cobble	S1024	11:48
August	4	East Bay	Sipp Bay	Rockweed	S1025	12:28
August	4	East Bay	Sipp Bay	Rockweed	S1026	12:58

August	4	East Bay	Sipp Bay	Unknown	S1031	23:00
August	4	East Bay	Sipp Bay	Unknown	S1032	23:10
August	5	East Bay	Sipp Bay	Unknown	S1033	0:08
August	5	East Bay	Sipp Bay	Unknown	S1034	0:20
August	5	East Bay	Sipp Bay	Unknown	S1035	1:00
August	5	Outer Bay	Carrying Place Cove	Unknown	S1041	12:19
August	5	Outer Bay	Carrying Place Cove	Unknown	S1042	12:47
August	5	Outer Bay	Carrying Place Cove	Mudflat	S1043	13:00
August	5	Outer Bay	Carrying Place Cove	Mudflat	S1044	13:14
August	6	Outer Bay	Carrying Place Cove	Unknown	S1051	0:53
August	6	Outer Bay	Carrying Place Cove	Unknown	S1052	1:10
August	6	Outer Bay	Carrying Place Cove	Mudflat	S1053	1:23
August	6	Outer Bay	Carrying Place Cove	Unknown	S1054	1:43
August	6	South Bay	Case Cove	Cobble	S1061	13:21
August	6	South Bay	Case Cove	Unknown	S1062	13:30
August	6	South Bay	Case Cove	Rockweed	S1063	13:41
August	7	Whiting Bay	Burnt Cove	Rockweed	S1071	15:01
August	7	Whiting Bay	Burnt Cove	Rockweed	S1072	15:41
August	7	Whiting Bay	Burnt Cove	Mudflat	S1073	16:29
August	7	Whiting Bay	Burnt Cove	Mudflat	S1074	16:46
August	8	Pennamaquan River	Hersey Cove	Cobble	S1081	14:35
August	8	Pennamaquan River	Hersey Cove	Cobble	S1082	14:42
August	8	Pennamaquan River	Hersey Cove	Grass	S1083	14:51
August	8	Pennamaquan River	Hersey Cove	Cobble	S1084	15:03
August	8	Pennamaquan River	Hersey Cove	Rockweed	S1085	15:21
August	8	Pennamaquan River	Hersey Cove	Unknown	S1086	15:31
August	31	Whiting Bay	Burnt Cove	Rockweed	S1101	11:00
August	31	Whiting Bay	Burnt Cove	Rockweed	S1102	11:27
August	31	Whiting Bay	Burnt Cove	Mudflat	S1103	12:20
August	31	Whiting Bay	Burnt Cove	Mudflat	S1104	12:30
August	31	Dennys Bay	Youngs Cove	Rockweed	S1111	22:30
August	31	Dennys Bay	Youngs Cove	Cobble	S1112	23:00
September	1	Dennys Bay	Youngs Cove	Unknown	S1121	10:50
September	1	Dennys Bay	Youngs Cove	Unknown	S1122	11:00
September	1	Dennys Bay	Youngs Cove	Grass	S1123	11:10
September	1	Dennys Bay	Youngs Cove	Mudflat	S1124	12:44
September	1	East Bay	Sipp Bay	Grass	S1131	21:37
September	1	East Bay	Sipp Bay	Cobble	S1132	21:48
September	1	East Bay	Sipp Bay	Grass	S1133	22:26
September	1	East Bay	Sipp Bay	Cobble	S1134	22:33
September	1	East Bay	Sipp Bay	Rockweed	S1135	23:02
September	1	East Bay	Sipp Bay	Rockweed	S1136	23:40
September	2	East Bay	Sipp Bay	Cobble	S1141	10:15
September	2	East Bay	Sipp Bay	Grass	S1142	10:24
September	2	East Bay	Sipp Bay	Grass	S1143	10:55
September	2	East Bay	Sipp Bay	Cobble	S1144	11:01
September	2	East Bay	Sipp Bay	Unknown	S1145	11:40
September	2	East Bay	Sipp Bay	Unknown	S1146	12:00
September	2	Outer Bay	Carrying Place Cove	Unknown	S1151	23:15
September	2	Outer Bay	Carrying Place Cove	Grass	S1152	23:35

September	3	Outer Bay	Carrying Place Cove	Mudflat	S1153	0:25
September	3	Outer Bay	Carrying Place Cove	Unknown	S1154	0:45
September	3	Outer Bay	Carrying Place Cove	Grass	S1161	12:00
September	3	Outer Bay	Carrying Place Cove	Unknown	S1162	12:22
September	3	Outer Bay	Carrying Place Cove	Unknown	S1163	12:32
September	3	Outer Bay	Carrying Place Cove	Mudflat	S1164	12:44
September	4	South Bay	Case Cove	Cobble	S1171	12:30
September	4	South Bay	Case Cove	Grass	S1172	12:41
September	4	South Bay	Case Cove	Unknown	S1173	13:00
September	5	Pennamaquan River	Hersey Cove	Cobble	S1180	13:05
September	5	Pennamaquan River	Hersey Cove	Cobble	S1181	13:15
September	5	Pennamaquan River	Hersey Cove	Unknown	S1182	13:40
September	5	Pennamaquan River	Hersey Cove	Grass	S1183	13:50
September	5	Pennamaquan River	Hersey Cove	Unknown	S1184	14:21
September	5	Pennamaquan River	Hersey Cove	Rockweed	S1185	14:40
November	18	Pennamaquan River	Hersey Cove	Unknown	3 tows	11:30
November	18	Dennys Bay	Youngs Cove	Unknown	1 tow	14:00
November	19	East Bay	Sipp Bay	Unknown	2 tows	0:15
November	19	Outer Bay	Carrying Place Cove	Unknown	2 tows	1:30

Table 4. Date and location of intertidal fyke net samples in Cobscook Bay during May, June, August, and September, 2013. Fyke is fyke set number; each set is composed of two fyke nets. Begin and End are the approximate times (EDT) when each set began and ended. Each fyke net was assumed to begin effective fishing at the time of high tide and to end effective fishing when the water level was low in the net. Samples partially or completely at night are highlighted in gray. CB is Cobscook Bay.

Month	Day	Bay	Locale	Fyke	Begin	End
May	4	Dennys Bay	Youngs Cove	F800	20:00	23:59
May	5	Dennys Bay	Youngs Cove	F810	9:02	11:53
May	5	East Bay	Sipp Cove	F820	20:42	23:30
May	6	East Bay	Sipp Cove	F830	9:30	11:43
May	6	Outer Bay	Carrying Place Cove	F840	21:20	0:00
May	7	Outer Bay	Carrying Place Cove	F850	9:47	13:20
June	1	Dennys Bay	Youngs Cove	F900	19:15	22:15
June	2	Dennys Bay	Youngs Cove	F901	7:45	10:45
June	2	Outer Bay	Carrying Place Cove	F903	19:02	22:30
June	3	Outer Bay	Carryijng Place Cove	F904	7:31	11:00
June	3	East Bay	Sipp Bay	F905	20:30	23:00
June	4	East Bay	Sipp Bay	F910	9:00	11:30
August	3	Dennys Bay	Youngs Cove	F1001	13:00	19:03
August	3/4	Dennys Bay	Youngs Cove	F1011	19:03	02:45
August	4	East bay	Sipp Cove	F1021	~10:00	13:15
August	4/5	East Bay	Sipp Cove	F1031	~22:30	01:30
August	5	Outer Bay	Carrying Place Cove	F1041	11:00	15:00
August	6	Outer Bay	Carrying Place Cove	F1051	23:00	02:30
Aug-Sep	31/1	Dennys Bay	Youngs Cove	F1101	21:10	00:20
September	1	Dennys Bay	Youngs Cove	F1111	9:45	13:20
September	1	East Bay	Sipp Cove	F1131	9:15	23:58
September	2	East Bay	Sipp Bay	F1146	9:40	12:20
September	2/3	Outer Bay	Carrying Place Cove	F1501	22:00	01:15
September	2/3	Outer Bay	Carrying Place Cove	F1160	10:20	13:45

Table 5. Number of individuals caught by all gears combined in Cobscook Bay, 2013. Limited sampling in November is not included in this table, but see Table 8.

Scientific name	Common name	May	June	August	September	Total
Clupea harengus	Atlantic herring	52	6153	1042	5417	12664
Pseudopleuronectes americanus	Winter flounder	2443	1600	798	365	5206
Gasterosteus aculeatus	Threespine stickleback	112	1848	157	362	2479
Alosa pseudoharengus	Alewife	5	0	1738	474	2217
Fundulus heteroclitus	Mummichog	133	394	796	46	1369
Menidia menidia	Atlantic silverside	79	26	17	536	658
Gasterosteus wheatlandi	Blackspotted stickleback	62	143	153	72	430
Melanogrammus aeglefinus	Haddock	0	0	208	135	343
Myoxocephalus octodecemspinosus	Longhorn sculpin	140	123	61	9	333
Merluccius bilinearis	Silver hake	5	59	207	47	318
Myoxocephalus aenaeus	Grubby	138	66	36	29	269
Urophycis tenuis	White hake	0	0	120	76	196
Urophycis chuss	Red hake	23	52	84	15	174
Microgadus tomcod	Atlantic tomcod	3	26	65	46	140
Osmerus mordax	Rainbow smelt	9	55	17	22	103
Pungitius pungitius	Ninespine stickleback	0	0	5	20	25
Scophthalmus aquosus	Windowpane	13	9	3	0	25
Pollachius virens	Pollock	0	2	5	6	13
Peprilus triacanthus	Butterfish	0	0	1	8	9
Lumpenus lumpretaeformis	Snakeblenny	5	0	2	0	7
Hemitripterus americanus	Sea raven	0	3	1	2	6
Hippoglossus hippoglossus	Atlantic halibut	0	0	3	3	6
Myoxocephalus scorpius	Shorthorn sculpin	0	4	2	0	6
Pleuronectes putnami	Smooth flounder	0	0	4	1	5
Cyclopterus lumpus	Lumpfish	0	1	1	2	4
Gadus morhua	Atlantic cod	2	0	0	2	4
Zoarces americanus	Ocean pout	0	2	2	0	4
Alosa aestivalis	Blueback herring	2	0	0	1	3
Leucoraja ocellata	Winter skate	1	1	0	1	3
Liparis atlanticus	Atlantic sea snail	2	1	0	0	3
Malacoraja senta	Smooth skate	0	0	3	0	3
Ulvaria subbifurcata	Radiated shanny	2	1	0	0	3
Apeltes quadricus	Fourspine stickleback	2	0	0	0	2
Hippoglossoides platessoides	American plaice	1	1	0	0	2
Triglops murrayi	Moustache sculpin	0	2	0	0	2
Anguilla rostrata	American eel	0	0	0	1	1
Brosme brosme	Cusk	1	0	0	0	1
Leucoraja erinacea	Little skate	0	0	0	1	1
Morone americana	White perch	0	0	0	1	1
Scomber scombrus	Atlantic mackerel	0	0	1	0	1
Total		3235	10572	5532	7700	27039

Table 6. Numbers of individuals caught by month by pelagic trawling in Cobscook bay, 2013.

Species	May	June	August	September	Total
Atlantic herring	50	6150	470	41	6711
Winter flounder	6	46	0	0	52
Silver hake	0	4	2	1	7
Alewife	0	0	0	6	6
Shorthorn sculpin	0	1	1	1	3
Lumpfish	1	1	0	0	2
Atlantic sea snail	1	0	0	0	1
Threespine stickleback	0	1	0	0	1
Blackspotted stickleback	1	0	0	0	1
Windowpane	1	0	0	0	1
Total	50	6150	470	41	6711

Table 7. Numbers of individuals caught by month by benthic trawling in Cobscook Bay, 2013.

Species	May	June	August	September	Total
Atlantic herring	2	3	566	5376	5947
Winter flounder	2442	1600	798	363	5203
Haddock	0	0	208	135	343
Longhorn sculpin	140	123	61	9	333
Silver hake	5	55	205	46	311
Alewife	4	0	29	237	270
Grubby	138	66	36	29	269
White hake	0	0	120	76	196
Red hake	23	52	84	15	174
Rainbow smelt	7	5	7	11	30
Windowpane	12	9	3	0	24
Atlantic tomcod	0	0	2	7	9
Butterfish	0	0	1	8	9
Snakeblenny	5	0	2	0	7
Sea raven	0	3	1	2	6
Atlantic halibut	0	0	3	3	6
Shorthorn sculpin	0	3	2	0	5
Atlantic cod	2	0	0	2	4
Ocean pout	0	2	2	0	4
Winter skate	1	1	0	1	3
Smooth skate	0	0	3	0	3
Radiated shanny	2	1	0	0	3
American plaice	1	1	0	0	2
Pollock	0	0	0	2	2
Moustache sculpin	0	2	0	0	2
Blueback herring	0	0	0	1	1
Cusk	1	0	0	0	1
Lumpfish	0	0	0	1	1
Little skate	0	0	0	1	1
Atlantic sea snail	1	0	0	0	1
Atlantic mackerel	0	0	1	0	1
Total	2786	1926	2134	6325	13171

Table 8. Numbers of individuals caught by month by intertidal seining in Cobscook Bay, 2013. For November, only those individuals kept for examination for sea lice are included. Other catch was released and not recorded. November catch not included in table totals or in Table 5.

Species	May	June	August	September	November	Total
Threespine stickleback	106	1802	157	362	(123)	2427
Alewife	0	0	1709	231		1940
Mummichog	133	394	796	46		1369
Atlantic silverside	79	26	17	536		658
Blackspotted stickleback	61	143	153	72	(104)	429
Atlantic tomcod	1	22	62	5		90
Rainbow smelt	2	50	9	4		65
Ninespine stickleback	0	0	5	20	(7)	25
Pollock	0	2	4	1		7
Atlantic herring	0	0	6	0		6
Smooth flounder	0	0	4	1		5
Fourspine stickleback	2	0	0	0		2
American eel	0	0	0	1		1
Winter flounder	0	0	0	1		1
Blueback herring	0	0	0	0		0
American eel	0	0	0	1		1
Total	384	2439	2922	1281	(234)	7026

Table 9. Numbers of individuals caught by month by fyke netting in Cobscook Bay, 2013.

Species	May	June	August	September	Total
Atlantic tomcod	2	4	1	34	41
Rainbow smelt			1	7	8
Pollock			1	3	4
Blueback herring	2				2
Alewife	1				1
Winter flounder				1	1
Total	5	4	3	45	57

Appendix E

FY13Q1 Water Power Report, Grid Investigations: SNL-EFDC Model Application to Cobscook Bay, ME, Sandia National Laboratories, December 31, 2012

FY13Q2 Water Power Report, Fine-Grid Model Calibration and MHK Incorporation: SNL: SNL-EFDC Model Application to Cobscook Bay, ME, Sandia National Laboratories, March 29, 2013

FY13Q3 Water Power Report, MHK Array Placement Analysis: SNL: SNL-EFDC Model Application to Cobscook Bay, ME, Sandia National Laboratories, June 30, 2013

FY13 Q1 Water Power Report

Grid Investigations:
SNL-EFDC Model Application to Cobscook Bay, ME

Submitted by

Water Power Technologies
Sandia National Laboratories
December 31, 2012

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and

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Table of Contents

Introduction 2

Previous Work 2

Local Model Setup 5

Expanding Grid 6

Rectangular Grid 8

Localized Rectangular Grid 10

Results 11

Discussion and Future Work 14

Acknowledgements 14

References 14

Figure 1: Cobscook Bay bathymetry showing locations of water-level collection stations. 3
Figure 2: Cross-correlation plot between SNL-EFDC output and NOAA data for Garnet Point (left), Coffin Point (center), and Gravelly Point (right). 4
Figure 3: Comparison of ADCP (symbols) to SNL-EFDC (red curves) speeds. 4
Figure 4: Flow in the vicinity of proposed MHK devices modeled with a coarse grid and points denoting the turbine locations. The devices are unresolved by the model grid. 5
Figure 5: Location of expanding grid. 7
Figure 6: Close-up of expanding grid with points denoting the turbine locations. 7
Figure 7: Location of rectangular grid. 8
Figure 8: Close-up of 5 m x 5 m rectangular grid. 9
Figure 9: Modeled flood velocities in the rectangular grid domain. No turbines are present in this simulation. 9
Figure 10: Location of localized rectangular grid. 10
Figure 11: Close-up of localized rectangular grid. 11
Figure 12: Water level (black) and velocity magnitude time series (blue). 12
Figure 13: Compass plot of velocity direction (north is 90^{o}) and magnitude (m/s). 12
Figure 14: Velocity vectors in the vicinity of the proposed MHK devices. 13

Introduction

Tidal MHK turbines are receiving a growing global interest. Because of reasonable investment, maintenance, reliability, and environmental friendliness, this technology is considered worthy of research investment. Furthermore, small-scale MHK energy from river or tidal currents can be a solution for power supply in remote areas. However, little is known about the potential effects of MHK device operation in coastal embayments, estuaries, or rivers, or of the cumulative impacts of these devices on aquatic ecosystems over years or decades of operation. This lack of knowledge affects the actions of regulatory agencies, the opinions of stakeholder groups, and the commitment of energy project developers and investors. For example, the power generating capacity of water-current MHK turbines will depend on the turbine type and number, and the current flow velocities, among other factors. Each MHK-device array's footprint and performance will depend on the type of turbines and the characteristics of the local system. There is an urgent need for practical, accessible tools and peer-reviewed publications to help industry and regulators evaluate environmental impacts and mitigation measures and to establish best siting and design practices.

This study focuses on the development of a hydrodynamic model for flow around individual MHK devices in Cobscook Bay, ME. This is the first deployment location of the Ocean Renewable Power Company (ORPC) TidGen™ units. One unit is currently deployed with 4 more to follow in the coming years. This FY13 Q1 report summarizes FY12 efforts to investigate potential changes to the physical environment imposed by operation of a five-MHK turbine array using the modeling platform SNL-EFDC(James et al., 2011; James et al., 2012; James et al., 2006a; James et al., 2010a; James et al., 2010b; James et al., 2006b). In FY12, SNL built a course grid, large scale model that included Cobscook Bay and all other landward embayments. Model results with and without an MHK array were compared with the large scale hydrodynamic model to facilitate an understanding of how this small 5-MHKturbine array might alter the Cobscook Bay environment. The present study focuses on the evaluation of higher resolution grid options to investigate the fine scale hydrodynamics in the vicinity of the individual MHK devices. The higher resolution model can help to better evaluate fish swimming behavior and potential changes due to the operation of MHK turbines. These modeling activities can assist cost-effective planning to benefit permitting and best siting practices including array design.

Previous Work

The large scale Cobscook Bay model was developed with Cartesian 100×100-m^2 cells. Bathymetric data was obtained from National Oceanographic & Atmospheric Administration National Geophysical Data Center. These data were interpolated onto the model cells using the nearest neighbor technique with results shown in Figure 1. Circulation in the Bay was driven by water elevation data collected at Eastport Maine. To ensure that these water-level data are appropriate drivers for the model, data were compared with the University of Maine FVCOM (Chen et al., 2004) model (Bao et al., 2012; Xu and Xue, 2010; Xu et al., 2006). Specifically, water levels at Eastport and at a location coincident with the SNL-EFDC model boundary were compared. The close match between all data sets gave confidence that data measured at Eastport can be used to drive the large scale SNL-EFDC model.

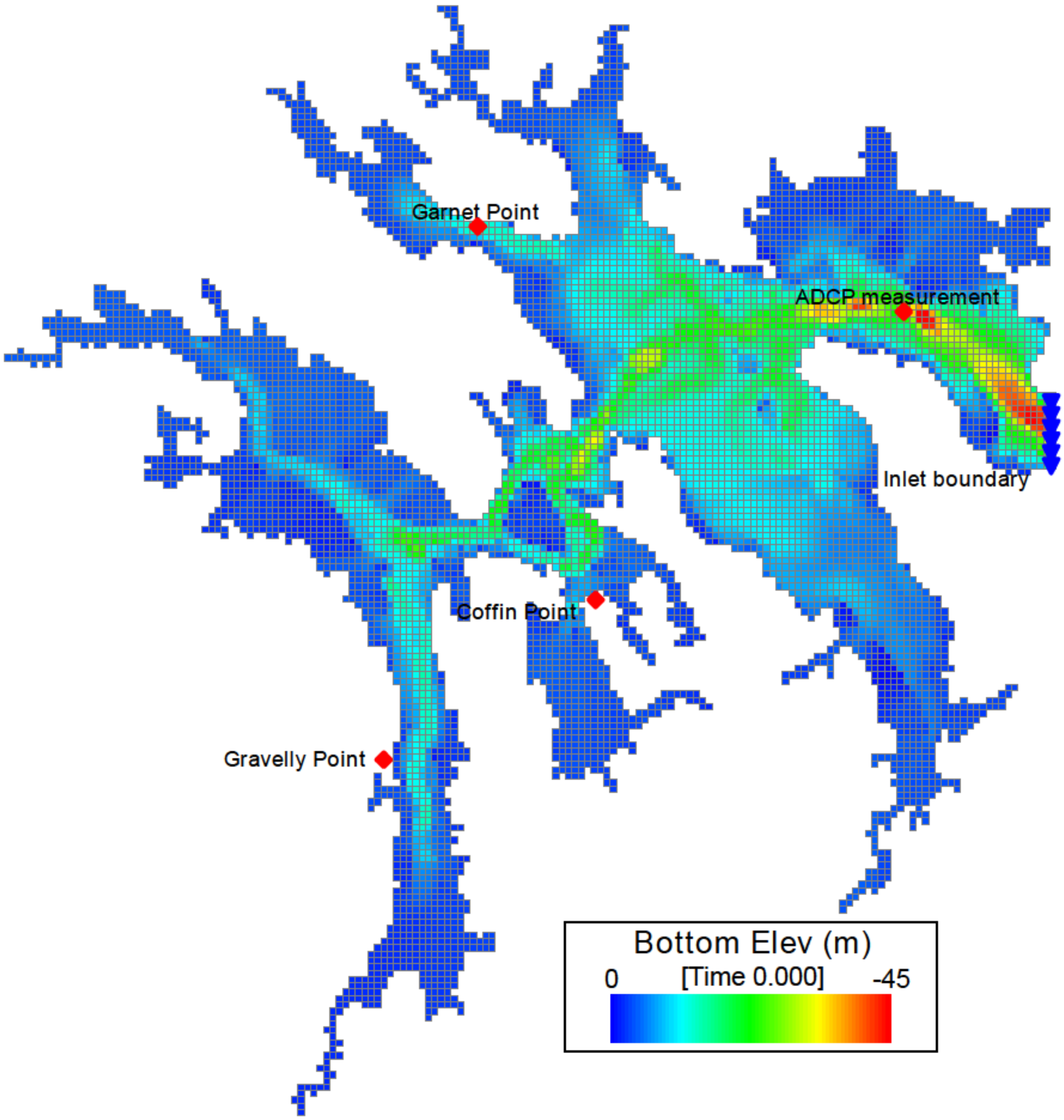

Figure 1: Cobscook Bay bathymetry showing locations of water-level collection stations.

Using the Eastport water-level data to drive the model at the inlet boundary (July 6th–30th, 2004), various comparisons were made at the three locations shown on Figure 1 where water level data are available from NOAA (Garnet, Coffin, and Gravelly Points). NOAA data, SNL-EFDC data, and even FVCOM data for comparison are presented on Figure 2. As evident, simulated water levels compare extremely well with the data. It is worth noting that modeling from the University of Maine that used only tidal and wind forcing showed good agreement with available depth, velocity, and tracer data near Cobscook Bay (Xu et al., 2006). Conclusions from that work indicate that temperature, and density gradients are not critical factors influencing hydrodynamic circulation in the bay.

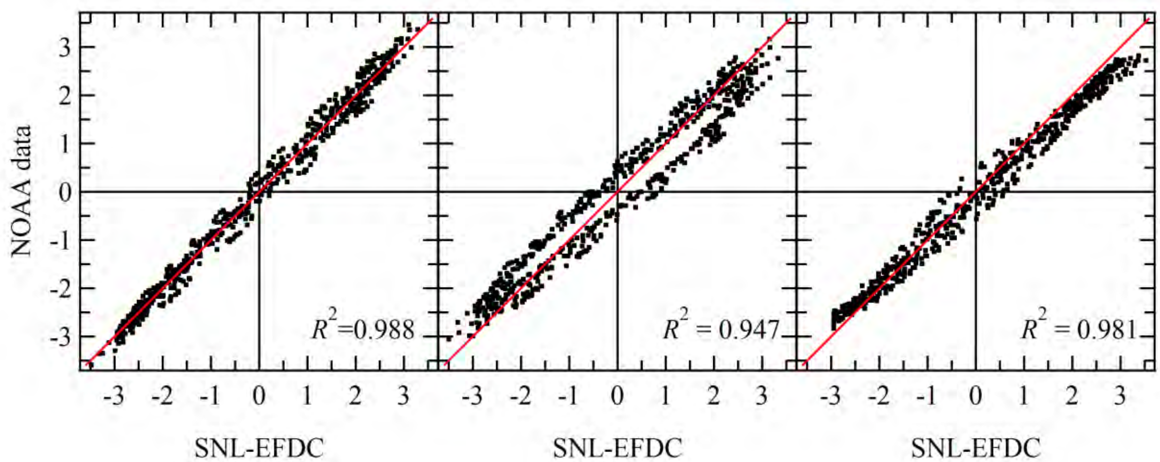

Figure 2: Cross-correlation plot between SNL-EFDC output and NOAA data for Garnet Point (left), Coffin Point (center), and Gravelly Point (right).

Acoustic Doppler Current Profiler (ADCP) data were collected by ORPC from July 5th through August 5th, 2011, at UTM-NAD83 (654,267-E, 4,974,792-N, shown on Figure 1). Figure 3 compares ADCP data to SNL-EFDC model results for depth-averaged water speed. SNL-EFDC under predicts the ADCP data by about 5% on average over the period of record. In agreement with what was reported by Bao et al. (2012), the phase and trend of the speeds are consistent between data and model, but the magnitude is generally, slightly under predicted.

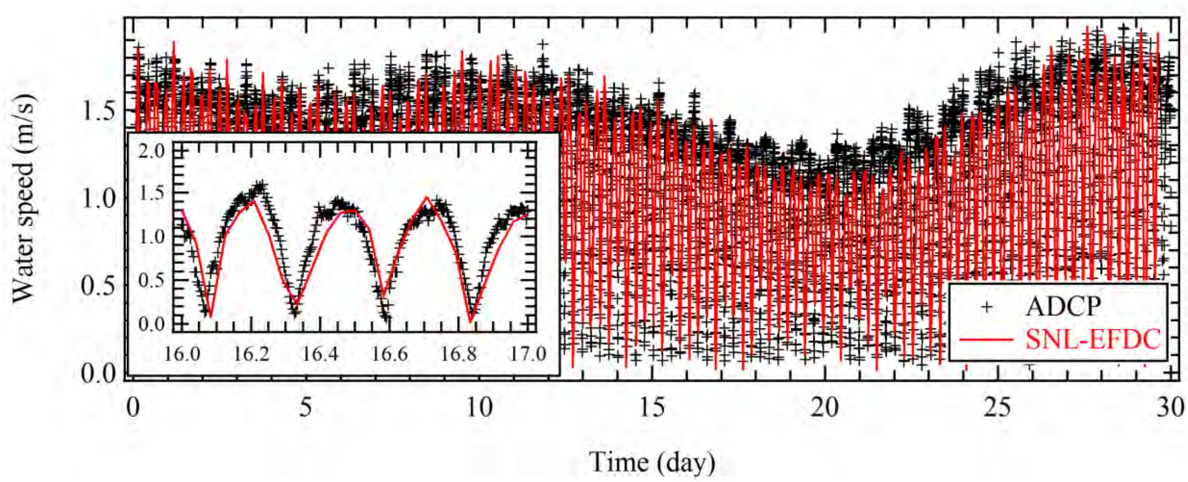

Figure 3: Comparison of ADCP (symbols) to SNL-EFDC (red curves) speeds.

Overall, the previous large scale SNL-EFDC model does a good job of simulating large scale (on the order of 100 m) flow in Cobscook Bay and it adequately reproduces available data sets for three water-level locations and an ADCP measurement. This work demonstrates that there are no significant changes in tidal range, flow rate, or velocity upon operation of the five ORPC tidal turbines. Therefore, the initial study concluded that the operation of 5tidal turbines in Cobscook Bay will have little to no effect on regional aquatic habitat as regional processes are unchanged.

Local Model Setup

The present study focuses on the evaluation of higher resolution grid options to investigate the fine scale hydrodynamics in the vicinity of the individual MHK devices. As noted, the large scale Cobscook Bay model was developed with Cartesian 100×100-m^2 cells. Since the OPRC cross-flow tidal turbines are approximately 30 m wide, single model grid cells were much larger than the turbines. The region of interest is shown in Figure 4. The black dots, representing the center points of the turbines, show there are only 3 to 4 grid cells in the region of turbine deployment. While this is sufficient for investigating large scale effects, near field (i.e. fine scale) hydrodynamics, which may be important to fish swimming patterns, are not resolved. Therefore, a local near field model with a resolution smaller than the individual turbines and their proposed wake effects is developed.

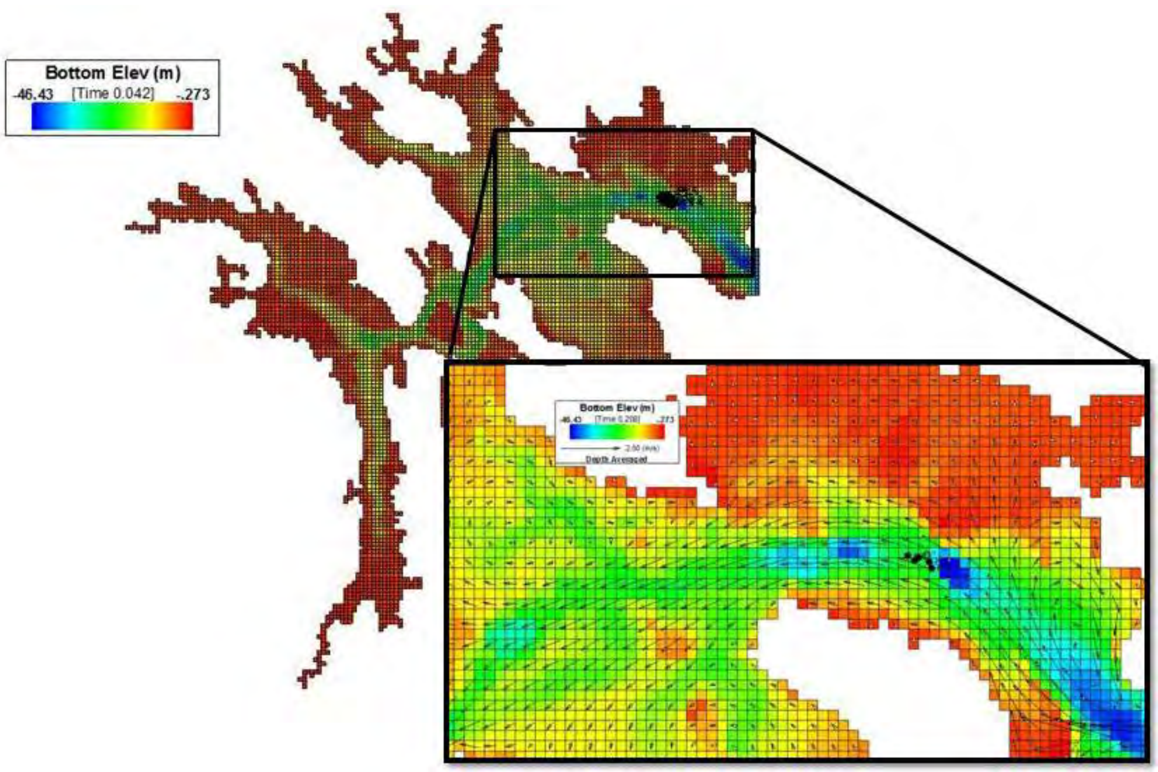

Figure 4: Flow in the vicinity of proposed MHK devices modeled with a coarse grid and points denoting the turbine locations. The devices are unresolved by the model grid.

The target grid resolution for resolving the near field hydrodynamics is a 5 m by 5 m grid cell. The key constraint for SNL-EFDC on the overall model extent when using a small, constant grid cell size is the total number of grid cells in the model. Typically for models being used in long term environmental evaluations lasting more than 1 month, a total grid cell number of 20,000 is considered the maximum. The maximum cell count is due time constraints required for model calibration, validation, and analysis. Any grid cell numbers higher than 20,000 can result in computational times that are untenable for a successful model study.

Generally a Cartesian (i.e. rectangular) grid cell is desired due to the ease of transferring results to fish behavior models, water quality models, and other models. While curvilinear and unstructured grids are commonly used in modeling, the time required for post processing the results into other modeling frameworks can be laborious. The present study focuses on the development of a rectangular grid. The three approaches investigated here are summarized in the following sections.

Expanding Grid

A common method for simulating a large domain and still obtaining high resolution in a region of interest is an expanding rectangular grid. A grid is created that has very high resolution in a small region and then uniformly expands outward. In order to reach the target 5 m grid resolution near the turbine locations, an expanding grid can be used. Figure 5 shows a location selected for the development of an expanding grid. The inset image shows that the grid extent is selected to provide natural boundaries for modeling convenience and still obtain a 5 m resolution in the vicinity of the turbines. More specifically, Figure 6 shows a close-up of the expanding grid The grid starts with a high resolution and then expands to a coarser resolution in order to allow the model extents to be lengthened.

Boundary conditions were obtained from the large scale SNL-EFDC model to drive the expanding grid model. Investigation of the velocities in the vicinity of the turbines revealed a common side-effect of expanding grids. When the flow is not parallel to the direction of grid expansion, the expanding grid can introduce errors in flow. The model showed significant variation in water level and velocity along the expanding grid lines. These effects are artifacts of the grid itself, and not system forcings. The expanding grid did not appropriately represent the near field hydrodynamics for this reason.

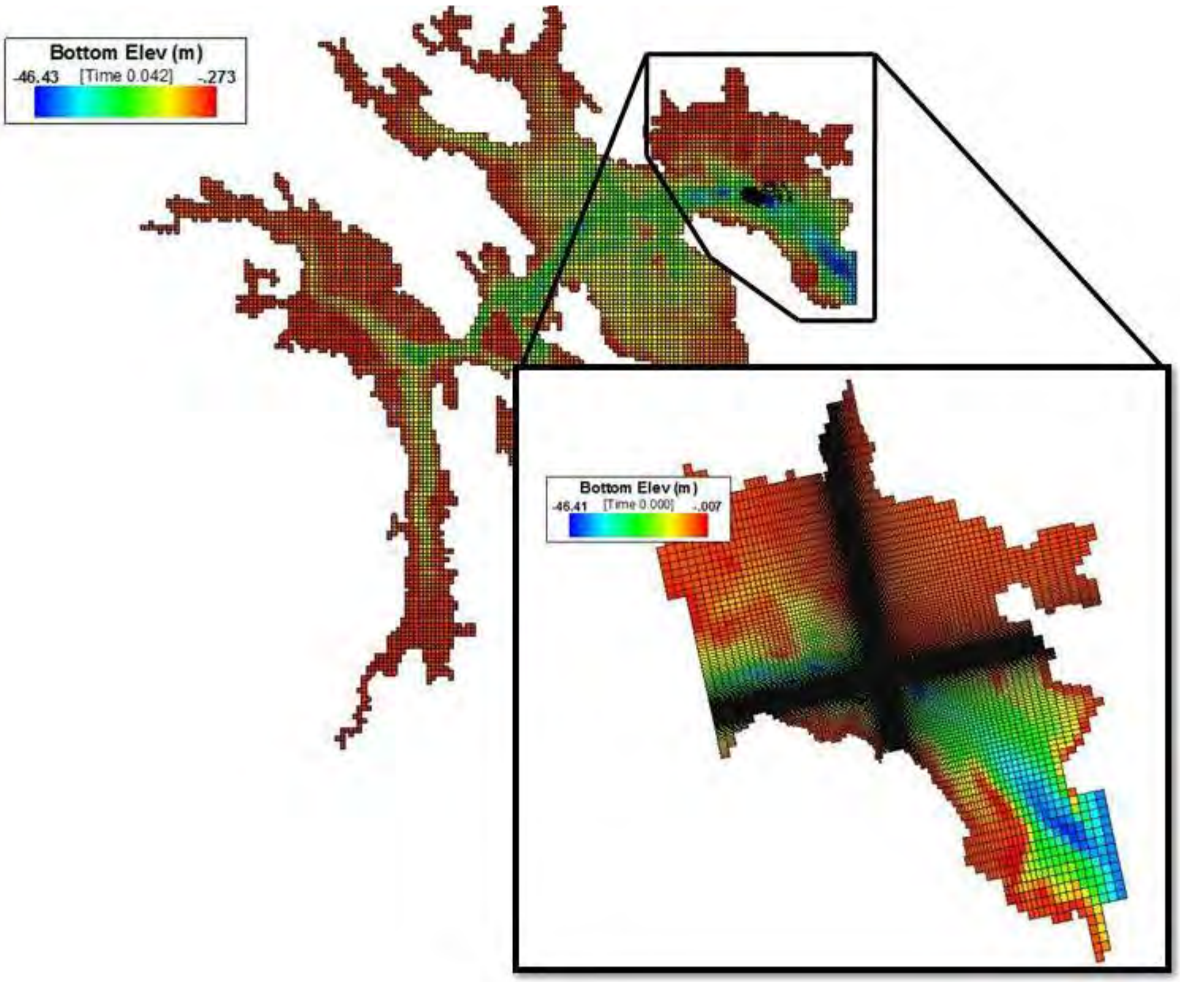

Figure 5: Location of expanding grid.

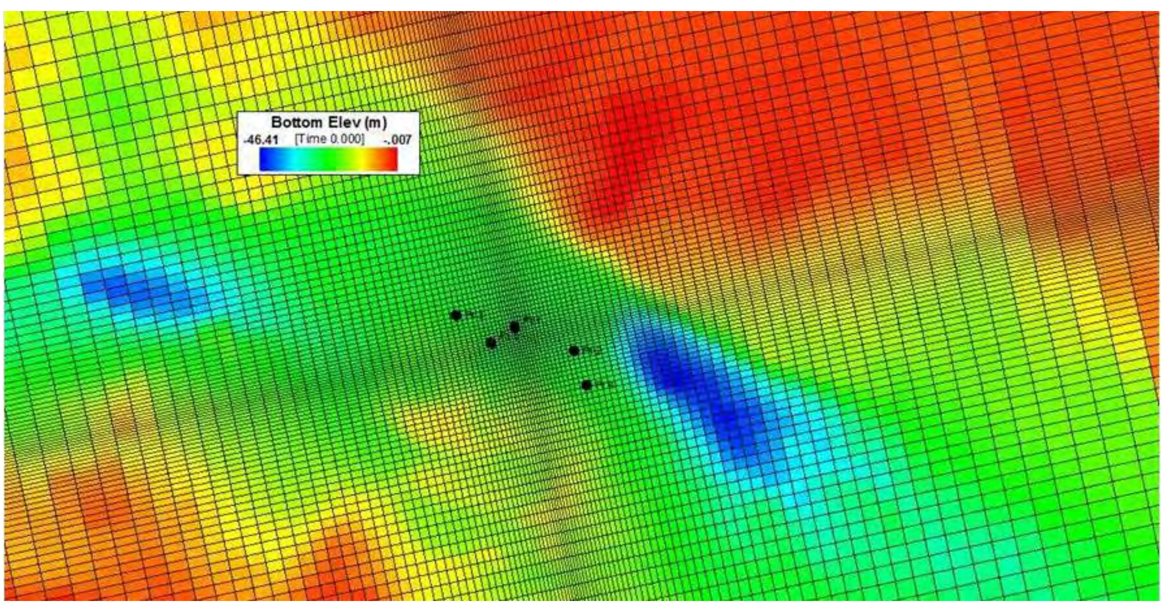

Figure 6: Close-up of expanding grid with points denoting the turbine locations.

Rectangular Grid

The next grid investigated was a simple rectangular grid of 5 m x 5 m cells oriented in the direction of net flow. As previously mentioned, an ADCP was deployed in the turbine region to measure flow velocities. Analysis of the ADCP data revealed the axis of the ebb and flood velocity direction was approximately 30 degrees south of east. By constructing a rectangular domain that was 870 m by 520 m in extent and contained 5 m by 5 m grid cells, the region of the turbine deployment was adequately resolved. To ease boundary specifications and best-capture flow patterns in the main channel, the domain was also rotated by 30 degrees (approximate direction of net flow).The total number of grid cells was approximately 25,000. This exceeds the rule-of-thumb for reasonable computation times, but was still investigated for potential future use.

Figure 7 shows a call out of the region the rectangular grid represents. As can be seen in Figure 8, the grid represents the region of the turbines very well. Boundary conditions for flow and water level at the model boundaries were obtained from the large-scale SNL-EFDC model and simulations were conducted. Figure 9 shows an example of flood tide velocities computed on this grid. The velocities are oriented in the key direction of flood and ebb tidal velocities in this region and the resolution is high enough to resolve the turbines. The simulations require approximately 5 hours to simulate a single day in 3-dimensions. While this may be suitable for some fine scale studies, another smaller domain gridding option was investigated.

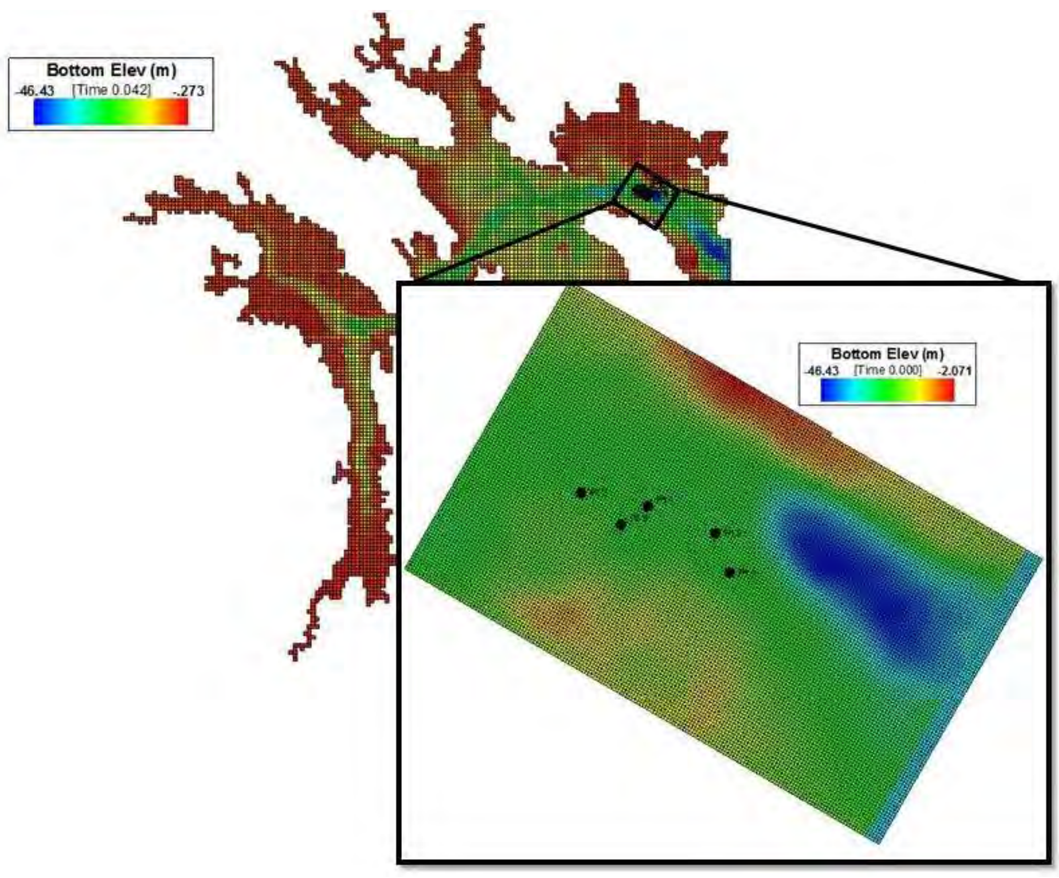

Figure 7: Location of rectangular grid.

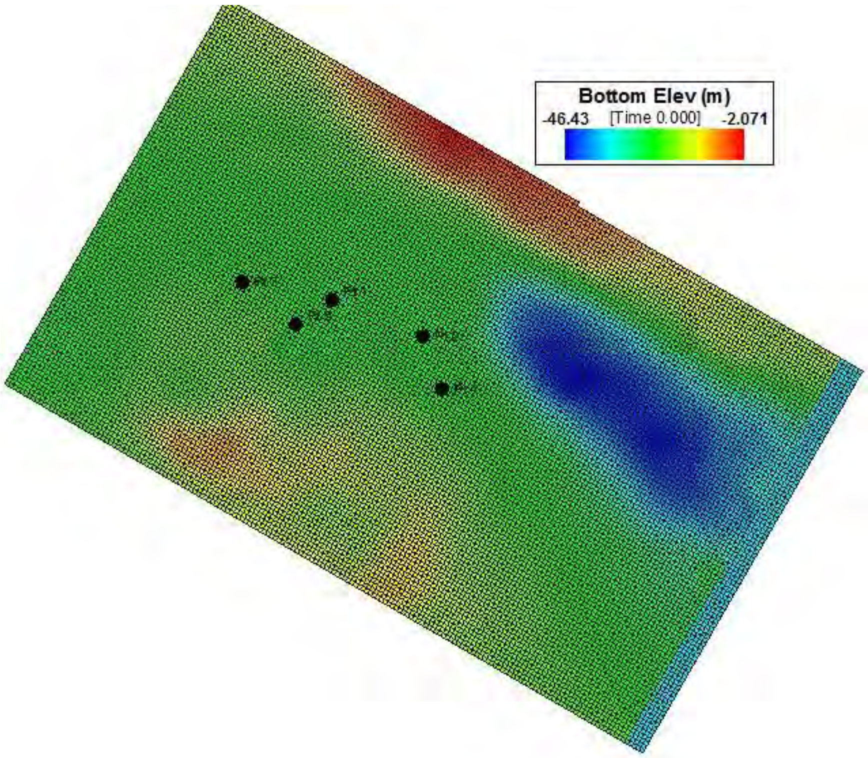

Figure 8: Close-up of 5 m x 5 m rectangular grid.

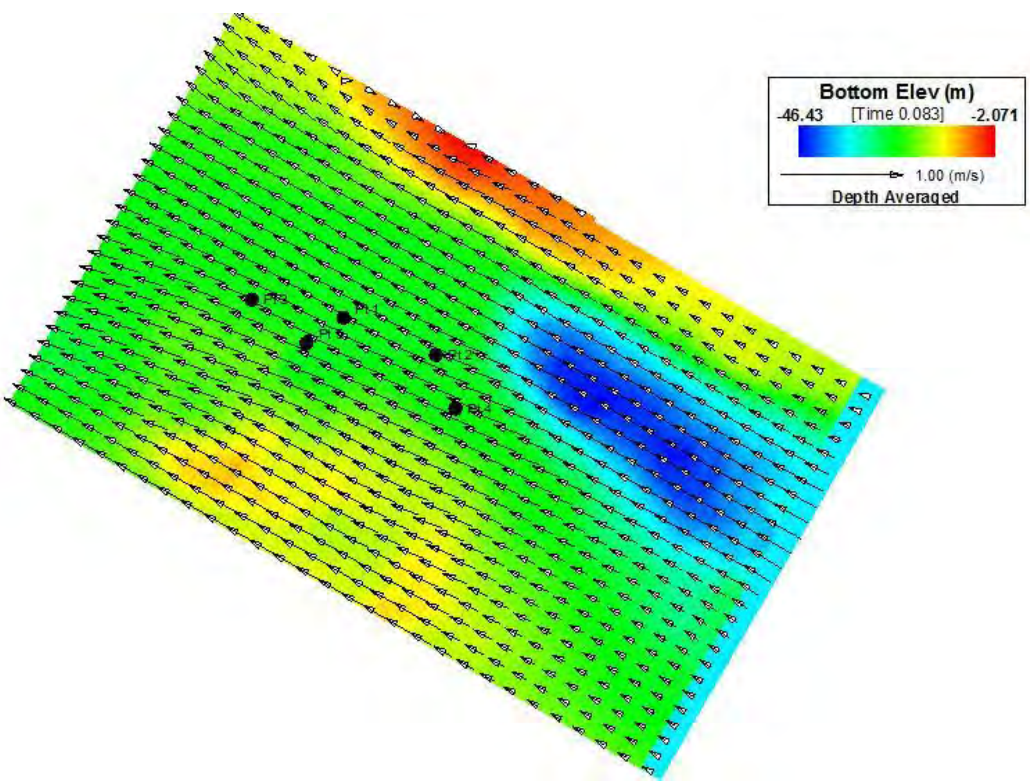

Figure 9: Modeled flood velocities in the rectangular grid domain. No turbines are present in this simulation.

Localized Rectangular Grid

A smaller domain, but again with a 5 m x 5 m grid oriented to the flow direction, was investigated to reduce the number of total grid cells, and hence, reducing computational times. Figure 10 shows the region of the localized grid. While the dimensions of the domain are only 350 m x 300 m, the setup can resolve the near field hydrodynamics of the individual turbines. Additionally, the domain has less than 8,000 grid cells allowing for relatively fast computations of 3-dimensional velocities for a wide number of cases.

Figure 11 shows a close up of the localized rectangular grid. Boundary conditions were obtained from the large scale SNL-EFDC model to drive this localized grid model, and the results are discussed in the following section. The benefit to a grid such as this is that it can be quickly generated to center on a region of interest. Any new grid can be quickly calibrated and validated due to the relatively small domain size. The flexibility of a grid such as this makes it a potentially powerful tool. The drawbacks of small domains are that they cannot be used to conduct large scale transport studies. Furthermore, site specific velocity measurements must be available for model calibration and validation.

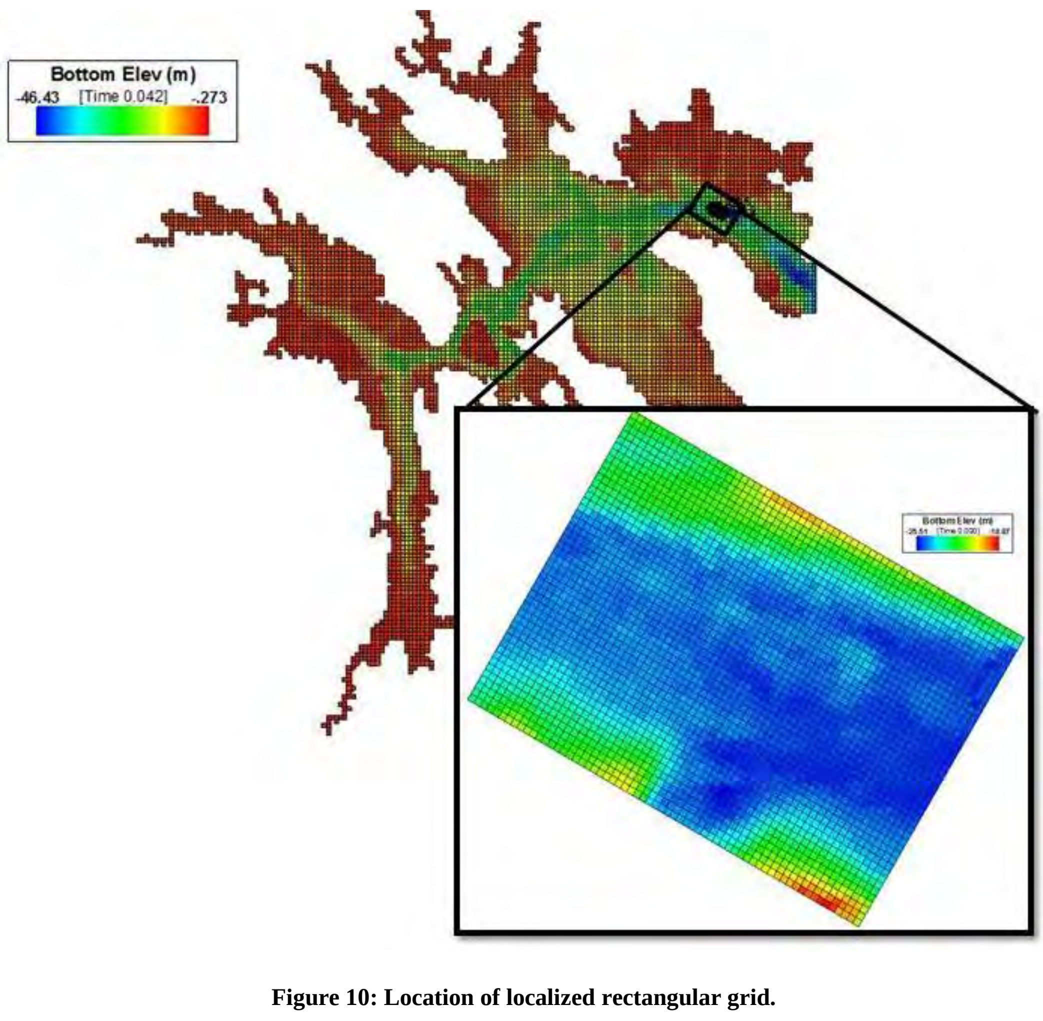

Figure 10: Location of localized rectangular grid.

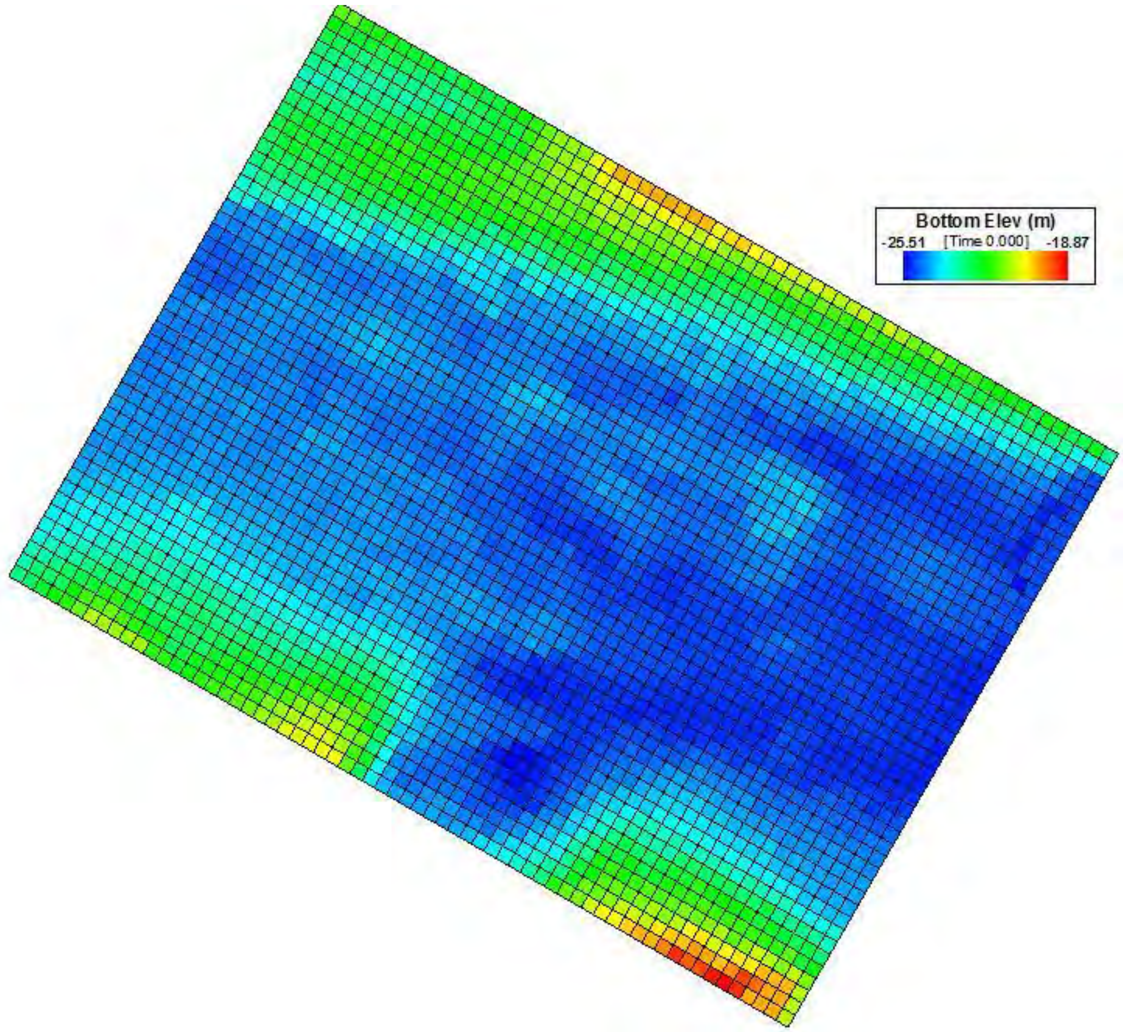

Figure 11: Close-up of localized rectangular grid.

Results

As expected, both the smaller 5 m x 5m rectangular model setups produced water levels throughout the model domains that were in agreement with validated water levels from the large model domain. For the localized rectangular grid, water levels extracted from the center of the domain are plotted in Figure 12 (black) along with the corresponding depth-averaged velocity magnitude (blue) for a one-day period. The semi-diurnal tidal behavior of Cobscook Bay is apparent. The water velocities peaked during periods of strong ebbing and flooding tides. A maximum velocity of approximately 0.9 m/s is within 10% of the measured neap tide velocities during this particular 24-hour period.

Overall the model produces velocity patterns and behavior consistent with both the measured data and validated large scale model. Numerical inconsistencies are essentially non-existent in the normal, rectangular smaller domain, higher resolution models. Therefore, since the model is forced with boundary conditions from the validated large scale model, it produced consistent results. Further calibration of the boundary conditions will provide accurate representation of the velocities and water levels over longer time periods.

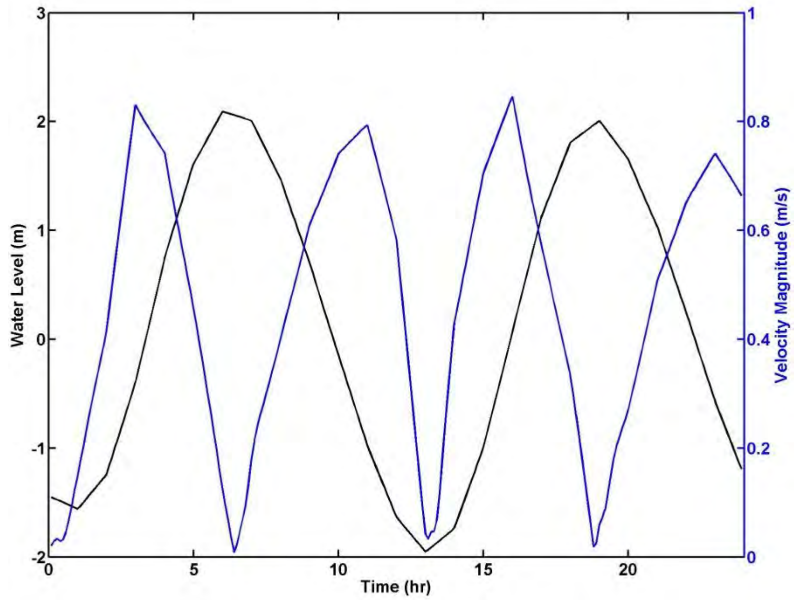

Figure 12: Water level (black) and velocity magnitude time series (blue).

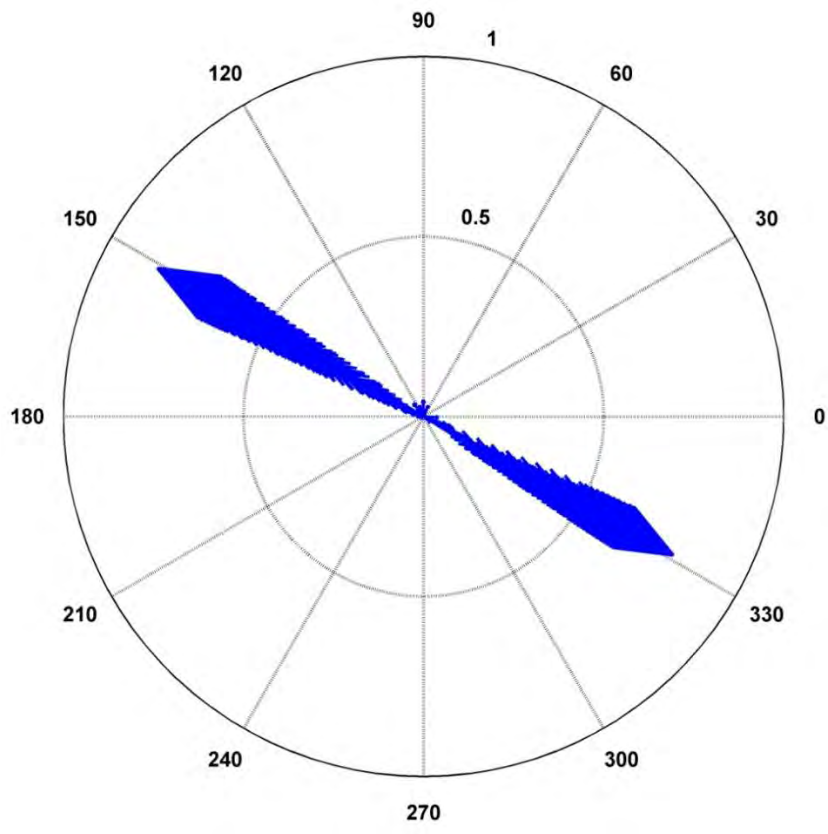

Figure 13: Compass plot of velocity direction (north is 90^o) and magnitude (m/s).

Figure 13 shows a compass plot of the flood and ebb velocity magnitude and direction. The direction and magnitude of the velocities are consistent with ADCP measurements for the 24 hour period simulated. Ongoing work is being conducted for final calibration and validation of the localized rectangular model using the measured ADCP data. The overall velocity field (Figure 14) compares favorably with those seen in the large-scale modeling effort. Overall these results provide encouragement that the rectangular grids (both localized and larger domain) can be used to investigate hydrodynamics on a 5 m grid scale.

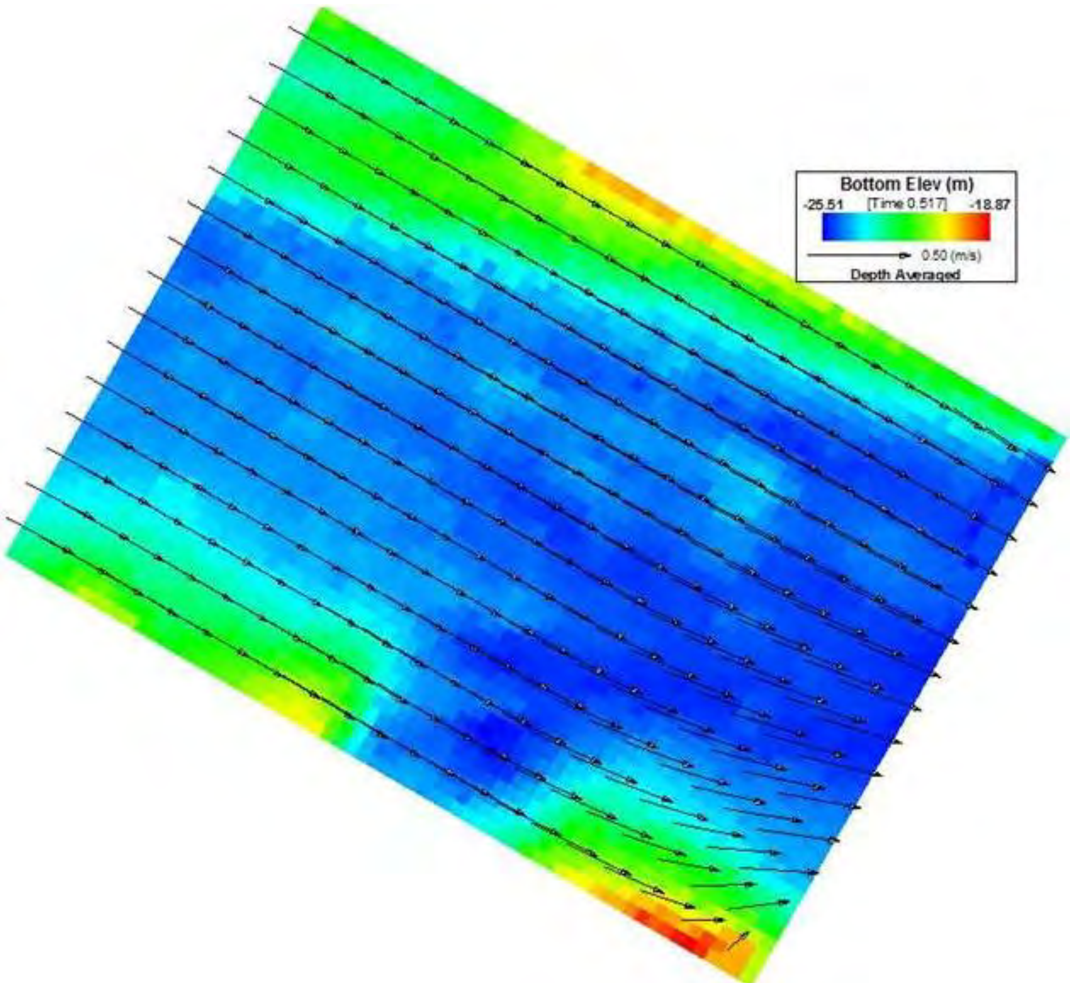

Figure 14: Velocity vectors in the vicinity of the proposed MHK devices.

Discussion and Future Work

The modeling effort presented herein was designed to evaluate the usage of various high resolution grids for resolving the near field hydrodynamics around the MHK turbines in Cobscook Bay. In particular, the present study focuses on the development of higher resolution grid options to investigate the fine scale hydrodynamics in the vicinity of the individual MHK devices. Three grid options were investigated in detail: an expanding grid, a high resolution rectangular grid, and a high resolution localized rectangular grid. Generally it was found that:

- The expanding grid can introduce errors in the region of significant grid size changes. The model showed significant variation in water level and velocity along the expanding grid lines. It was concluded that an expanding grid cannot appropriately represent the near field hydrodynamics for this reason.
- The high resolution rectangular grid oriented in the key direction of flood and ebb tidal velocities can resolve tidal flow accurately. However, the simulations require approximately 5 hours to simulate a single day. While this may be suitable for some fine scale studies, the computational times are too large for many studies.
- A high resolution grid with a smaller domain size can also accurately simulate flows in the vicinity of the turbines. The benefit of a small domain is that it can be quickly generated to center on a region of interest. Additionally, a new grid can be quickly calibrated and validated due to the relatively small domain size and rapid computational times. The flexibility of a grid such as this makes it a potentially powerful tool for local hydrodynamics and scour studies. The drawback is that the domain cannot be used to conduct large scale transport studies (e.g. sediment transport, water quality) which necessitate the information from a larger scale model. Feedback loops between the nested models and the larger domain models can overcome these limitations. Furthermore, site specific velocities measurements must be available for model calibration and validation.

Overall, the evaluation preliminarily shows that a high resolution rectangular domain can be generated to represent the region of interest in Cobscook Bay. There are tradeoffs in domain size and computational time for the two rectangular domains developed, and specific study goals can guide grid needs. Future work will calibrate and validate these models with water-level and ADCP measurement within the grid domains. Ongoing work by SNL will also more accurately investigate near field hydrodynamics and potential for environmental alterations within and around the MHK arrays. Further simulations will include adding various array configurations and estimating their effects on system hydrodynamics.

Acknowledgements

Sandia would like to thank Dr. HuijieXue and Min Bao at the University of Maine for their FVCOM model output as well as discussion and guidance on this Cobscook Bay model development.

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FY13 Q2 Water Power Report

Fine-Grid Model Calibration and MHK Incorporation: SNL-EFDC Model Application to Cobscook Bay, ME

Submitted by

Water Power Technologies
Sandia National Laboratories
March 29, 2013

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Table of Contents

Introduction 2

Model Setup 3

Domain Size 4

Model Calibration 5

MHK Turbine Incorporation 7

Turbine Properties and Turbine Incorporation 7

Turbine Effects on Flow. 8

Wake Recovery and its Effect on Turbine Performance 9

Summary and Future Work 14

Acknowledgements 14

References 14

Figure 1: Cobscook Bay bathymetry showing locations of water-level collection stations. 3
Figure 2: Modified localized domain showing the proposed location of MHK devices (black squares) and the location of the deployed ADCP (red circle). 4
Figure 3: Velocity magnitude (m/s) model calibration plot. The only parameter changed between simulations was the specified flow rate time series at the southeast boundary. 6
Figure 4: Comparison of velocity magnitude (m/s) between measured ADCP data (black) and model results (light blue). Negative values imply an ebb tide cycle. 6
Figure 5: Model domain with the cells specified as containing an MHK device filled in red. 7
Figure 6: Contours of velocity magnitude (m/s) during a typical flood tidal cycle. Wakes are seen behind the MHK devices. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle. 10
Figure 7: Close-up of velocity magnitude (m/s) contours during a typical flood tidal cycle. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle. 10
Figure 8: Contours of velocity magnitude (m/s) during a typical ebb tidal cycle. Wakes are seen behind the MHK devices. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle. 11
Figure 9: Close-up of velocity magnitude (m/s) contours during a typical ebb tidal cycle. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle. 11
Figure 10: A typical vertical velocity (m/s) profile directly behind an MHK device. 12
Figure 11. Velocity deficit contour during a peak ebb tide. 12
Figure 12. Velocity deficit contour during a peak flood tide. 13
Figure 13: Typical velocity profiles upstream (+) and downstream (-) of a tidal turbine. 13

Introduction

Power generation with Marine Hydro Kinetic (MHK) turbines is receiving growing global interest. Because of reasonable investment, maintenance, reliability, and environmental friendliness, this technology could make an impact to our national (and global) energy markets and is considered worthy of research investment. Furthermore, in remote areas, small-scale MHK energy from river, tidal, or ocean currents can be a solution for local power supply. However, little is known about the potential effects of MHK device operation in coastal currents and embayments, estuaries, or rivers, or of the cumulative impacts of these devices on aquatic ecosystems over years or decades of operation. This lack of knowledge affects the actions of regulatory agencies, the opinions of stakeholder groups, and the commitment of energy project developers and investors. For example, the power generating capacity of water-current MHK turbines will depend on the turbine type and number, and the current flow velocities, among other factors. Each MHK-device array's footprint and performance will depend on the type of turbines and the characteristics of the local system. There is an urgent need for practical, accessible tools and peer-reviewed publications to help industry and regulators evaluate environmental impacts and mitigation measures and to establish best sitting and design practices.

Sandia National Laboratories has been investigating the potential environmental impacts and performance of individual MHK devices in Cobscook Bay, ME. Cobscook Bay is the first deployment location of the Ocean Renewable Power Company (ORPC) TidGen™ units. One unit is currently deployed with 4 more to follow in the coming years. In FY12, Sandia National Laboratories (SNL) built a course grid, large scale model that included Cobscook Bay and all other landward embayments using the modeling platform SNL-EFDC. Model results with and without an MHK array were compared with the large scale hydrodynamic model to facilitate an understanding of how this small 5-MHKturbine array might alter the Cobscook Bay environment.

In SNL's FY13 Q1 report, three different high resolution grid options were evaluated, including a focused expansion grid, a high resolution rectangular grid, and a high resolution localized rectangular grid. Overall, results showed a high resolution rectangular domain can be generated to represent local scale hydrodynamics in the region of interest in Cobscook Bay. Tradeoffs were seen between domain size and computational time for the two rectangular domains developed; specific study goals should guide grid needs. Since SNL's FY13 Q1 report, a high resolution localized rectangular grid centered on the proposed MHK array was created and calibrated using Doppler Current Profiler (ADCP) data collected by ORPC from July 5th through August 5th, 2011 (654,267-E, 4,974,792-N, shown on Figure 1). MHK devices were incorporated into the calibrated domain to investigate flow effects caused by the devices.

The present report focuses on the calibration and initial implementation of a higher resolution grid that will be used to optimize array placement in order to maximize power generation while minimizing potential environmental effects. Potential changes in local-scale hydrodynamics are also discussed.

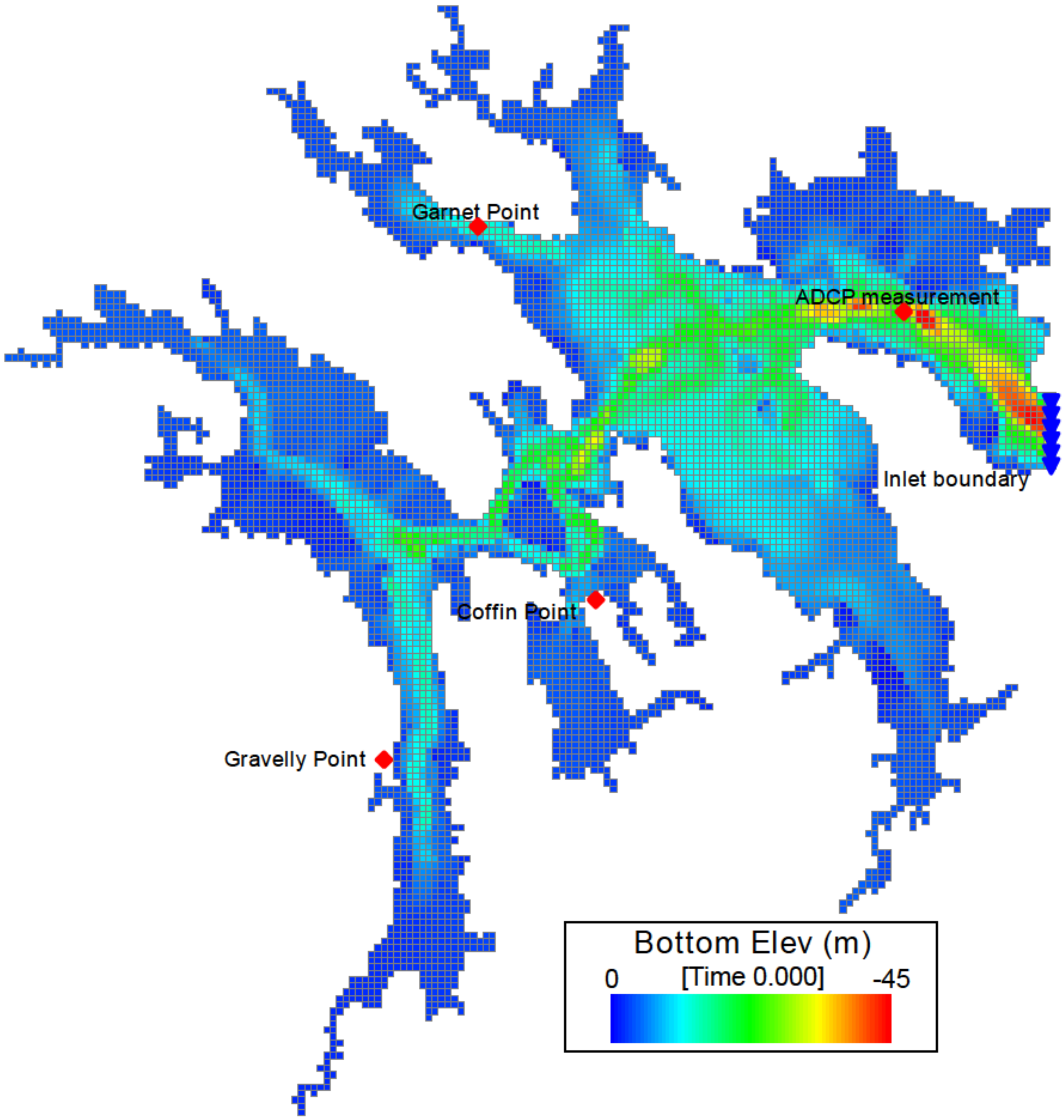

Figure 1: Cobscook Bay bathymetry showing locations of water-level collection stations.

Model Setup

The large scale Cobscook Bay model developed in FY12 contained Cartesian 100×100-m^2 cells. Since the OPRC cross-flow tidal turbines are approximately 30 m wide, single model grid cells were much larger than the turbines. While this is sufficient for investigating large scale environmental effects, near field (i.e. fine scale) hydrodynamics, which are important to fish swimming patterns and local benthic habitat, are not resolved. Therefore, a local near field model with a resolution smaller than the individual turbines and their expected wake effects was developed. During SNL's FY13 Q1 gird investigation, the high resolution localized rectangular grid was found to accurately simulate flow patterns. However, the domain tested was not properly centered on the proposed MHK deployment locations, so the position and extents of the localized domain were redefined. The modified domain is shown in Figure 2, where the 5 proposed MHK locations are marked by black squares, and the ADCP measurement location is represented by a red circle.

Domain Size: The created domain was 530 m long by 220 m wide, and contained 5×5-m² cells with 5 vertical (sigma) layers. Analysis of the ADCP data revealed the axis of the ebb and flood velocity direction was approximately 30 degrees south of east. To ease boundary specifications and best-capture flow patterns in the main channel, the domain was rotated by 30 degrees (approximate direction of net flow).The total number of grid cells was approximately 4,664.

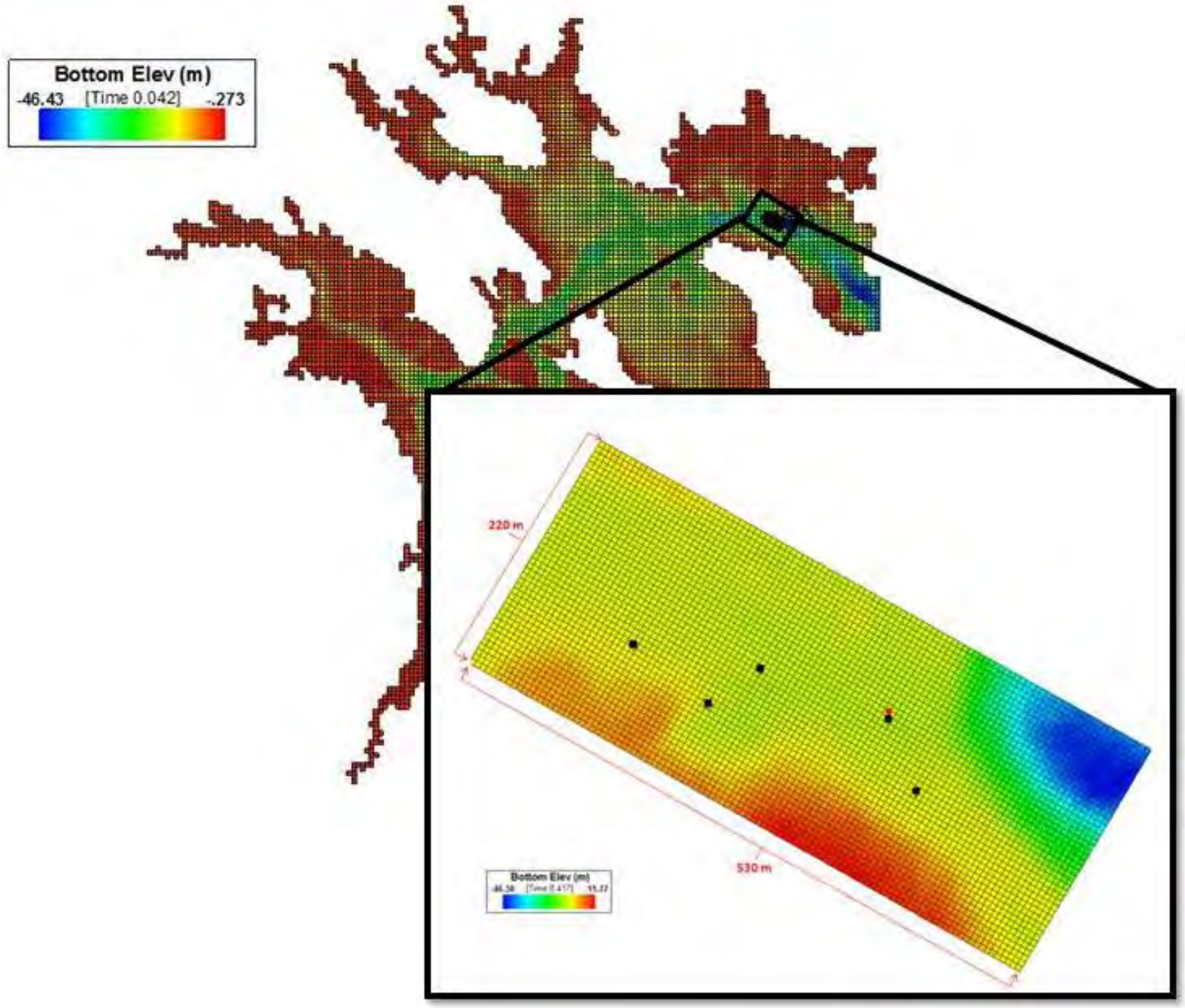

Figure 2: Modified localized domain showing the proposed location of MHK devices (black squares) and the location of the deployed ADCP (red circle).

Boundary Conditions: The localized domain was driven by outputted water levels and flow rates from large scale Cobscook Bay model. A time variant water level was specified on the northwest face, and flow rates were specified on the southeast face. Because of grid size differences, the outputted flow rates from the global model required scaling during model calibration. The two longer domain edges (northeast and southwest walls) were prescribed as non-momentum flux walls with zero wall shear. This condition is adequate for domain boundaries that are closely aligned with the net direction of flow.

Model Calibration: As mentioned, because flow rates were transferred from the global Cobscook Bay model to the localized domain, scaling was required. Flow rates are calculated within EFDC as a function of current speed and cell depth. Because of a factor twenty refinement in grid cell size, bathymetric features are better represented in the localized domain. The more accurate depth representation leads to changes in calculated flow rates. The overall trends outputted from the global domain in respect to relative magnitude and directions of flow are accurate, but the rates needed to be scaled in order to match the higher resolution of the localized domain.

The ADCP data collected by ORPC was used to calibrate the flow conditions. Flow rates directly extracted from the global domain were first used to drive the localized domain. Velocity magnitudes outputted from the localized domain at the location of the ADCP were then compared to actual ADCP measurements. The predicted velocity was higher than the measured velocity (see red line in Figure 3), so a series of simulations were run at various fractions of the outputted flow rates from the global model. All parameters besides the prescribed flow rate were held constant. Predicted velocity magnitudes over a day period are shown in Figure 3. The ADCP data was best-fit by scaling the input flow rates by roughly 0.83.

To further calibrate and validate the model, a simulation was run for the entire time period that ADCP data was available (July 5th through August 5th, 2011). The model accurately predicted flow patterns measured by the ADCP, but several deviations were seen between the measured and modeled velocities during peak flow. The inputted flow was modified where velocity peaks deviated to best match the measured values. Predicted velocities from the calibrated localized domain are compared to ADCP measurements and the global-scale model results in Figure 4. To illustrate directionality, a negative sign was assigned to velocity magnitudes occurring during ebb tides. The calibrated domain closely matched the ADCP measurements. The root mean square error (RMSE) in velocity between the localized domain and measured results during peak ebb and flood events was 0.012 m/s and 0.003 m/s. Predicted velocities during velocity peaks were always within 4%. Mean and max velocities, and the RMSE for the localized domain and the ADCP measurements are presented in Table 1.

Table 1: Model fit statistics.

	Max Velocity (m/s)		Mean Velocity (m/s)		RMSE (m/s)*	
	Ebb	**Flood**	**Ebb**	**Flood**	**Ebb**	**Flood**
ADCP Measurements	1.95	-1.98	1.08	-1.10	na	na
Localized Domain Predictions	1.92	-2.00	1.02	-1.06	0.012	0.003

* Root Mean Square Error was calculated from the peak velocity during each tidal cycle

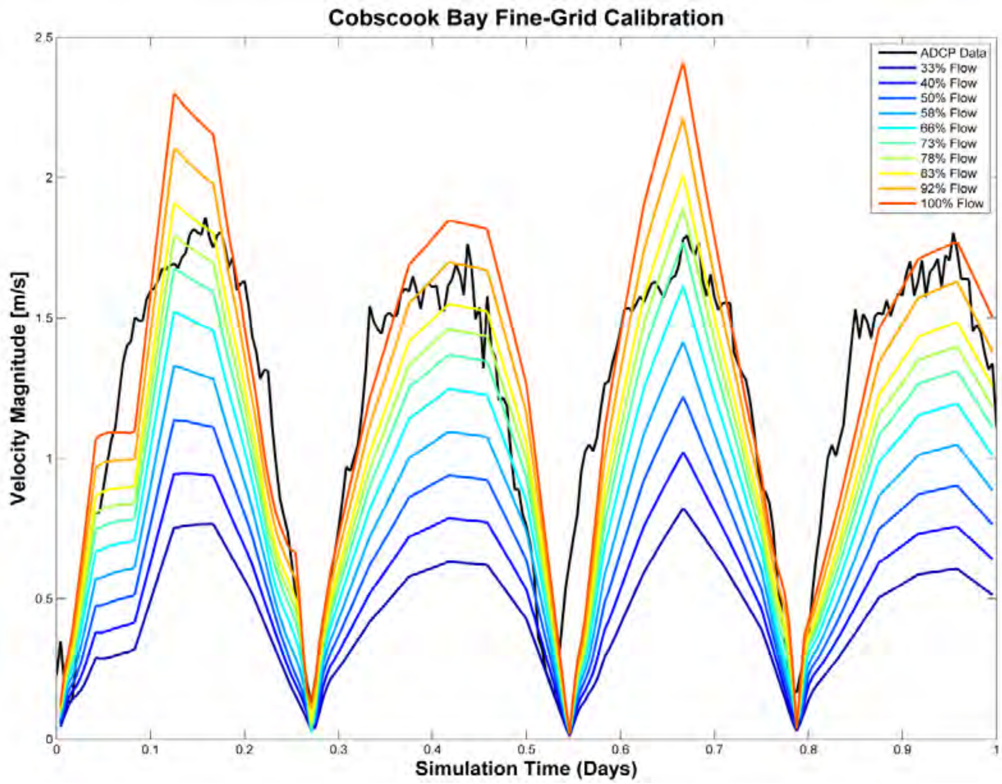

Figure 3: Velocity magnitude (m/s) model calibration plot. The only parameter changed between simulations was the specified flow rate time series at the southeast boundary.

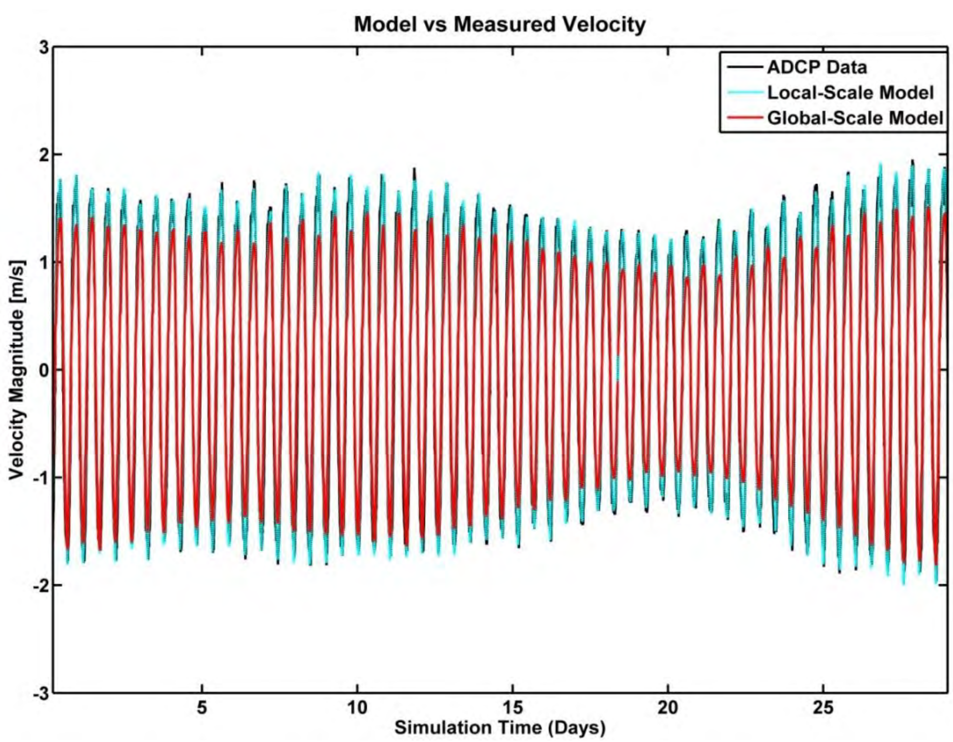

Figure 4: Comparison of velocity magnitude (m/s) between measured ADCP data (black), local model results (blue), and global model results (red). Negative values imply an ebbing tide.

MHK Turbine Incorporation

Turbine Properties and Turbine Incorporation: ORPC has a five-turbine array planned within Cobscook Bay. The location of each deployment is given in Table 2.The TidGenTM cross-flow turbines are each 30.28 m (100 ft) long and 4.3 m (14.1 ft) high with blade bottoms 9 m (29.5 ft) from the sediment bed. The support structures are assumed to occupy 3 m (9.8 ft) of the width and to extend from the sediment bed to 11.2 m (36.7 ft) in height.

Table 2: Center location of the proposed five ORPC turbines. Latitude/longitude and UTM eastings/northings are given.

Turbine	Longitude	Latitude	Easting	Northing
1	−67.0458750	44.9100591	654256	4974818
2	−67.0445353	44.9096565	654363	4974775
3	−67.0472154	44.9102783	654150	4974839
4	−67.0442623	44.9090942	654386	4974713
5	−67.0464226	44.908145	654213	4974789

Turbines were added into the localized domain once the model was calibrated (Figure 5). Because the grid cells in the domain were 5×5-m^2, and the turbines are roughly 30 m wide, each device was defined by six cells. Thrust coefficients were specified as $C_T = 0.8$, and the drag coefficients for the support structures were assigned a value of $C_D = 1.2$. A relatively high thrust coefficient was chosen to be environmentally conservative; physical environmental changes are expected to increase as more energy is removed from the tidal channel. Different turbine properties can be implemented into future analysis if needed.

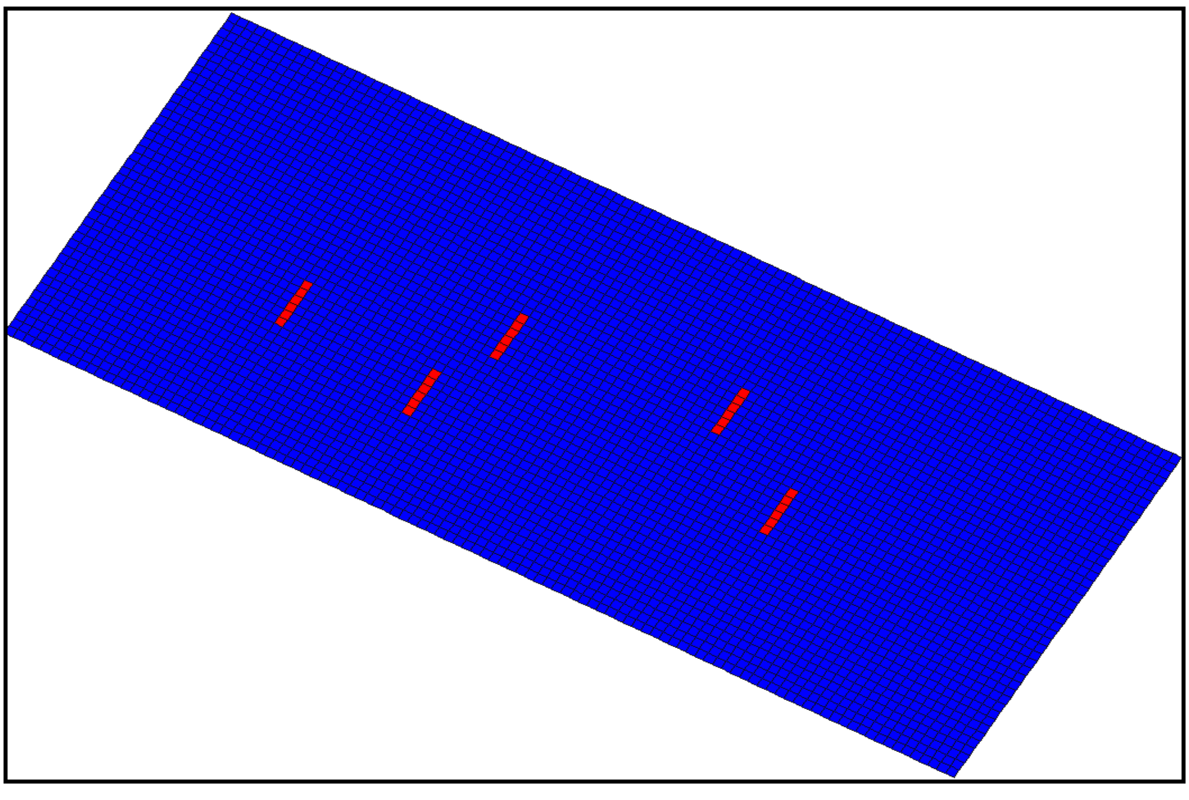

Figure 5: Model domain with the cells specified as containing an MHK device filled in red.

Power from a turbine is calculated as:

$$P = \frac{1}{2} C_{\mathrm{T}} \rho A_{\text{flow facing}} U^3, \qquad (1)$$

where ρ is the fluid density, U is the incoming velocity, and $A_{\text{flow facing}}$ is the flow-facing area of the MHK turbine. It was assumed that the turbine is always aligned with the flow direction (although this may be impossible in a three-dimensional, bi-direction flow). From the power equation, the local force, F, applied on the water column was:

$$F = \frac{P}{U} = \frac{1}{2} C_{\mathrm{T}} \rho A_{\text{flow facing}} U^2. \qquad (2)$$

Given this formulation and the known turbine area, model-calculated velocities were used to specify the force applied on the flow by the MHK device. This force was decomposed into vector components based on the directional velocity components. Area-weighted forces were then applied to each vertical face of the model cell in which the MHK (or support) resided. If the MHK device occupied only a portion of a vertical (sigma) model layer, appropriate weighting was applied. An analogous computation applies for the MHK support structures where C_{T} is replaced by C_{D}.

Turbine Effects on Flow: A simulation was run for the calibrated time period with the incorporated MHK turbines. As expected, momentum extracted from the flow by the devices resulted in a velocity deficit in the wake of the turbines. Typical velocity contours calculated during both flooding and ebbing tides are presented in Figure 6 through Figure 9. Bathymetry plays an important role on water velocity even with the MHK devices in place. Velocities are highest in shallower regions of the domain. When peak flows occur, and the greatest amount of water can be deflected by the turbine blades and support structure, velocities in the domain are still highest near shallow waters (long edges of the domain) as opposed to between closely spaced devices. A vertical velocity profile extracted directly behind a MHK turbine is presented in Figure 10. The lower velocities seen between roughly 12.5 and 17.5 m are the result of momentum extraction from the device. The profile was extracted from the domain were the depth was 25.3 m, and the blades of the turbine began at a depth of 16.3 m and span to roughly 12 m (blades are 4.3 m long).

To examine the potential environmental impacts caused by changes in local scale flow patterns due to the turbines, the percent difference in velocity magnitude($V_{diff,\%}$) throughout the model domain with and without MHK turbines present was calculated:

$$V_{diff,\%} = \frac{V_{no\ MHK} - V_{with\ MHK}}{V_{no\ MHK}} \times 100 \qquad (3)$$

where $V_{no\ MHK}$ is the velocity magnitude computed from the simulation with no tidal turbines, and $V_{with\ MHK}$ is the velocity magnitude computed form the simulation with tidal turbines. This enables the creation of spatial maps of velocity change that result from the introduction of turbines in the tidal system. Velocity difference expressed as percentages are presented in Figure 11 (typical ebb) and Figure 12 (typical flood). For the purposes of this discussion velocity deficit corresponds to positive values of the percent difference in velocity magnitude that occurs in the wake of a turbine. This is not to be confused with the classical definition of velocity deficit that is dependent on the turbine incident velocity with the turbine array in place. During both ebb and flood tides, the velocity deficit reaches a maximum value roughly 15 to 25 m behind the tidal turbines (in the heart of the wake). The exact magnitude of the velocity deficit was dependent on the incident flow velocity; strong currents created larger deficits. During peak flow events, the maximum velocity deficit was between 40 to 60 percent.

Potential sediment transport trends can be identified by examining Figure 11 and Figure 12. Locations with increased velocities (negative deficits) have a greater chance of erosion than would be present without the turbines. These areas often lied adjacent to the devices, where a fraction of the approaching water was deflected in the cross-stream direction due to the high pressure region existing directly in front of the devices. Flow also accelerated beneath the turbines. The velocity increases however are relatively small and are not likely to cause significant changes in erosion. In order to better access erosion potential, site-specific sediment data and critical shear stresses are required. Similar to the regions of increased velocity, each turbine creates a wake that is marked by decreased velocities. These lower energy regions are more likely to experience sediment deposition than would be encountered without the presence of the turbines. Again, site-specific sediment data is needed to better assess potential deposition.

<u>Wake Recovery and its Effect on Turbine Performance:</u> Velocity profiles were extracted upstream and downstream of the tidal turbines to investigate wake recovery. Vertically averaged hub height velocities at various distances from a turbine during a typical peak velocity event are shown in Figure 13. Flow approaching the turbine slows due to device-created pressure variations. Flow that passes through the device further losses momentum as kinetic energy from the flow is transferred to the device. Water velocities typically reached a minimum value roughly 15 to 25 m downstream of the turbine. The flow then increased as momentum was transferred back into the wake region from adjacent fluid. Typically, velocities recovered to 95% of their incident magnitude within 130 m. The exact wake extent was dependent on the incident velocity, bathymetry, and the proximity of other devices. Turbulence generation also has a large effect on wake recovery. Turbulence increases mixing and momentum transfer, which in turn can speed wake recovery.

Wake recovery is an important factor to consider when deciding turbine placement. The power generated by a turbine is proportional to the incident velocity raised to a power of three. In order to maximize power generation, the largest incident velocity possible is desired. However, practical restraints exist regarding the available footprint for device placement. Therefore devices need to be placed such that they fit within a specified region, but are spaced far enough apart to allow significant wake recovery. The shape and positioning of the array, as well as the physical conditions of the site are important. Although the wake recovery value mentioned above gives insight into the type of spacing required between devices, further simulations are required to optimize array shape and location, and validate the ideal spacing.

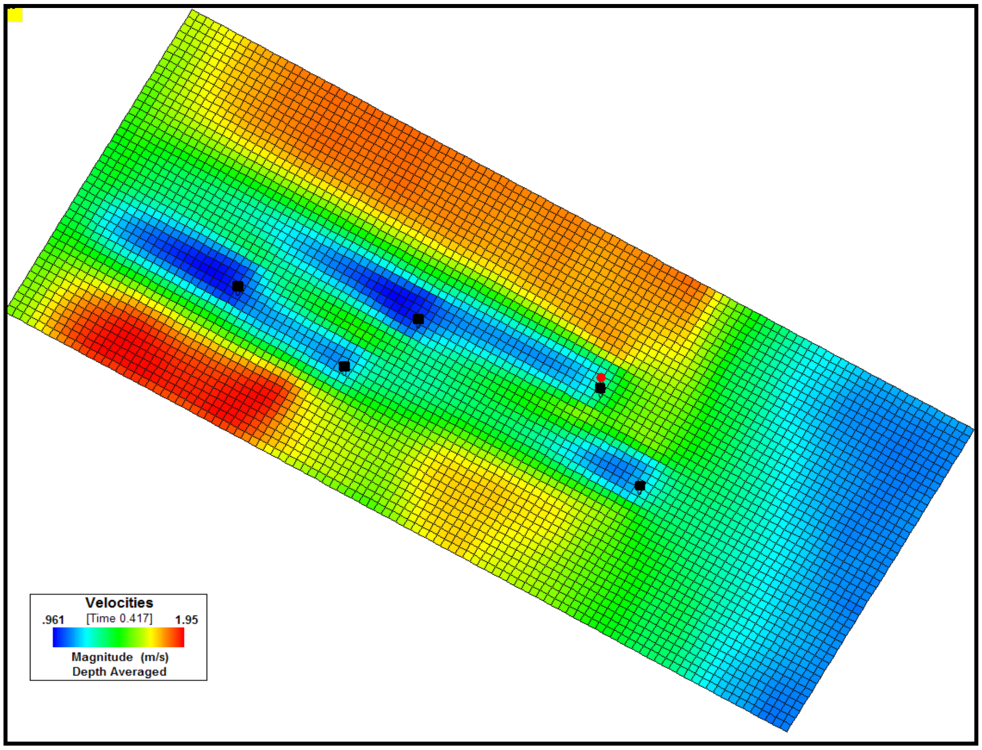

Figure 6: Contours of velocity magnitude (m/s) during a typical flood tidal cycle. Wakes are seen behind the MHK devices. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle.

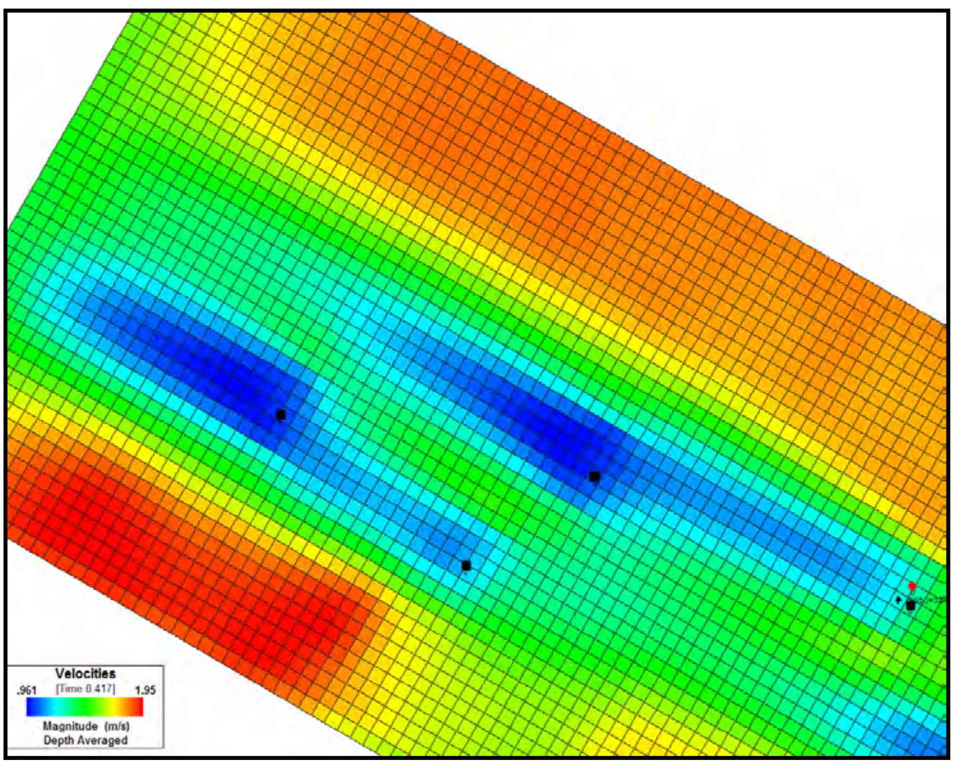

Figure 7: Close-up of velocity magnitude (m/s) contours during a typical flood tidal cycle. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle.

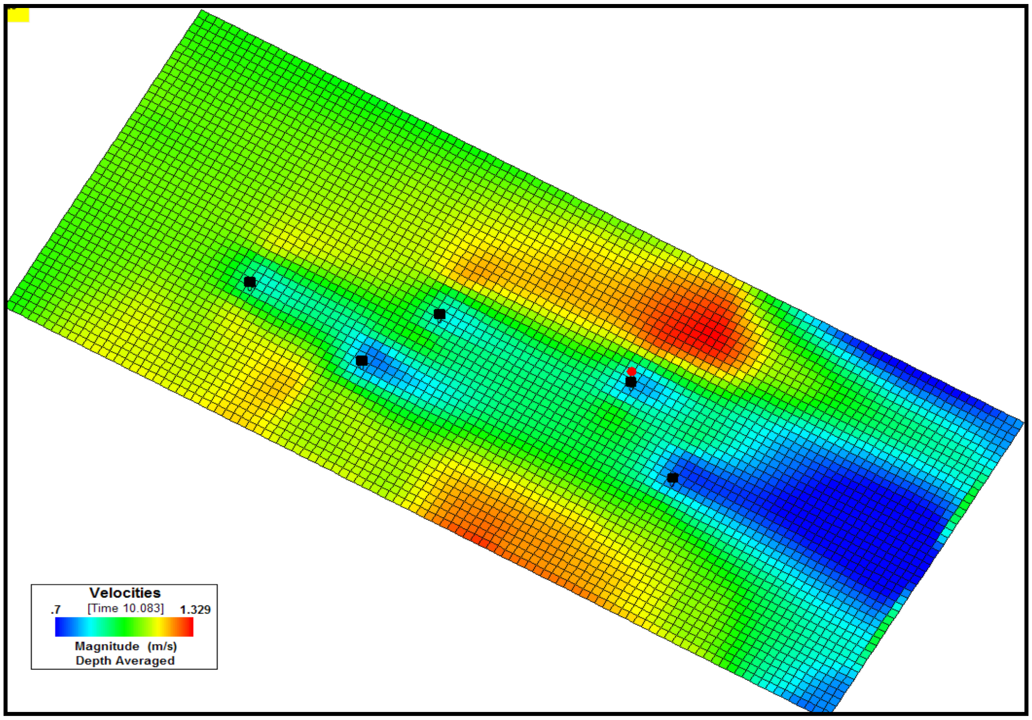

Figure 8: Contours of velocity magnitude (m/s) during a typical ebb tidal cycle. Wakes are seen behind the MHK devices. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle.

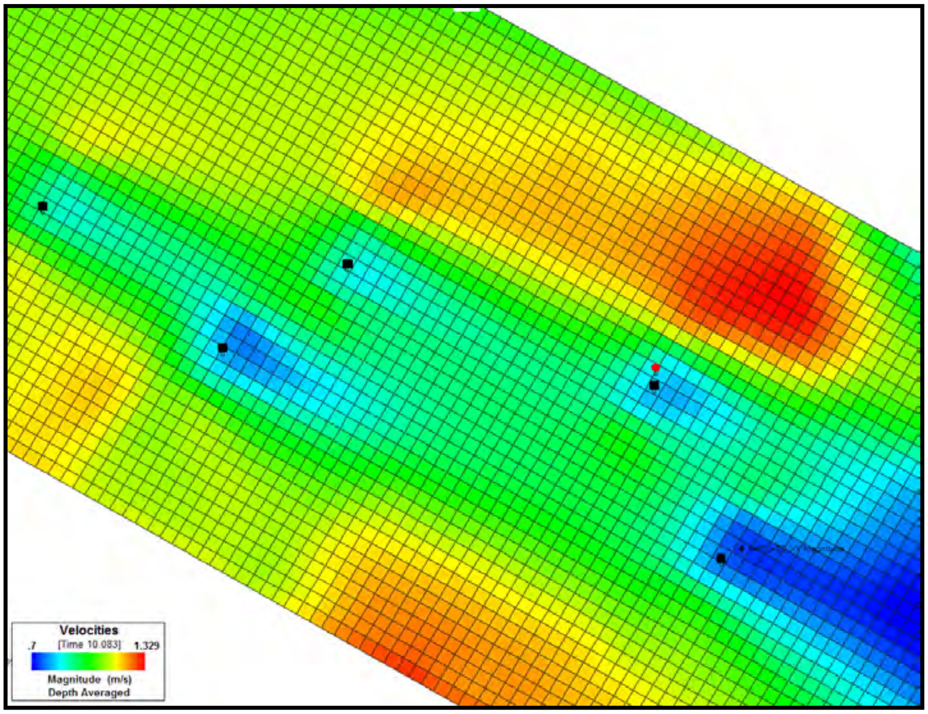

Figure 9: Close-up of velocity magnitude (m/s) contours during a typical ebb tidal cycle. The center locations of the devices are marked by a black square, and the ADCP location is marked by a red circle.

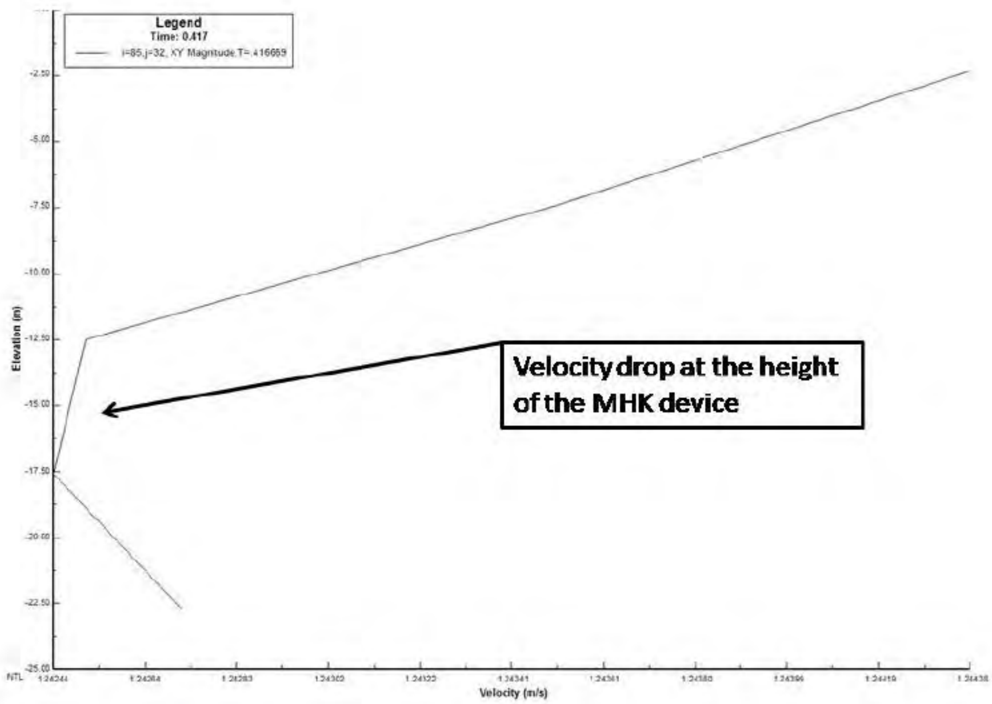

Figure 10: A typical vertical velocity (m/s) profile directly behind an MHK device.

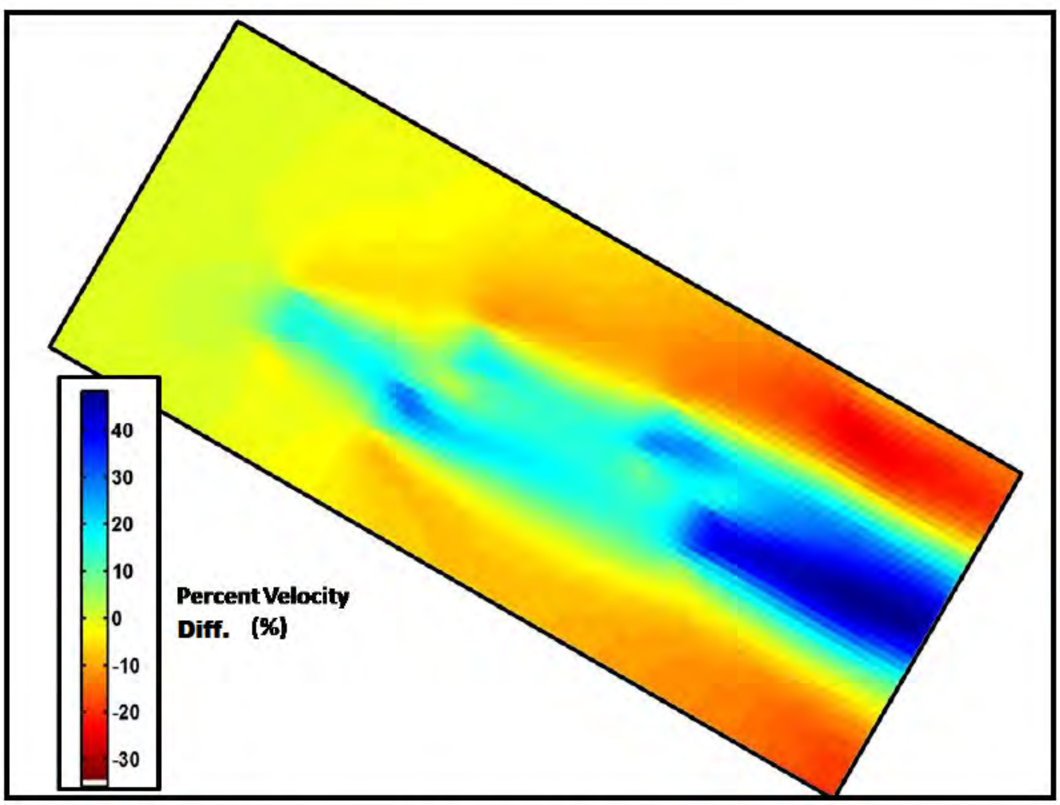

Figure 11. Contours of the percent difference in velocity magnitude during a peak ebbing tide.

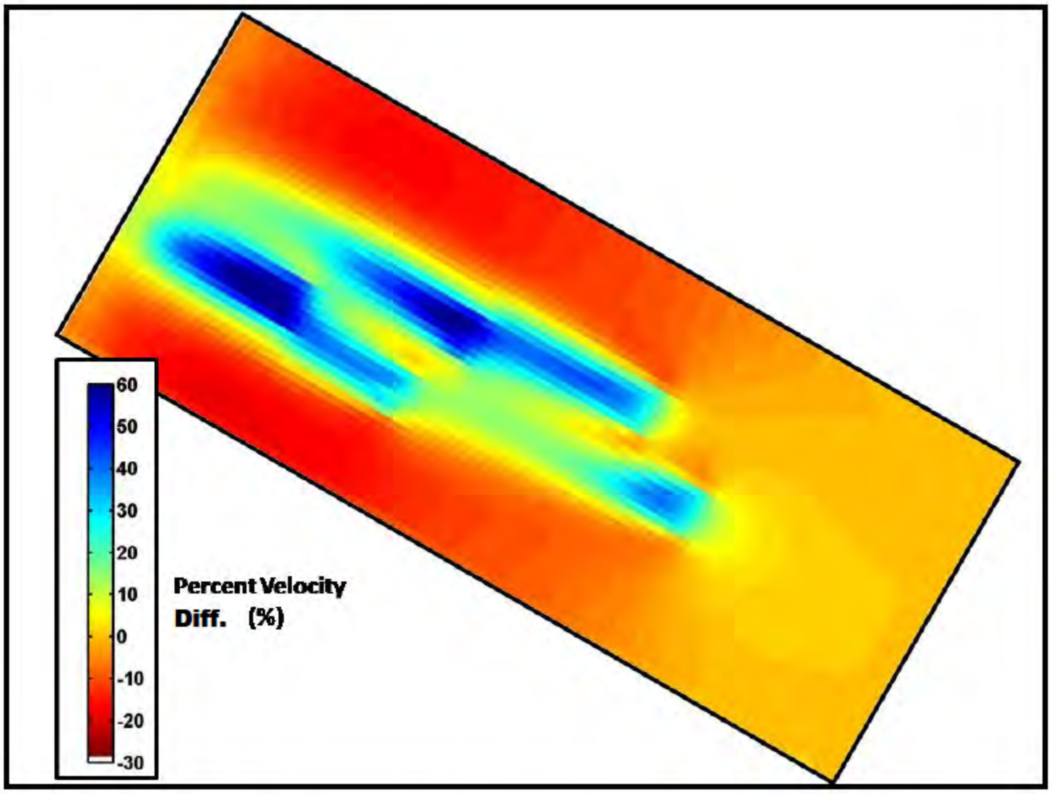

Figure 12. Contours of the percent difference in velocity magnitude during a peak flooding tide.

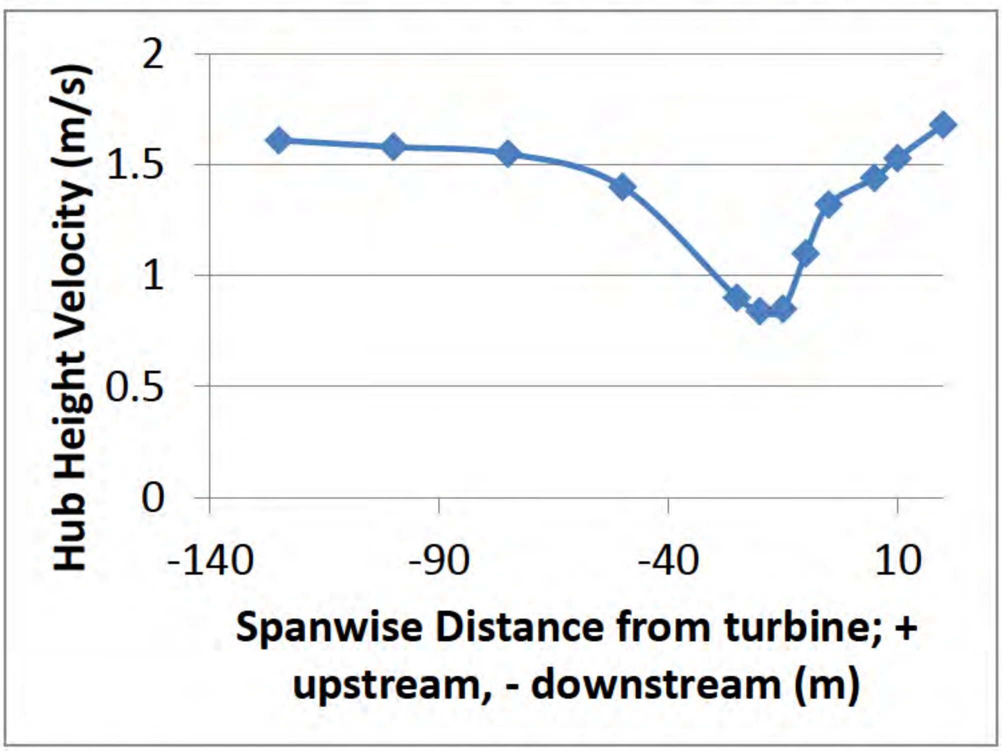

Figure 13: Typical velocity (m/s) profiles upstream (+) and downstream (-) of a tidal turbine.

Summary and Future Work

A local-scale hydrodynamic model was developed and calibrated for a region within Cobscook Bay, ME. The model was centered on the location of the deployed ORPC TidGen^{TM} unit, and the four to come. Water levels and calibrated flow rates extracted from a previously developed global-scale model were used to drive flow in the local domain. Modeled velocities were in excellent agreement with ADCP data, suggesting the model accurately predicts system hydrodynamics.

To investigate the potential environmental impacts of the tidal turbines, and to begin to examine optimum turbine placement, tidal turbines were incorporated into the simulations. General sediment transport trends were identified, where regions with higher potential for erosion or deposition were noted. Differences in velocity fields with and without turbines were also investigated including a glimpse into velocity deficits created by the turbines and wake recovery. Typically velocities recovered to 95% of their incident magnitude within 130 m downstream of the devices.

The developed model will be used in future studies to further examine optimum array size and placement, and to assess and minimize localized environmental impacts. The following work is planned:

- Run simulations with various array shapes, array positioning, and device spacing. The power extraction of each turbine will be monitored for array optimization purposes.
- Velocities predicted by the simulations will be monitored to investigate potential sediment transport trends and ensure problematic array placements are avoided.
- The global model created in FY 12 will be further calibrated to ease the transfer of flowrates between the domains. This may require investigating the interpolation technique used to define the bathymetry in the global model. Model sensitivity testing may also be required, where simulation parameters such as bed roughness, vegetation, and wetting and drying can be adjusted.
- During the calibration of the global model, if data gaps exist, they will be identified. If feasible, potential field investigations will be discussed and planned.

Acknowledgements

Sandia would like to thank Dr. HuijieXue and Min Bao at the University of Maine for their FVCOM model output as well as discussion and guidance on this Cobscook Bay model development.

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FY13 Q3 Water Power Report

MHK Array Placement Analysis: SNL-EFDC Model Application at Cobscook Bay, ME

Submitted by

Water Power Technologies

Sandia National Laboratories

June 30, 2013

Kurt Nelson and Craig Jones – Sea Engineering

and

Jesse Roberts – Sandia National Laboratories

Table of Contents

Introduction 2
Model Setup 3
  Physical Domain Parameters 4
  Boundary Conditions 5
  Model Calibration 5
MHK Properties and Incorporation in SNL-EFDC 7
  Turbine Properties 7
  Power Generation and Momentum Extraction 7
MHK Simulations 7
  ORPC Preliminary Array Configuration 8
  Alternative Deployment Locations Based On an Optimization Analysis 9
Summary and Future Work 15
Acknowledgements 16
References 16

Introduction

Power generation with marine hydrokinetic (MHK) current energy converters (CECs), often in the form of underwater turbines, is receiving growing global interest. Because of reasonable investment, maintenance, reliability, and environmental friendliness, this technology can contribute to national (and global) energy markets and is worthy of research investment. Furthermore, in remote areas, small-scale MHK energy from river, tidal, or ocean currents can provide a local power supply. However, little is known about the potential environmental effects of CEC operation in coastal currents and embayments, estuaries, or rivers, or of the cumulative impacts of these devices on aquatic ecosystems over years or decades of operation. This lack of knowledge affects the actions of regulatory agencies, the opinions of stakeholder groups, and the commitment of energy-project developers and investors. For example, the power-generating capacity of CECs will depend, among other factors, upon CEC type and number and the local flow velocities. There is an urgent need for practical, accessible tools and peer-reviewed publications to help industry and regulators evaluate environmental impacts and mitigation measures, while establishing best sitting and design practices.

Sandia National Laboratories (SNL) has been investigating the potential environmental impacts and performance of individual tidal energy converters (TECs) in Cobscook Bay, ME; TECs are a subset of CECs that are specifically deployed in tidal channels. Cobscook Bay is the first deployment location of Ocean Renewable Power Company's (ORPC) TidGen™ units. One unit is currently deployed with four more to follow. In FY12, SNL built a coarse-grid, regional-scale model that included Cobscook Bay and all other landward embayments using the modeling platform SNL-EFDC (Figure 1). Model results with and without a TEC array were compared with the regional-scale hydrodynamic model to assess how the small five-TEC array might alter the Cobscook Bay environment. Simulation demonstrated that there are no significant changes in regional tidal range, flow rate, or the broader flow patterns upon operation of the five ORPC tidal turbines.

In FY13 Q1, SNL developed and evaluated three different high-resolution grids to study near-field hydrodynamics important to fish swimming patterns, local sediment transport, and array performance. These grids included a telescoping-mesh grid and two high-resolution, rectangular, refined grids. Model results demonstrated that the rectangular refined grids can simulate local-scale hydrodynamics in the study region in Cobscook Bay, with expected trade-offs between domain size/grid resolution and computational expense.

In FY13 Q2, a high-resolution refined-grid rectangular grid centered on the proposed MHK array was created and calibrated against Acoustic Doppler Current Profiler (ADCP) data collected by ORPC from July 5 through August 5, 2011 (654,267-E, 4,974,792-N labeled as "ADCP measurement" on Figure 1). MHK devices were incorporated into the calibrated domain to investigate resulting flow-field changes. General sediment dynamics trends were identified, where regions with higher potential for erosion or deposition were noted. Differences in velocity fields with and without turbines were also investigated including the velocity deficits created behind the turbines and commensurate wake recovery. Typically depth-averaged velocities recovered to 95% of their incident magnitude within 130 m downstream of the devices.

This report focuses on the development of an optimization framework using SNL-EFDC to optimize device placement to maximize array performance and minimize environmental effects (by minimizing flow alteration magnitudes that could affect fish-swimming and sediment-transport behavior). In the process of developing this methodology, the need for a larger domain was recognized. A new (refined-grid) domain was constructed and calibrated that encompassed the entire available MHK placement region (array footprint) and the optimization framework was used to identify an optimal array configuration at this site. Finally, power-production results are compared between ORPC's preliminary array layout, and the SNL-EFDC-optimized placement.

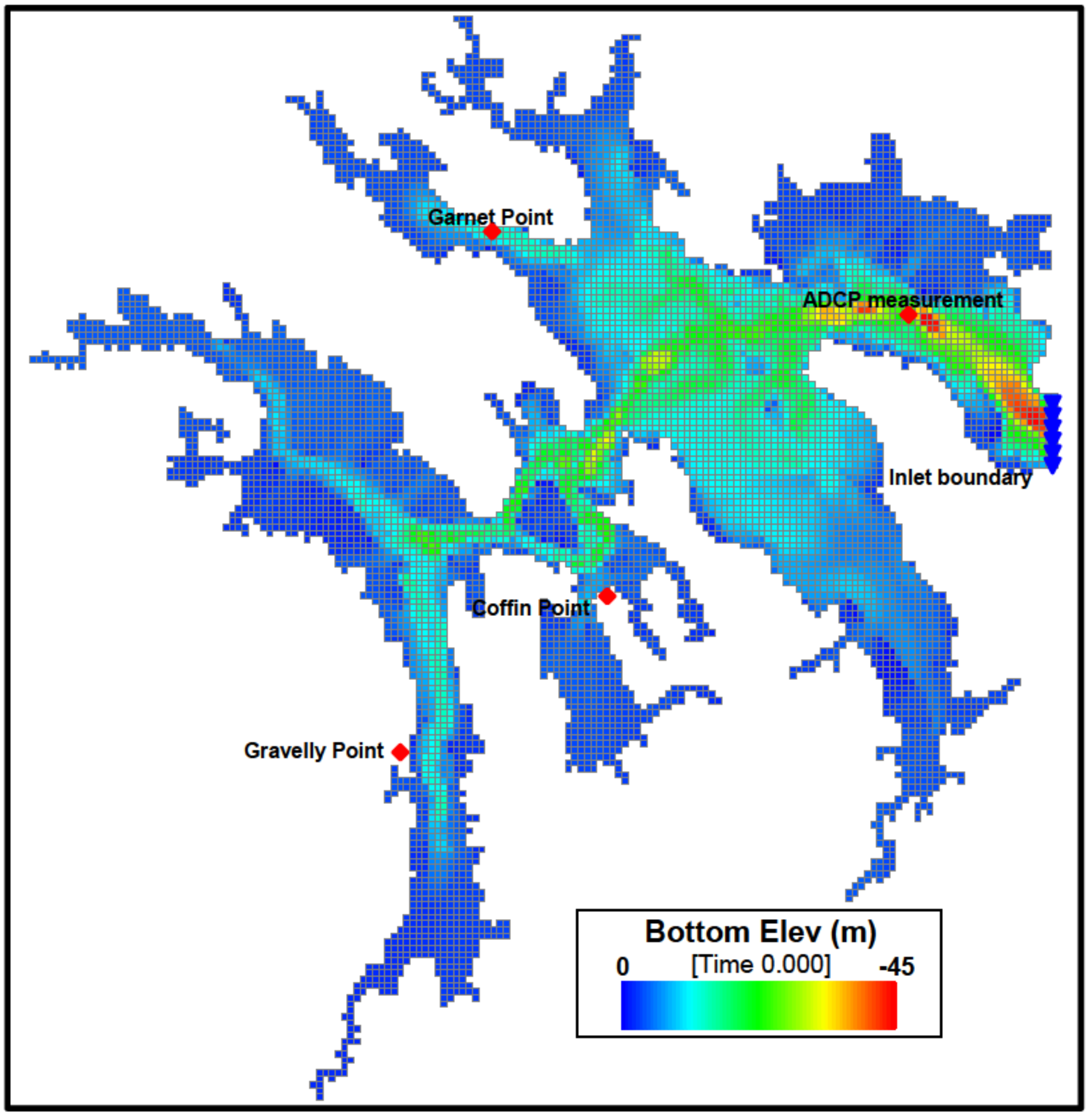

Figure 1. Cobscook Bay bathymetry showing locations of water-level collection stations, the ADCP measurement, and the tidal inlet boundary.

Model Setup

The regional-scale Cobscook Bay model developed in FY12 comprised Cartesian 100×100-m^2 cells. Because the ORPC cross-flow tidal turbines are approximately 30 m wide, model grid cells were much larger than the turbines. While this is sufficient for investigating large-scale effects, near-field (i.e., fine-scale) hydrodynamics, which are important to fish swimming patterns and detailed device-performance analyses, are not resolved. Therefore, a local, near-field model with a grid resolution smaller than the individual turbines and their anticipated wake effects was developed similar to that from FY13 Q2. The differences between the newly developed, refined grid and the previous fine-scale model are the domain extents and grid resolution. The previous grid did not include the entire available placement footprint (as it was unknown prior to development in Q2). Also, because all possible array configurations should be considered in an optimization study, the domain was extended. This extension was accomplished by changing the grid cell size to 10×10 m^2 from 5×5 m^2, an adjustment that balanced a reasonable cell count with computational demand.

Physical Domain Parameters

The new domain is 1,120 m long by 430 m wide with 4,816 10×10-m^2 cells and five vertical (sigma) layers. Analysis of the ADCP data revealed the axis of the ebb and flood velocities was approximately 30° south of east. To ease boundary specifications and best-capture flow patterns in the main channel, the domain was rotated by 30 degrees (approximate direction of net flow). The inset in Figure 2 shows the newly constructed, refined grid, where the study region is outlined with a solid black rectangle, and the placement footprint is outlined with a dashed black rectangle. The placement footprint is 30.5 m (100 ft) within the border of the study area. As seen in Figure 2, the southeast boundary of the domain was extended past the relatively deep trench (~45 m deep) near the study region. By extending the domain past the trench, numerical stability issues due to boundary specification across sharp bathymetry gradients were avoided.

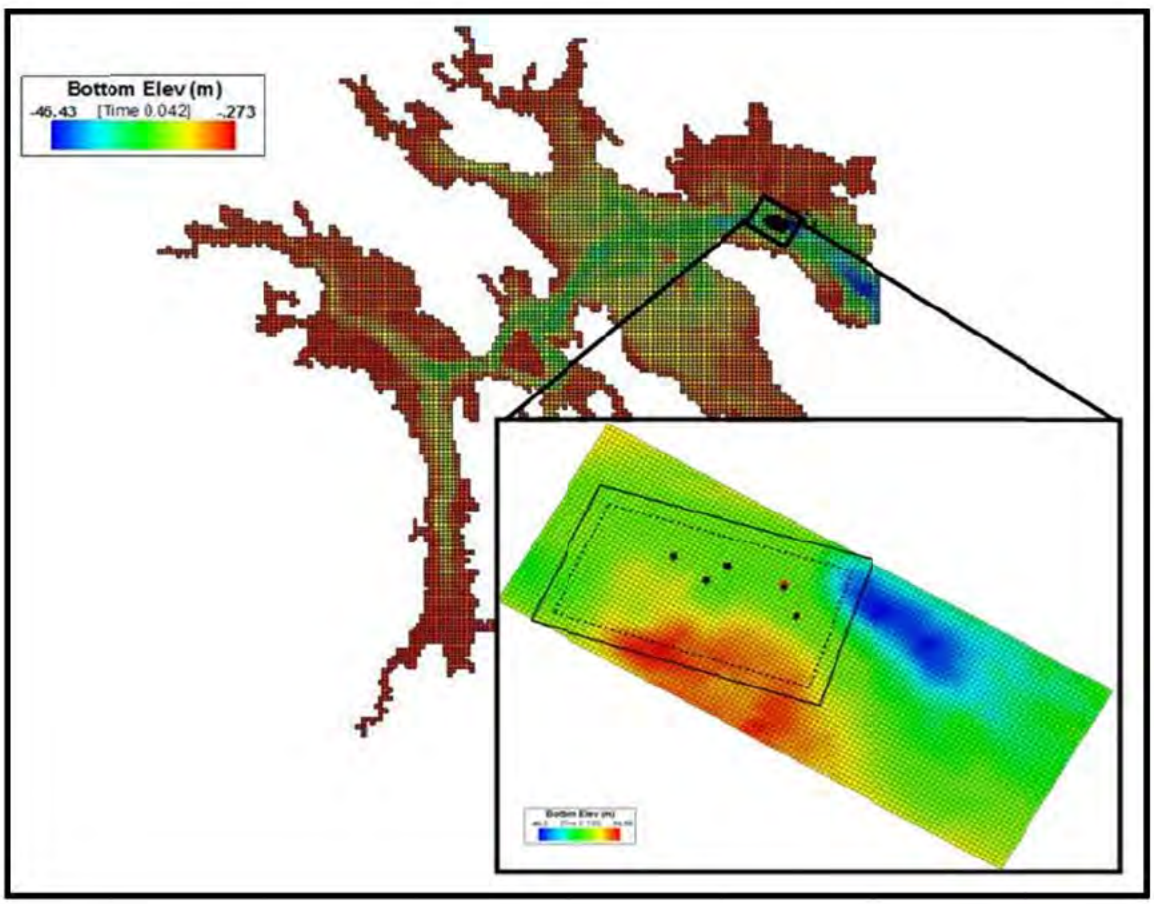

Figure 2. Regional-scale domain with inset showing the refined-grid domain with proposed locations of MHK devices (black squares) as well as the location of the ADCP (red circle). The study region is outlined in the refined-grid domain with a solid black rectangle, and the placement footprint is outlined with a dashed black rectangle.

Boundary Conditions

The new refined-grid model was driven by water levels and flow rates extracted from the regional-scale Cobscook Bay model. A time-variant water level was specified on the northwest face, and flow rates were specified on the southeast face. The two longer domain edges (northeast and southwest faces) were prescribed as no-flux walls with zero wall shear stress. This condition is adequate for domain boundaries that are aligned with the net direction of flow.

Model Calibration

When flow rates were transferred from the regional-scale Cobscook Bay model to the refined-grid domain, scaling was required. Flow rates are calculated within SNL-EFDC as a function of average flow speed and cell depth. Because of a factor of 10 refinement in grid cell size, bathymetric features are more accurately represented in the refined-grid domain. The more accurate depth representation leads to discrepancies in calculated flow rates. Moreover, the "flow inertia" from the region outside the refined-grid model domain (in the regional-scale model) cannot be captured by the refined-grid model and this is partially accounted for in the scaling factor. The overall trends outputted from the regional-scale domain with respect to relative magnitude and direction of flow are accurate, but the rates needed to be scaled to match the higher resolution of the refined-grid domain.

The ADCP data collected by ORPC were used to calibrate the scaling factor. Flow rates directly extracted from the regional-scale domain were first used to drive the refined-grid domain. Velocity magnitudes outputted from the refined-grid domain at the location of the ADCP were then compared to actual ADCP measurements. The refined-grid-predicted model velocities were higher than the measured velocities, so a series of simulations were run at various fractions (0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, and 0.90) of the output flow rates from the regional-scale model. All other parameters (e.g., outlet water levels) were held constant. Simulated velocities at the deployment location of the ADCP are shown in Figure 3. To illustrate directionality, a negative sign was assigned to velocities from ebb tides. Peak flood tides were often best matched by scaling the outputted flow from the regional-scale domain by a factor between 0.70 and 0.85, while ebb tides were best matched using a scaling factor between 0.55 and 0.65. To calibrate the new refined-grid domain, the scaling factor that best fit each tidal peak was identified and applied to the input flow table. Simulated velocities from the calibrated refined-grid model are compared to ADCP measurements in Figure 4. The calibrated domain closely matched the ADCP measurements for the entire deployment period modeled (July 5 through August 2, 2011).

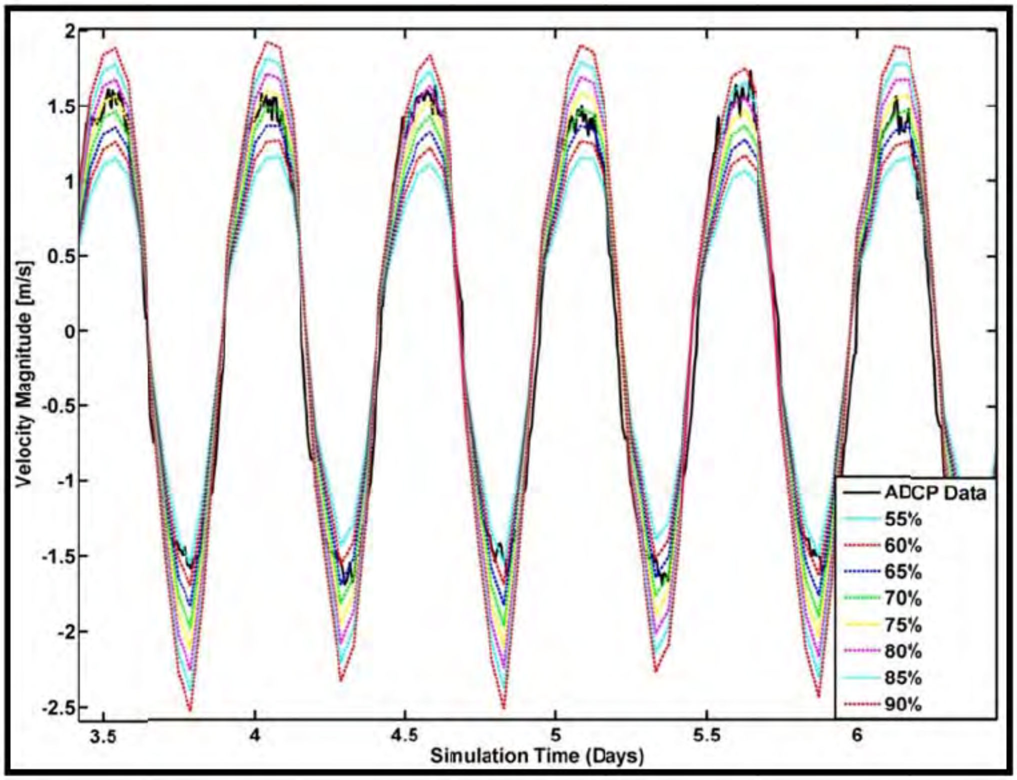

Figure 3. Depth averaged ADCP data compared to velocity magnitudes (m/s) extracted from simulations forced by different scaling factors of the regional-scale domain output flow. The only parameter changed between simulations was the specified flow rate time series at the southeast boundary. Negative velocities indicate ebb tide.

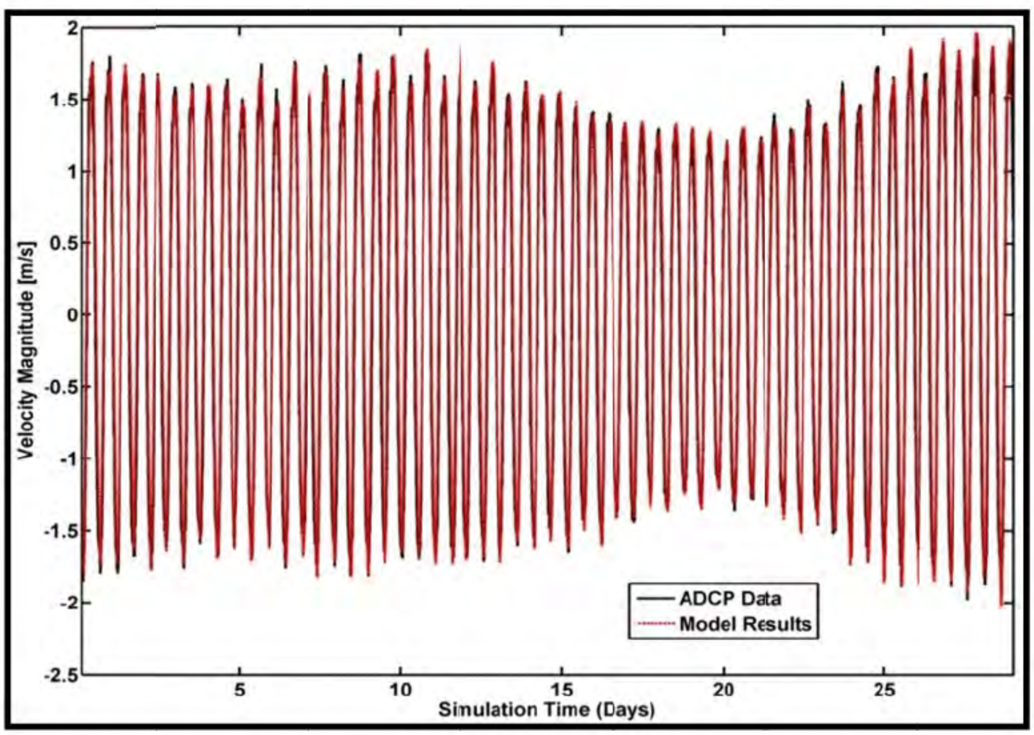

Figure 4. Comparison of velocity magnitude (m/s) between the measured ADCP data (black), and model predicted values (red). Negative velocities indicate ebb tide.

MHK Properties and Incorporation in SNL-EFDC

The power generated by MHK turbines comes from energy (momentum) removed from the flow field around the turbines. This behavior is represented in SNL-EFDC using momentum sink, turbulence source, and turbulence-dissipation source equations at model cells containing turbines. Momentum extraction and wake generation/dissipation depend upon both the properties of the turbines and the incident flow conditions. Below, a general description of the principles governing SNL-EFDC is presented along with the turbine properties used during the optimization simulations.

Turbine Properties

The specifications for the TidGen™ cross-flow turbines used in the present model are 30.28 m (100 ft) long and 4.3 m (14.1 ft) high with blade bottoms 9 m (29.5 ft) from the sediment bed. The support structures occupy a total of 3 m (9.8 ft) of width and extend from the sediment bed to 11.2 m (36.7 ft) height. Turbines were added to the refined-grid domain once the model was calibrated. Because the cells in the refined-grid domain were $10\times10\ \text{m}^2$, and the turbines are roughly 30 m wide, each device spans three cells. Thrust coefficients were specified as $C_\text{T} = 0.8$, and the drag coefficients for the support structures were assigned a value of $C_\text{D} = 1.2$. A relatively high thrust coefficient was chosen to be environmentally conservative; physical environmental changes are expected to increase as more energy is removed from the tidal channel. Different turbine properties can be implemented in future analyses as the data become available.

Power Generation and Momentum Extraction

The power produce by a turbine is:

$$P = \frac{1}{2} C_\text{T} \rho A_\text{flow facing} U^3, \qquad (0)$$

where ρ is the fluid density, U is the incoming velocity, and $A_\text{flow facing}$ is the flow-facing area of the MHK turbine. The turbines were assumed to always be aligned with the flow direction (although this may not always hold true in a three-dimensional, bi-direction flow). From the power equation, the force, F, applied against the flow is:

$$F = \frac{P}{U} = \frac{1}{2} C_\text{T} \rho A_\text{flow facing} U^2. \qquad (0)$$

Given this formulation and the known turbine area, model-calculated velocities were used to specify the force applied on the flow by the MHK device. This force was decomposed into vector components based on the directional velocity components. Area-weighted forces were then applied to each vertical face of the model cell in which the MHK (or support) resided. If the MHK device occupied only a portion of a vertical (sigma) model layer, appropriate weighting was applied. An analogous computation applies for the MHK support structures where C_T is replaced by C_D.

MHK Simulations

The un-optimized, five-turbine array layout developed by ORPC was compared to an alternative array configuration identified with the SNL-EFDC optimization framework developed here. Power generation was calculated for both array configurations over 29 days (the calibration period of July 5 through August 2, 2011). The optimization analysis is presented below along with the simulation results from both model setups.

ORPC Preliminary Array Configuration

The preliminary, un-optimized, locations for the five-turbine array are listed in Table 1. The turbines fall within the placement footprint (i.e., inside the study region and at least 30.5 m [100 ft] away from its border), and are in water depths greater than 23 m. The depth restriction was chosen to ensure sufficient clearance between the top of the devices and the water surface, allowing safe vessel passage.

Table 1. Center location of the proposed five ORPC turbines.

Turbine	Longitude	Latitude	Easting	Northing
1	–67.0458750	44.9100591	654256	4974818
2	–67.0445353	44.9096565	654363	4974775
3	–67.0472154	44.9102783	654150	4974839
4	–67.0442623	44.9090942	654386	4974713
5	–67.0464226	44.908145	654213	4974789

As expected, momentum extracted from the turbines lead to a velocity deficit in the wake of each MHK device. Velocity contours extracted at roughly the same depth (sigma layer 3) as the turbines are shown in Figure 5. The contours correspond to a flood tide and are representative of typical conditions during peak flow. The turbine locations are marked by black squares, and the location of the ADCP is labeled with a red circle. Predicted flow patterns were similar to those presented in SNL's FY13 Q2 report; flow velocities drop in the wake of each turbine and increase above, below, and around the turbines. The five ORPC turbines generated a total of about 107 MW-hr over the 29-day simulation.

Potential sediment dynamics trends can be identified by examining the flow patterns around the MHK devices. Water velocities often increased around the devices in all directions as a fraction of the approaching water is deflected around the high-pressure region directly in front of the devices. Increased velocities below a device allow for potential sediment mobilization; however the velocity increases were relatively small, often within 5% of what was predicted without the presence of the turbines. To better define erosion potential, site-specific sediment data and critical shear stresses for sediment erosion are required.

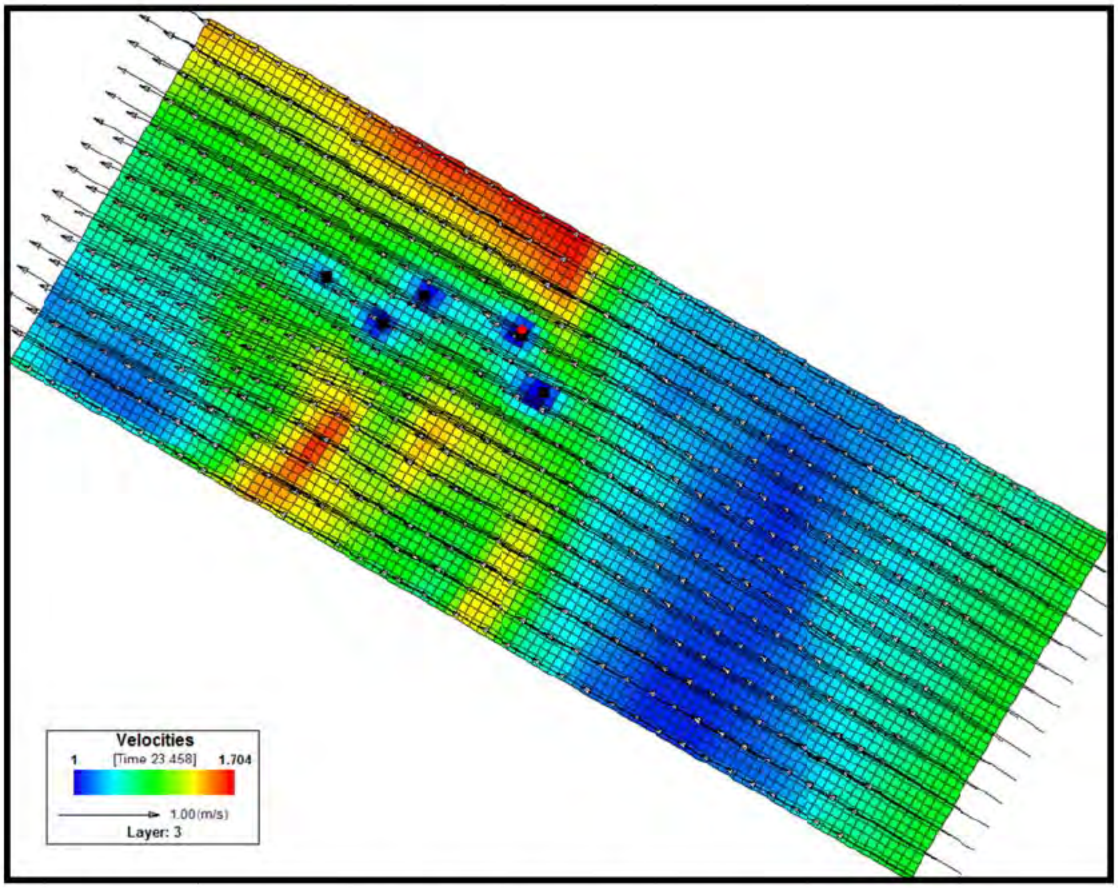

Figure 5. The ORPC-planned turbine array with velocity contours extracted during a typical flood tide at roughly the water depth of the turbines (sigma layer 3).

Alternative Deployment Locations Based On an Optimization Analysis

To narrow down the near infinite array-configuration possibilities within the ORPC-permitted footprint in Cobscook Bay, a methodology was developed to sequentially identify optimal device placement locations using SNL-EFDC. The procedure as applied to Cobscook Bay is outlined below:

1) Assess the natural hydrodynamic patterns occurring within the placement footprint (no MHK devices).
2) Identify the region within the footprint with the highest velocities that span the length (30 m) of a turbine (i.e., find the three adjacent cells with the largest average velocity) in at least 23 m of water at mean low low water level.
3) Add an MHK device in the high-velocity region identified in Step 2, and run simulations to reassess hydrodynamics in the placement footprint given the MHK addition.
4) Evaluate the hydrodynamic changes brought about by the addition of the MHK turbine. The evaluation can be done by comparing modeled velocities with and without the presence of the turbine(s). Percent velocity recovery is defined as:

$$R_{\%}(i) = 100 \frac{v_{\mathrm{MHK}}(i)}{v_{\mathrm{natural}}(i)}, \qquad (0)$$

where $R\%(i)$ is the percent velocity recovery in cell i, $v_{MHK}(i)$ is the velocity in cell i from a simulation with the MHK(s), and $v_{natural}(i)$ is the velocity in cell i from a simulation without the MHK(s).

5) If pertinent, establish a threshold for $R_{\%}$ that meets local environmental standards. Check if $R_{\%}(i)$ is acceptable for all cells within the domain. If $R_{\%}(i)$ is not acceptable everywhere within the model domain, go back to Step 2.
    - Note: No threshold value for $R_{\%}$ has been discussed for Cobscook Bay. However, this concept can be used to evaluate potential adverse sediment transport and ecological changes to determine what the maximum decrease (or increase) in velocity should be to ensure that adverse effects are avoided. To illustrate how these criteria operate within the optimization analysis, a minimum threshold was set at $R_{\%}(i) \geq 95$ (i.e., depth-averaged velocities cannot drop below 95% of what they would be without the presence of a turbine).
6) Repeat Steps 2 through 6 for each additional turbine.

The methodology identifies regions where velocities are largest thereby optimizing the power output of deployed MHK turbines. At the same time, environmental considerations are assessed to avoid array configurations that could potentially negatively impact sediment dynamics trends and ecology.

When beginning the optimization analysis, velocity patterns were originally analyzed over several tidal cycles. However, multiple-day simulations are computationally demanding and required more than 24 hours of computing time to complete. Upon examining velocity contours over several tidal cycles, it was recognized that the spatial patterns observed during both ebb and flood tides were similar between events; the flow patterns predicted during flood tides are self-similar, only the magnitude of the velocities occurring during the events changes (this is also true for ebb tides). This means that $R_{\%}(i)$ do not change significantly between various flood cycles or even between flood and ebb cycles. To demonstrate, velocity magnitudes extracted during 10 peak tidal events (the five highest ebb and five highest floods from the 29-day simulation period) were averaged and compared to the velocity contours created by averaging velocities from two short simulations representative of typical ebb and flood tides. The resulting averaged velocity fields were normalized by the maximum velocity within each domain so that spatial velocity patterns could be easily compared. The normalized velocity fields are presented in Figure 6; the left panel is the 10-event average, and the right panel is the average of a typical ebb and flood. The plots presented in Figure 6 where rotated 60 degrees clockwise to better fit report formatting (i.e., the previous southeast border is now at the bottom of the plot). The images were also cropped to focus on the turbine-placement footprint. The results indicate that the spatial velocity patterns predicted by simply forcing the model by representative conditions closely match those of the 10-peak average. This demonstrates that simulations can be run over a single ebb and flood tidal cycle when assessing hydrodynamics in the optimization analysis. Boundary conditions were those that created the highest velocities predicted during the 29-day calibration period.

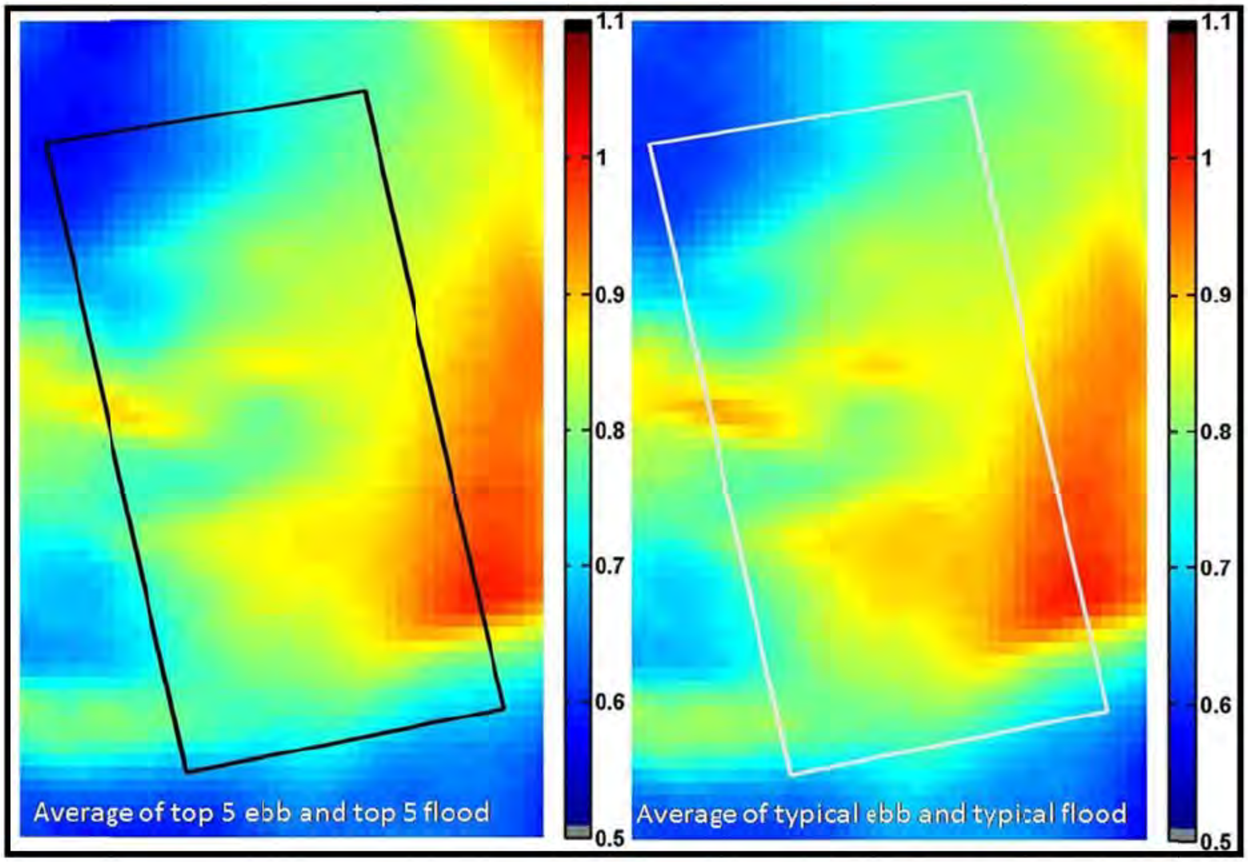

Figure 6. Normalized velocity contours (unitless) of averaged velocities for 10 peak (5 ebb and 5 flood) events occurring July 5 through August 5, 2011 (left panel), and average across a single ebb and flood tide forced at conditions representative of typical peak flows in Cobscook Bay (right panel). The placement footprint is outlined by rectangles.

The optimization analysis started by modeling the flow patterns during a typical ebb and flood event around the turbine that is currently deployed in Cobscook Bay (same forcing conditions that were compared to the 10-peak average results). The predicted velocity contours where then averaged to locate high-velocity regions within the placement footprint. The average-velocity contours are in the left panel of Figure 7. Note all velocities examined in the optimization analysis are depth averaged; when looking at the velocity deficit in the water column at the depth of the turbine, the wake is much more pronounced (see Summary and Future Work for further details on this point). The placement footprint is outlined by a white rectangle, and the location of the turbine is indicated with gray cells. In Figure 7, and subsequent figures, cells with depths less than 23 m are blacked out. Next, the three adjacent cells with the highest average velocity are identified and circled in gray in the left panel of Figure 7. Then the $R_{\%}$ in each cell within the domain was calculated and checked to ensure the 95% threshold was met (right panel of Figure 7). It was, so a second MHK was added into the domain, and the process was repeated until deployment locations for all five turbines had been identified. This evolution is presented in Figure 7 through Figure 11. When defining the location for the fourth MHK device (Figure 10), several simulations were ran before identifying a deployment location that was in a region of highest velocity and did not cause a drop in $R_{\%}$ below 95. The highest velocity region created in the three-turbine simulation was actually four cells away from the upper-most turbine in Figure 9; but, when placing the fourth turbine in these cells the $R_{\%}$ of the four-turbine simulation dropped below 95 within a few nearby cells.

Once the optimization defining all five turbine locations was complete, the new five-turbine array configuration was simulated over the calibration period (July 5 through August 2, 2011). The optimally placed TidGen™ units generated about 125 MW-hr over the 29-day simulation. This corresponds to a 17% increase in power generation over the preliminary ORPC array layout (107 MW-hr) that did not use optimization techniques.

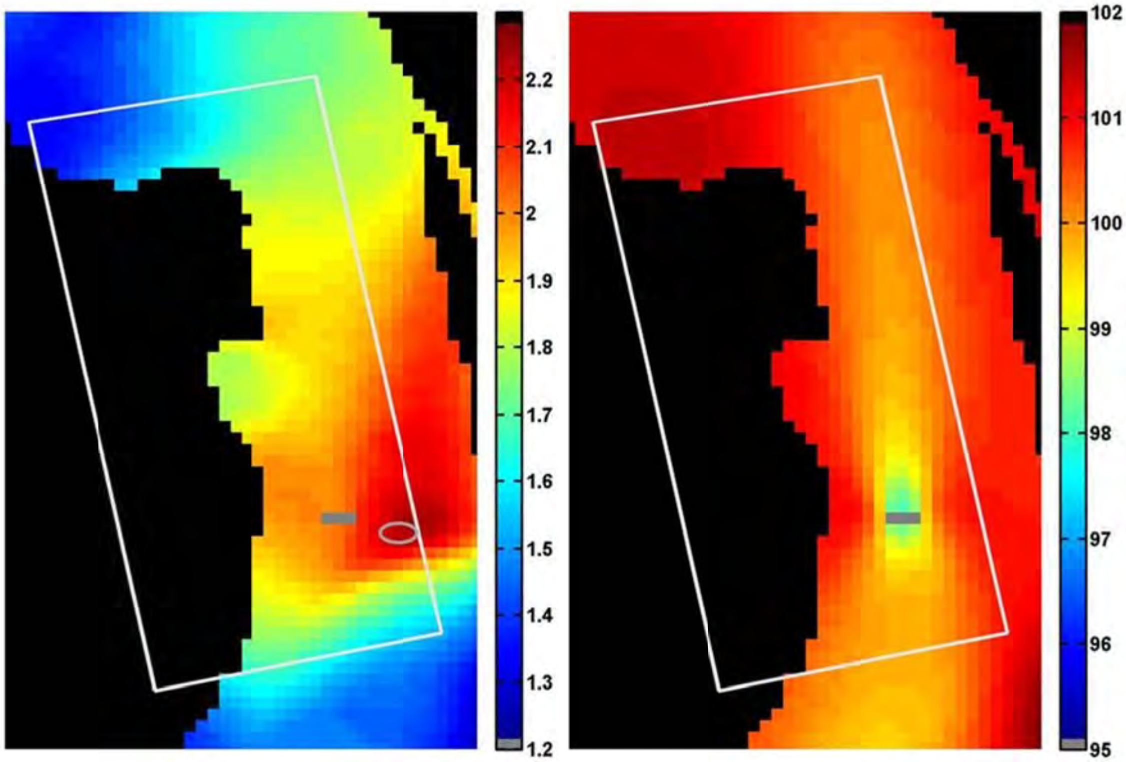

Figure 7. (Left panel) Averaged ebb and flood velocity contours (m/s), and (right panel) $R_{\%}$ (unitless) predicted by simulating one MHK device. The placement footprint is outlined by white rectangles, and the optimized deployment location of the next MHK device is marked by the gray oval. Cells with depths less than 23 m are blacked out.

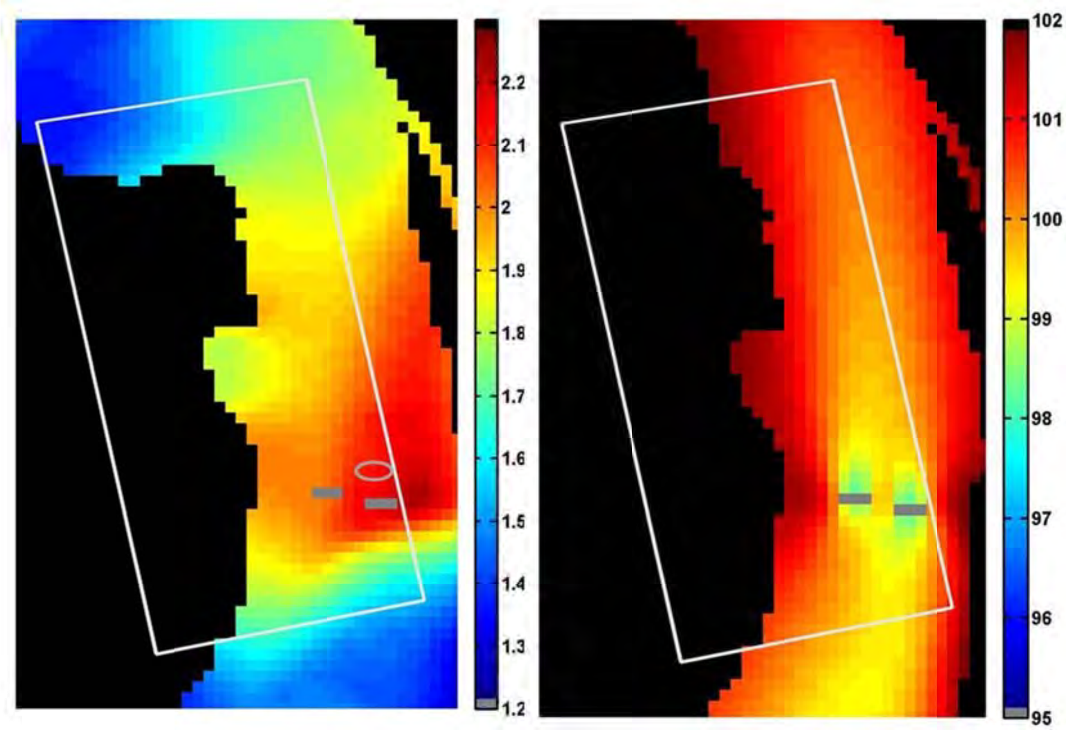

Figure 8. (Left panel) Averaged ebb and flood velocity contours (m/s), and (right panel) $R_{\%}$ (unitless) predicted by simulating two MHK devices. The placement footprint is outlined by white rectangles, and the optimized deployment location of the next MHK device is marked by the gray oval. Cells with depths less than 23 m are blacked out.

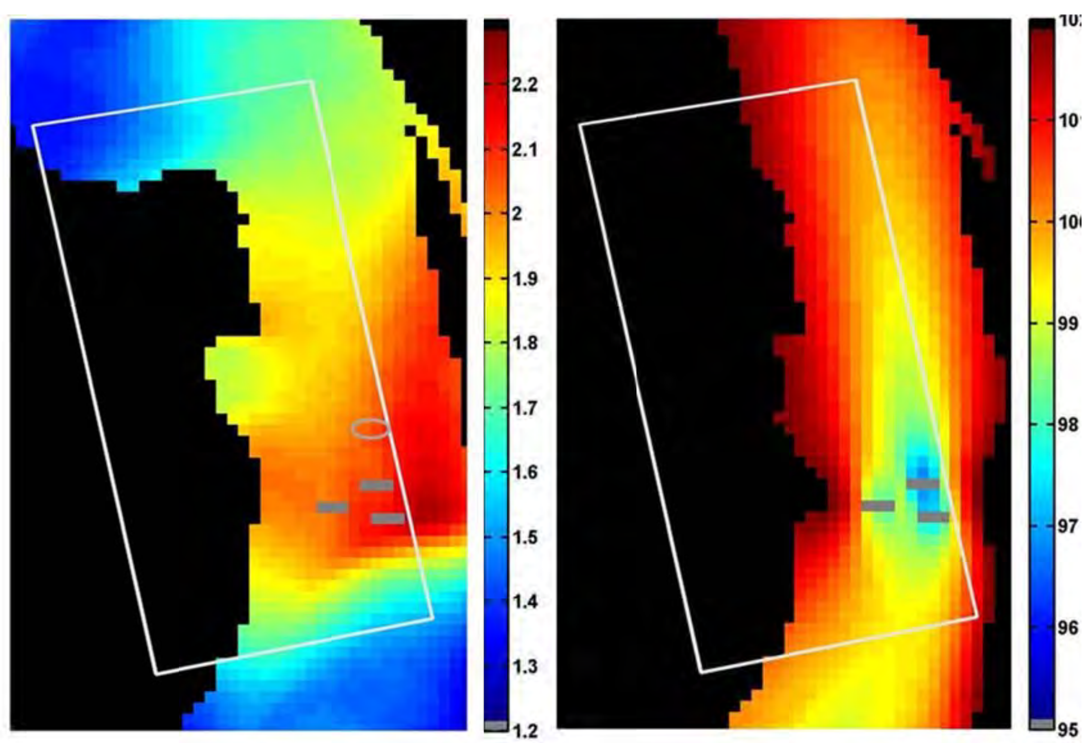

Figure 9. (Left panel) Averaged ebb and flood velocity contours (m/s), and (right panel) $R_{\%}$ (unitless) predicted by simulating three MHK devices. The placement footprint is outlined by white rectangles, and the optimized deployment location of the next MHK device is marked by the gray oval. Cells with depths less than 23 m are blacked out.

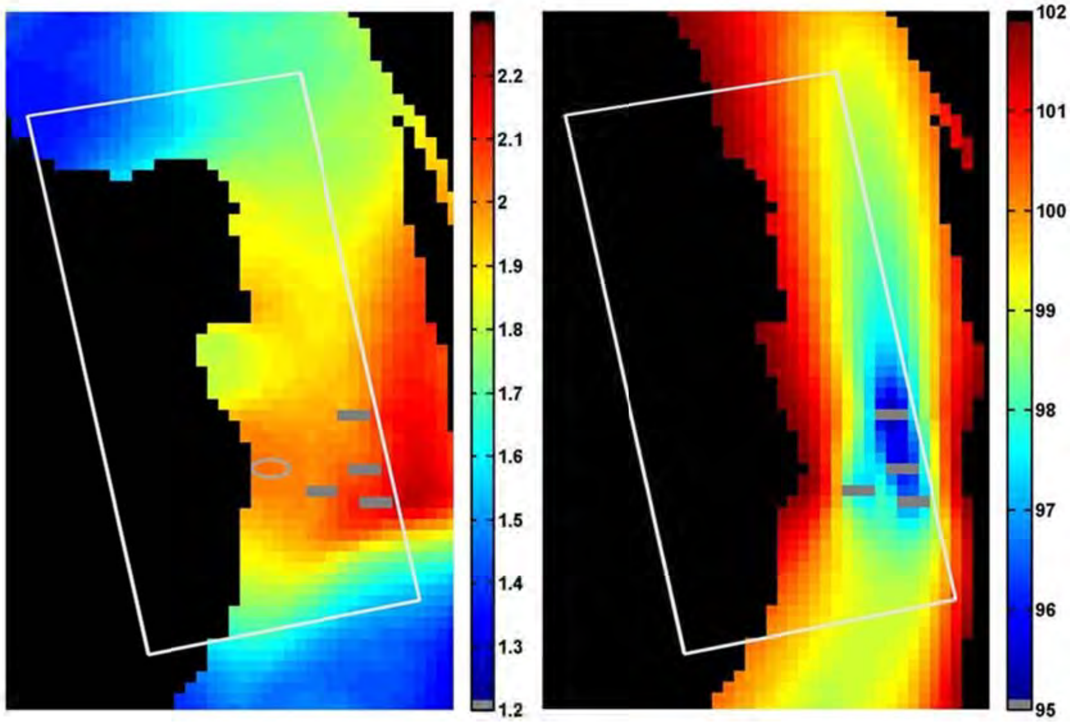

Figure 10. (Left panel) Averaged ebb and flood velocity contours (m/s), and (right panel) $R_{\%}$ (unitless) predicted by simulating four MHK devices. The placement footprint is outlined by white rectangles, and the optimized deployment location of the next MHK device is marked by the gray oval. Cells with depths less than 23 m are blacked out.

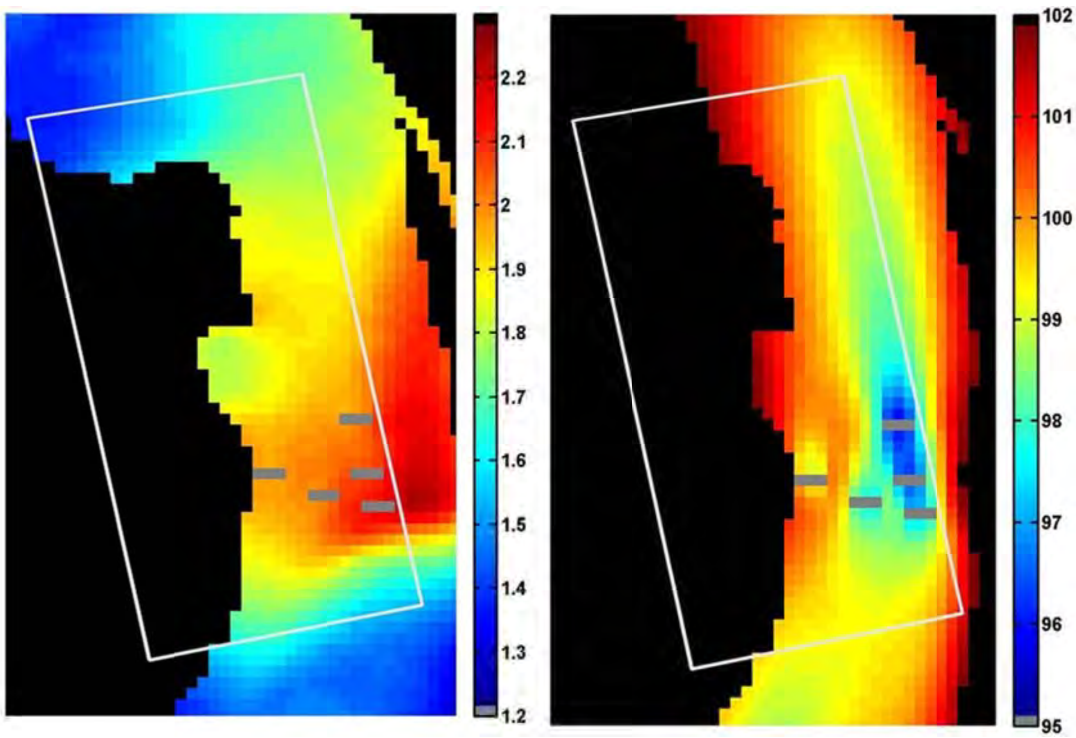

Figure 11. (Left panel) Averaged ebb and flood velocity contours (m/s), and (right panel) $R_{\%}$ (unitless) predicted by simulating five MHK devices. The placement footprint is outlined by white rectangles, and the optimized deployment location of the next MHK device is marked by the gray oval. Cells with depths less than 23 m are blacked out.

Summary and Future Work

A framework was developed using SNL-EFDC to optimize the placement of MHK devices to maximize array performance and minimize environmental effects due to flow alterations. Hence, the procedure identifies ideal deployment locations to generate the greatest amount of power while also taking into account environmental considerations to avoid potentially adverse effects on sediment dynamics and system ecology. While developing this methodology, the need for a larger domain was recognized. A new domain that contained the entire available MHK placement footprint was constructed and calibrated. Water levels and calibrated flow rates extracted from a previously developed regional-scale model were used to drive flow in the newly created, refined-grid domain. Modeled velocities were in close agreement with ADCP data, suggesting the model accurately predicts system hydrodynamics.

Once the optimization analysis was complete, simulations compared ORPC's preliminary (un-optimized) array configuration to the SNL-EFDC optimized arrangement over the calibration period (July 5 through August 2, 2011). The optimized array configuration produced 125 MW-hr of energy, a 17% increase in power generation over the ORPC-planned array (107 MW-hr).

The optimization analysis examined depth-averaged velocities when assessing hydrodynamic patterns and $R_{\%}$. Depth-averaged velocities were used to facilitate the transfer of data between SNL-EFDC and the post-processing software used to assess velocity fields and $R_{\%}$. However, when conducting the array-optimization analyses, power production may be increased and environmental concerns more thoroughly examined by also considering flow in specific model layers; particularly flows at the depth of the turbines. This is because the flow velocity incident to the turbine at hub height is most important to turbine performance. By conducting the analysis based on depth-averaged velocities, the wake behind each turbine is partially obscured. This point is illustrated in Figure 12, where velocity contours from a single-turbine simulation during a typical ebb tide are plotted. The left panel in Figure 12 shows depth-averaged velocity contours, and the right panel shows flow-speed contours extracted from sigma layer 3 where roughly 75% of the turbine and foundation reside (the remaining 25% are in sigma layer 2). The wake behind the turbine is apparent in sigma layer 3 as the blue color directly behind the device; however the wake is not as obvious in the depth-averaged panel. In future optimization studies, the procedure will be modified to specifically consider velocities at the depth where the turbine is deployed.

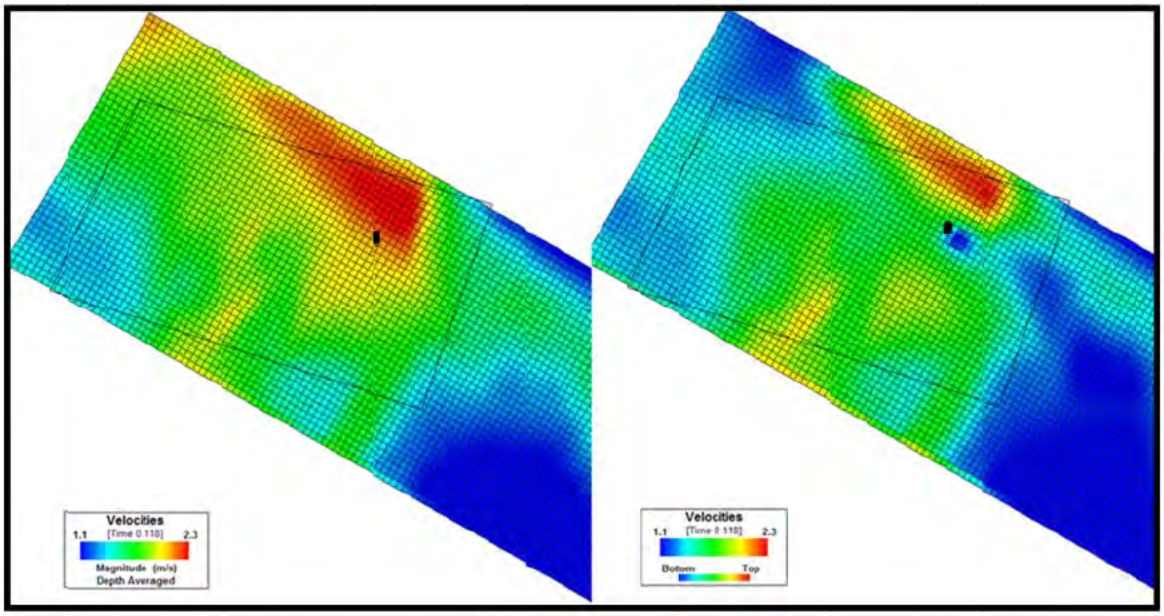

Figure 12. Comparison between depth-averaged velocity magnitude (m/s) and the velocity magnitude (m/s) at roughly the depth of the turbine for a single turbine simulation during ebb tide.

Acknowledgements

SNL would like to thank Prof. HuijieXue and Min Bao at the University of Maine for their FVCOM model output as well as discussion and guidance on Cobscook Bay model development.

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Appendix F

ORPC Marine Mammal Recorder Sheets

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Sem, JT

Date: 1/22/13

Start Time: 1:30 pm ~~[illegible]~~

End Time: 2:32 pm

Location of Observation (approximate):

- Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W) ✓
- Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
- Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
- Western Passage ______
- Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
						NONE	SA
						NONE	JT

Updated April 18, 2012

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Cecil Coates John Turner

Date: 02/22/2013

Start Time: 1:50 PM

End Time: 3:15

Location of Observation (approximate):
- ✓ Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
- Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
- Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
- Western Passage ______
- Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
			vis unlimited clear, SS 1			one gray seal left area on our arrival Heading 150°	CT

Updated April 18, 2012

Marine Mammal Species Observation Log

ORPC
OCEAN RENEWABLE POWER COMPANY

Observer(s): John T
Date: 2-25-13
Start Time: 10:20
End Time: 11:20

Location of Observation (approximate): (Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ____________________
Other ____________________

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
~	~	~	~	~	~	~	JT

Updated April 18, 2012

Marine Mammal Species Observation Log

OCEAN RENEWABLE POWER COMPANY

Observer(s): JT

Date: 3-4-2015

Start Time: 8:00 AM

End Time: 2:30 pm

Location of Observation (approximate): (Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W))
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
—	—	—	Sunny Windy	—	—	—	JT

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): J.I

Date: 3-22-13

Start Time: 1:30

End Time: 3:15

Location of Observation (approximate): ~~Capt. E~~ – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
—	—	—	overcast	—	—	—	JI

Marine Mammal Species Observation Log

Observer(s): JT

Date: 3-24-13

Start Time: 9:45 PM

End Time: 5:30 AM

Location of Observation (approximate): ~~Capt. E~~ – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)

Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)

Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)

Western Passage ______

Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
—	—	—	Clear, Calm	—	—	—	JT

Updated April 18, 2012

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): JT.

Date: 3-25-2013

Start Time: 9:45 PM

End Time: 5:30 AM

Location of Observation (approximate): ~~Capt. E~~ – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
—	—	—	clear windy	—	—	—	JH

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Nate, Sean, John

Date: 4-2-13

Start Time: 10:30

End Time: 1700

Location of Observation (approximate):
Capt. E – ~~Tid~~Gen #1 (44°54'34.98"N, 67° 2'43.98"W) ✓
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
						no sightings	

Updated April 18, 2012

Marine Mammal Species Observation Log

ORPC
OCEAN RENEWABLE POWER COMPANY

Observer(s): Nate, John, Sean
Date: 4-3-13
Start Time: 7:30
End Time: 10:30

Location of Observation (approximate): ✓ Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
						no sightings	

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): John, Sybille, Jaime
Date: 5-21-13
Start Time: 7:45
End Time: 9:30

Location of Observation (approximate): Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
8:15	Captain E		Foggy Calm Sea	Seal	1	swimming	JM

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): N. Johnson
Date: 7/15/13
Start Time: 09:35
End Time: 11:20

Lady H long/lat.
10:15 – 25.062/26.903
10:35 30.032/37.727
10:40 32.988/35.252
10:44 33.561/36.163

Location of Observation (approximate): ✓ Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

- TGU Retrieval
- Obs. from Lady H.

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
10:15	—	—	—	—	—	No observations	NJ
10:35	—	—	—	—	—	"	NJ
10:40	354°	75 m	calm/clear	Harbor Seal	1	Bottling	NJ
10:44	—	—	—	—	—	No sightings	NJ
11:03	—	—	—	—	—	"	NJ

Updated April 18, 2012

10:58 – Start retrieval
11:02 – End retrieval

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Dave Mark Butch
Date: June 10 2013
Start Time: 0622
End Time: 0830

Location of Observation (approximate):
- Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
- Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
- (circled) Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
- Western Passage ______
- Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
0630		1/4 mile or less	Nice, calm	Seal	1	East of Project Area	DWT

Updated April 18, 2012

Marine Mammal Species Observation Log

ORPC
OCEAN RENEWABLE POWER COMPANY

Observer(s): DWT MR SK
Date: 6/13/13
Start Time: 9
End Time: 11:15

Location of Observation (approximate): Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage
Other

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
				0	0		

Updated April 18, 2012

Protected Species Observation Log – AAM Testing

ORPC
OCEAN RENEWABLE POWER COMPANY

Observer(s): Jaime, John
Date: 6-18-13
Start Time: 0600
End Time: 1000

Location of Observation (approximate): TidGen 001 (44°54'34.98"N, 67° 2'43.98"W)

Time	Source Level (dB)	Frequency (kHz)	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
900	210	90-120		30	Clear Calm	Seals	~~3~~ 1	Swimming	Jm
9:00	210	90-120		100	clear calm	Seals	2	playing	Jm

*See next page for observation protocols

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 6/18/13
Observer(s): DT MR
Start time: 6
End time: 11

Species of concern:
seals
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
Seals	All Morning	Estes Head CB Project Area	5 seals, Different Times

Protected Species Observation Log – AAM Testing

Observer(s): John & Jamie
Date: 6-19-2013
Start Time: 6:40 AM
End Time: 11:02 AM

Location of Observation (approximate): TidGen 001 (44°54'34.98"N, 67° 2'43.98"W)

Time	Source Level (dB)	Frequency (kHz)	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
6:05	210	90-120	20°	-	Sunny. clear 0 54°	SEAL	1	playing in water	JT
7:27	210	90-120	313° NW	287M	Sunny clear 0 59°	Seal	1	splashing in water	JT

*See next page for observation protocols

8:52 whale sighting by Tide tracker @ NW corner marker

Updated May 16, 2013

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 6/19/13
Observer(s): DWT MR
Start time: 6 ~~[illegible]~~
End time: 11

Species of concern:
seals
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
Seal	1030	Estes Head	
Whale minke?	8 or 9	CB North & West of TGU Sight	could only see the spray over a 30-40 minute period

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 6/20/13
Observer(s): DT MR
Start time: 0645
End time: 1230

Species of concern:
seals
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
2 porpoise Buckman	0700	Buckman Head	
6 Seals	0700-1215	Buckman to CB	

Protected Species Observation Log – AAM Testing

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Jaime, John
Date: 6-20-13 70°
Start Time: 7:05 AM
End Time: 11:51 AM

Location of Observation (approximate): TidGen 001 (44°54'34.98"N, 67° 2'43.98"W)

Time	Source Level (dB)	Frequency (kHz)	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
7:10	none	none			Calm, 0 TEM 66° Sunny, clear	Seal	1	travel	Jm
8:23	210	90-120	90°	150m	Calm TEM 66° sunny, clear	Seal	1	Travel	JT
9:19	218	90-120	325°	80m	Calm sunny clear	Seal	1	Travel	JT
10:07	210	90 120	85°	286 M	Calm Sunny clear	Seal	1	Travel	J T
10:30	210	90-120	70°	20m	Calm Sunny clear	Seal	1	travel	J T
10:46	210	90-120	60°	15 m	Calm Sunny clear	Seal	1	Travel	J T

*See next page for observation protocols

Protected Species Observation Log – AAM Testing

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): Jaime, John
Date: 6-21-13
Start Time: 8:06 AM
End Time: 12:54 PM

Location of Observation (approximate): TidGen 001 (44°54'34.98"N, 67° 2'43.98"W)

Time	Source Level (dB)	Frequency (kHz)	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
8:25	—	—			clear, calm, 0	Seal	1	Swimming	JM
11:35	210	90-120	130°	40	CLEAR, CALM	Seal	1	Swimming	JT
12:53	210	90-120	220°	60	clear, calm	Seal	1	Swimming	JM

*See next page for observation protocols

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 7/11/13
Observer(s): DWT JM JH
Start time: 12
End time: 3 15

Species of concern:
seals (circled)
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
Seal	12:45 – 2	TGU 001 site	same seal twice

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 7/12/13
Observer(s): DWT DS JM
Start time: 0700
End time: 0945

Species of concern:
seals
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
0	—	TGU Site	

Marine Mammal Species Observation Log

ORPC
OCEAN RENEWABLE POWER COMPANY

Observer(s): JT. DT. MR.
Date: 8-7-2013
Start Time: 5:00 AM
End Time: 7:45 AM

Location of Observation (approximate):
Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
✓ Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other Tide GEN Site, off Lubec

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
6:10	–	100 YARDS	Sunny, clear	SEAL	1	Playing Around	JT

ATTACHMENT II

RTE AND MARINE MAMMAL SPECIES OBSERVATIONS
ORPC BETA TGU PROJECT

Date: 10/4/13
Observer(s): DWT MR
Start time: 9 15
End time: 11

Species of concern:
seals
whales
dolphins/harbor porpoise/sea turtles

Species observed	Time of observation	Location	Notes (observed activity/behavior, etc)
Ø			

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): DT JT
Date: 11/12/13
Start Time: 10
End Time: 12

Location of Observation (approximate):
Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage ______
Other ______

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
CBTEP site No Observations							

Marine Mammal Species Observation Log

ORPC OCEAN RENEWABLE POWER COMPANY

Observer(s): JT DT
Date: Dec 12 2013
Start Time: 11
End Time: 12 30

Location of Observation (approximate): Capt. E – TidGen #1 (44°54'34.98"N, 67° 2'43.98"W)
Energy Tide 2 – Shackford Head (44°54.020'N 67°01.582'W)
Lubec Come-Ashore (44°54'12.71"N, 67° 3'12.13"W)
Western Passage
Other Trip to CBTEP Site

Time	Estimated Bearing	Estimated Distance	Weather Conditions (visibility, sea state)	Species	Quantity	Notes (observed behavior/direction of travel)	Initals
nothing observed							

Updated April 18, 2012

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Appendix G

Report to ORPC on Bird Studies in Cobscook Bay, Maine, Third Winter Season Period of Investigation, November 2012 – April 2013, Peter D. Vickery, Ph.D., July 2013

Report to ORPC on Bird Studies in Cobscook Bay, Maine

Third Winter Season

Period of Investigation

November 2012 - April 2013

Prepared by
Peter D. Vickery, Ph.D.

July 2013

Introduction

We conducted waterfowl and seabird inventories off the waters of North Lubec where ORPC Maine, a subsidiary of Ocean Renewable Power Company (collectively, "ORPC") has installed a single device TidGen® Power System (Fig. 1) as part of the Cobscook Bay Tidal Energy Project (CBTEP). We monitored the waters off North Lubec from November, 2012 through April, 2013. The purpose of these inventories was to determine the species and numbers of seabirds and other birds that use the proposed Deployment Area of the CBTEP, the onshore Landing Site where the bundled cables are likely to come ashore in North Lubec, and the waters immediately off the Landing Site. We also wanted to determine the behaviors of the species that used these specific areas. These results should help determine whether the presence of ORPC's power system might potentially impact the birds that use these specific parts of eastern Cobscook Bay, and should help ORPC minimize potential impacts when it deploys and operates additional equipment.

Background

Cobscook Bay is a rich marine environment with 5-7 meter tides and strong currents (Larsen 2004). This bay is an important fishing area and we regularly observed 12-20 scallop draggers in the bay during our surveys in December and February. Numerous salmon pens are also scattered throughout the bay; boats service these pens on a daily basis.

Cobscook Bay is considered an important area for wintering ducks, especially American Black Ducks (*Anas rubripes*; Longcore and Gibbs 1988). This bay also supports substantial numbers of seaducks (C. Bartlett, pers. obs.) but it is unclear whether ducks and other seabirds use the eastern portions of Cobscook Bay, especially the Deployment Area. Large numbers of Razorbills (*Alca torda*) are also known to occur in winter in the Bay of Fundy and nearby Grand Manan Island, New Brunswick (Huettmann et al. 2005).

Seaducks (scaup, eiders, scoters, Long-tailed Duck [*Clangula hyemalis*], goldeneyes, mergansers), loons, grebes, cormorants, and alcids are all diving birds foraging for benthic invertebrates or fish. Although most species dive to shallow depths (2-10 meters), a few species can dive to depths of over 100 meters (Table 1) and it is possible that these diving birds might interact with the bottom-mounted TidGen™ Turbine Generator Unit (TGU), the top of which is approximately 15 meters below the surface at low tide. Because of this potential interaction, we were interested in documenting the number of diving birds that use the Deployment Area and Landing Site, along with these birds' behaviors. We paid specific attention to species known to dive to depths of 20 meters or more; these include Long-tailed Duck (*Clangula hyemalis)*, White-winged Scoter (*Melanitta fusca*), Common Loon (*Gavia immer*), Black Guillemot (*Cepphus grylle*), and Razorbill (*Alca torda*) (Table 1).

We paid special attention to federal and state endangered, threatened, and special-conWen species and communicated with the Maine Department of Inland Fisheries and Wildlife to confirm that the updated list of these bird species in Maine was accurate (http://www.maine.gov/ifw/wildlife/species/endangered_species/state_federal_list.htm; see Appendix 1).

Table 1. Diving depths of waterbirds and seabirds known to occur in Cobscook Bay, North Lubec, Maine.[1] Diving depths taken from species accounts, Birds of North America (see Literature Cited).

WATERFOWL		Diving Depth	Food Taken	Occurrence in Cobscook Bay
Greater Scaup	Aythya marila	7.0 meters [1]	Benthic Invertebrates	Common
Common Eider	Somateria mollissima	+/- 10 meters [1]	Benthic Invertebrates	Common
Surf Scoter	Melanitta perspicillata	9 meters [1]	Benthic Invertebrates	Common
White-winged Scoter	Melanitta fusca	5-20 meters [1]	Benthic Invertebrates	Common
Black Scoter	Melanitta americana	3- <10 meters [1]	Benthic Invertebrates	Common
Long-tailed Duck	Clangula hyemalis	66 meters [1]	Benthic Invertebrates	Common
Bufflehead	Bucephala albeola	<3 meters [1]	Benthic Invertebrates	Common
Common Goldeneye	Bucephala clangula	2 - 9 meters [1]	Benthic Invertebrates	Common
Hooded Merganser	Lophdytes cucullatus	<10 meters [1]	Fish and crustaceans	Uncommon
Red-breasted Merganser	Mergus serrator	5 - 10 meters [1]	Fish and crustaceans	Common
LOONS AND GREBES				
Red-throated Loon	Gavia stellata	2 - 9 meters [1]	Fish and crustaceans	Rare
Common Loon	Gavia immer	to 60 meters [1]	Fish and crustaceans	Common
Horned Grebe	Podiceps auritus	< 10 meters [1]	Fish and crustaceans	Uncommon
Red-necked Grebe	Podicaps grisegena	< 10 meters [1]	Fish and crustaceans	Uncommon
CORMORANTS				
Double-crested Cormorant	Phalacrocorax auritus	<8 meters [1]	Fish	Common
Great Cormorant	Phalacrocorax carbo	<20 meters [1]	Fish	Common
ALCIDS				
Thick-billed Murre	Uria lomvia	to 210 meters [1]	Fish and invertebrates	Rare
Razorbill	Alca torda	10 - >100 m [1]	Schooling fish	Occasional
Black Guillemot	Cepphus grylle	5 - 35 meters [1]	FIsh and invertebrates	Common

STUDY OBJECTIVES

The objective of this study was to determine the species and numbers of seabirds and other birds that use the Deployment Area of the TidGen™ Power System. We also wanted to determine the behaviors of these seabirds.
We also wanted to determine which species used the onshore Landing Site where the bundled cables come ashore, and the waters immediately off the Landing Site.

SURVEY SITE

ORPC On-Shore Station Landing Site - North Lubec
We used the ORPC On-shore Station Landing Site in North Lubec as the location for our land-based observations because we wanted to determine the species composition, numbers, and behavior close to this proposed facility area where the bundled power and data cables for the TidGen® Power System come ashore. We used these land-based surveys to determine which species used the Landing Site and the waters immediately adjacent to the Landing Site (Fig. 1; A) and the mid-channel surrounding the Deployment Area (Fig. 1; B). The land-based surveys covered a broad mid-channel area (B in figure 1). We also surveyed the beach east of the Landing Site.

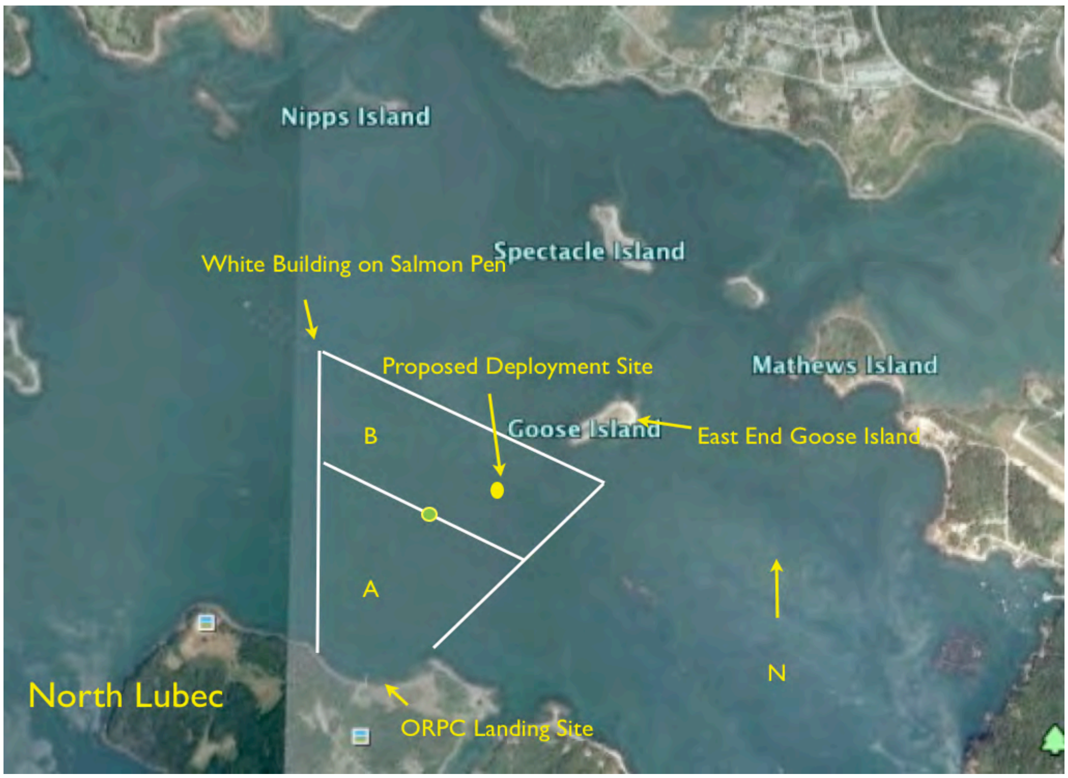


Figure 1. Land-based surveys were conducted from the On-shore Station Landing Site in North Lubec, Maine. The surveys was separated into the near shore area (A) just offshore from the Landing Site and the mid-channel area (B) where the TidGen® Power System was deployed. We also monitored the beach east of the Landing Site (yellow arrow at ORPC Landing Site).

The land-based survey area for the nearshore Landing Site and the mid-channel was delineated by an imaginary line extending from the ORPC Landing Site to the east end of Goose Island (Fig. 1). The west side of the survey area was defined by a line extending from the western boundary of the Landing Site to a white building on a salmon farm directly northwest of the Landing Site. The northern edge of the inshore area (A) was marked by a green navigation buoy north of the Landing Site. The mid-channel area (B) was delimited by the green buoy and a white marker west of Goose Island. The beach and adjacent pond to the east of the Landing Site were clearly visible from this position.

The two separate areas in the water surveys (mid-channel, nearshore area) were not independent. If one or more birds moved from one survey area to another area during a 15-minute survey, these birds were included in both areas because they occupied both areas during the survey period.

The TidGen® TGU was not operational for the entire winter survey period. It was retrieved for for maintenance on three occasions. It was retrieved on Oct 25, 2012 and was re-deployed on Dec 7, 2012. It was retrieved a second time on Jan 22, 2013 and was redeployed on Feb 22, 2013. It was retrieved a third time for a day on Feb 25, 2013 and was redeployed on Feb 26, 2013. During our study period, it was operational from Feb 27 to April 20, 2013 but not earlier in the winter.

SURVEY METHODS

This phase of this study documented the number of wintering waterfowl and seabirds that used the nearshore North Lubec Landing Site and the general deployment mid-channel area.

Wintering Waterfowl and Seabirds

Starting in November 2012, we continued surveys for wintering waterfowl and seabirds from the Landing Site at North Lubec. Each survey was conducted for a period of 3 hours. Each survey was divided into 15-minute periods and the maximum number of each species and its behavior (see below) were recorded during each period. For reporting purposes, we condensed the 15-minute observation periods into hour units by selecting the largest count in each of the four 15-minute periods. We then used the average of these hour counts to determine the number of individuals present for each survey date (see Figs. 2 - 9). Data are presented as the average number of birds seen per month. In the winters of 2010-2011 and 2011-2012, we sometimes conducted more than one survey per month. If this was the case, we computed and report the average of these monthly surveys. We were unable to conduct our survey in February 2013 due to inclement weather and icy road conditions.

Behaviors

We registered all behaviors of birds on the water's surface. Birds were identified as Loafing (floating on the surface), Diving (active feeding below the surface), or Surface Feeding (active feeding on the surface) (Holm and Burger 2002). Birds that flew past the survey area but did not land on the water were recorded but were not included in this report.

Observers used 8x or 10x binoculars and a 20-60x telescope for the land-based surveys. We used a continuous scan method to identify and count all species present (Martin and Bateson 1986).

RESULTS

We conducted five land based surveys at North Lubec between November 27, 2012 and April 23, 2013 (Table 2). These surveys totaled 15 hours of observation time.

Table 2. Surveys of the area of interest for ORPC in eastern Cobscook Bay, Maine were conducted from the Landing Site in North Lubec. This table provides the locality, date of survey, duration of survey, and information regarding whether the TidGen® was deployed and operational in North Lubec during bird surveys in the winter of 2012-2013.

Survey Site	Survey Date	Duration (hours)	TidGen® Deployed	TidGen® Operational
North Lubec	Nov 27, 2012	3	No	No
North Lubec	Dec 20, 2012	3	Yes	No
North Lubec	Feb 27, 2013	3	Yes	Yes
North Lubec	Mar 25, 2013	3	Yes	Yes
North Lubec	Apr 23, 2013	3	Yes	Yes

Waterfowl and Seabirds

These results are separated into two broad ecological categories based on feeding behaviors. Diving birds, including eiders and other seaducks, loons, grebes, cormorants, and guillemots, differ substantially from surface feeding birds, i.e., dabbling ducks and large gulls.

Diving Birds:

Common Eiders have declined during the three years of this study (Fig. 2). There were fewer Common Eiders during the winter of 2012 - 2013 than in the previous two winters (Fig. 2). In the first two winters, this species was observed more regularly in the mid-channel area. However, in 2012-2013, Common Eiders were absent in both the mid-channel and the near shore in October and November 2012. During the 2012-2013 field season, the largest count was in the mid-channel in December 2012 (average: 48 individuals) but numbers declined thereafter (Fig. 2). The maximum count for 2010-2011 was 33.1 individuals in November and February 2011. In 2011-2012, the maximum eider count in the mid-channel was 77 individuals in March 2012. Common Eiders do not occur in any numbers in the near shore; the only substantial flock was 40 individuals in December 2011 (Fig. 2).

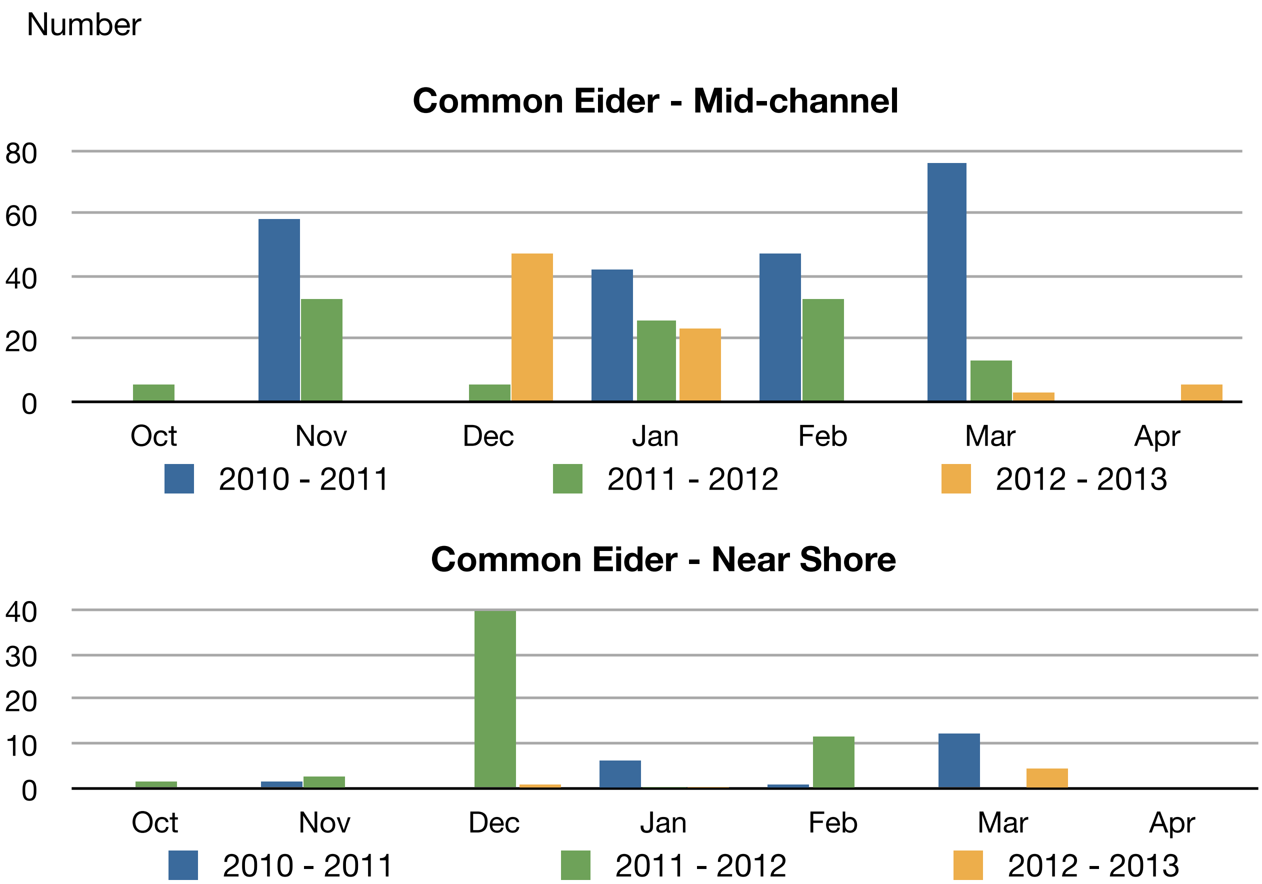


Figure 2. Common Eiders have been regular in the mid-channel of the Cobscook Bay study area, Maine. They were less numerous in 2012-2013 than in 2010-2011 or 2011-2012. Eiders occurred in small numbers in the near shore area of North Lubec. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Long-tailed Ducks remained uncommon in the mid-channel, occurring on two occasions in 2012-2013 (max. 4, Feb 2013); three times in the winter of 2010-2011 (max. of 5.5 individuals, Jan 2011); and four times in 2011-2012 (max. of 10.5 individuals, Feb 2012). This species was seen twice in the near shore of North Lubec in 2012-2013 (4 in Feb 2013; 1 in April 2013); four times in 2010-2011 (max. 5.5 individuals, Jan 2011) and on six occasions in 2011-2012 (max. 3.5 in Feb 2011).

Red-breasted Mergansers continued to occur in small numbers, with a maximum of 3.5 individuals in March 2011, in the near shore and the mid-channel, North Lubec, Maine (Fig. 3).

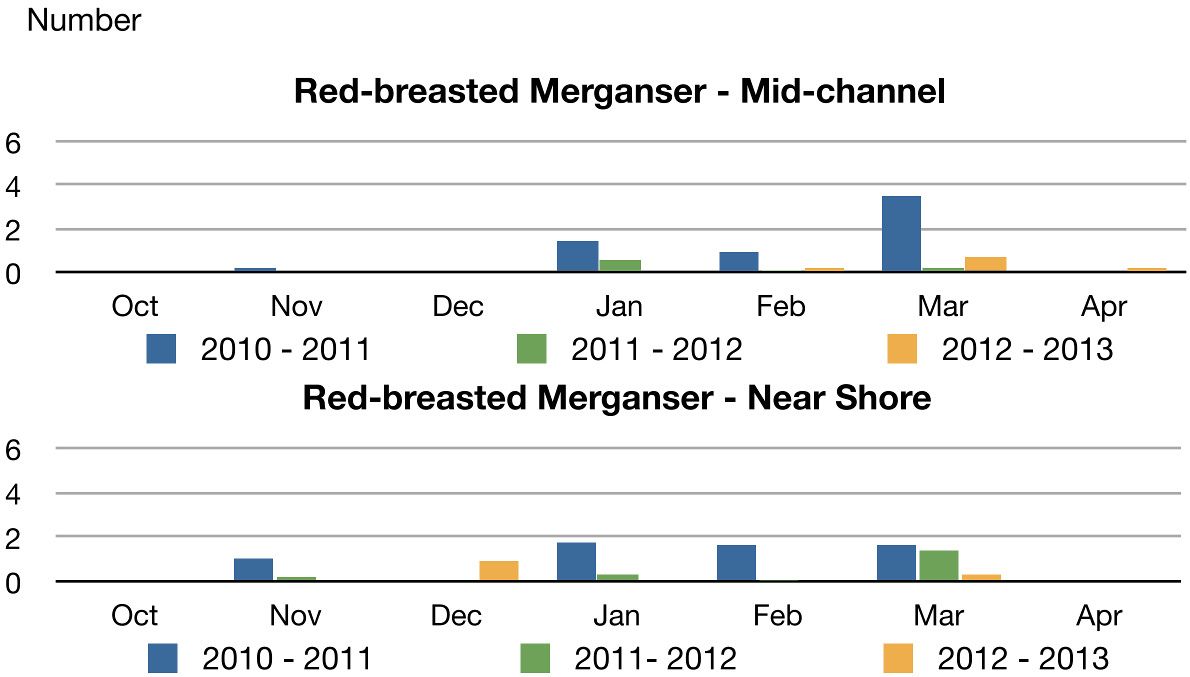


Figure 3. Red-breasted Mergansers occurred in small numbers in both the near shore and the mid-channel of the study area of Cobscook Bay, Maine. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Other ducks were generally uncommon and irregular. We observed scoters, primarily Surf Scoters, on four occasions in 2010-2011; the only time we noted >3 individuals was January 15, 2011 when we observed an average of 55.5 individuals. Two hundred White-winged Scoters appeared briefly in the mid-channel on January 15, 2011 but remained for less than 15 minutes and never reappeared in large numbers. We observed scoters on three occasions in 2011-2012; never more than 2 individuals. This species was observed flying west into the upper reaches of Cobscook Bay on several occasions, but the fact that it did not return to the general Deployment Area appears to indicate that this area does not provide optimal feeding habitat for this species. Common Goldeneyes were seen almost exclusively in the near shore at North Lubec (Table 3). We did not observe Common Goldeneyes in the winter of 2011-2012. A single Barrow's Goldeneye (*Bucephala islandica*) was seen in near shore on Feb 12, 2011. We observed Hooded Mergansers (*Lophdytes cucullatus*) in the near shore on two occasions and also in mid-channel once (Table 3).

Common Loons were regular in small numbers in the study area during all three field seasons (Fig. 4). We observed Red-throated Loon (*Gavia stellata*) on two occasions: in near shore (Table 3).

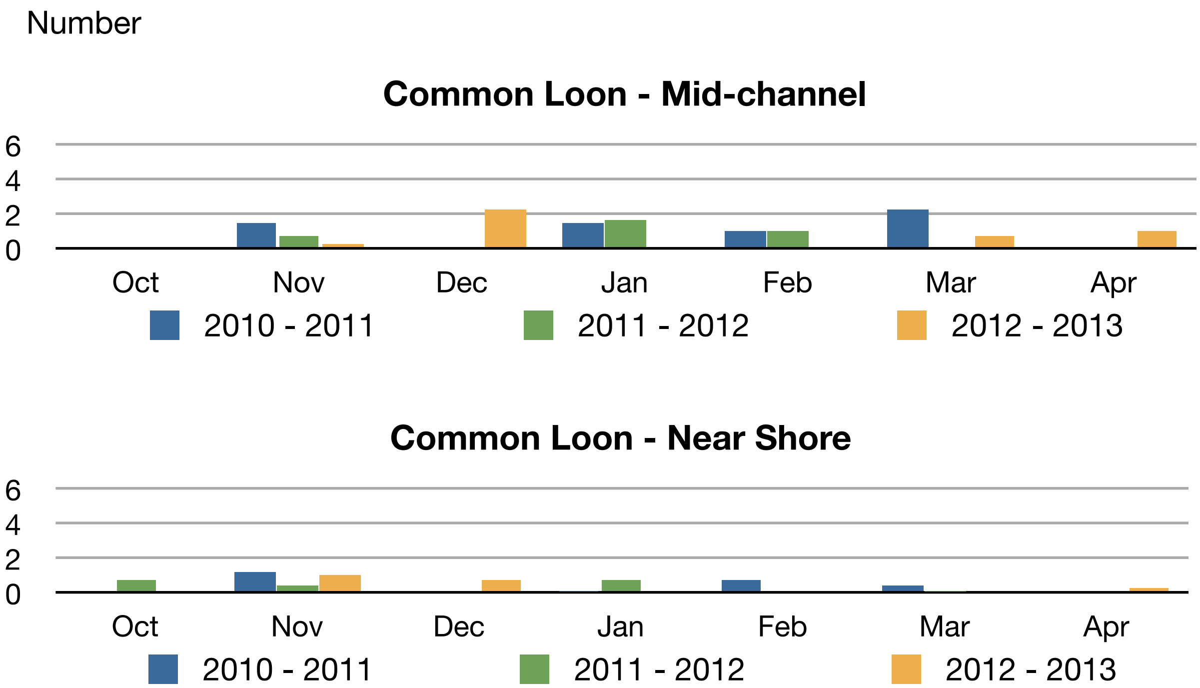
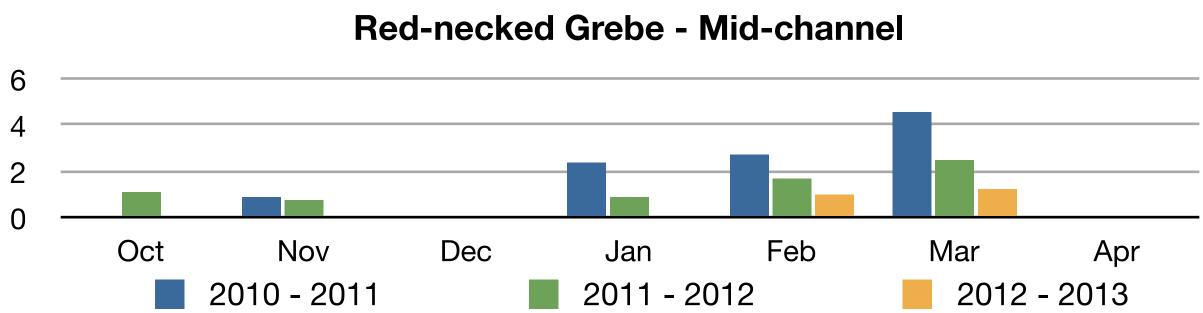


Figure 4. Small numbers of Common Loons were regular in both the mid-channel and in the near shore area of North Lubec, Maine. These birds appeared to be resident and we detected no obvious movement of wintering loons. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Red-necked Grebes were also regular in small numbers, <5 individuals, in both the near shore area and the mid-channel in Cobscook Bay, Maine (Fig. 5). In 2012-2013, this species was only observed in February and March. During the past three winters, single Horned Grebes (*Podiceps auritus*) were seen a total of four occasions in the near shore area and twice in the mid-channel (Table 3).

Number



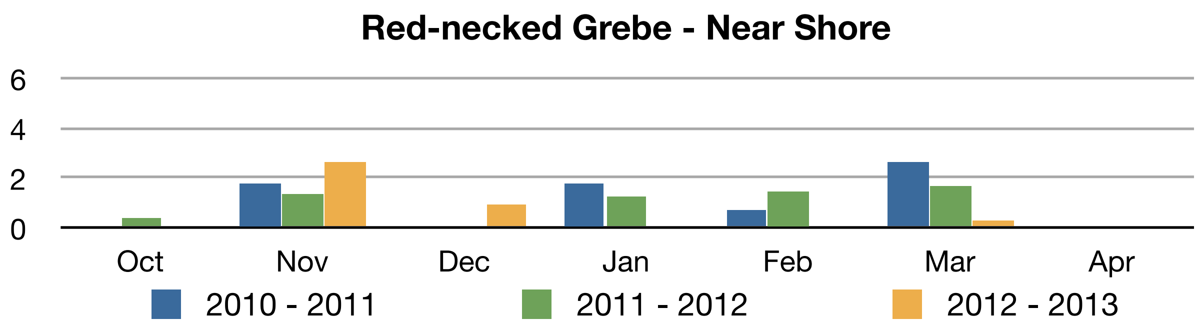


Figure 5. Red-necked Grebes were slightly more numerous in the mid-channel between January and March in all three winters. We observed a maximum of an average of 4.2 individuals in the mid-channel in March 2011. This species was regular but less numerous in the near shore area off North Lubec, Maine. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Cormorant spp. (Great and Double-crested) were present in small numbers and were slightly more numerous in 2010-2011 (Fig. 6). Cormorants occurred in very small numbers in the near shore area. Double-crested Cormorants were observed until November, and then departed the area, migrating south. Great Cormorants, the regular wintering cormorant species in Maine, were present from late December to March. We counted a maxima of 3.5 Great Cormorants in January 2011. There were substantially fewer Great Cormorants in the winters of 2011-2012 and 2012-2013.

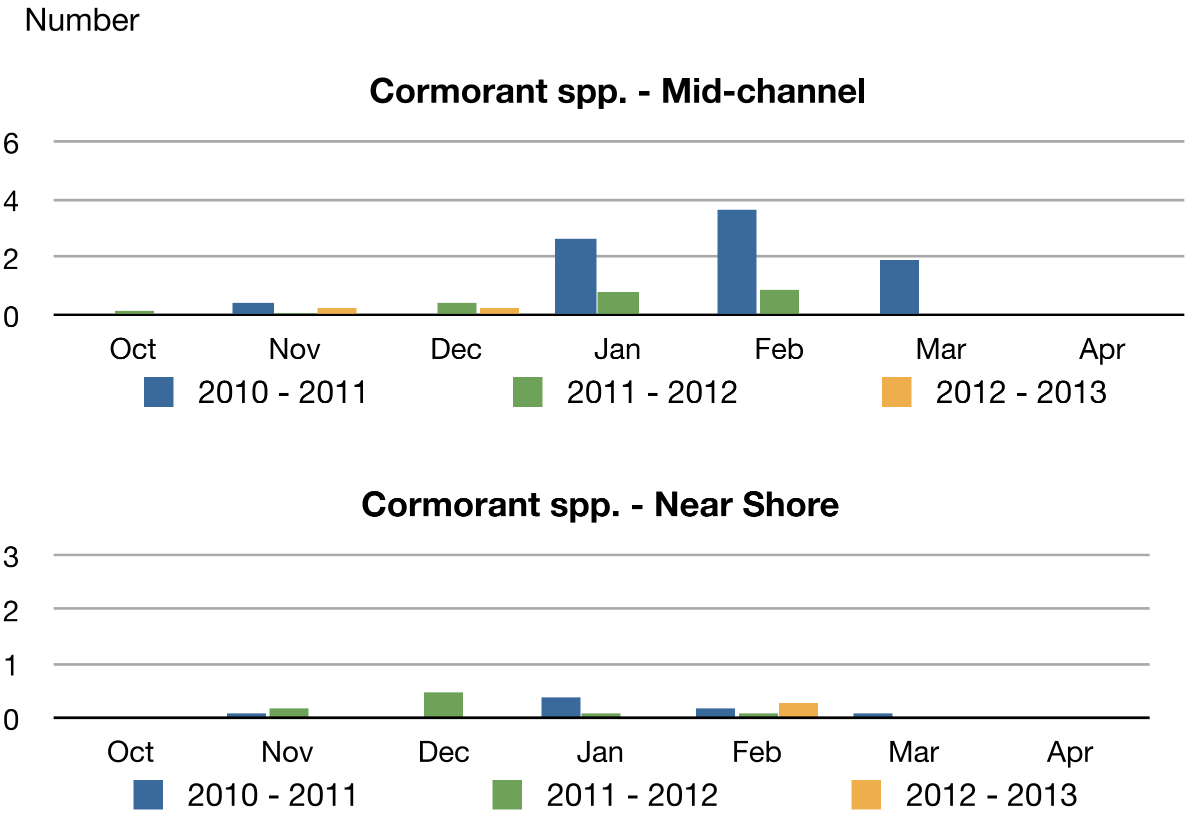


Figure 6. Cormorants were generally uncommon in the mid-channel and in the near shore at North Lubec, Maine. We counted a maxima of 3.5 cormorants in January 2011. Few Great Cormorants were observed in 2011-2012 and 2012-2013. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Black Guillemots were uncommon in winter (Fig. 7). We observed fewer than five individuals per survey in the mid-channel or the near shore during the period between October and April (Fig. 7). Razorbills were uncommon and were observed on five occasions; notably, three Razorbills were seen Nov 2010, and 9 individuals were seen January 2012 (Table 3).

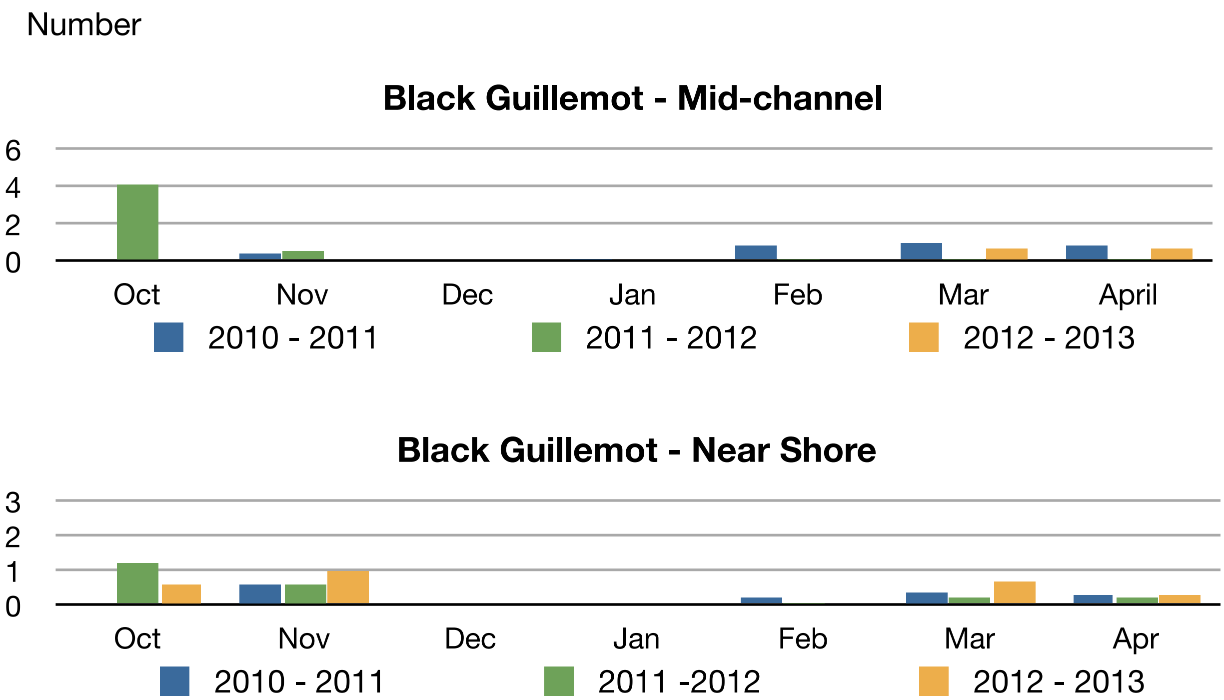


Figure 7. Black Guillemots in Cobscook Bay, Maine, were present in small numbers. This species was slightly more numerous in October and early November than during the winter months. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Surface Feeding Birds:

Three species of dabbling ducks (Mallard [*Anas platyrhynchos*], American Black Duck, Northern Pintail [*Anas acuta*]) were observed almost exclusively along the shore line in the near shore area of North Lubec, Maine, (Fig. 8). Dabbling duck numbers increased from January to early March 2011, but diminished thereafter. This increase was likely due to northbound migrants. We did not observe this trend in 2012 (Fig. 8). Three migrant Canada Geese (*Branta canadensis*) were seen once along the near shore, March 2012 (Table 3).

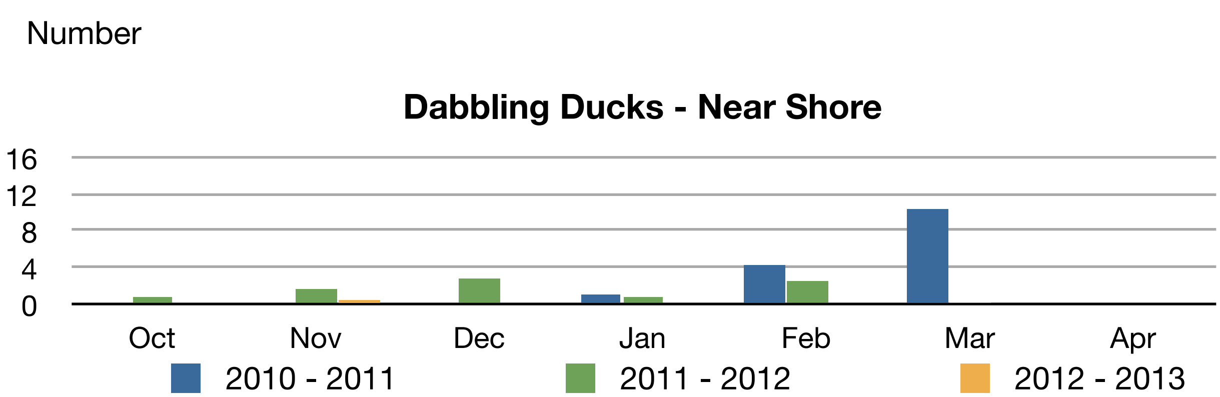
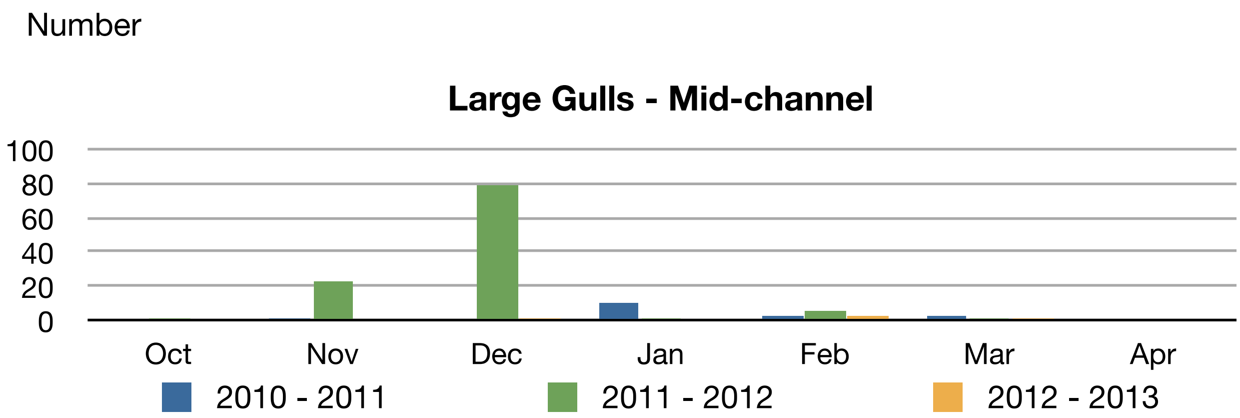


Figure 8. Small numbers of dabbling ducks occurred along the shoreline adjacent to the Landing Site at North Lubec, Maine. The largest concentration of 10.2 dabbling ducks was observed March 2011. These were probably migrants as few ducks were observed after this date. We did not conduct surveys in April 2011 and 2012, and also in February 2013.

Large gull species were comprised of Great Black-backed Gulls (*Larus marinus*), Herring Gulls (*L. argentatus*), Ring-billed Gulls (*L. delawarensis*), and Glaucous Gull (*L. hyperboreus*). Large gulls were generally present in small numbers except in the mid-channel in December 2011, when we observed an average of 80 individuals, primarily Ring-billed Gulls and Great Black-backed Gulls (Fig. 9). Large gulls were largely absent from Cobscook Bay in the winter of 2012-2013.



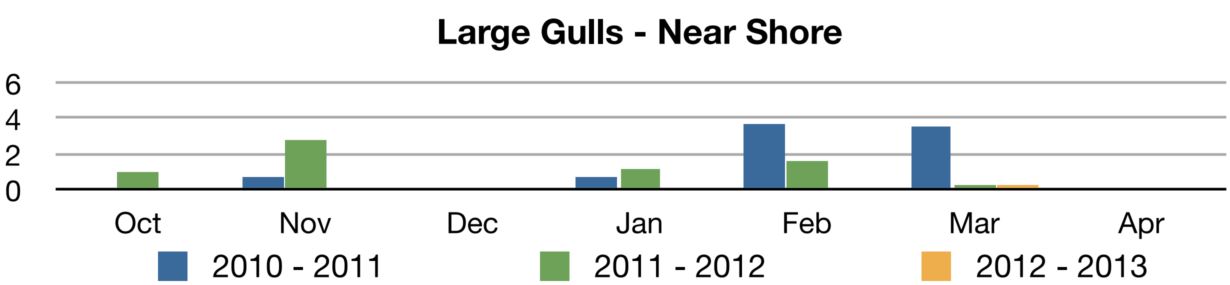


Figure 9. Large Gulls were not numerous in the mid-channel during the winter of 2010 - 2011 but were present in substantial numbers in December 2011. Large Gulls occurred in small numbers in the near shore area of North Lubec, Maine. We did not conduct surveys in April 2011 and 2012, and also in February 2013. Note: scale differs in this figure.

During the winter of 2012-2013, a single Bonaparte's Gull (*Chroicocephalus philadelphia*) was observed on a single occasion, in November 2013. In the first field season this species appeared in large numbers for a short period in late November and December 2011. Three hundred individuals were observed feeding in the mid-channel in November 2011 and 500 individuals were feeding in the mid-channel in December 2011. This species was not present on January 2012 and was not seen for the remainder of the winter. We did not observe Bonaparte's Gulls during the winter of 2011-2012.

Eleven species were uncommon and irregular in the Cobscook Bay, Maine study area in winter (Table 3). Great Blue Herons (*Ardea herodias*) are common in summer and early fall but depart by early November. The other species were unusual between late October and April.

Table 3. Several species of birds were uncommon or rare in the study site at Cobscook Bay, Maine, during the winters of 2010-2011, 2011-2012, and 2012-2013.

	Date	Nov	Jan	Feb	Mar	Oct	Nov	Mar	Nov	Jan	Feb	Mar
	Year	2010	2011	2011	2011	2011	2011	2012	2012	2012	2013	2013
Species	Site											
Canada Goose								3				
Common Goldeneye	North Lubec		3		1							2
	Mid-channel		13									
Barrow's Goldeneye	North Lubec			1								
Hooded Merganser	North Lubec	2					2					
Red-throated Loon	North Lubec	4									1	
	Mid-channel	1			1						1	
Horned Grebe	North Lubec			1		1	1				1	
	Mid-channel						1				1	
Wilson's Storm-Petrel (*Oceanites oceanites***)**	North Lubec					2						
	Mid-channel					2						
Great Blue Heron	North Lubec	1				1						
Black-legged Kittiwake (*Rissa tridactyla***)**	Mid-channel	3										
Ring-billed Gull (*Larus delawarensis***)**	North Lubec							1	1			
Razorbill	North Lubec	3		1						2	1	
	Mid-channel									7	1	1
Alcid spp.										6		

Diving Behavior

Common Eiders, Red-necked Grebes, and Black Guillemots spent substantially less time feeding in 2012-2013, compared to the previous two winters (Table 4). During the first two winter seasons, most diving seabirds spent >75% of their time actively feeding but this was only true for Common Loons and cormorants in 2012-2013 (Table 4). Common Eiders were observed loafing 98% of the time which was substantially different from the previous two winters.

Table 4. There was a decline in feeding activity for Common Eiders, Red-necked Grebes, and Black Guillemots in the 2012-2013 season. The largest decline

	Proportion of Time Feeding (%)			
Diving Birds	Species	2010-2011	2011-2012	2012-2013
	Common Eider	65	40	2
	Common Loon	86	94	89
	Red-necked Grebe	82	98	52
	Cormorant spp.	83	93	75
	Black Guillemot	76	100	44

Bald Eagle and shoreline:

We only observed a single Bald Eagle once in 2012-2013. It was seen flying past the study area on Feb 27, 2013. This was notably different from the 2011-2012 season when we recorded one to four Bald Eagles on all nine surveys. Bald Eagles were formerly listed as federally and state endangered, but this species was down-listed to threatened and is no longer listed at any level (http://www.maine.gov/ifw/wildlife/species/endangered_species/state_federal_list.htm). Dabbling ducks were the primary birds to use the shoreline at this time of year. We observed a single Great Blue Heron on October 23, 2011.

DISCUSSION

Wintering Waterfowl and Seabirds: We observed a decline in several species of seabirds in the Cobscook Bay study area in 2012-2013, compared to the previous two winters. Common Eider (Fig.2), Red-breasted Merganser (Fig. 4), and Cormorant (Fig.6) numbers were all down. There were very few large gulls as well (Fig. 9). However, Common Loon (Fig. 4), Red-necked Grebe (Fig. 5), and Black Guillemot (Fig. 7) numbers were generally similar during this three year period.

Diving Behavior:
Common Loons and cormorants fed at a similar rate as in the previous two winters but Common Eiders, Red-necked Grebes, and Black Guillemots spent less time diving for prey (Table 4). Common Eiders were observed diving only 2% of the time while they loafed on the surface for 98% of the time. This species dives for invertebrate prey such as Blue Mussels (*Mytilus edulis*) and other invertebrates. Although we saw this species regularly in the study area, the limited diving activity in the Deployment Area appears to indicate that this site is not a major feeding ground for this species. It seems unlikely that there will be substantial interaction between these diving birds and the TidGen™ Power System.

Endangered and Threatened Species:
We surveys did not find any federally or state endangered or threatened species. We observed a single Bald Eagle on only one occasion. The fact that this species was largely absent suggests that food resources were not as available as in the previous two winters. This species was removed as a threatened species in 2009 (Charles Todd, pers. comm.; MDIF&W).

Conclusion:
It is unclear whether the observed declines in seabird numbers were related to reduced prey abundance. This seems to be a reasonable possibility but it should be noted that these seabirds feed on different prey. Eiders are bottom feeders, consuming benthic invertebrates, whereas mergansers, cormorants, feed primarily on fish and crustacea. One would expect that loons, grebes, and Black Guillemots, which also feed on fish and crustaceans, but did not decline, would have been present in reduced numbers. This was not the case. C. Bartlett (pers. comm.) reported that there were generally fewer large gulls in the Eastport area in the winter of 2012-2013.

It seems unlikely that the operation of the TidGen® affected seabird numbers because it was not deployed in November 2012, a period when we observed no eiders or Red-breasted Mergansers.

Potential Impact for ORPC Activities in Winter:
The small number of birds found in the Deployment Area and along the near shore or shoreline at the expected Landing Site in the winter season indicates that ORPC installation and maintenance activities are unlikely to have any notable affect on birds at this season. The winter season provides an excellent opportunity for major installation activities.

Future Monitoring Schedule

Calendar of expected TidGen™ Power System installations in Cobscook Bay:

Winter 2013-2014: two additional TidGen™ devices are deployed to create a three-device TidGen™ Power System:

Monitoring schedule:

Continue post-deployment monitoring between November 2013 - April 2014 for 6 months - 1/month, weather permitting.

Final Report of 2013-2014 Winter Season due August 2014:

Literature Cited

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Larsen, P. F. 2004. Introduction to ecosystem modeling in Cobscook Bay, Maine:a boreal, macrotidal estuary. Northeastern Naturalist 11:1-12.

Longcore, J. R., and J. P. Gibbs. 1988. Distribution and Numbers of American Black Ducks along the Maine coast during the severe winter of 1980-1981. Pages 377 - 387 in Waterfowl in winter (M. W. Weller, ed.), University of Minnesota Press, Minneapolis.

Martin, P., and P. Bateson. 1986. Measuring behaviour: an introductory guide. Cambridge University Press, Cambridge.

Vickery, P. D. 2012. Report to ORPC on impact of TidGen™ Power System installation on birds in the Deployment Area in Cobscook Bay, Maine. Pp.8, available from ORPC, Portland, Me.

Appendix H

Agency Review Responses

Nathan Johnson

From: David Bean - NOAA Federal [david.bean@noaa.gov]
Sent: Friday, January 31, 2014 3:08 PM
To: Nathan Johnson
Cc: Jeff Murphy - NOAA Federal; Sean McDermott - NOAA Federal
Subject: change of NMFS staff for Adaptive Management Team

Hi Nate,

I wanted to notify you on the staffing change for the ORPC Cobscook Bay Tidal Energy project Adaptive Management Team
(AMT). I will be replacing Jeff Murphy as the Protected Resources staff person working with ORPC on the AMT.
I have the draft 2013 Environmental Management Report for review and will be providing any comments we might have concerning endangered species.

Thanks for your attention in this matter and look forward to working with you and ORPC on the future development of this project.

Dave
--

….>`~(((*>.....>`~((*>….>`~((*>…..>`~(((*>….>`~(((*>
David Bean
Fisheries Biologist
NOAA's National Marine Fisheries Service
Maine Field Station
17 Godfrey Drive
Orono, Maine 04473
Phone: 207-866-4172
Fax: 207-866-7342
Email: David.Bean@noaa.gov
….>`~(((*>......>`~((*>….>`~((*>…..>`~(((*>….>`~(((*>

Nathan Johnson

From: Megan.L.Drewniak@uscg.mil on behalf of Drewniak, Megan L LT [Megan.L.Drewniak@uscg.mil]
Sent: Thursday, February 20, 2014 2:00 PM
To: Nathan Johnson
Subject: RE: ORPC: CBTEP 2013 Environmental Monitoring Report, Agency Review Draft

Nate,

Thank you for including me on this agency review draft. The CG does not have any comments or additional input at this time.

Respectfully,

LT Megan Drewniak
Sector Northern New England
Waterways Management Division Chief
259 High Street
South Portland, ME 04107
Office: (207)-741-5421
Cell: (207) 899-6291
Megan.L.Drewniak@uscg.mil

-----Original Message-----
From: njohnson@orpc.co [mailto:njohnson@orpc.co]
Sent: Tuesday, February 18, 2014 9:40 AM
To: Michelle Magliocca - NOAA Federal; David Bean - NOAA Federal; Beyer, Jim R; 'Shepard, Steven'; Sean McDermott - NOAA Federal; Mercer, Linda; Drewniak, Megan L LT
Cc: Gayle Zydlewski; Moira Brown; Clement, Jay L NAE
Subject: FW: ORPC: CBTEP 2013 Environmental Monitoring Report, Agency Review Draft

CBTEP Adaptive Management Team:

This is a brief notice that the 30-day regulatory review period for the attached CBTEP 2013 Environmental Report ends on February 24, 2013 (next Monday). We look forward to your input on this draft.

Please note that we received the final Benthic Sampling Report from MER Associates last week. This final draft incorporated results of intertidal sample processing that wasn't complete at the time of our submittal. MER's discussion of the intertidal results is provided below:

Compared to the 2011 samples results, the mid-level (M) shows a reduction in both number of species and abundance, but this reduction appears related to the reduced amount of rockweed cover, (which provides both habitat as well as protection from desiccation) in 2013 within the level; the reduced amount of rockweed may or may not be related to the installation of the cable since rockweed cover is naturally patchy in the intertidal as shown in Figure 5 and 6. Results for the lower intertidal level (L) are very similar to those of the 2011 sampling event with number of species higher in 2013, although the dominant species remain the same, and abundance being very similar.

The intertidal benthic cores are dominated by oligochaetes representing 2,298 or 79.1% of the 3,144 organisms found in the samples; these are found primarily in the lower intertidal lever with some in the middle intertidal level. The isopod, Idotea sp., is found in the lower level (associated with rockweeds) and represents 9.4% of the benthic cores population. Amphipods, Talochestia sp., found in the upper (H) area associated with wrack weed, and Gammarus spp. found in the lower level, represent 7.1% and 6.0% of the population, respectively. Together, these species represent 3,008 or 95.7% of the organisms found in the benthic cores taken in the intertidal area.

The results of the intertidal benthic infauna core samples show strong similarity between the 2011 and 2013 samples, the number of species being the same and the dominant taxa being oligochaetes and nematodes in the mid-level. In the lower level (L) the number of species is higher in 2013 compared to 2011, but the population is again dominated by oligochaetes and nematodes. The 2011 lower level benthic core samples also contained blue mussels, Mytilus edulis, which were absent in 2013. Again, as mentioned above, the lack of small mussels may be related to the increase in green crabs observed at the site. The 2013 samples contained isopods and amphipods not seen in 2011. These latter differences are likely attributable to normal seasonal and inter-annual differences.

MER's report is attached to this email and will be included as an Appendix in the final submittal to FERC. Following the 30-day regulatory review period we intend to incorporate and address any comments received from the Adaptive Management Team and submit the final draft to FERC on March 2.

Best regards,

Nate J

From: Nathan Johnson
Sent: Friday, January 24, 2014 3:26 PM
To: 'Michelle Magliocca - NOAA Federal'; 'Jeff Murphy - NOAA Federal'; 'Beyer, Jim R'; 'Shepard, Steven'; 'Sean McDermott - NOAA Federal'; Mercer, Linda; 'Megan.L.Drewniak@uscg.mil'
Cc: 'Gayle Zydlewski'; 'Clement, Jay L NAE'; 'Moira Brown'
Subject: ORPC: CBTEP 2013 Environmental Monitoring Report, Agency Review Draft

CBTEP Adaptive Management Team:

ORPC Maine, LLC (ORPC) is pleased to submit the attached draft 2013 Environmental Monitoring Report for the Cobscook Bay Tidal Energy Project (P-12711). Operational accomplishments made by ORPC in 2013 enabled the collection of significant performance and environmental monitoring interaction data related to the TidGen(r) Power System. The 2013 environmental monitoring results continued to build an increased knowledge of marine life interaction with the TidGen(r) Power System and indicated negligible environmental effects for many elements of the monitoring plans.

This agency review draft is being submitted in accordance with our FERC license for the project, requiring a 30-day regulatory review. Due to file size the attached report does not include appendices. The full report with appendices is available at the following link:

Click here to view ORPC 2013 Enviro Report <https://www.dropbox.com/l/7uFJ7iZ4kZYqsFY3354L5c>

We look forward to your input and as always welcome any questions you may have.

Thank you again for your time and input on this Project.

Best regards,

Nate J

Nathan Johnson
DIRECTOR OF ENVIRONMENTAL AFFAIRS

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CLEAN, PREDICTABLE POWER FROM OCEANS AND RIVERS

Nathan Johnson

From: Sean McDermott - NOAA Federal [sean.mcdermott@noaa.gov]
Sent: Monday, February 24, 2014 4:13 PM
To: Nathan Johnson
Cc: Michelle Magliocca - NOAA Federal; David Bean - NOAA Federal; Beyer, Jim R; Shepard, Steven; Mercer, Linda; Megan.L.Drewniak@uscg.mil; Gayle Zydlewski; Moira Brown; Clement, Jay L NAE
Subject: Re: FW: ORPC: CBTEP 2013 Environmental Monitoring Report, Agency Review Draft

Nathan,
Thanks for sharing this draft for review by the Adaptive Management Team prior to filing with FERC. This report documents the process and findings very well. We understand the monitoring will be in hiatus, as described in the report. To that end we do not have recommendations at this time. Please keep us posted as ORPC gets closer to the next deployment phase.

One comment on the report. The acoustics monitoring subsection Under Environmental Monitoring Results (Section 9.2) identifies data for the test until in freewheel and generating mode. The results seem to indicate the level of noise generated does not exceed limits known to cause injury. I also recall statements made suggesting the natural background noise at this site is very high. It might be worth noting the ambient level of noise to put the project into context.

Lastly, we support the continued cooperative arrangement between OPRC Maine and the University of Maine, Orono. The monitoring completed by the University has been tremendously useful in understanding the level of potential impacts associated with the test units. We also look forward to improvements to the fisheries monitoring techniques to gain better understanding of fish-project interaction.

Thanks again.

-Sean

On Tue, Feb 18, 2014 at 9:40 AM, Nathan Johnson <njohnson@orpc.co> wrote:

CBTEP Adaptive Management Team:

This is a brief notice that the 30-day regulatory review period for the attached CBTEP 2013 Environmental Report ends on February 24, 2013 (next Monday). We look forward to your input on this draft.

Please note that we received the final Benthic Sampling Report from MER Associates last week. This final draft incorporated results of intertidal sample processing that wasn't complete at the time of our submittal. MER's discussion of the intertidal results is provided below:

Compared to the 2011 samples results, the mid-level (M) shows a reduction in both number of species and abundance, but this reduction appears related to the reduced amount of rockweed cover, (which provides both habitat as well as protection from desiccation) in 2013 within the level; the reduced amount of rockweed may or may not be related to the installation of the cable since rockweed cover is naturally patchy in the intertidal as shown in Figure 5 and 6. Results for the lower intertidal level (L) are very similar to those of the 2011 sampling event with number of species higher in 2013, although the dominant species remain the same, and abundance being very similar.

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MER's report is attached to this email and will be included as an Appendix in the final submittal to FERC. Following the 30-day regulatory review period we intend to incorporate and address any comments received from the Adaptive Management Team and submit the final draft to FERC on March 2.

Best regards,

Nate J

From: Nathan Johnson
Sent: Friday, January 24, 2014 3:26 PM
To: 'Michelle Magliocca - NOAA Federal'; 'Jeff Murphy - NOAA Federal'; 'Beyer, Jim R'; 'Shepard, Steven'; 'Sean McDermott - NOAA Federal'; Mercer, Linda; 'Megan.L.Drewniak@uscg.mil'
Cc: 'Gayle Zydlewski'; 'Clement, Jay L NAE'; 'Moira Brown'
Subject: ORPC: CBTEP 2013 Environmental Monitoring Report, Agency Review Draft

CBTEP Adaptive Management Team:

ORPC Maine, LLC (ORPC) is pleased to submit the attached draft 2013 Environmental Monitoring Report for the Cobscook Bay Tidal Energy Project (P-12711). Operational accomplishments made by ORPC in 2013 enabled the collection of significant performance and environmental monitoring interaction data related to the TidGen® Power System. The 2013 environmental monitoring results continued to build an increased knowledge of marine life interaction with the TidGen® Power System and indicated negligible environmental effects for many elements of the monitoring plans.

This agency review draft is being submitted in accordance with our FERC license for the project, requiring a 30-day regulatory review. Due to file size the attached report does not include appendices. The full report with appendices is available at the following link:

Click here to view ORPC 2013 Enviro Report

We look forward to your input and as always welcome any questions you may have.

Thank you again for your time and input on this Project.

Best regards,

Nate J

Nathan Johnson
DIRECTOR OF ENVIRONMENTAL AFFAIRS

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CLEAN, PREDICTABLE POWER FROM OCEANS AND RIVERS

--
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STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION

PAUL R. LEPAGE
GOVERNOR

PATRICIA W. AHO
COMMISSIONER

February 19, 2014

Nathan Johnson, Director of Environmental Affairs
Ocean Renewable Power Company
120 Exchange Street, Suite 508
Portland, ME 04101

RE: 2014 Environmental Monitoring Report for the Cobscook Bay Tidal Power Project

Dear Mr. Johnson;
This is in response to your request for comments on the 2014 Monitoring Report. The Department concurs with the statements in the report that the creation of Adaptive Management Team (AMT) has been a success for this project. The AMT has allowed the applicant and the regulatory agencies to come to consensus regarding changes to the environmental monitoring plan in an effective and efficient manner.

The Department recognizes the difficulty ORPC has had with both the operation of the TidGen and the collection of some of the data for the environmental monitoring, specifically, the fish and marine life interaction studies. We look forward to the time when ORPC can overcome these technical challenges and be able to provide meaningful data for these critical studies and produce power. The Department agreed with the AMT when it decided to forego further environmental monitoring while the TidGen was not in the water. The environmental monitoring will commence, as appropriate, once the TidGen is placed back in the water. The Department concurs with the remainder of the report; however we will differ to the experts in their area of expertise to make the final comments.

If you have any questions please call me at (207) 446-9026 or e-mail me at Jim.R.Beyer@maine.gov.

Sincerely,

JAMES R. BEYER
Regional Licensing and Compliance Manager
Division of Land Resource Regulation
Bureau of Land & Water Quality
Eastern Maine Regional Office - Bangor

STATE OF MAINE
DEPARTMENT OF MARINE RESOURCES
MARINE RESOURCES LABORATORY
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PAUL R. LEPAGE
GOVERNOR

PATRICK C. KELIHER
COMMISSIONER

February 21, 2014

Nathan E. Johnson
ORPC
120 Exchange St., Suite 508
Portland, ME 04101

Dear Mr. Johnson,

Thank you for the opportunity to review ORPC's annual report to the Federal Energy Regulatory Commission for the Cobscook Bay Tidal Energy Project (P-12711). The Maine Department of Marine Resources (DMR) continues to support the adaptive management approach that ORPC has undertaken for the Cobscook Bay Tidal Energy Project monitoring program.

As you noted, we discussed the 2013 environmental monitoring results during the September 10, 2013 the Adaptive Management Team meeting. The DMR has no additional comments on the environmental and biological monitoring results (Articles 405, 406, 407, and 410) that are presented in the report, or on the MER Benthic Report.

The DMR concurred with Adaptive Management Team on ORPC's decision to forego monitoring while the TidGen is out of the water. We look forward to continued participation on the adaptive management process when monitoring is resumed.

Sincerely,

Linda P. Mercer

Linda P. Mercer
Director
Bureau of Marine Science

http://www.Maine.gov/dmr

PHONE: (207) 633-9500 FAX:
(207) 633-9579

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Appendix I

Summary of 2013 Environmental Monitoring

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Summary of 2013 Environmental Monitoring



Introduction

ORPC Maine, LLC, a wholly-owned subsidiary of Ocean Renewable Power Company, LLC (collectively ORPC), submitted its 2013 Environmental Monitoring Report for the Cobscook Bay Tidal Energy Project (Project) on March 3, 2014 in compliance with ORPC's Federal Energy Regulatory Commission (FERC) pilot project license, P-12711. The 2013 environmental monitoring results continued to increase knowledge about marine life interaction with the TidGen® Power System and indicated negligible environmental effects for many elements of the monitoring plans.

Project Operation

ORPC received its pilot project license on February 12, 2012. The Project installation commenced on March 20, 2012 and concluded with the installation of the turbine generator unit (TGU) on August 14, 2012. First power was delivered to Bangor Hydro Electric Co. (now Emera Maine) on September 5, 2012. The TGU was retrieved and redeployed several times during the winter of 2012/2013 for maintenance. After successfully redeploying the TGU on February 22, 2013, ORPC successfully ran the power system at approximately 98% availability until April 21, 2013, enabling significant data related to system operation (performance and environmental interaction) to be gathered. The TGU was retrieved in July 2013 and, per federal licensing and funding requirements, subjected to a detailed inspection of its components. The inspection resulted in significant lessons learned and the charting of a technology road map to guide future product improvements, cost reductions and operational enhancements. The U.S. Department of Energy has further invested in ORPC's technology optimization program through two awards for the advancement of power takeoff technology and turbine control mechanisms.

Adaptive Management for Environmental Monitoring

ORPC developed an Adaptive Management Plan as required by the FERC pilot project license. Federal and state resource agencies participate with ORPC on the Adaptive Management Team (AMT) and provide oversight on the Plan. Through the adaptive management process, ORPC has requested modifications to environmental monitoring to clarify elements of the plan and reduce frequency of monitoring surveys based on increased knowledge of species presence and environmental effects. With AMT concurrence, ORPC's license modifications have been accepted by FERC. This process demonstrates a clear reduction in effort and cost on the part of ORPC based on the risk reduction demonstrated by environmental monitoring results.

2013 Environmental Monitoring Results

Acoustic Monitoring
Measurements of the in-water noise level related to the TidGen® Power System demonstrated that sound levels in the vicinity did not exceed 120 dB re 1 μPa2/Hz at any frequency while the turbine was rotating, both while generating and when freewheeling (rotating without generating). Further, the integrated rms levels from 20 Hz to 20 kHz did not exceed 120 dB re 1 μPa2, the level some regulators have used to establish level B harassment of marine mammals.

Benthic and Biofouling Monitoring
Observations of the exposed cable(s) indicated there continues to be little, if any, evidence of scouring or disturbance to the bottom or the associated faunal community. Results of the post-deployment benthic sampling survey indicated a healthy and highly productive benthic community with no discernible continuing effects from either the installation or operation of the cable. Assessments conducted in July 2013 indicated minor biofouling on the TGU with more significant growth on the bottom support frame; however, the functionality of the system did not appear to be compromised.

Fisheries and Marine Life Interaction Monitoring
Hydroacoustic assessments conducted by the University of Maine (UMaine) demonstrate that while fish density was indeed variable, patterns were repeatable and will be useful in understanding the effects of devices. Data collected from the side-looking sonar during operation was minimal and only limited to when the TidGen® Power System was not generating. However, available data allowed UMaine to identify some key issues that should be addressed in the future with the goal of collecting data while the turbine is generating power.

Hydraulic Monitoring
Hydrodynamic modeling conducted by Sandia National Laboratories continued to contribute to an understanding of hydraulic effects of the TidGen® Power System. Their work investigated velocity deficits created by the turbines and wake recovery as well as optimization of turbine arrays. Results of the scour monitoring continued to indicate minimal change in seabed elevation around the foundation piles.

Marine Mammal Monitoring
Marine mammal observations made by trained ORPC personnel in 2013, including during periods of operation, maintenance and retrieval indicated no changes in marine mammal presence or behavior. There was no evidence of marine mammal strike with system components during deployment and retrieval or with TGU foils during operation. In addition, the continued presence of marine mammals in the vicinity of the Project indicated that the TidGen® Power System was not acting as a deterrent or a barrier to passage into the inner portions of Cobscook Bay.

Sea and Shorebird Monitoring
The Center for Ecological Research observed a decline in several species of seabirds in the Cobscook Bay study area in 2012-2013; however, they determined that it was unlikely that the operation of the TidGen® Power System affected seabird numbers because it was not deployed in November 2012, when no eiders or Red-breasted Mergansers were observed.

<u>2014 Environmental Monitoring</u>
ORPC collaborated with the Project’s AMT to modify levels of environmental monitoring during the current technology optimization phase. As a result, FERC issued a temporary variance from environmental monitoring on October 29, 2013. In 2014 ORPC will build on the knowledge base of fisheries and marine life interaction with our power systems through two innovative projects:

> *OCGen® Module Mooring Project:* This project, which will be installed at the Cobscook Tidal Energy Project site, will demonstrate ORPC’s floating turbine system and associated anchoring system. OCGen® represents a significant advancement in marine hydrokinetic technology and deployment procedures. ORPC will work in conjunction with UMaine to collect fisheries interaction data around the OCGen® module using hydroacoustics.
>
> *RivGen® Power System Commercialization Project:* ORPC will installation its RivGen® Power System at the Village of Igiugig, Alaska on the Kvichak River in 2014. This presents a unique opportunity to gather fisheries interaction data in a shallow, clear water environment.

For further information:
The entire ORPC 2013 Environmental Monitoring Report for the Cobscook Bay Tidal Energy Project is available on ORPC’s website. For any additional information, contact Nathan Johnson, Director of Environmental Affairs, at njohnson@orpc.co or (207)-221-6254.