Fisheries and Marine Life Interaction Monitoring Plans Annual Report

March 2013

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1.0 Introduction

1.1 Study Context and Purpose

Ocean Renewable Power Company, LLC (ORPC) has deployed a TidGen™ Power System in outer Cobscook Bay, Maine, as the first stage of the Cobscook Bay Tidal Energy Project (Figure 1). This installation 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.

1.2 Study Design

1.2.1 Fisheries monitoring plan

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 tidal, seasonal and spatial variability in the presence of fish 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 vertical distribution and relative abundance of fish at the project and control site (for relative comparison). Pre-deployment data were collected in 2010, 2011, and early 2012, and will be compared to post-deployment data to quantify changes in fish presence, biomass, and vertical distribution associated with the installation of the TidGen™ power system. Surveys are planned through the year 2017.

1.2.2 Marine life interaction monitoring plan

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, and will attempt to quantify changes in behavior in response to the TidGen™ unit. Side-looking hydroacoustic data will be collected for three years after the deployment of the TidGen™ Power System.

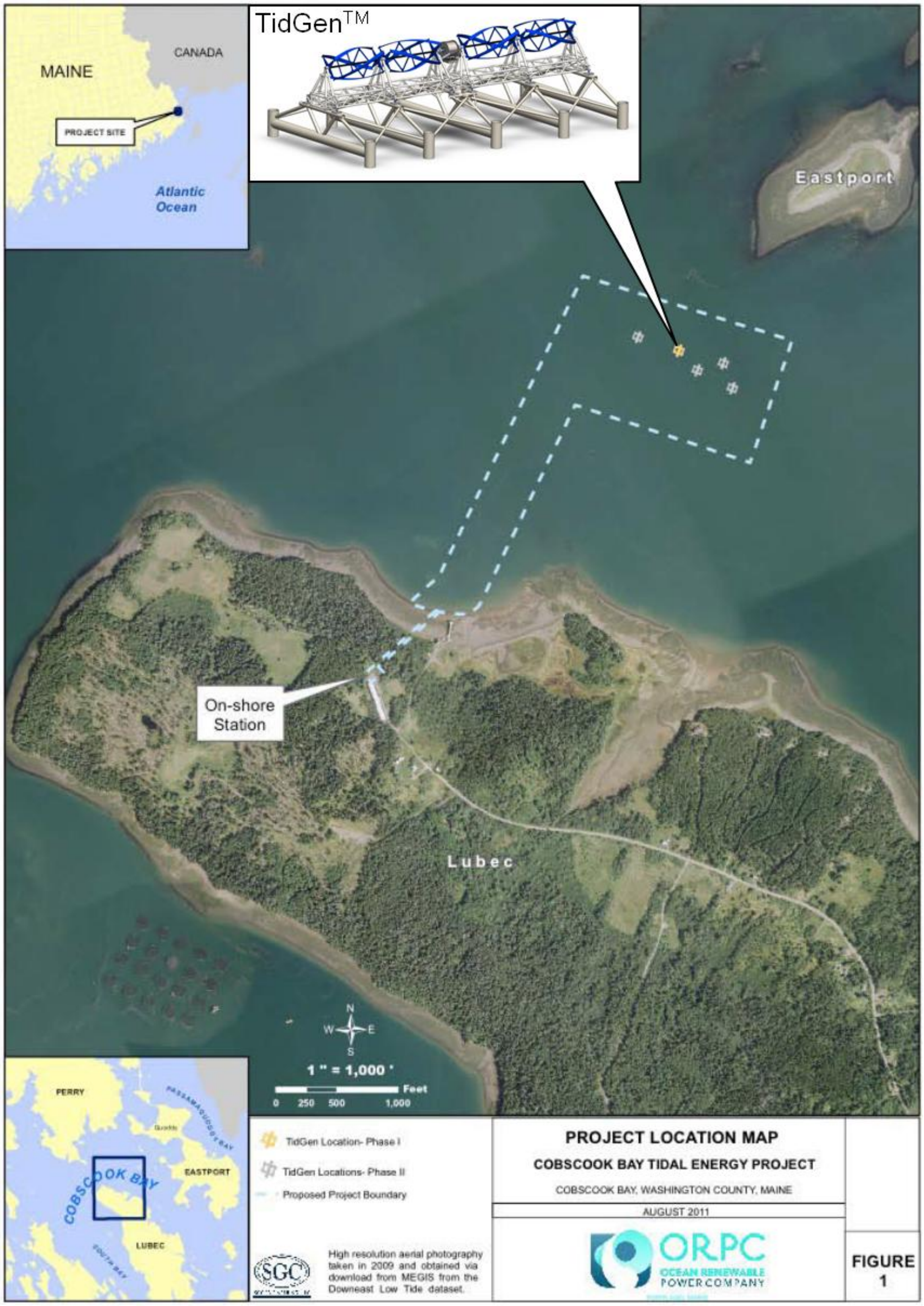


Figure 1. Cobscook Bay Tidal Energy Project location map and TidGen™ device drawing (CBTEP Fisheries and Marine Life Interaction Plan, 2012). The yellow icon represents the present location of a TidGen™ device. The grey icons represent potential TGU locations to complete an array in the future.

1.3 In This Report

This first report details: (1) approach to date; (2) preliminary results; and (3) challenges to date, how they are being addressed, and future work.

2.0 Approach

2.1 Fisheries Monitoring Plan (down-looking hydroacoustic surveys)

2.1.1 Study design

To compare the relative abundance and vertical distribution of fish at the project site and a control site nearby, both before and after turbine deployment, down-looking hydroacoustic surveys are conducted from a research vessel for one 24-hour period several times per year at each site (Table 1). Locations during pre-deployment sampling include one site at the project location (CB1) and one control site (CB2), approximately 1.6 km seaward of the project site (Figure 2). During post-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 activity and related safety concerns around the TidGen™. January and March were pre-deployment surveys, so only CB1b and CB2 were sampled. CB1b in March was only sampled for 12 hours due to extreme weather. There was no November sample because the TGU was removed for maintenance.

The down-looking surveys are 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. In May 2012, a Simrad EK60 200 kHz split beam echosounder was added to the previous sampling protocol. The transducers are mounted over the side of the research vessel 1.8 meters below the surface, and they ensonify (alternately, every 0.5 seconds) an approximately conical volume of water extending to the sea floor. A 600 kHz Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP) is set to record mean current speed in 1 meter bins to the sea floor every 30 minutes during the survey. ADCP data are used to determine slack tide periods during sampling.

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, CB1b, and CB2, 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			

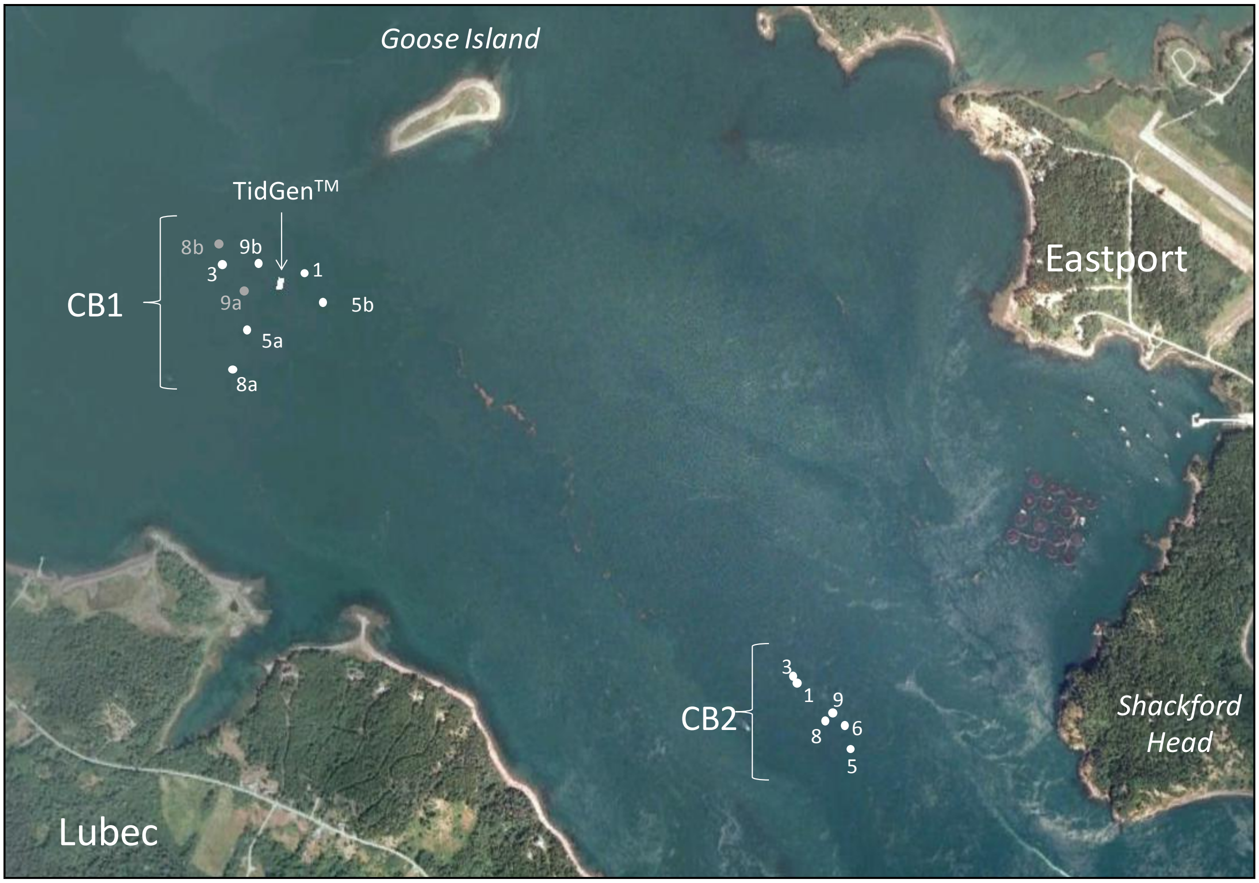


Figure 2. Fisheries Monitoring Plan study area and down-looking hydroacoustic survey locations for 2012. Each point represents the mooring location for one 24-hour survey. Numbers indicate the month of each survey; a and b indicate CB1a or CB1b, if applicable. Darker points (8b and 9a at CB1) are approximate due to GPS error.

The single-beam transducer, used for relative comparison to baseline data collected in 2010 and 2011, does not provide information on an acoustic target's location within the ensonified beam cross-section. This lack of angular data prevents meaningful target strength (TS) data, and therefore estimates of absolute fish abundance, from being acquired. Instead, a relative hydroacoustic measure of fish biomass is used to examine changes in fish biomass over time. This relative measure is also used to assess vertical distribution of fish biomass in the water column.

Comparisons of fish biomass and vertical distribution are 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) statistical design. In the future, split beam data will be used to provide accurate TS on single fish and potentially allow quantitative measures of fish movement.

2.1.2 Data processing

Hydroacoustic data are processed using Echoview® software (5.3, Myriax Pty. Ltd., Hobart, Australia), and statistical analyses are carried out in MATLAB (r2011b, The MathWorks, Inc., Natick, MA, USA). 200 kHz frequency data are used in analyses. Processing includes scrutinizing the data and removing areas of noise (e.g., from electrical interference, a passing boat's depth sounder, high boat motion). Hydroacoustic interference from entrained air is common in the upper 10 m of the water column; analyses are therefore limited to the lowest 15 m of the water column. Unwanted hydroacoustic signals (such as plankton, krill, and fish larvae) are excluded by eliminating backscatter from targets with TS less than -60 dB. Most fish have a 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 will be excluded from analyses. Fish presence is measured on a relative scale using volume backscatter (S_V), which is a measure of the sound scattered by a unit volume of water and is assumed proportional to biomass (Simmonds and MacLennan 2005). S_V is expressed in the logarithmic domain as decibels, dB re 1 m^{-1}. Area backscatter, s_a, is the summation of volume backscatter over a given depth range, and is also proportional to fish biomass (Simmonds and MacLennan 2005). s_a is expressed in the linear domain ($m^2 \cdot m^{-2}$) and is used for vertical distribution comparisons.

Because flowing tides are the focus of this study, hydroacoustic data during slack tides are not included in analyses. Slack tides span one hour, centered at the time of low or high water. Mean current speed is obtained for each half hour by averaging ADCP data from surface to seafloor. The recorded time with the lowest water flow value is deemed slack. The half hour before and after this time is then removed from hydroacoustics data processing and analyses.

Inspected hydroacoustic data are divided into 30-minute segments. Echoview is used to calculate the mean S_v of the water column for each 30-min interval. For each interval, s_a is calculated for 1-m layers within the water column. By calculating the proportion of total water column s_a that is contributed by each 1-m layer of water, the vertical distribution of fish is constructed for each 30-min time interval. Layers are measured upward from the sea floor, rather than downward from the surface, as the turbine is installed at a fixed distance above the bottom (top of turbine at 9.6 m above the sea floor). In the future, split beam data will be processed similarly to determine whether it can be used for comparison to previously collected single beam data. At minimum, split beam data will be used to (1) make meaningful comparisons of the vertical distribution of fish using s_a; (2) quantify the number of fish tracks observed in 1 m layers measured up from the sea floor; and (3) provide accurate TS for tracked fish. Analyses comparing S_v between the single and split beam systems are underway.

Statistical comparisons of overall fish biomass and vertical distribution can be conducted among survey dates using t-test and linear regression analyses, as in Viehman 2012. Briefly, mean water column S_v values for each entire 24 h survey can be compared to other 24 h surveys using t-tests (significance level = 0.05). Vertical distributions can be compared by linear regression of one distribution onto the other. Shape similarity is indicated by a significant fit (significance level of 0.05) and a positive slope. Negative slope or insignificant fit indicates dissimilar distributions. For a full description of single-beam data analyses methods used and results from pre-deployment data collected, see Viehman 2012.

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

2.2.1 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 3). 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 of the TidGen™ device (Figure 3). The actual sampled volume used in data analysis is smaller, extending to the far edge of the turbine (78.1 m) rather than beyond. This is 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 and downstream of the device during the ebb tide. 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.

The echosounder records data continuously (though to date, collection has been intermittent; see Sections 3.2.1 and 4.2). Continuous data collection at a fast sample rate (4 to 6 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 within the beam (Figure 4). 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, where fish would be likely to encounter the turbine; above the turbine zone (A, Figure 3a); and beside the turbine zone (B, Figure 3a). Fish numbers and movement in each zone provide indicators of turbine avoidance. The total sampling volume to 78.1 m range (for a 7° cone) is 1,866 m^3, and of this, 607m^3 are within the turbine zone, 345 m^3 are beside the turbine zone, and 914 m^3 are above the turbine zone.

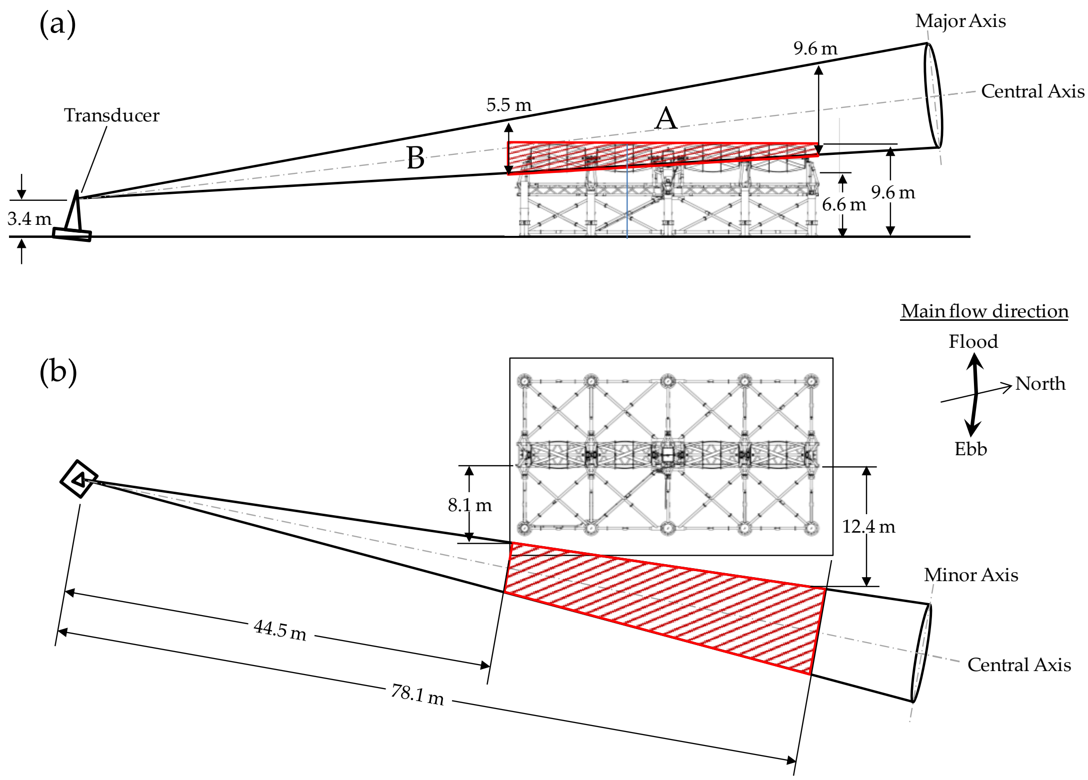


Figure 3. Marine Life Interaction Monitoring Plan setup. TidGen™ device and Simrad EK60 support structure shown from (a) the seaward side and (b) above. Hydroacoustic beam represented as 7° cone (half-power beam width) in solid black lines. Red hatched area indicates sampled volume within the turbine zone, A indicates the volume sampled above the turbine, and B indicates the volume sampled beside the turbine. Flow directions shown were provided by ORPC.

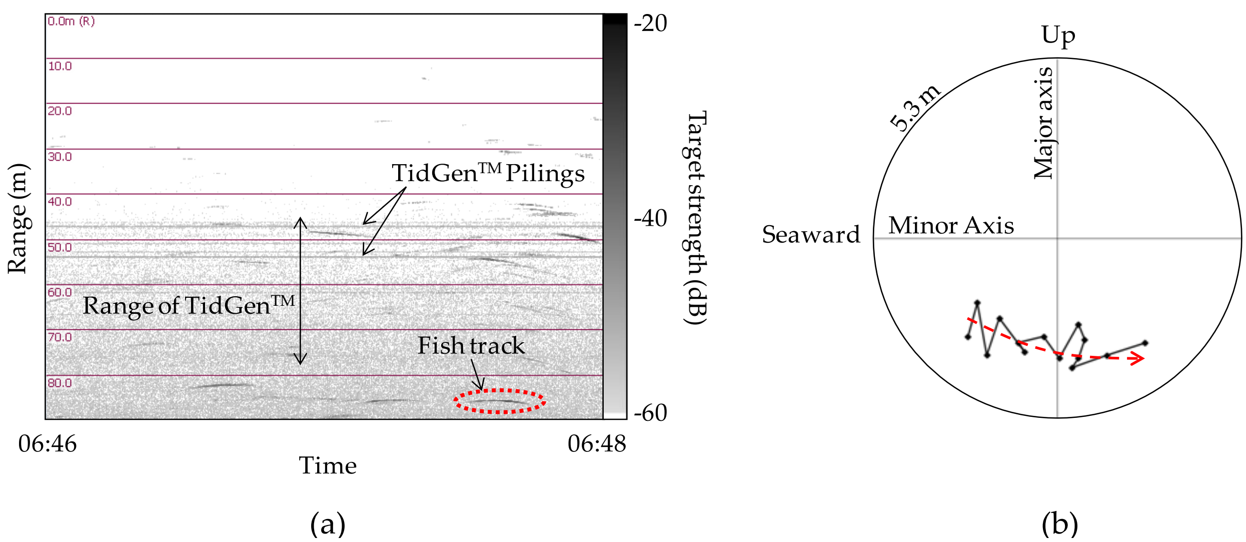


Figure 4. (a) Sample of side-looking hydroacoustic data from 9/30/2012 during the flood tide. (b) Fish in red dashed oval in (a) tracked through beam cross section. Outer circle represents 3.5° off-axis, or 5.3 m at this range. Each dot is a single detection of the fish. Red dashed arrow indicates direction of movement.

Other data collected (provided by ORPC) include current speed and direction, turbine movement in rotations per minute (RPM), and turbine operation state (generating or not). Current speed and direction are collected by a flow meter mounted to the TidGen™ support frame.

2.2.2 Data processing

Echoview is used to process raw side-looking split beam hydroacoustic data. Processing in Echoview begins 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), and setting a TS threshold of -60 dB (consistent with down-looking approach) to exclude plankton and other small objects from analyses. Echoes from single targets are detected, excluding those more than 3.5° from the central axis of the beam or beyond 78.1 m from the transducer (due to the increase in surface noise interference). Single target detection parameters are summarized in Table 2. Echoview's fish tracking module is then used to trace the paths of individual fish through the sampled volume. Schools of fish are excluded from analyses. Fish track data are then exported from Echoview to be further analyzed using MATLAB. The data for each fish track include time of fish detection, location of the fish within the beam over time (range, depth, major and minor off-axis angles), fish TS, and fish swimming speed and direction. Data can then be grouped by month for further analyses.

Flood and ebb tide data are treated separately for all except overall summary data (e.g., total fish TS distribution and fish numbers). This is because a fish's approach to the turbine is sampled during the flood tide while its departure from the turbine is sampled during the ebb tide, and behaviors during each are assumed to differ (Viehman 2012; Viehman and Zydlewski submitted).

Table 2. Single target detection settings in Echoview.

Parameter	Value	Units
Target strength threshold	-60.00	dB
Pulse length determination level	6.00	dB
Minimum normalized pulse length	0.60	Unitless
Maximum normalized pulse length	1.50	Unitless
Beam compensation model	Simrad LOBE	
Maximum beam compensation	6.00	dB
Maximum standard deviation of minor-axis angles	1.000	Degrees
Maximum standard deviation of major-axis angles	1.000	Degrees

Target strength

Target strength (TS) is a point source measure and is the relative amount of acoustic energy reflected back toward the transducer by an object, represented in decibels (dB; 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). Depending on the species known to be in the area, TS may be used to identify with some probability the species of a detected fish and its size. The TS distribution is therefore extracted for each month of data in order to provide information on the size of fish sampled. The fish community of Cobscook Bay is also being assessed by UMaine (preliminary results from 2012 are included in the Appendix A), and results from that study will aid in identifying probable species represented by hydroacoustic targets.

Number and location of fish tracks

The total number of fish tracks detected by Echoview for each month of hydroacoustic data provides an index of the abundance of fish in the sampled volume over time.

The location of each fish in the sampled volume is used to place it in one of the three zones (in the turbine zone, beside the turbine zone, or above the turbine zone; Figure 3a). Density of fish in each zone is calculated for each ebb and flood tide by dividing the total number of fish detected in each zone by the volume sampled within the zone over the course of the tide. This volume is 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 time sampled. The linear distance of water is the mean current speed multiplied by the sampling duration. In this way, fish counts were normalized for varying sample times and volumes, allowing the direct comparison of densities from different tidal stages. Densities obtained from each tidal stage are then grouped by month and can be compared to those from other months using a t-test (significance level = 0.05).

Fish swimming speed and direction of movement

The speed and direction of movement of each fish is compared to the current speed and direction at the time of fish detection (when data are available). Higher deviation from the current speed or direction within the turbine zone than in other zones may indicate avoidance behavior. For each month, the difference in fish speed and direction from current speed and direction in each zone is calculated for each tidal stage (flood or ebb) and can be compared to corresponding values from other months using t-tests (significance level = 0.05).

If current speed and direction information is not available (see section 3.2.1), the distributions of fish movement direction and speed and their variance can be used as indicators of avoidance. More variable movement directions are associated with avoidance reactions (e.g., diverting above, below, or to the side of the turbine, or reversing direction; Viehman 2012). Variance in speed and direction within each zone can be compared using one-way ANOVA tests (significance level of 0.05).

3.0 Results to Date

3.1 Fisheries monitoring plan (down-looking hydroacoustics)

Down-looking hydroacoustics data for the Fisheries Monitoring Plan have been collected as outlined in Section 2.1. Total water column fish biomass was determined at each site for each month (Figure 5). Vertical distribution of fish biomass by 1 meter depth layers (measured upward from the sea floor) was determined at each site for each month (Figure 6 and Appendices B and C). Pre-deployment data from 2010 and 2011 were analyzed previously and are not included here, but full analyses are available in Viehman 2012. March had the lowest biomass and May had the highest. As the summer months progressed, biomass decreased.

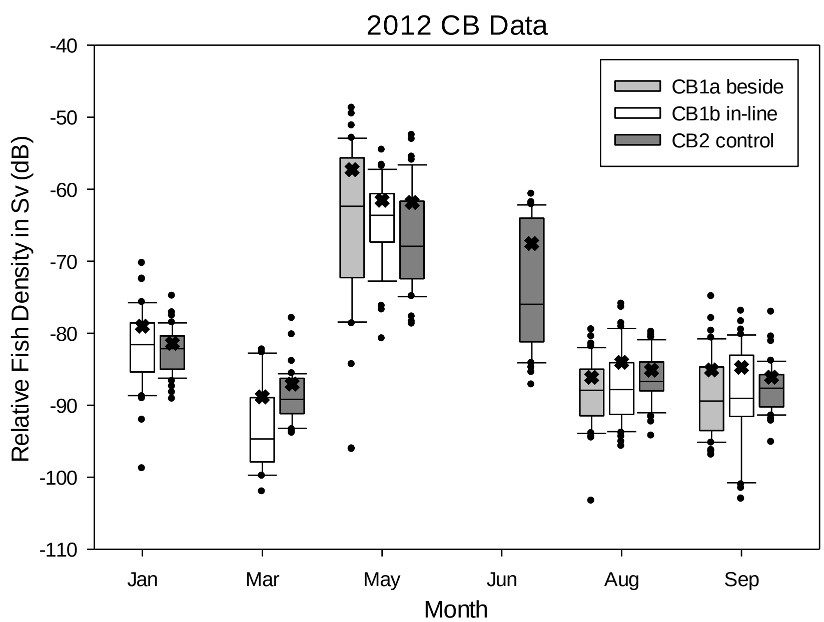


Figure 5. Total water column fish biomass recorded in Cobscook Bay at three sites in 2012. Sv (in dB) is displayed on the y-axis. Each site is represented for each month that data were collected. The box plot shows the 25th, 50th, and 75th percentiles. Each whisker represents the 10th and 90th percentile. The "x" on each is the overall mean. Dots outside the whiskers are outliers and display the variability in fish biomass over a 24 hour period.

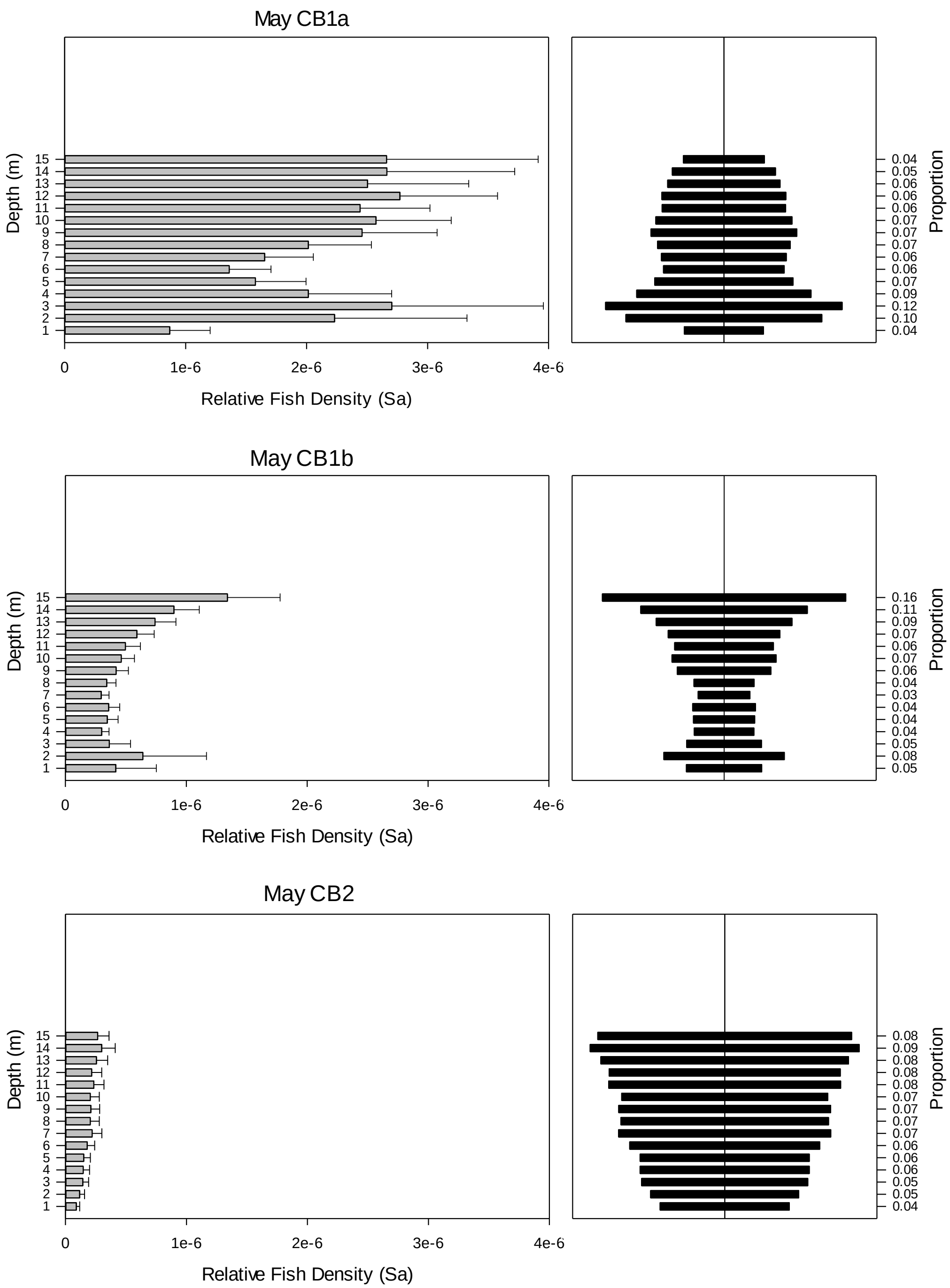


Figure 6. Relative fish densities (+ 1standard error) for Cobscook Bay in May 2012. S_a is an area-relative measure of biomass. Depth strata start at the ocean floor. Note the upper depth strata were not included due to changing tidal levels and entrained air in the upper water column close to the surface (<10 m). Graphs on right are for visual display of how fish are proportionally distributed in the water column. Depth strata are on the left y-axis and proportions of fish density are shown on the right y-axis. Data for January, March, June, August, and September are included in Appendices.

3.2 Marine life interaction monitoring plan (side-looking hydroacoustics)

3.2.1 Data availability

Data collection for the Marine Life Interaction Monitoring Plan began on August 29, 2012. The echosounder can be remotely accessed, acoustic data collection is automated, and data are stored on an ORPC server that is backed up periodically at the University. Due to various operational constraints since the start of data collection, collection has not been continuous (Figure 7). Gaps exist in the side-looking hydroacoustic data whenever the turbine or acoustic system was being repaired or adjusted, during periods of turbine deployment or removal, and whenever divers were present near the echosounder support structure. Additionally, hydroacoustic data have not yet been collected when the turbine was generating power, though collection has been possible while the turbine was free-spinning (moving but not generating power) or still (brake applied). This was because of electrical interference between the data and power transmission cables running together along the seabed to the shore station, and resulted in data gaps 3 to 5 hours in length on days when the turbine was generating. This issue is currently being addressed; however, to date, side-looking hydroacoustic data exist only for times when the turbine was free-spinning or still. As echosounder communication issues are resolved, data collection will become more continuous and reliable. For a discussion of these issues and remedial measures taken or planned, see Section 4.2.

Collection of water current speed and direction data has also been intermittent. For times when data are available, current direction is not reliable due to the alignment of the flow meter, and therefore was not used in the following analyses. Turbine RPM data were combined with power generation data to determine when the turbine was still, free-spinning, or spinning and generating power. Small gaps exist in all three of these data sets, and the first set of RPM data is not accurate due to a communication error that has since been corrected (Figure 7).

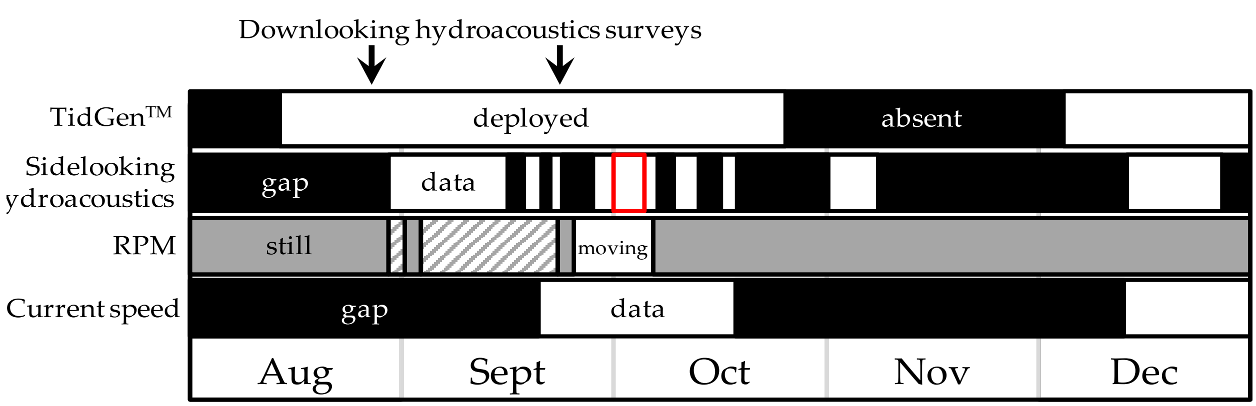


Figure 7. Summary of Marine Life Interaction Monitoring Plan data availability to date. Hatch lines represent revolutions per minute (RPM) data that are not accurate, but indicate that the turbine was free-spinning. Red box highlights data subset analyzed for this report.

Given these gaps in information, a subset of the data collected since August 2012 was analyzed for this report (Figure 8). This subset spans October 1st to October 5th, when the turbine was present and fully operating (that is, the brake was not applied, and the turbine would spin when sufficient current speeds were reached, sometimes generating power; Figure 8). Current speed, RPM, and power generation data are available for this time. The turbine was free-spinning for several tidal stages, resulting in approximately 13 hours of ebb tide data and 8 hours of flood tide data to analyze (Table 3).

As full months of data are not yet available, monthly comparisons have not been carried out as described in the methods section. The distribution of fish TS was created, and fish density was calculated for each zone during flood and ebb tide. The direction of fish movement was examined qualitatively. Sample size is low (4 ebb tides and 3 flood tides), so variances were large and statistical analyses were not carried out; however, this provides an example of future results.

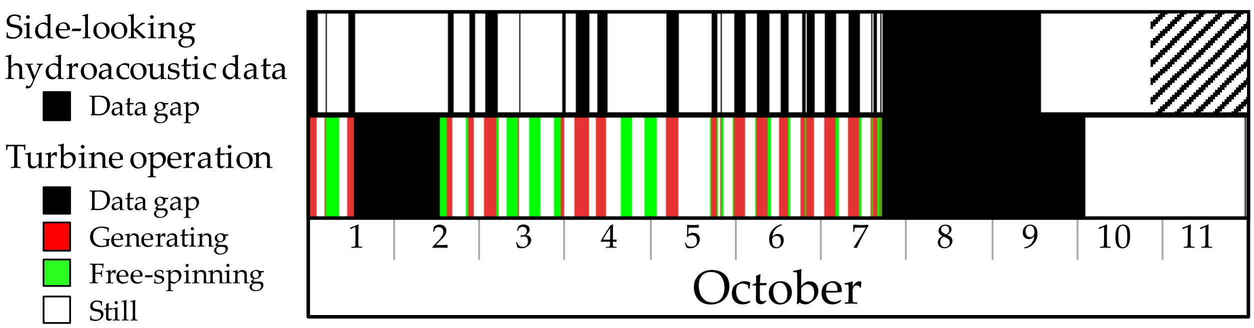


Figure 8. Turbine operational state and side-looking hydroacoustic data availability on dates analyzed for this report. Hatch lines represent hydroacoustic data that were available but could not be used due to interference from rough surface conditions. The green (free-spinning) segments in October 1-5 were analyzed for this report.

Table 3. Summary of data subset analyzed to date.

Fileset	Date	Start time	End time	Tidal stage	Mean current speed (m·s^{-1})	Duration (hrs)	Total fish tracked
1	10/1/2012	02:06	06:11	Ebb	1.26	4.08	2,538
2	10/2/2012	09:20	11:12	Flood	0.40	1.85	247
3	10/3/2012	03:19	06:27	Ebb	0.06	3.15	3,681
4	10/3/2012	09:47	12:36	Flood	0.31	2.82	1,300
5	10/3/2012	16:20	18:18	Ebb	0.41	1.97	1,873
6	10/4/2012	10:22	13:38	Flood	0.34	3.27	1,644
7	10/4/2012	16:47	20:27	Ebb	0.62	3.67	2,360

3.3.1 Results from subset analyzed

A total of 13,643 fish tracks were detected in the acoustic data subset. 3,191 of these were detected during flood tides, and 10,452 detected during ebb tides.

Target strength

The TS distribution of these fish is shown in Figure 9. The distribution is slightly bimodal, with peaks at -57 dB and -50 dB and most detections lying near these values.

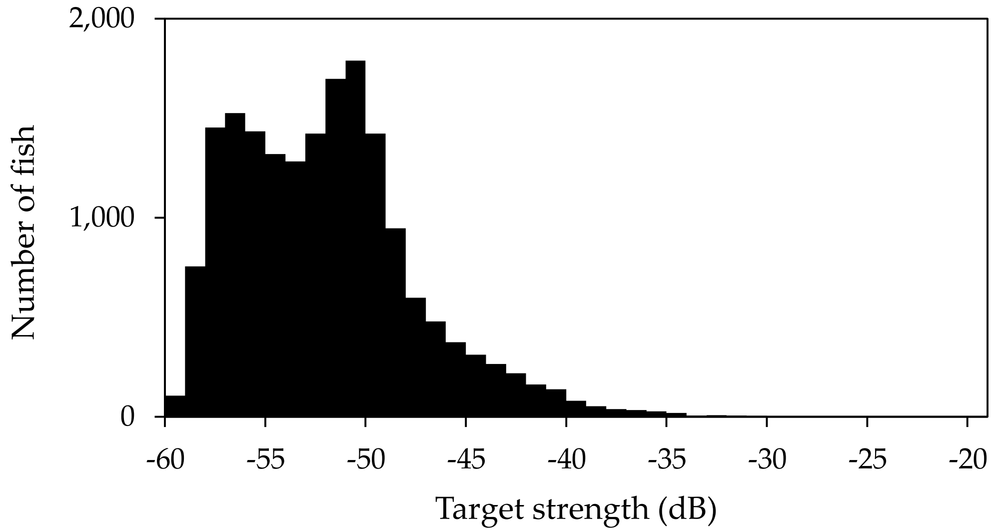


Figure 9. Target strength distribution of all fish detected in data subset.

Fish density

The mean density of fish in each sampling zone is shown in Figure 10. Density appeared to be greater beside and above the turbine than in the turbine zone, though no tests for statistical significance have been carried out due to the low sample size. At this point, densities in the zone beside the turbine may be disproportionately large compared to the densities above and in the turbine zone, possibly due to noise reducing the number of fish detected.

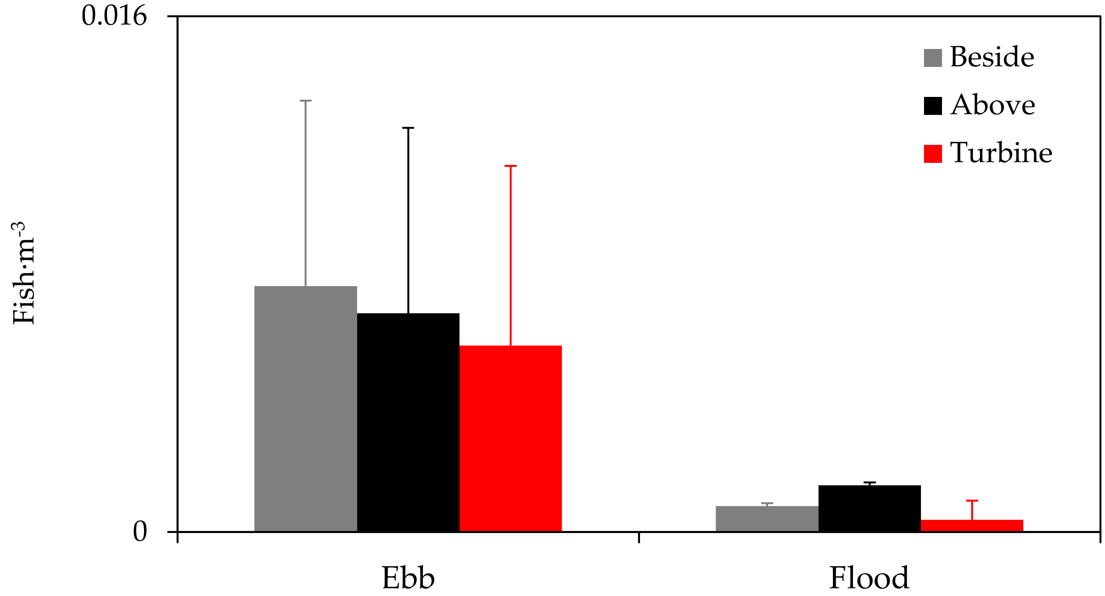
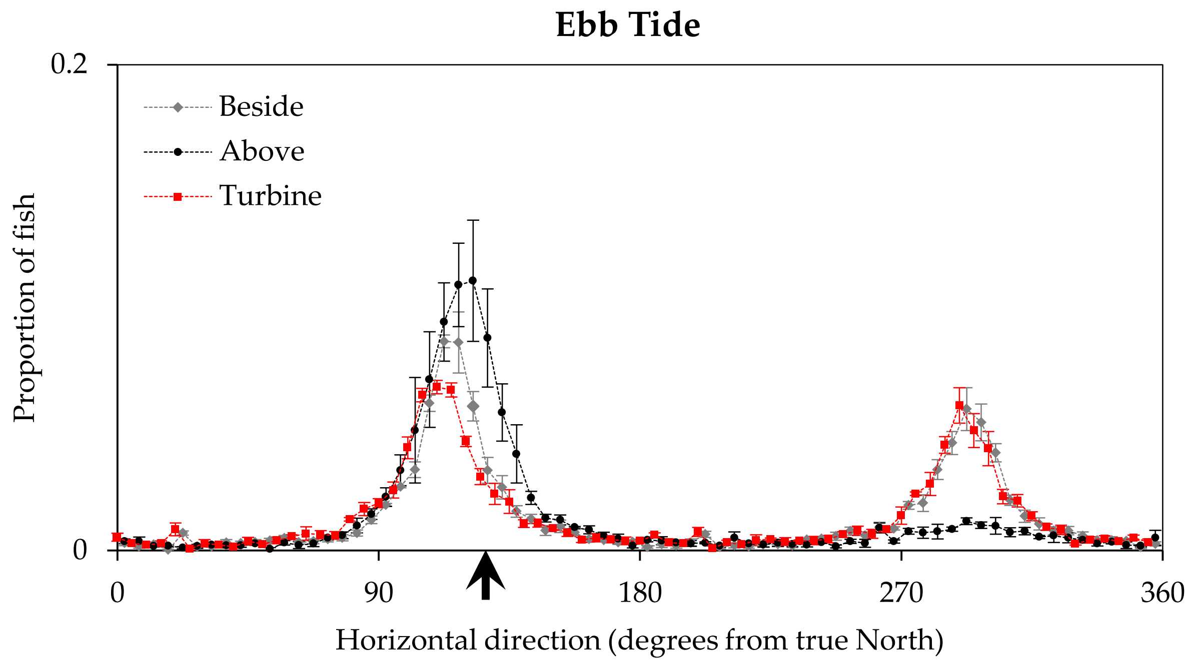


Figure 10. Mean fish density (+1 standard error) in each sampling zone during flood and ebb tide.

Direction of fish movement

The compass heading distribution for fish in each sampling zone was bimodal with peaks at the predominant current directions, indicating fish moving primarily with or against the prevailing current (Figure 11). Due to the small sample size, statistical significance was not tested. Against-current tracks were nearly as prevalent as with-current tracks in the region beside the turbine. Above the turbine, fish moved with the prevailing current almost exclusively. In the turbine zone during the flood tide, a greater proportion of fish were tracked moving against the current than with it. Overall, variance in direction of tracks above the turbine and in the turbine zone appeared greater during flood tides than during ebb tides. However, without current direction data, variation in fish track directions cannot be attributed to fish behavior alone.

The vertical direction distribution for fish beside the turbine peaked at 0°, indicating that most fish in this zone moved horizontally (Figure 12). There were no clear peaks in the distribution for fish in the turbine zone or above it, with vertical movement spread across all directions. Variance in vertical direction appeared greater during the flood tides than the ebb tides.



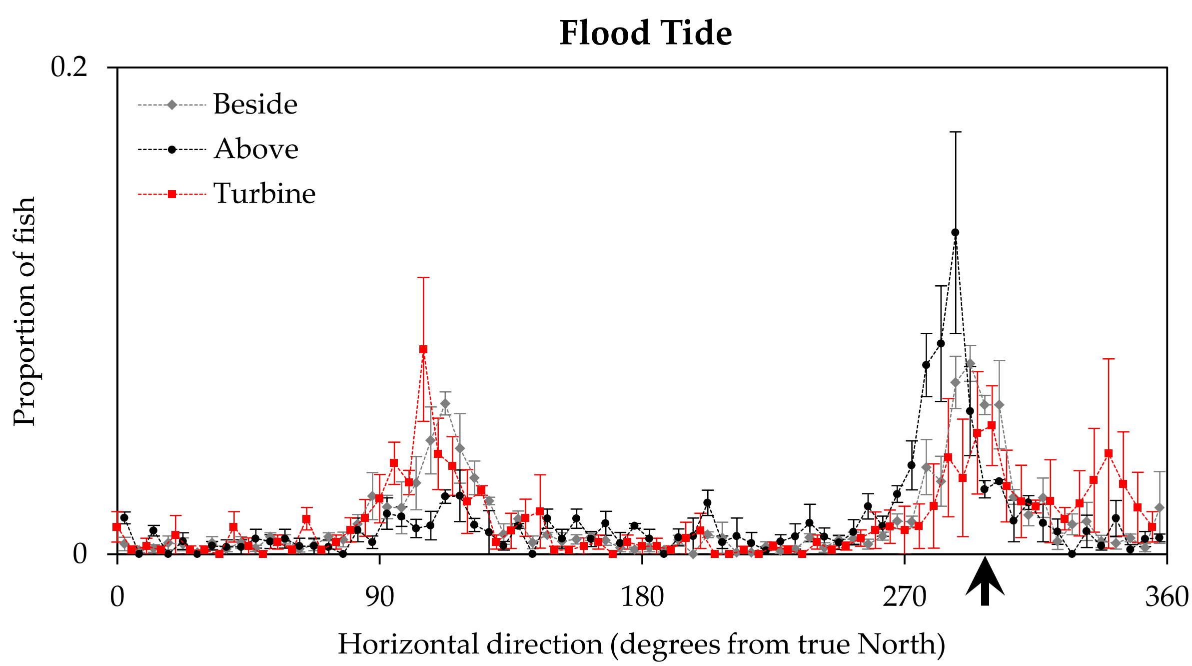
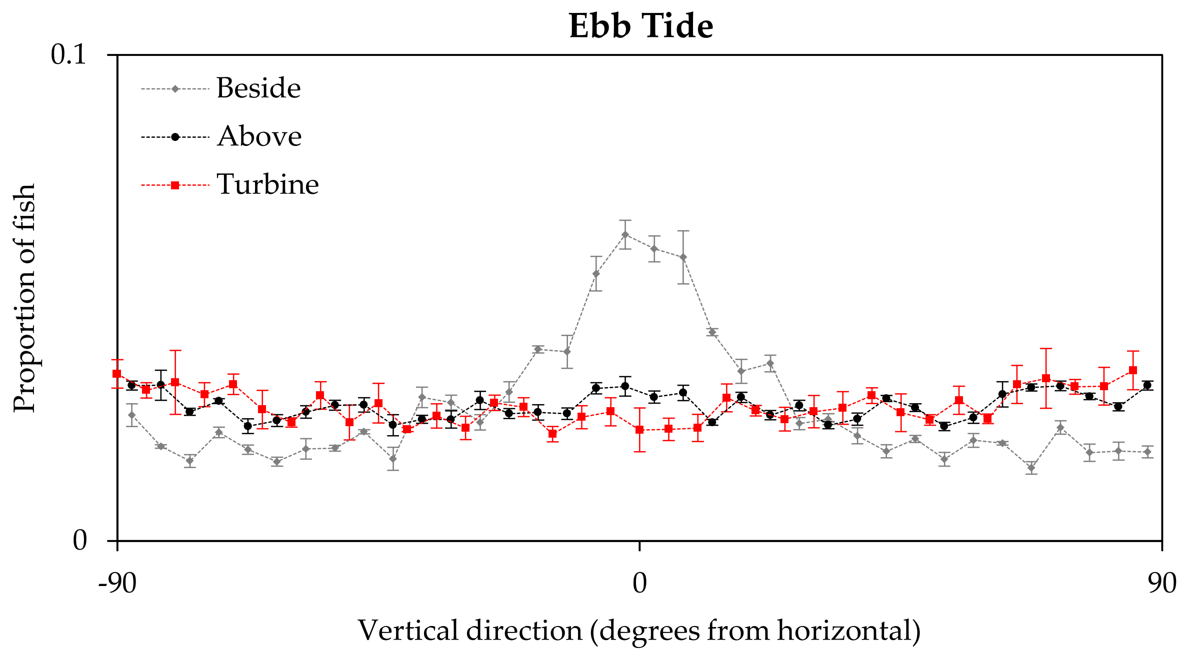


Figure 11. Distribution of horizontal direction of fish movement in each turbine zone for ebb and flood tides. 0°, 90°, 180°, and 270° are North, East, South, and West, respectively. Mean proportion of fish shown on vertical axis. Error bars represent ± 1 standard error. Arrows show predominant direction of tidal flow, obtained by ORPC.



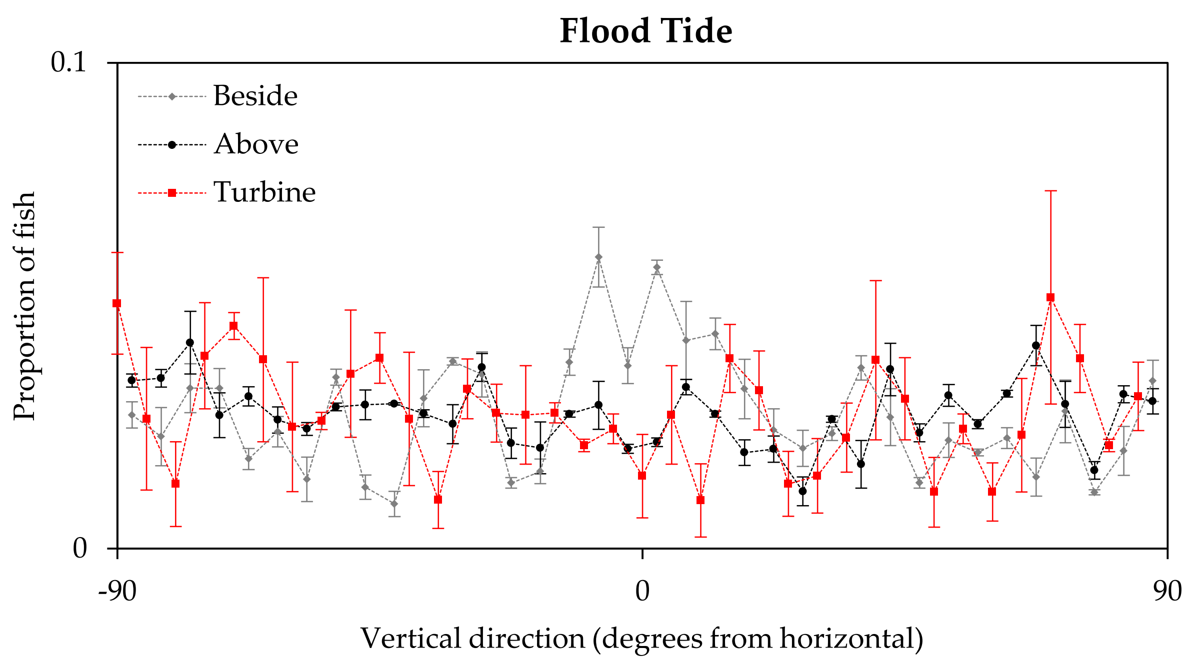


Figure 12. Distribution of vertical direction of fish movement in each turbine zone for ebb and flood tides. -90° degrees is downward, 90° is upward. Mean proportion of fish shown on vertical axis. Error bars represent ± 1 standard error.

4.0 Challenges & Future: Operational Constraints and Reconciliation

Ideal data collection is difficult under the best circumstances, and the highly dynamic environment of Cobscook Bay combined with construction activities associated with the TidGen™ project have affected data collection to date. Outlined below are the obstacles encountered within each monitoring plan and a discussion of how these have been or will be addressed as data collection continues.

4.1 Fisheries Monitoring Plan (down-looking hydroacoustic surveys)

As shown in Figure 2, sampling locations have so far been highly variable. Ideally, these locations would be consistent over time. This variability has been mainly due to construction activities surrounding the deployment, maintenance, and retrieval of the TidGen™ device, and the safety protocols involved (e.g., minimum safe distances for moorings). Additionally, November 2012 down-looking surveys were cancelled due to re-deployment of the turbine, causing sampling dates to deviate from the proposed schedule (CBTEP Fisheries and Marine Life Interaction Plan, 2012). Sampling locations and times will become more consistent with what was initially proposed as activity in the project area decreases. In addition, there has been a recent deployment of a large mooring block near the TGU that will be a permanent mooring for CB1b, minimizing spatial variation at that site. Site CB1a spatial variation will be decreased with the use of a more precise GPS unit.

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

The goal of this plan is to collect and assess continuous data on the behavior of fish and other marine life in the vicinity of the turbine while it is operating. However, the operation of the side-looking echosounder at the turbine site is largely dependent on work carried out on the turbine. As discussed in Section 3.2.1, gaps exist in the hydroacoustic data collected to date which limit possible analyses. The largest gaps correspond to turbine operations (e.g., work on the undersea cables, retrieval or redeployment of the turbine). Smaller gaps occur when communication with the echosounder from shore is interrupted. These interruptions occur when the turbine is generating power, as the electric current in the undersea cables interferes with the neighboring data transmission cable of the echosounder. ORPC has taken several steps to remedy this issue and continues to work towards continuous data transfer. As construction activity in the area decreases and communication issues are resolved, the dataset will become more continuous and will be processed as described in this report.

Sound reflection off of turbine support structures and the surface may affect fish detection within the turbine zone, and the extent of this effect must be examined. Interference with the returned acoustic signal not only makes it difficult for Echoview to track fish, but also affects the calculation of fish track parameters such as TS and direction of movement. Additionally, clear gaps exist in the detected fish tracks at the range of each piling and even at the intervening crossbars of the TidGen™ support frame (visible as faint horizontal lines in Figure 4a). It is likely that the detection of fish echoes at these ranges is confounded by the sound reflected by the turbine support structure. To help determine the extent of this effect, the number of fish tracks obtained by Echoview must be compared with the number of fish tracks obtained by manually counting. Fish tracks may be obvious to the eye even when surrounded by interference that limits their detectability in Echoview. Comparing a manual count of fish tracks to the Echoview-generated count will determine if this is indeed an issue that must be addressed.

If so, there are several options available to explore:

1. Re-aim the transducer until reflection of sound from the turbine support frame no longer interferes with fish tracking. The disadvantage to this is that the beam would be even farther from the turbine face, and will therefore limit the usefulness of behavioral analyses. This method also does not help to reduce the effect of surface noise on the data at greater ranges.
2. Increase the threshold to -50 dB to eliminate most noise from the echogram altogether. This method will also result in the exclusion of fish with weaker acoustic signatures, such as mackerel or small herring. However, small fish are those that tend to interact with turbine blades (Viehman 2012), and most of the fish tracked so far have target strength less than -50 dB (Figure 9). Also, this option is not immune to the effects of surface noise and does not address the effect of very strong targets (such as the pilings) confounding Echoview's fish detection process.
3. Alter the method of fish detection. Image processing techniques may be useful when tracking fish in data with a low signal to noise ratio (e.g. Balk and Lindem 2000).

These options will be assessed as data collection and data quality continue to improve.

Current speed and direction are being collected by ORPC using a flow meter on the turbine support frame. While current speed data collected thus far have been accurate, direction data cannot be used due to the alignment of the flow meter. Once this is corrected, future data analyses will be carried out using both current speed and direction.

4.3 Final Remarks

Since the implementation of the Fisheries and Marine Life Interaction Monitoring Plans, great progress has been made in the setup and collection of data. New sampling locations and survey equipment have been integrated into the continuing down-looking acoustic surveys, and the side-looking Simrad echosounder has been successfully installed at the TidGen™ site and can be remotely operated from shore. Several obstacles remain to be addressed. For the Fisheries Monitoring Plan, these include achieving constant survey locations and further automation of data processing. Issues facing the Marine Life Interaction Plan include continuous data collection, noise reduction, processing automation, and full analyses of data collected to date. All of these concerns are currently being addressed, or will be, in the near future. Results presented here are preliminary analyses of a subset of data collected to date, and analyses in future reports will follow a similar approach. As data collection becomes more continuous and quality improves, we will continue to adopt and refine our analysis techniques.

5.0 References

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Appendix A : Report to the Maine Department of Marine Resources on Special License No. 2012-36-02 granted to the University of Maine to conduct fish capture research in Cobscook Bay.

2012 Annual Report: Special License Number ME 2012-36-02
University of Maine, School of Marine Sciences
Gayle Zydlewski, James McCleave, Jeffrey Vieser
16 November 2012

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.

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).

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 day time, with some night sampling.

Trawling and intertidal sampling were conducted during neap tides primarily in May, June, August and September, 2012. Forty midwater tows and 40 benthic tows were made over the four months, with 16 tows of each type being at night in central and outer Cobscook Bay (Tables 1, 2). One hundred eighty one seine hauls were made over the four months, with 36 hauls being at night (Table 3). Twenty five fyke net sets were made, with each set being two fyke nets nearby at the same location; 14 sets were at night (Table 4). Sixty additional seine hauls were made at a subset of locations in March, April, and November, with 13 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 28,000 individual fish of 36 species were caught (all gears and dates combined) (Table 5).[1] Individuals of many species were primarily smaller (juvenile) specimens, but a few adult Atlantic herring (*Clupea harengus*) were caught in pelagic trawls (Table 6). Atlantic herring dominated the pelagic catch, and most were early juveniles. Winter flounder (*Pseudopleuronectes americanus*) juveniles dominated the catch in benthic trawls, but species richness was greatest among gears in the benthic trawls (26 species caught at least once) (Table 7).

Threespine stickleback (*Gasterosteus aculeatus*), Atlantic silverside (*Menidia menidia*), blackspotted stickleback (*Gasterosteus wheatlandi*), and alewife (*Alosa pseudoharemgus*) dominated the catches in intertidal seine tows, but in widely varying proportions in the four primary months of sampling (Table 8). Only six 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. Threespine sticklebacks were 10 times more abundant and blackspotted sticklebacks seven times more abundant in 2012 than 2011, but seining effort only increased threefold. Likewise, the 40-fold increased abundance of Atlantic silverside cannot be explained on increased seining effort. The decrease in abundance of winter flounder is probably real, as benthic trawling effort was similar in the two 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.

No Atlantic salmon (*Salmo salar*), shortnose sturgeon (*Acipenser brevirostrum*), or Atlantic sturgeon (*A. oxyrhynchus*) were captured in any gear. One harbor seal entered a fyke net on June 28, 2012, and drowned; it 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 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

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[1] Catch numbers in Tables 5-9 are provisional.

cues are restricted. Sampling effort at night with both midwater and benthic trawls was increased in 2012 compared with 2011.

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 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).

An application for an extension of our special license for 2013 will be forthcoming involving a few modest changes to our scope of work.

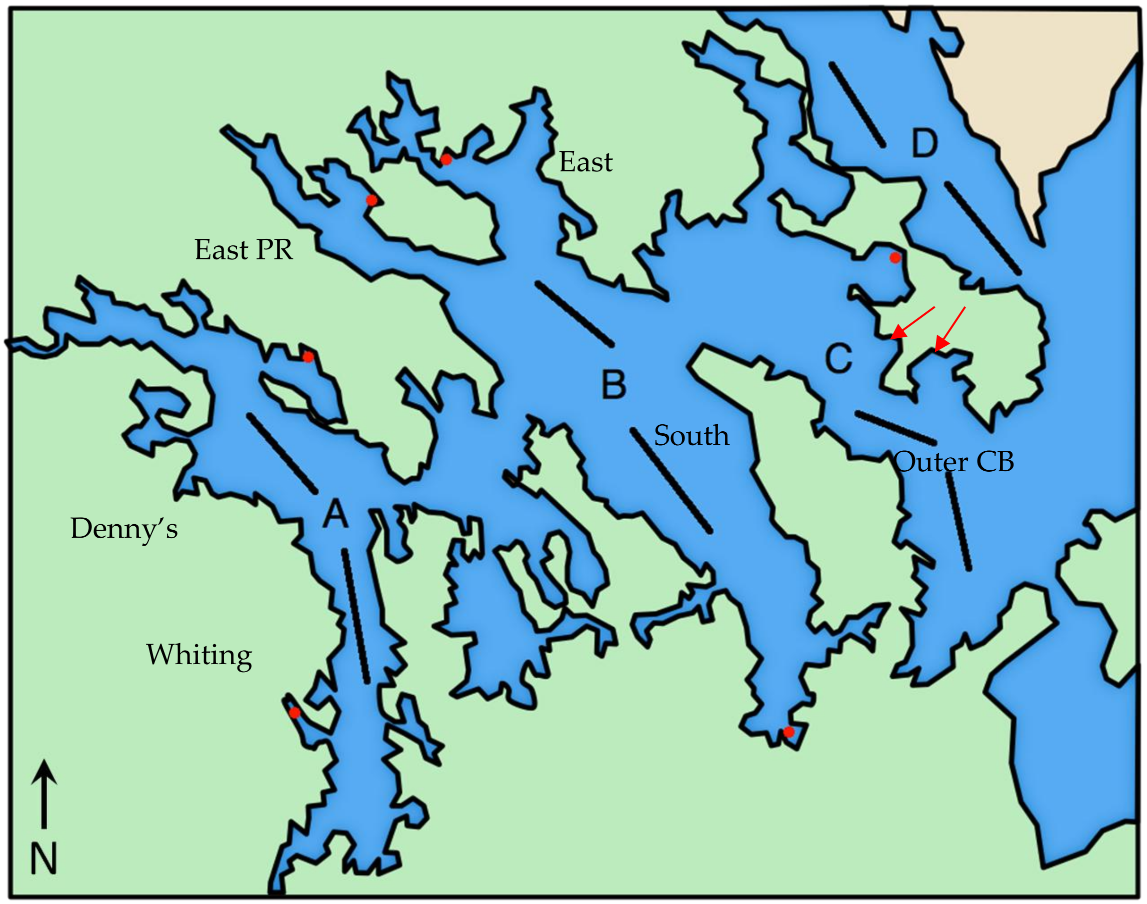


Figure 1. Map of Cobscook Bay and Western Passage of Passamaquoddy Bay showing mid-water and benthic trawl lines (black lines) fished in 2012 (Cobscook Bay) and planned for 2013 (all), as well as regular seine and fyke net sampling locations (red dots) and seining locations specifically for sticklebacks (red arrows). 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). 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, 2012. 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. CB is Cobscook Bay.

Month	Day	Bay	GPS Begin	GPS End	Tide	Tow	Begin	End
May	25	Outer CB	44°53.543′ 67°00.968′	44°53.943′ 67°01.712′	Low	P401	21:38	21:53
	25	Outer CB	44°55.837′ 67°01.371′	44°53.454′ 67°00.762′	Low	P402	22:06	22:26
	26	East	44°55.025′ 67°05.773	44°54.453 67°04.631	Low	P403	21:52	22:12
	26	South	44°53.744′ 67°04.827′	44°52.985′ 67°04.123′	Flood	P404	22:29	22:49
	27	Outer CB	44°53.950′ 67°01.470′	44°53.417′ 67°00.278	High	P405	16:02	16:22
	27	Outer CB	44°53.415′ 67°00.535′	44°53.925′ 67°01.628′	Ebb	P406	16:39	16:59
	28	Whiting	44°52.483′ 67°08.739′	44°51.029′ 67°08.599′	Flood	P407	16:47	17:08
	28	Dennys	44°53.388′ 67°09.843′	44°52.825′ 67°08.841′	Ebb	P408	18:30	18:46
	29	South	44°53.165′ 67°04.310′	44°54.061′ 67°05.209′	Low	P409	11:24	11:45
	29	East	44°54.518′ 67°05.121′	44°55.282′ 67°06.025′	Low	P410	12:00	12:23
June	24	Outer CB	44°53.767′ 67°01.407′	44°53.248′ 66°59.576′	Flood	P501	21:10	21:30
	24	Outer CB	44°53.356′ 67°00.484′	44°54.263′ 67°02.066′	Flood	P502	23:10	23:30
	25	East	44°55.208′ 67°05.936′	44°54.505′ 67°04.824′	Ebb	P503	21:25	21:50
	25	South	44°53.897′ 67°04.961′	44°53.118′ 67°04.251′	Low	P504	22:10	22:30
	26	Outer CB	44°53.370′ 67°00.313′	44°53.957′ 67°01.696′	High	P505	16:45	17:05
	26	Outer CB	44°53.762′ 67°01.321′	44°53.357′ 66°59.773	Ebb	P506	17:20	17:43
	27	South	44°53.004′ 67°03.985′	44°53.890′ 67°04.810′	Low	P507	11:20	11:41
	27	East	44°54.490′ 67°05.315′	44°55.456′ 67°06.109′	Low	P508	11:54	12:15
	28	Whiting	44°52.545′ 67°08.771′	44°51.288′ 67°08.576′	Low	P509	06:33	06:53

	28	Dennys	44°53.362′ 67°09.890′	44°52.715′ 67°08.794′	Ebb	P510	08:12	08:27
August	26	Outer CB	44°53.923′ 67°01.531′	44°53.333′ 66°59.941′	Ebb	P601	19:42	20:02
	26	Outer CB	44°53.694′ 67°01.347′	44°53.280′ 66°59.487′	Ebb	P602	20:30	20:50
	27	East	44°55.423′ 67°06.086′	44°54.395′ 67°04.881′	Ebb	P603	20:45	21:05
	27	South	44°52.901′ 67°04.005′	44°53.807′ 67°04.394	Ebb	P604	22:00	22:20
	28	Outer CB	44°53.337′ 66°59.895′	44°53.761′ 67°01.076′	High	P605	09:00	09:23
	28	Outer CB	44°53.736′ 67°01.410′	44°59.886 66°59.883′	Ebb	P606	09:35	09:55
	29	Whiting	44°52.113′ 67°08.655′	44°50.941′ 67°08.671′	Flood	P607	09:52	10:12
	29	Dennys	44°53.361′ 67°09.839′	44°52.771′ 68°08.832′	Ebb	P608	11:27	11:49
	30	South	44°53.490′ 67°04.709′	44°52.566′ 67°03.655′	Flood	P609	10:00	10:20
	30	East	44°55.376′ 67°06.265′	44°54.443′ 67°04.885′	Ebb	P610	11:45	12:10
September	23	Outer CB	44°54.081′ 67°01.827′	44°53.416′ 66°59.280′	Ebb	P701	10:14	10:35
	23	Outer CB	44°53.262′ 66°59.760′	44°53.816′ 67°01.311′	Flood	P702	12:19	12:39
	24	East	44°55.241′ 67°06.214′	44°54.463′ 67°05.039′	Low	P703	12:45	13:06
	24	South	44°53.711′ 67°04.768′	44°52.898′ 67°04.129′	Flood	P704	13:22	13:42
	25	Outer CB	44°53.335′ 67°00.201′	44°54.161′ 67°02.083′	Flood	P705	19:04	19:25
	25	Outer CB	44°53.956′ 67°01.661′	44°53.531′ 67°00.854′	Flood	P706	19:44	20:05
	26	Whiting	44°52.099′ 67°08.660′	44°50.946′ 67°08.680′	Flood	P707	08:30	08:56
	26	Dennys	44°53.179′ 67°09.323	44°52.771′ 67°08.626′	Ebb	P708	10:13	10:28
	26	East	44°54.712′ 67°05.550′	44°55.535′ 67°06.321′	Flood	P709	18:50	19:10
	26	South	44°52.903′ 67°04.045′	44°53.704′ 67°04.796′	High	P710	20:40	21:00

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 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. CB is Cobscook Bay.

Month	Day	Bay	GPS Begin	GPS End	Tide	Tow	Begin	End
May	25	Outer CB	44°53.030′ 67°00.337′	44°52.275′ 66°59.878′	Ebb	B401	20:22	20:44
	25	Outer CB	44°52.330′ 66°59.842′	44°53.190′ 67°00.359′	Ebb	B402	20:54	21:04
	26	East Bay	44°54.770′ 67°05.401′	44°55.400′ 67°06.111′	Ebb	B403	21:03	21:23
	26	South Bay	44°52.754′ 67°04.045′	44°53.587′ 67°04.893′	Flood	B404	23:03	23:23
	27	Outer CB	44°53.107′ 67°00.467′	44°52.347′ 66°59.939′	Flood	B405	14:50	15:10
	27	Outer CB	44°52.253′ 66°59.859′	44°53.080′ 67°00.123′	Flood	B406	15:21	15:41
	28	Whiting	44°51.104′ 67°08.602′	44°52.087′ 67°08.646	High	B407	17:25	17:47
	28	Dennys	44°52.899′ 67°08.966′	44°53.378′ 67°09.864′	High	B408	18:01	18:18
	29	South	44°53.917′ 67°04.891′	44°52.002′ 67°04.211′	Ebb	B409	10:50	11:10
	29	East	44°55.450′ 67°06.223′	44°54.665′ 67°05.334′	Flood	B410	12:32	12:53
June	24	Outer CB	44°52.961′ 67°00.207′	44°52.187′ 66°59.630′	Flood	B501	21:50	11:17
	24	Outer CB	44°52.401′ 66°59.834′	44°53.223′ 67°00.608′	Flood	B502	22:30	23:00
	25	East	44°54.721′ 67°05.387′	44°55.367′ 67°06.007′	Ebb	B503	20:50	21:10
	25	South	44°52.692′ 67°03.975′	44°53.444′ 67°04.637′	Flood	B504	22:50	23:10
	26	Outer CB	44°52.982′ 67°00.336′	44°52.241′ 66°59.870′	Flood	B505	15:30	15:50
	26	Outer CB	44°52.231′ 66°59.897′	44°53.019′ 67°00.173′	Flood	B506	16:08	16:28
	27	South	44°53.789′ 67°04.787′	44°53.145′ 67°03.959	Ebb	B507	10:42	11:02
	27	East	44°55.559′ 67°06.199′	44°54.747′ 67°05.348′	Flood	B508	12:28	12:49
	28	Whiting	44°51.147′ 67°08.580′	44°52.081′ 67°08.692′	High	B509	07:05	07:26

	28	Dennys	44°52.793′ 67°08.844′	44°53.327′ 67°09.787′	Ebb	B510	07:40	08:00
August	26	Outer CB	44°53.140′ 67°00.395′	44°52.112′ 66°59.759′	Ebb	B601	21:16	21:36
	26	Outer CB	44°52.077′ 66°59.705′	44°52.929′ 67°00.314′	Ebb	B602	21:51	22:12
	27	East	44°54.788′ 67°05.574′	44°55.505′ 67°06.260′	High	B603	20:05	20:25
	27	South	44°53.716′ 67°04.737′	44°52.917′ 67°03.788′	Ebb	B604	21:25	21:45
	28	Outer CB	44°52.863′ 67°00.195′	44°52.038′ 66°59.667′	Ebb	B605-B	10:35	10:55
	28	Outer CB	44°52.177′ 66°59.762′	44°53.020′ 67°00.337′	Ebb	B606	11:05	11:25
	29	Whiting	44°51.158′ 67°08.591′	44°52.051′ 67°08.668′	High	B607	10:27	10:47
	29	Dennys	44°52.970′ 67°09.093′	44°53.372′ 67°09.817′	Ebb	B608	11:00	11:20
	30	South	44°52.622′ 67°03.775′	44°53.453′ 67°04.545′	High	B609	10:32	10:54
	30	East	44°54.766′ 67°05.531′	44°55.455′ 67°06.139′	Ebb	B610	11:10	11:30
September	23	Outer CB	44°52.079′ 66°59.684′	44°52.950′ 67°00.285	Ebb	B701	11:00	11:20
	23	Outer CB	44°52.999′ 67°00.389′	44°52.187′ 66°59.811′	Low	B702	11:33	11:53
	24	East	44°54.648′ 67°05.501′	44°55.487′ 67°06.181′	Ebb	B703	12:06	12:26
	24	South	44°52.729′ 67°03.890′	44°53.514′ 67°04.642′	Flood	B704	13:54	14:15
	25	Outer CB	44°52.916′ 67°00.294′	44°52.148′ 66°59.731′	High	B705	20:22	20:43
	25	Outer CB	44°52.238′ 66°59.887′	44°53.110′ 67°00.446	Ebb	B706	20:55	21:15
	26	Whiting	44°51.204′ 67°08.578′	44°52.070′ 67°08.681′	Flood	B707	09:07	09:28
	26	Dennys	44°52.956′ 67°09.123′	44°53.344′ 67°09.840′	High	B708	09:44	09:59
	26	East	44°55.488′ 67°06.212′	44°54.705′ 67°05.507′	Flood	B709	19:20	19:40
	26	South	44°53.632′ 67°04.853′	44°52.835′ 67°04.034′	Flood	B710	20:00	20:20

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 March, April, and November, 2012. 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. CB is Cobscook Bay.

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
March	8	Outer CB	Broad Cove	Ebb	Not recorded	W1	12:00
	8	Outer CB	Broad Cove	Ebb	Not recorded	W2	12:30
	8	Outer CB	Deep Cove	Ebb	Not recorded	W3	13:15
	8	Outer CB	Deep Cove	Ebb	Not recorded	W4	13:45
	8	Outer CB	Deep Cove	Ebb	Not recorded	W5	14:15
	9	East	Sipp Cove	High	Not recorded	W6	11:49
	9	East	Sipp Cove	Ebb	Not recorded	W7	11:55
	9	East	Sipp Cove	Ebb	Not recorded	W8	12:20
	9	Outer CB	Carrying Place Cove	Ebb	Not recorded	W9	13:25
	9	Outer CB	Carrying Place Cove	Ebb	Not recorded	W10	13:40
	9	Outer CB	Carrying Place Cove	Ebb	Not recorded	W11	13:55
	9	East	Sipp Cove	Ebb	Not recorded	W12	14:20
	9	East	Sipp Cove	Ebb	Not recorded	W13	14:55
	10	Pennamaquan	Hersey Cove	Ebb	Not recorded	W14	13:40
	10	Pennamaquan	Hersey Cove	Ebb	Not recorded	W15	13:45
	10	Pennamaquan	Hersey Cove	Ebb	Not recorded	W16	13:50
	10	Pennamaquan	Hersey Cove	Ebb	Not recorded	W17	14:10
	10	Pennamaquan	Hersey Cove	Ebb	Not recorded	W18	14:15
	10	Dennys	Youngs Cove	Ebb	Not recorded	W19	14:50
	10	Dennys	Youngs Cove	Ebb	Not recorded	W20	14:55
	10	Dennys	Youngs Cove	Ebb	Not recorded	W21	15:00
	10	Dennys	Youngs Cove	Ebb	Not recorded	W22	15:25
April	13	Pennamaquan	Hersey Cove	High	Not recorded	A1	17:55
	13	Pennamaquan	Hersey Cove	High	Not recorded	A2	18:00
	13	Pennamaquan	Hersey Cove	Ebb	Not recorded	A3	18:25
	13	Pennamaquan	Hersey Cove	Ebb	Not recorded	A4	18:40
	13	Pennamaquan	Hersey Cove	Ebb	Not recorded	A5	18:50
	13	Dennys	Youngs Cove	Ebb	Not recorded	A6	19:45
	13	Dennys	Youngs Cove	Ebb	Not recorded	A7	20:00
	13	Dennys	Youngs Cove	Ebb	Not recorded	A8	20:40
	13	Dennys	Youngs Cove	Ebb	Not recorded	A9	20:50
	14	Outer CB	Broad Cove	High	Not recorded	A10	06:30
	14	Outer CB	Deep Cove	Ebb	Not recorded	A11	07:00
	14	Outer CB	Deep Cove	Ebb	Not recorded	A12	07:10
	14	Outer CB	Broad Cove	Ebb	Not recorded	A13	07:50
	14	Outer CB	Broad Cove	Ebb	Not recorded	A14	08:20
	14	Outer CB	Deep Cove	Ebb	Not recorded	A15	08:50
	14	Outer CB	Deep Cove	Ebb	Not recorded	A16	09:10
	14	Outer CB	Broad Cove	Ebb	Not recorded	A17	09:30

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
	14	East	Sipp Cove	High	Not recorded	A18	18:20
	14	East	Sipp Cove	High	Not recorded	A19	18:30
	14	East	Sipp Cove	High	Not recorded	A20	18:40
	14	Outer CB	Carrying Place Cove	Ebb	Not recorded	A21	20:30
	14	Outer CB	Carrying Place Cove	Ebb	Not recorded	A22	21:00
	14	East	Sipp Cove	Ebb	Not recorded	A23	22:10
	14	East	Sipp Cove	Ebb	Not recorded	A24	22:30
May	25	South	Case Cove	Ebb	Cobble	S401	15:55
	25	South	Case Cove	Ebb	Mudflat	S402	16:20
	25	South	Case Cove	Ebb	Sea grasses	S403	16:45
	26	Outer CB	Broad Cove	High	Cobble	AS401	15:53
	26	Outer CB	Broad Cove	High	Cobble	AS402	16:14
	26	Outer CB	Deep Cove	Ebb	Not recorded	AS403	16:48
	26	Outer CB	Deep Cove	Ebb	Rockweed/cobble	AS404	17:07
	26	Pennamaquan	Hersey Cove	Ebb	Cobble	S404	16:10
	26	Pennamaquan	Hersey Cove	Ebb	Cobble	S405	16:35
	26	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S406	16:52
	26	Pennamaquan	Hersey Cove	Ebb	Rockweed	S407	17:25
	26	Pennamaquan	Hersey Cove	Ebb	Rockweed	S408	17:45
	27	Whiting	Burnt Cove	Ebb	Rockweed	S409	06:40
	27	Whiting	Burnt Cove	Ebb	Rockweed	S410	07:10
	27	Whiting	Burnt Cove	Ebb	Mudflat	S411	07:35
	27	Whiting	Burnt Cove	Ebb	Mudflat	S412	08:15
	27	Whiting	Burnt Cove	Ebb	Mudflat	S413	08:35
	28	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S414	06:05
	28	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S415	06:15
	28	Outer CB	Carrying Place Cove	Ebb	Mudflat	S416	07:00
	28	Outer CB	Carrying Place Cove	Ebb	Mudflat	S417	07:15
	28	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S418	–
	28	Outer CB	Carrying Place Cove	Ebb	Cobble/grasses	S419	–
	28	Outer CB	Carrying Place Cove	Ebb	Mudflat	S420	–
	29	East	Sipp Bay	Ebb	Sea grasses	S421	06:12
	29	East	Sipp Bay	Ebb	Cobble	S422	06:25
	29	East	Sipp Bay	Ebb	Rockweed	S423	06:35
	29	East	Sipp Bay	Ebb	Cobble	S424	07:26
	29	East	Sipp Bay	Ebb	Not recorded	S425	07:34
	29	East	Sipp Bay	Ebb	Rockweed	S426	08:35
	29	East	Sipp Bay	Ebb	Rockweed	S427	08:55
	29	East	Sipp Bay	Ebb	Sea grasses	S428	19:00
	29	East	Sipp Bay	Ebb	Cobble	S429	19:08
	29	East	Sipp Bay	Ebb	Sea grasses	S430	19:40
	29	East	Sipp Bay	Ebb	Sea grasses	S431	19:50
	29	East	Sipp Bay	Ebb	Rockweed	S432	20:20
	29	East	Sipp Bay	Ebb	Rockweed	S433	20:35
	30	Dennys	Youngs Cove	Ebb	Cobble	S434	08:15

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
	30	Dennys	Youngs Cove	Ebb	Rockweed	S435	08:28
	30	Dennys	Youngs Cove	Ebb	Sea grasses	S436	08:42
	30	Dennys	Youngs Cove	Ebb	Cobble	S437	09:15
	30	Dennys	Youngs Cove	Ebb	Rockweed	S438	09:40
	30	Dennys	Youngs Cove	Ebb	Mudflat	S439	10:30
	30	Dennys	Youngs Cove	Ebb	Sea grasses	S440	21:14
	30	Dennys	Youngs Cove	Ebb	Cobble	S441	21:27
	30	Dennys	Youngs Cove	Ebb	Not recorded	S442	21:42
	30	Dennys	Youngs Cove	Ebb	Cobble	S443	22:05
	30	Dennys	Youngs Cove	Ebb	Rockweed	S444	22:20
	30	Dennys	Youngs Cove	Ebb	Not recorded	S445	22:40
	30	Dennys	Youngs Cove	Ebb	Mudflat	S446	23:15
June	23	South	Case Cove	Ebb	Cobble	S501	15:56
	23	South	Case Cove	Ebb	Mudflat	S502	16:25
	23	South	Case Cove	Ebb	Sea grasses	S503	16:50
	23	Pennamaquan	Hersey Cove	Ebb	Cobble	S504	14:46
	23	Pennamaquan	Hersey Cove	Ebb	Cobble	S505	15:00
	23	Pennamaquan	Hersey Cove	Ebb	Cobble	S506	15:15
	23	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S507	15:30
	23	Pennamaquan	Hersey Cove	Ebb	Cobble	S508	15:55
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S509	04:49
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S510	05:20
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S511	16:41
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S512	16:50
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S513	~17:00
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S514	~17:20
	25	East	Sipp Cove	Ebb	Cobble	S515	04:00
	25	East	Sipp Cove	Ebb	Cobble	S516	04:15
	25	East	Sipp Cove	Ebb	Sea grasses	S517	04:26
	25	East	Sipp Cove	Ebb	Cobble	S518	04:50
	25	East	Sipp Cove	Ebb	Rockweed	S519	05:12
	25	East	Ipp Cove	Ebb	Rockweed	S520	05:30
	25	East	Sipp Cove	Ebb	Rockweed	S521	06:15
	25	East	Sipp Cove	Ebb	Sea grasses	S522	16:36
	25	East	Sipp Cove	Ebb	Sea grasses	S523	16:45
	25	East	Sipp Cove	Ebb	Sea grasses	S524	17:10
	25	East	Sipp Cove	Ebb	Cobble	S525	17:45
	25	East	Sipp Cove	Ebb	Rockweed	S526	18:50
	26	Outer CB	Broad Cove	Ebb	Cobble	AS501	17:09
	26	Outer CB	Broad Cove	Ebb	Cobble	As502	17:20
	26	Outer CB	Broad Cove	Ebb	Cobble	AS503	18:05
	26	Outer CB	Broad Cove	Ebb	Cobble	AS504	18:27
	26	Outer CB	Deep Cove	Ebb	Not recorded	AS505	19:06
	26	Outer CB	Deep Cove	Ebb	Nor recorded	AS506	19:27
	26	Outer CB	Deep Cove	Ebb	Cobble/mudflat	AS507	19:50

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
	26	Outer CB	Deep Cove	Ebb	Not recorded	AS508	20:12
	27	Whiting	Burnt Cove	Ebb	Rockweed	S532	08:55
	27	Whiting	Burnt Cove	Ebb	Rockweed	S533	09:25
	27	Whiting	Burnt Cove	Ebb	Mudflat	S534	10:10
	27	Whiting	Burnt Cove	Ebb	Mudflat	S535	10:25
	28	Dennys	Youngs Cove	Ebb	Sea grasses	S527	08:45
	28	Dennys	Youngs Cove	Ebb	Rockweed	S528	08:57
	28	Dennys	Youngs Cove	Ebb	Cobble	S529	09:30
	28	Dennys	Youngs Cove	Ebb	Rockweed	S530	09:40
	28	Dennys	Youngs Cove	Ebb	Not recorded	S531	10:00
	28	Dennys	Youngs Cove	Ebb	Cobble	S536	–
	28	Dennys	Youngs Cove	Ebb	Rockweed	S537	21:03
	28	Dennys	Youngs Cove	Ebb	Cobble	S538	21:15
	28	Dennys	Youngs Cove	Ebb	Sea grasses	S539	21:35
	28	Dennys	Youngs Cove	Ebb	Mudflat	S540	21:40
August	25	Outer CB	Deep Cove	High	Cobble	AS601	18:00
	25	Outer CB	Deep Cove	Ebb	Cobble	AS602	18:27
	25	Outer CB	Deep Cove	Ebb	Cobble/grasses	AS603	18:55
	25	Outer CB	Deep Cove	Ebb	Cobble/grasses	AS604	19:10
	25	Outer CB	Broad Cove	Ebb	Not recorded	AS605	19:30
	25	Outer CB	Broad Cove	Ebb	Cobble	AS606	19:50
	25	Outer CB	Broad Cove	Ebb	Cobble	AS607	20:10
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S601	07:39
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S602	07:48
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S603	08:07
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S604	08:20
	26	Outer CB	Carrying Place Cove	Ebb	Mudflat	S605	08:36
	26	Outer CB	Carrying Place Cove	Ebb	Mudflat	S606	08:51
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S607	20:23
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S608	20:35
	26	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S609	20:50
	26	Outer CB	Carrying Place Cove	Ebb	Mudflat	S610	21:15
	27	East	Sipp Cove	Ebb	Sea grasses	S611	08:16
	27	East	Sipp Cove	Ebb	Rockweed	S612	08:25
	27	East	Sipp Cove	Ebb	Not recorded	S613	08:42
	27	East	Sipp Cove	Ebb	Cobble	S614	09:20
	27	East	Sipp Cove	Ebb	Sea grasses	S615	09:35
	27	East	Sipp Cove	Ebb	Rockweed	S616	10:04
	27	East	Sipp Cove	Ebb	Rockweed	S617A	10:15
	27	East	Sipp Cove	High	Cobble	S617B	20:15
	27	East	Sipp Cove	Ebb	Sea grasses	S618	20:30
	27	East	Sipp Cove	Ebb	Cobble	S619	21:20
	27	East	Sipp Cove	Ebb	Sea grasses	S620	21:40
	27	East	Sipp Cove	Ebb	Rockweed	S621	22:25
	27	East	Sipp Cove	Ebb	Cobble	S622	22:40

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
	28	Pennamaquan	Hersey Cove	High	Cobble	S623	09:30
	28	Pennamaquan	Hersey Cove	Ebb	Cobble	S624	09:41
	28	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S625	10:00
	28	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S626	10:18
	28	Pennamaquan	Hersey Cove	Ebb	Cobble	S627	10:34
	28	Pennamaquan	Hersey Cove	Ebb	Cobble	S628	10:44
	29	Dennys	Youngs Cove	Ebb	Cobble	S629	11:47
	29	Dennys	Youngs Cove	Ebb	Sea grasses	S630	12:10
	29	Dennys	Youngs Cove	Ebb	Rockweed	S631	12:35
	29	Dennys	Youngs Cove	Ebb	Mudflat	S632	13:45
	30	Dennys	Youngs Cove	Ebb	Cobble	S633	00:55
	30	Whiting	Burnt Cove	Ebb	Rockweed	S634	13:49
	30	Whiting	Burnt Cove	Ebb	Rockweed	S635	14:21
	30	Whiting	Burnt Cove	Ebb	Mudflat	S636	14:52
	30	Whiting	Burnt Cove	Ebb	Mudflat	S637	15:35
	31	South	Case Cove	Ebb	Cobble	S638	13:00
	31	South	Case Cove	Ebb	Rockweed	S639	13:27
	31	South	Case Cove	Ebb	Sea grasses	S640	13:35
September	22	Outer CB	Deep Cove	Ebb	Not recorded	AS701	17:32
	22	Outer CB	Deep Cove	Ebb	Not recorded	AS702	18:10
	22	Outer CB	Broad Cove	Ebb	Not recorded	AS703	18:48
	23	Whiting	Burnt Cove	Ebb	Rockweed	S701	08:47
	23	Whiting	Burnt Cove	Ebb	Rockweed/flat	S702	09:25
	23	Whiting	Burnt Cove	Ebb	Rockweed	S703	09:35
	23	Whiting	Burnt Cove	Ebb	Mudflat	S704	09:43
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S705	07:40
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S706	08:05
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S707	08:30
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S708	09:00
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S709	20:00
	24	Outer CB	Carrying Place Cove	Ebb	Sea grasses	S710	20:30
	24	Outer CB	Carrying Place Cove	Ebb	Mudflat	S711	21:30
	25	East	Sipp Cove	High	Sea grasses	S712	07:48
	25	East	Sipp Cove	High	Cobble	S713	08:10
	25	East	Sipp Cove	Ebb	Cobble	S714	08:40
	25	East	Sipp Cove	Ebb	Sea grasses	S715	09:00
	25	East	Sipp Cove	Ebb	Rockweed	S716	09:40
	25	East	Sipp Cove	Ebb	Cobble	S717	20:20
	25	East	Sipp Cove	Ebb	Sea grasses	S718	20:45
	26	Dennys	Youngs Cove	Ebb	Rockweed	S719	10:30
	26	Dennys	Youngs Cove	Ebb	Cobble	S720	11:05
	26	Dennys	Youngs Cove	Ebb	Sea grasses	S721	11:30
	26	Dennys	Youngs Cove	Ebb	Rockweed	S722	23:00
	26	Dennys	Youngs Cove	Ebb	Cobble	S723	23:35
	26	Dennys	Youngs Cove	Ebb	Mudflat	S724	01:27

Month	Day	Bay	Locale	Tide	Habitat	Tow	Time
	27	South	Case Cove	Ebb	Cobble	S751	11:10
	27	South	Case Cove	Ebb	Sea grasses	S752	11:37
	27	Pennamaquan	Hersey Cove	High	Cobble	S761	10:03
	27	Pennamaquan	Hersey Cove	Ebb	Cobble	S762	10:13
	27	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S763	10:24
	27	Pennamaquan	Hersey Cove	Ebb	Sea grasses	S764	10:37
	27	Pennamaquan	Hersey Cove	Ebb	Rockweed/cobble	S765	11:35
	27	Pennamaquan	Hersey Cove	Ebb	Rockweed/cobble	S766	11:48
November	2	Outer CB	Deep Cove	High	Cobble	N1	13:35
	2	Outer CB	Deep Cove	Ebb	Cobble	N2	13:54
	2	Outer CB	Deep Cove	Ebb	Not recorded	N3	14:10
	2	Outer CB	Broad Cove	Ebb	Sea grasses	N4	15:12
	2	Outer CB	Broad Cove	Ebb	Not recorded	N5	16:00
	2	Outer CB	Broad Cove	Ebb	Rockweed	N6	16:15
	2	Outer CB	Broad Cove	Ebb	Rockweed/cobble	N7	16:40
	2	East	Sipp Cove	High	Sea grasses	6#1	14:10
	2	East	Sipp Cove	Ebb	Cobble	6#2	14:15
	2	East	Sipp Cove	Ebb	Cobble	6#3	14:20
	2	East	Sipp Cove	Ebb	Not recorded	6#4	14:30
	2	Dennys	Youngs Cove	Ebb	Sea grasses	6#5	15:20
	2	Dennys	Youngs Cove	Ebb	Cobble/mix	6#6	15:30
	2	Dennys	Youngs Cove	Ebb	Sea grasses	6#7	15:40

Table 4. Date and location of intertidal fyke net samples in Cobscook Bay during May, June, August, and September, 2012. 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. BT is baited minnow trap that caught fish. CB is Cobscook Bay.

Month	Day	Bay	Locale	Fyke	Begin	End	BT
May	28	Outer CB	Carrying Place Cove	F401	17:15	20:00	
	29	East	Sipp Cove	F402	18:30	21:45	
	30	Dennys	Youngs Cove	F403	19:00	21:30	
June	24	Outer CB	Carrying Place Cove	F501	03:30	06:15	
	24	Outer CB	Carrying Place Cove	F502	16:00	18:15	
	25	East	Sipp Cove	F503	03:30	07:00	
	25	East	Sipp Cove	F504	16:00	19:00	
	27	Dennys	Youngs Cove	F505	18:30	23:00	
	28	Dennys	Youngs Cove	F506	06:00	10:30	
	28	Dennys	Youngs Cove	F507	18:30	23:15	
August	25	Outer CB	Carrying Place Cove	F601	18:00	21:00	
	26	Outer CB	Carrying Place Cove	F602	06:30	10:00	
	26	Outer CB	Carrying Place Cove	F603	19:00	22:15	
	27	East	Sipp Bay	F604	07:45	09:30	
	27	East	Sipp Bay	F605	20:15	23:00	X
	28-29	Dennys	Youngs Cove	F606	21:15	00:00	X
	29	Dennys	Youngs Cove	F607	10:45	13:15	X
	29-30	Dennys	Youngs Cove	F608	23:00	02:00	
September	23	Outer CB	Carrying Place Cove	F701	18:40	21:00	
	24	Outer CB	Carrying Place Cove	F702	06:20	09:45	
	24	Outer CB	Carrying Place Cove	F703	18:50	22:10	
	25	East	Sipp Bay	F704	07:30	10:00	X
	25	East	Sipp Bay	F705	20:00	22:45	
	26	Dennys	Youngs Cove	F706	09:30	12:30	
	26-27	Dennys	Youngs Cove	F707	22:00	01:20	

Table 5. Capture data, by month, all gear types combined, for sampling in Cobscook Bay in 2012.

Month	March	April	May	June	August	September	November	Total
Species	**Number of individuals**							
Threespine stickleback, *Gasterosteus aculeatus*	5	>4	895	903	8439	4631	77	>14954
Atlantic herring, *Clupea harengus*			2558	1231		3		3792
Atlantic silverside, *Menidia menidia*		>75	70	52	37	1858	>335	>2427
Winter flounder, *Pleuronectes americanus*			1119	892	130	162		2303
Black spotted stickleback, *Gasterosteus wheatlandi*	1	5	221	237	716	331	32	1543
Alewife, *Alosa pseudoharengus*				735	289	92	7	1123
Mummichog, *Fundulus heteroclitus*		11	188	195	133	298	5	830
Silver hake, *Merluccius bilinearis*			32	216	8	2		258
Rainbow smelt, *Osmerus mordax*			31	118	16	18		183
Longhorn sculpin, *Myoxocephalus octodecemspinosus*			87	86	4	6		183
Grubby, *Myoxocephalus aenaeus*			46	54	6	8		114
Atlantic tomcod, *Microgadus tomcod*			2	16	26	22		66
Butterfish, *Peprilus triacanthius*					53	11		65
Fourspine stickleback, *Apeltes quadracus*					33	10		43
White hake, *Urophycis tenuis*				5	8	28		41
Red hake, *Urophycis chuss*			6	7		11		24
Snakeblenny, *Lumpenus lampretaeformis*			15	6				21
Sea raven, *Hemitripterus americanus*			8	6	1			15
Ninespine stickleback, *Pungitius pungitius*					12	3		15
Atlantic cod, *Gadus morhua*			7	4				11
Atlantic halibut, *Hippoglossus hippoglossus*			2	5	1	1		9
Blueback herring, *Alose aestivalis*				2	2	3		7
Atlantic mackerel, *Scomber scombrus*					4	2		6
Pollock, *Pollachius virens*						5		5
Shorthorn sculpin, *Myoxocephalus scorpius*				3				3

Month	**March**	**April**	**May**	**June**	**August**	**September**	**November**	**Total**
Radiated shanny, *Ulvaria subbifurcata*				1	1	1		3
Spiny dogfish, *Squalus acanthias*					3			3
Winter skate, *Raja ocellatus*				2				2
Smooth skate, *Malacoraja senta*			2					2
Lumpfish, *Cyclopterus lumpus*				1				1
Rock gunnel, *Pholis gunnellus*				1				1
Little skate, *Raja erinacea*				1				1
Goosefish, *Lophius americanus*				1				1
Fourbeard rockling, *Enchelyopus cimbrius*			1					1
Windowpane, *Scophthalmus aquosus*				1				1
Clearnose skate, *Raja eglanteria*						1		1
Total	6	>95	5290	4782	9922	7507	>456	>28058

Table 6. Numbers of individuals caught by month in pelagic trawling in Cobscook Bay, 2012.

Species	May	June	August	September	Total
Atlantic herring	2539	726	0	1	3266
Rainbow smelt	4	4	0	0	8
Butterfish	0	0	3	1	4
Silver hake	1	2	0	0	3
Threespine stickleback	1	1	0	0	2
Alewife	0	1	0	0	1
Goosefish	0	1	0	0	1
Atlantic mackerel	0	0	1	0	1
Total	2545	735	4	2	3286

Table 7. Numbers of individuals caught by month in benthic trawling in Cobscook Bay, 2012.

Species	May	June	August	September	Total
Winter flounder	1119	890	125	162	2296
Silver hake	31	214	8	2	255
Longhorn sculpin	87	86	4	6	183
Rainbow smelt	13	100	1	0	114
Grubby	46	54	6	8	114
Butterfish	0	1	50	10	61
Atlantic herring	8	50	0	0	58
White hake	0	5	8	28	41
Red hake	6	6	0	11	23
Snakeblenny	15	6	0	0	21
Sea raven	8	6	1	0	15
Atlantic cod	7	4	0	0	11
Atlantic halibut	2	5	1	1	9
Alewife	0	5	3	1	9
Atlantic mackerel	0	0	3	2	5
Shorthorn sculpin	0	3	0	0	3
Radiated shanny	0	1	1	1	3
Spiny dogfish	0	0	3	0	3
Smooth skate	2	0	0	0	2
Winter skate	0	2	0	0	2
Fourbeard rockling	1	0	0	0	1
Windowpane	0	1	0	0	1
Lumpfish	0	1	0	0	1
Rock gunnel	0	1	0	0	1
Little skate	0	1	0	0	1
Clearnose skate	0	0	0	1	1
Total	1345	1442	214	233	3234

Table 8. Numbers of individuals caught by month in intertidal seining in Cobscook Bay, 2012.

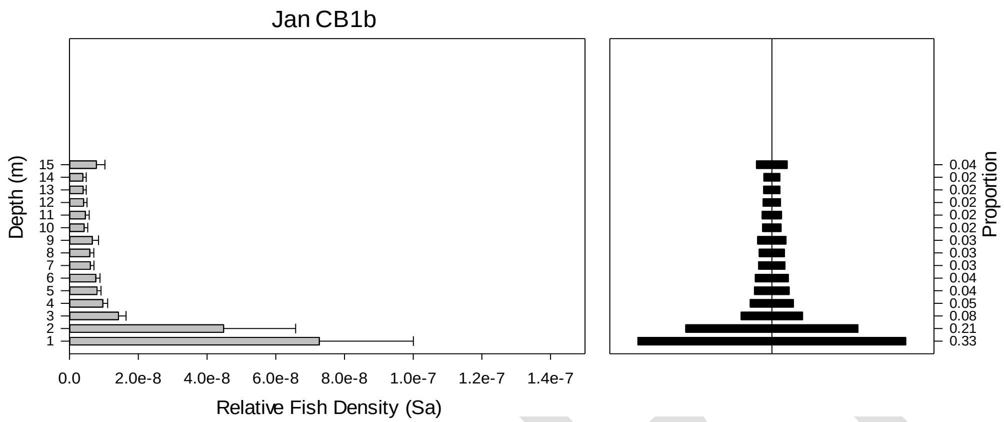
Species	March	April	May	June	August	September	November	Total
Threespine stickleback	5	>4	894	902	8333	4623	77	14838
Atlantic silverside	0	>75	70	52	37	1858	>335	2427
Blackspotted stickleback	1	5	221	237	716	331	32	1543
Alewife	0	0	0	728	286	91	7	1112
Mummichog	0	11	188	195	133	298	5	830
Atlantic herring	0	0	11	455	0	1	0	467
Fourspine stickleback	0	0	0	0	32	10	0	42
Rainbow smelt	0	0	14	14	6	7	0	41
Ninespine stickleback	0	0	0	0	12	3	0	15
Blueback herring	0	0	0	2	2	3	0	7
Atlantic tomcod	0	0	0	5	0	0	0	5
Red hake	0	0	0	1	0	0	0	1
Total	6	>95	1398	2591	9557	7225	>456	21328

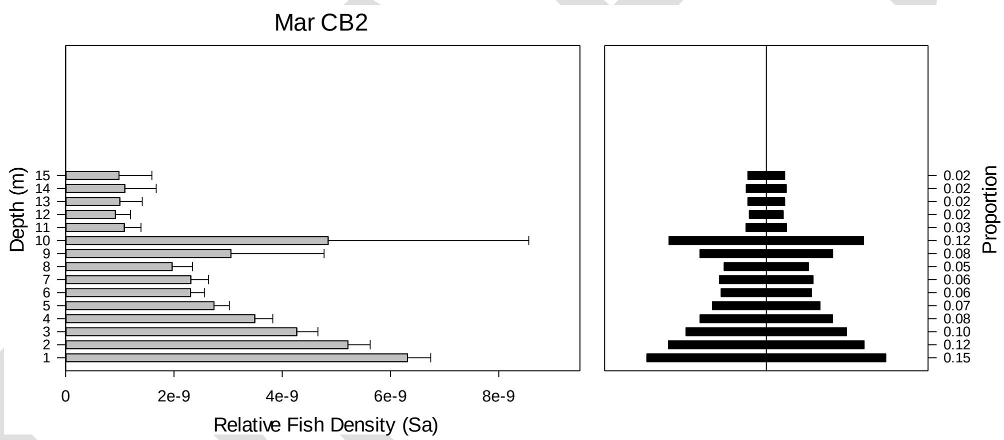
Table 9. Numbers of individuals caught by month in fyke netting and limited baited minnow trapping in Cobscook Bay, 2012. Only those baited trap sets that caught fish are included.

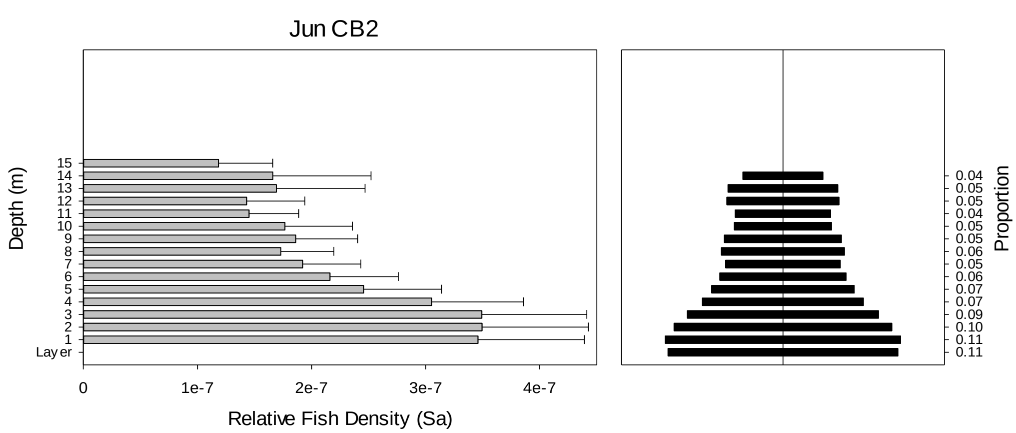
Gear	Species	May	June	August	September	Total
Fyke net	Atlantic tomcod	2	11	25	22	60
	Alewife	0	1	0	0	1
	Winter flounder	0	2	5	0	7
	Rainbow smelt	0	0	9	11	20
	Atlantic herring	0	0	0	1	1
	Pollock	0	0	0	5	5
	Total	2	14	39	39	94
Baited trap	Threespine stickleback			106	8	114
	Atlantic tomcod			1		1
	Fourspine stickleback			1		1
	Total	0	0	108	8	116

Appendix B

Vertical fish distributions for Cobscook Bay 2012, pre-deployment (Jan – Jun). Note that x-axes are not standardized across graphs. CB1a is 'next to", CB1b is 'in-line with' the turbine and CB2 is the control site.

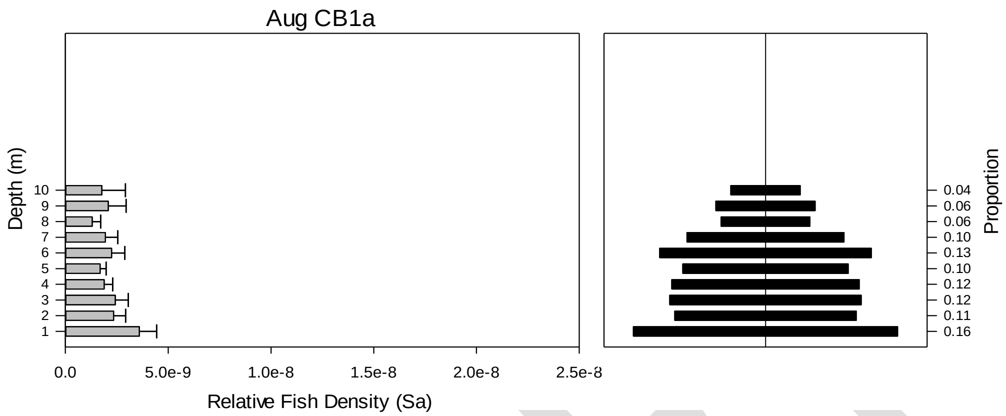


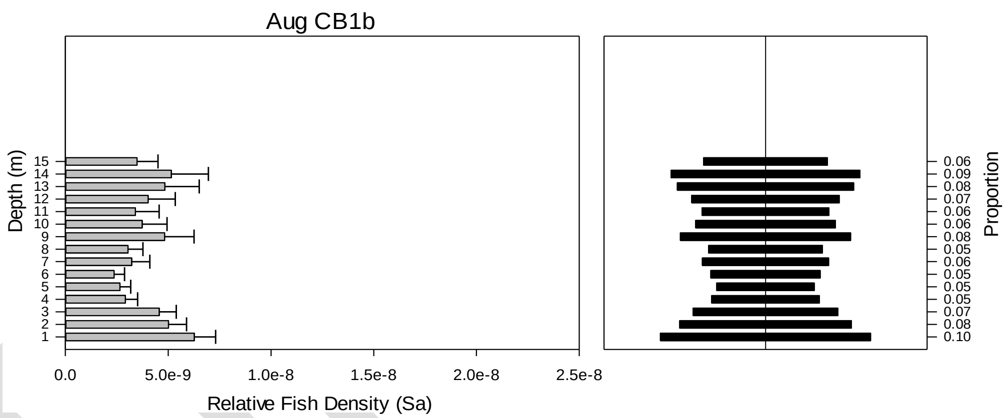


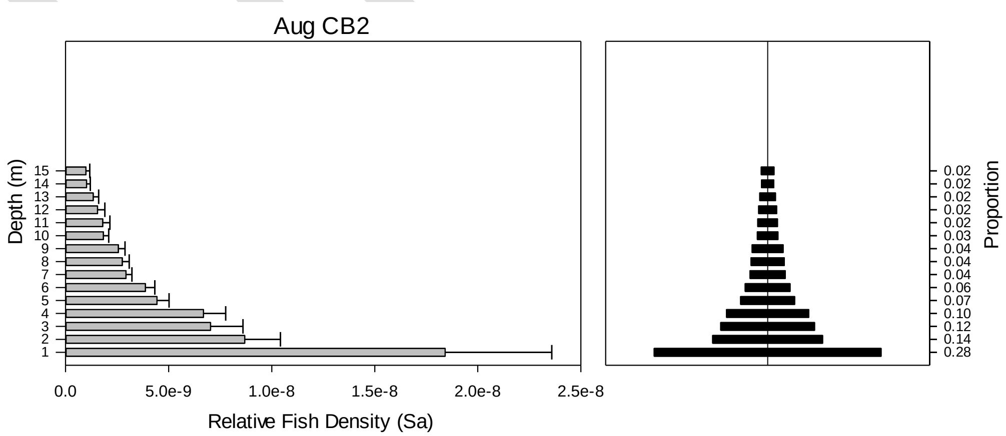


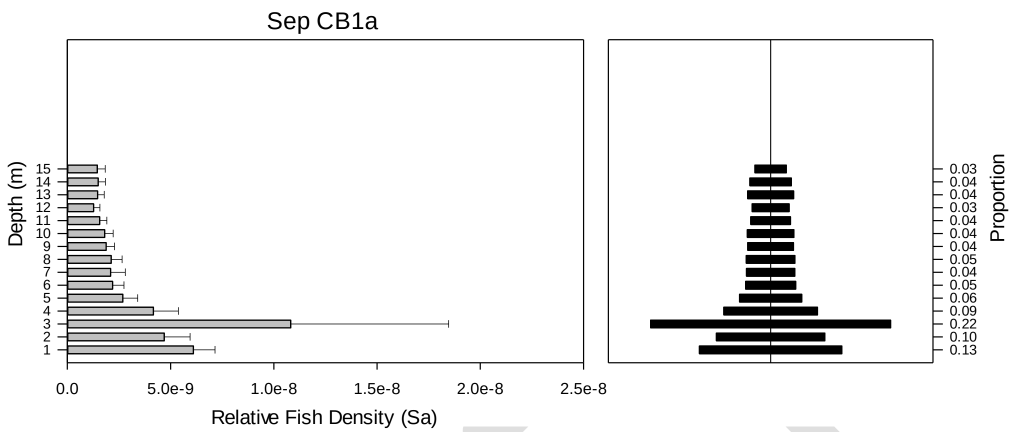
Appendix C

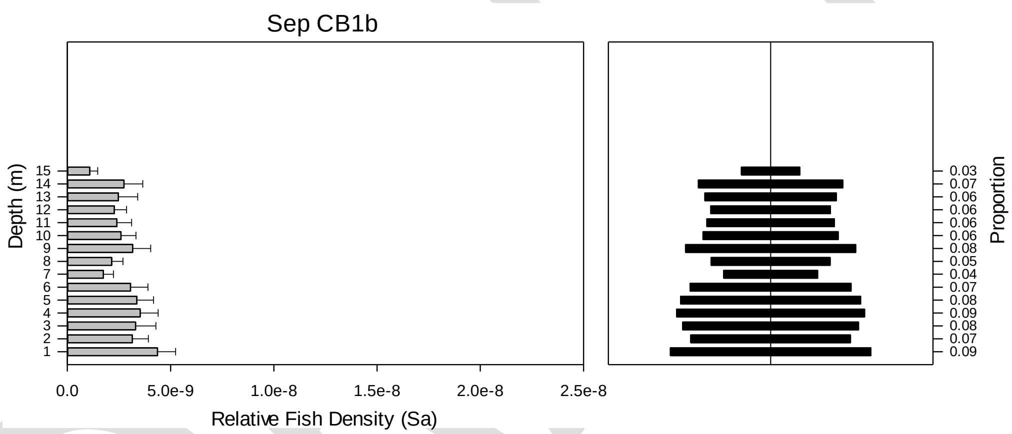
Vertical fish distributions for Cobscook Bay 2012, post-deployment (Aug and Sep). Note that x-axes are not standardized across graphs. CB1a is 'next to", CB1b is 'in-line with' the turbine and CB2 is the control site.

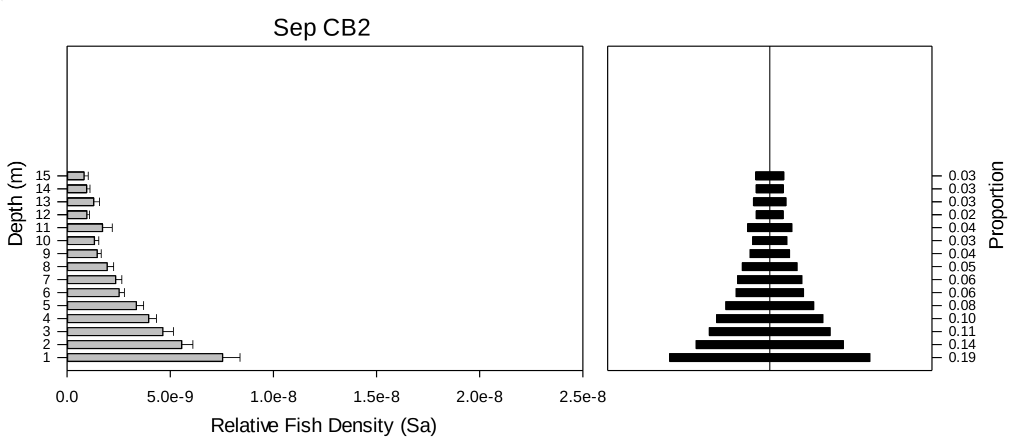







Sep CB1a
Depth (m)
Relative Fish Density (Sa)
Proportion
0.0
5.0e-9
1.0e-8
1.5e-8
2.0e-8
2.5e-8
0.03
0.04
0.04
0.03
0.04
0.04
0.04
0.05
0.04
0.05
0.06
0.09
0.22
0.10
0.13


Sep CB1b
Depth (m)
Relative Fish Density (Sa)
Proportion
0.0
5.0e-9
1.0e-8
1.5e-8
2.0e-8
2.5e-8
0.03
0.07
0.06
0.06
0.06
0.06
0.08
0.05
0.04
0.07
0.08
0.09
0.08
0.07
0.09


Sep CB2
Depth (m)
Relative Fish Density (Sa)
Proportion
0.0
5.0e-9
1.0e-8
1.5e-8
2.0e-8
2.5e-8
0.03
0.03
0.03
0.02
0.04
0.03
0.04
0.05
0.06
0.06
0.08
0.10
0.11
0.14
0.19