**Please note:** While FORCE appreciates the significant work involved in this study, subsequent review by our science team has identified substantial analytical errors, listed below, that invalidate the results of this study and their subsequent interpretation. This report should not be referenced, nor form the basis of other work. It remains in our document collection only for archival purposes. Interested readers are encouraged to review a related, more recent report (completed 2019), found here.

**Methodological errors:**

- Instrument calibration settings were invalid because of calibration data acquisition procedures adopted during field operations, and inadequate quality control of calibration analytical processes afterwards.

- Standard data quality controls and data processing procedures were not followed leading to incorrect values being included in the analysis.

- Substantial analytical and computer coding errors were made in the way that tide phases, diel states, and “with” and “against” were assigned to the data and reported in the document.

- Data was mislabelled and errors were made in the way that data was aggregated (e.g., differing-sized integration bins), with some data being duplicated in the dataframe used for analysis.

- Hydroacoustic post-processing software was not certified for use with the EK80 echosounder data (automated warnings generated by the software were ignored).

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Fundy Ocean Research Center for Energy (FORCE)

# Marine Fish Monitoring at FORCE:
## Report on processing and analysis of surveys from May, July and August 2017

**Prepared by:** Aurélie Daroux, Louise McGarry and Gayle Zydlewski, University of Maine, School of Marine Sciences

This is a report of the Environmental Effects Monitoring Plan (EEMP) fish-surveys for May, July and August 2017. It includes a brief description of the surveys, the results for those surveys, analysis within the wider context of the EEMP (2016-2017 with historical surveys from 2011-2012) and needs moving forward.

**Summary:** Three 24-hour surveys were run by FORCE staff in May, July and August 2017. The turbine was present, although not generating electricity, during the May survey. Having been removed in June 2017, the turbine was not present during the July and August 2017 surveys. Among the three months sampled during this reporting period, May and July had higher variability in fish densities than August. This is consistent with previous sampling in 2016 as well as 2011 and 2012, when fish densities were more variable in May and dropped in August. Seasonal shifts could be linked to shifts in species presence in the region, e.g., alewife and Atlantic herring migrations through the Minas Passage in spring of each year.

Fish vertical distributions were variable with some similarities and differences relative to data collected in 2016. There were obvious differences between the May 2016 and 2017 surveys. In both 2016 and 2017, the CLA site relative fish densities were generally low in May with the highest densities at a distance of 30-40 m off the sea bottom; in the reference site densities were higher in 2017 at depths of 15-30 m. This may be linked to the fact that these two surveys occurred at different dates within the month and the fish species sampled during those periods were likely different. May seems to be an important month, with high and variable fish densities, for continued monitoring. In August of both years fish were more evenly distributed throughout the water column in both the CLA and reference sites with slightly higher densities near the surface (35-40 m above the bottom) in 2017.

When the May, July, and August 2017 data are included with data from previous surveys, all factors tested (year, month, site, turbine presence/absence, tidal cycle, and diel cycle) had statistically significant effects on relative fish density. It is likely that the unbalanced nature of the current dataset (12 surveys without a turbine, 3 with an operational turbine) affects the performance of the model. Statistical verification of the approach will be completed in early 2018.

Note that the original field sampling protocol called for the south across-channel transect to be conducted in continuous wave mode (South CW) and the northward return transect in frequency modulated mode (North FM). However, the two modes (FM and CW) were interchanged for surveys conducted in May, July, and August 2017. While this can be fixed post-survey data coding will need to be manually adjusted (and possibly missed) in analyses. In future surveys the convention should be standardized.

Aurélie Daroux left her position at the University of Maine in August and trained Louise McGarry to process and analyze data using the same methods. A processing manual has been created for future reference. This document, so far, has been designed to be comprehensible for people with knowledge in hydroacoustic data processing in Echoview, and in using R for statistical analyses.

## Introduction

This project is an extension of previous work conducted at the FORCE site (Daroux and Zydlewski 2017), designed to assess indirect effects of deployed TISEC devices in the FORCE CLA by quantifying fish behavior changes, measured as changes in spatial distribution mid-field to any turbine deployment. The scope of this report was to process and analyze data collected in three surveys (during May, July, and August 2017) and place those data within the context of previous surveys from 2011, 2012, 2016, and 2017.

Indirect effects are changes in the mid-field, within 10’s of meters of a turbine, likely associated with turbine presence but not including direct interaction with the turbine. Specific objectives of the overall project include: (1) testing for indirect effects of TISEC devices on relative fish density throughout the entire water column; (2) testing for indirect effects of TISEC devices on fish vertical distributions; and (3) estimating the probability of fish being at the same depth of the turbine based on the vertical distribution of fish relative to a deployed TISEC device depth. Objective # 3 is not addressed in this report because an operating turbine was not present and transects over the turbine were not conducted during this contracting period.

Logistical difficulties and safety considerations in tidally dynamic regions can be barriers to performing quantitative fisheries surveys using physical capture of fish. As such, objectives one and two are being accomplished using mobile surveys with a down-looking hydroacoustic echosounder (EK80) mounted to a medium-sized boat (the *Nova Endeavor*) using field methods with post-survey data processing and statistical analysis techniques to assess effects of turbine presence of fish distributions.

# Material and methods

## Historical data: 2011-2012

In 2011 and 2012, 7 hydroacoustic mobile surveys were conducted using a split beam echosounder (SIMRAD EK60) operating at 120 kHz using the charter vessel FUNDY SPRAY (Melvin and Cochrane 2014). Transmitting power was set at 500W, pulse duration was 1.024 and ping rate at 1/s (to reduce interference with other devices). Raw data and calibration settings from these 7 historical surveys were provided by Gary Melvin and re-processed using our own data processing methods (see part 4 of Materials and Methods: Data processing in Daroux and Zydlewski 2017).

**Table 1: Summary of the historical dataset surveys conducted in Minas Passage between August 22, 2011 and May 31, 2012. Times here are in GMT.**

| Survey | Start date | Start time | End date | End time | Day/ Night | Temperature (°C) | Turbine presence |
|---|---|---|---|---|---|---|---|
| 1 | 2011-08-22 | 11:45:18 | 2011-08-22 | 21:28:30 | D | 15.41 | No |
| 2 | 2011-09-19 | 10:55:27 | 2011-09-19 | 20:22:39 | D | 15.7 | No |
| 3 | 2011-10-03 | 09:53:06 | 2011-10-03 | 20:25:26 | D | 15.0 | No |
| 4 | 2011-11-22 | 14:22:38 | 2011-11-22 | 22:35:59 | D/N | 10.3 | No |
| 5 | 2012-01-25 | 18:32:58 | 2012-01-25 | 16:15:18 | D/N | 3.57 | No |
| 6 | 2012-03-19 | 14:23:30 | 2012-04-19 | 13:33:06 | D/N | 2.5 | No |
| 7 | 2012-05-31 | 12:09:40 | 2012-05-31 | 23:12:16 | D/N | 9.51 | No |

## Contemporary data: 2016-2017

The survey design and the echosounder system settings used for historical data collection were used to collect a comparable contemporary dataset. Data were collected with a Simrad EK80 scientific echosounder, mounted over the side of a medium sized boat, the Nova Endeavor. Transducer settings were: pulse duration of 1.024 ms (consistent with historical settings), power of 250 W (recommended by Simrad), and ping interval of 250 ms (lower than the historical dataset collection settings, which was fixed at 1 s to minimize interference with other devices).

Nine surveys were performed in 2016 and 2017 (Table 2), with 5 surveys without a turbine present (May, August and October 2016; **July and August 2017**) and 4 surveys with a turbine deployed (November 2016, January, March, and **May 2017**).

**Table 2: Summary of contemporary surveys conducted in Minas Passage between May 28, 2016 and August 31, 2017. Times are local. Note that surveys 1-6 were processed, analyzed and reported in Daroux and Zydlewski 2017. New results processed and analyzed in this report are for surveys 7-9.**

| Survey | Start date | Start time | End date | End time | Day/ Night | Temperature (°C) | Turbine presence |
|---|---|---|---|---|---|---|---|
| 1 | 2016-05-28 | 06:01 | 2016-05-29 | 05:35 | D/N | 7 | No |
| 2 | 2016-08-13 | 09:09 | 2016-08-14 | 07:40 | D/N | 15 | No |
| 3 | 2016-10-07 | 05:45 | 2016-10-08 | 04:21 | D/N | 15 | No |
| 4 | 2016-11-24 | 08:38 | 2016-11-25 | 09:07 | D/N | 8.0 | Yes |
| 5 | 2017-01-21 | 06:55 | 2017-01-22 | 05:55 | D/N | 1.5 | Yes |
| 6 | 2017-03-21 | 08:24 | 2017-03-22 | 06:04 | D/N | 4 | Yes |
| 7 | 2017-05-04 | 19:57 | 2017-05-05 | 18:21 | D/N | 5 | Yes (free spinning) |
| 8 | 2017-07-03 | 21:34 | 2017-07-04 | 19:09 | D/N | 12 | No |
| 9 | 2017-08-30 | 18:53 | 2017-08-31 | 17:37 | D/N | 15.7 | No |

Two calibrations (one for the CW mode and one for the FM mode) were performed before each survey. The survey design was composed of 4 grids traversed over 24 hours, which included 2 tidal cycles (one grid per tidal stage). For each grid, every 1.8-km transect was performed twice, “with” and “against” the tidal current. A grid began at transect N0 (always beginning the first transect with the ebbing tide and conducting it with the current), and each successive transect was traversed in numerical order (N0 to N5). Then a southward across-channel transect (South_FM) terminated near the Passage’s southern coastline. This was the only transect performed in frequency modulated mode. The across-channel transect was followed by 3 reference transects (S1 to S3), with and against the current. To finish the grid, a northward return transect (North_CW) returned the vessel to N0 (Table 3 and Figure 1). A grid consisted of one full time through all transects. Generally, two grids were conducted during the day and two at night.

Note that the original grid plan called for the south across-channel transect to be conducted in continuous wave mode (South CW) and the northward return transect in frequency modulated mode (North FM). However, the two modes (FM and CW) were interchanged for surveys conducted in May, July, and August 2017. *For this report the across-channel transect conducted in May, July, and August 2017 were renamed South_FM and North_CW to reflect the survey activity*. **In future surveys the convention should be standardized.**

**Table 3: Latitude and longitude in decimal degrees used as Minas Channel transects for contemporary surveys in 2016 and 2017.**

| | West End | | East End | |
|---|---|---|---|---|
| **CLA transects:** | **Lat** | **Lon** | **Lat** | **Lon** |
| N0 | 45.3730 | -64.4400 | 45.3684 | -64.4178 |
| N1 | 45.3714 | -64.4414 | 45.3666 | -64. 4188 |
| N2 | 45.3697 | -64.4424 | 45.3646 | -64.4197 |
| N3 | 45.3681 | -64.4434 | 45.3628 | -64.4207 |
| N4 | 45.3664 | -64.4443 | 45.3610 | -64.4217 |
| N5 | 45.3646 | -64.4453 | 45.3593 | -64.4226 |
| **Cross-channel transects:** | **Lat** | **Lon** | **Lat** | **Lon** |
| North_CW | 45.3646 | -64.4453 | 45.3352 | -64.4605 |
| South_FM | 45.3276 | -64.4388 | 45.3681 | -64.4178 |
| **Reference transects:** | **Lat** | **Lon** | **Lat** | **Lon** |
| S1 | 45.3352 | -64.4605 | 45.3313 | -64.4372 |
| S2 | 45.3334 | -64.4615 | 45.3296 | -64.4380 |
| S3 | 45.3317 | -64.4623 | 45.3276 | -64.4388 |

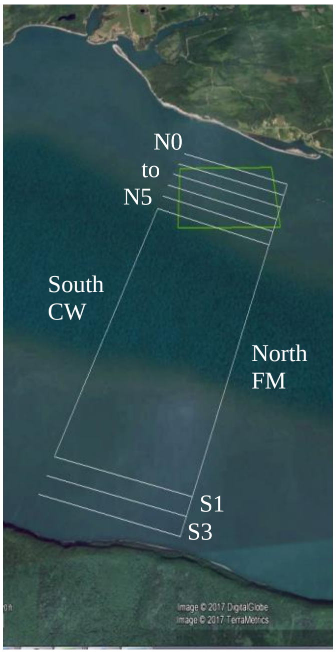


**Figure 1:** Contemporary survey grid design. The green square represents the CLA. White lines show one complete grid, with transects at the CLA (N0-N5) and reference (S1-S3) sites connected by cross-channel transects (South CW and North FM). Note that the transect (North or South) on which the echosounder was set to FM or CW was inverted for May, July, and August 2017 surveys.

## Data processing

Data processing was performed using the software Echoview® (version 7.1.35; Myriax, Hobart, Australia), which is specialized for the analysis of hydroacoustic data. The data were cleaned (threshold applied and entrained air removed), split into analysis bins, and echo integrated. The full description of the data processing can be found in the 2017 Final report (Daroux and Zydlewski 2017).

To detect only fish, we used a target strength (TS) threshold of -60 dB and a Sv threshold of -66 dB, according the methods from Higginbottom *et al.*(2008). This method allowed us to detect only fish greater than 10cm in length.

## Data Analyses

Data analysis was conducted with the software R (R Core Team, Vienna, Austria). We examined changes in water column fish density and vertical distribution of fish.

### 1. Water column fish density

To test for indirect effects of the single deployed TISEC device on fish density (throughout the water column), we used data exported for 20 m distance bins. The data distribution was not normal, with 50% of values equal to zero (empty water column). To test the effect of site (CLA or reference) and turbine (presence or absence) a two-stage, zero-inflated generalized linear model (GLM) was created for sv values (volume backscatter in the linear domain, or relative fish density) on the full dataset (historical data and contemporary data combined).

- The first model used tested sv as a function of fish presence (presence = 0 if sv = 0, or 1 if sv > 0).
    - ***1st stage** = GLM (sv ~ fish presence)*
- We then applied the prediction from the first stage to the second stage model and added variables of interest (site and turbine):
    - ***2nd stage A** = GLM (sv ~ 1st stage + site + turbine)*
- To also test for an effect of time of year, we performed another two-stage GLM that incorporated survey month:
    - ***2nd stage B** = GLM (sv ~ 1st stage + site + month)*
- To test for the significance of the environmental parameters diel and tidal cycles as well as the diel variable interacting with the location/site:
    - ***3rd stage** = GLM (sv ~ 1st stage + location + month + year + turbine + diel + tide + diel*site + diel*tide)*

### 2. Fish vertical distribution

To examine indirect effects of a single TISEC device on fish vertical distribution, we worked with data exported by 1 meter depth bins for each individual transect. We calculated the proportion of area backscatter, sa, contributed by each layer (sa for each layer divided by the sa summed for all layers). Depth varied over the course of each transect, between transects, and with the tidal stage (from 40 to 65 meters). As such, we examined only the distribution within the first 50 meters above the bottom.

# Results and discussion

## 1. Water column fish density

Changes in fish density were explored as a function of several factors (turbine, survey, month, diel and tidal cylces). Boxplots were used to visualize sv data. All following boxplots show the median (thick horizontal line), interquartile range (colored box), and 10$^{th}$ and 90$^{th}$ percentiles (whiskers). A large number of 0's (empty water column) resulted in heavily skewed distributions, so non-zero variation is best visualized by the extent of the box and whiskers. The mean is shown by the empty circle in some figures, as an indicator of the extreme value (outliers') influence. In all plots, the red color is associated with the CLA site and the blue color with the reference site.

### A. Turbine presence or absence

Relative fish density was similar at both the CLA and reference sites when the turbine was present (Figure 2). The importance of the reference site is demonstrated by the similarity in changes in fish density at both sites (Figure 2), relative fish density increased ***at both sites*** when the turbine was present. These similarities enable us to not falsely associate changes with the deployment of the turbine.

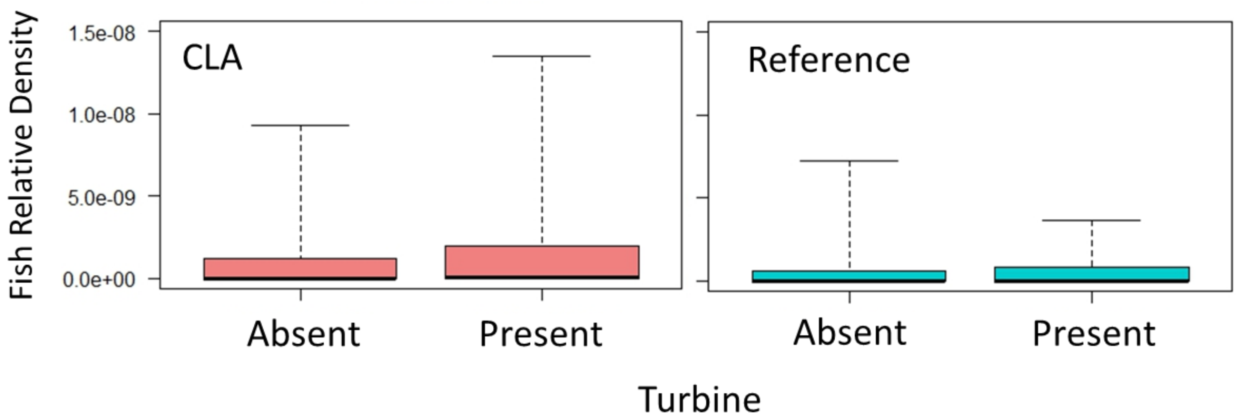


**Figure 2: Boxplot of sv (relative fish density) by site and turbine factor (turbine absent or present). Turbine absent data include the historical dataset (2011-2012) and part of the contemporary dataset (May, August, October 2016; July and August 2017); Turbine present data include November 2016 and January, March, and May 2017 of the contemporary dataset.**

### B. Historic and Contemporary

Fish density was similar among sites but varied by survey timing (Figures 3 and 4). The seasonal variation was similar for historical (2011-2012) and contemporary (2016-2017) data. Generally, relative fish densities during November and January surveys were most variable with decreased variability in March, heightened variability in May and July with less variability again in August. These variations could be related to differences in fish aggregation or fishes of different sizes being present during different times of year. For example, larger fish or denser aggregations could result in larger sv values, hence increasing data variability, but perhaps not enough to change the median sv value.

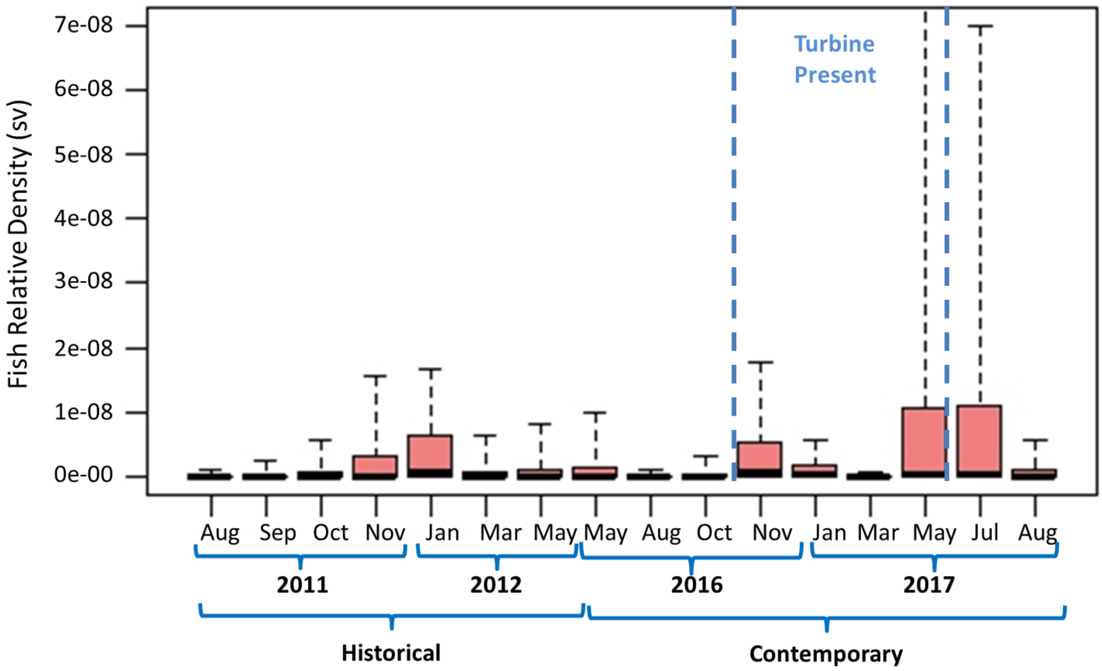


**Figure 3a: Boxplot of sv (relative fish density) by survey for the CLA site. The dashed blue vertical lines indicate surveys conducted while the turbine was present.**

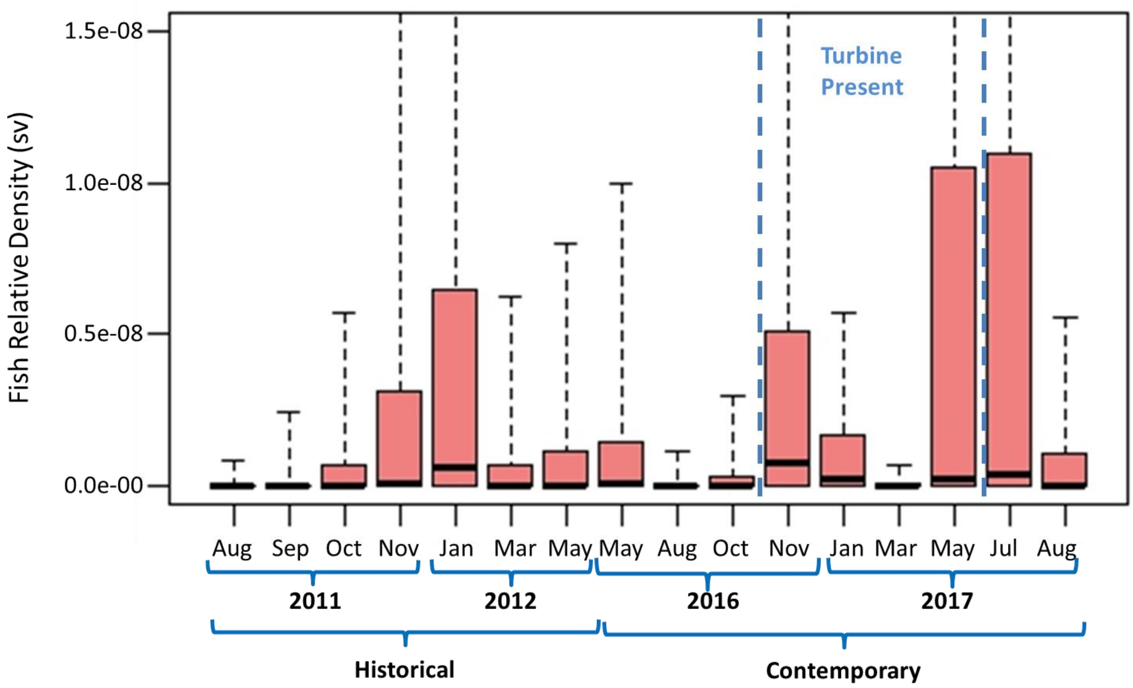


**Figure 3b: Figure 3a with y-axis expanded to show detail.**

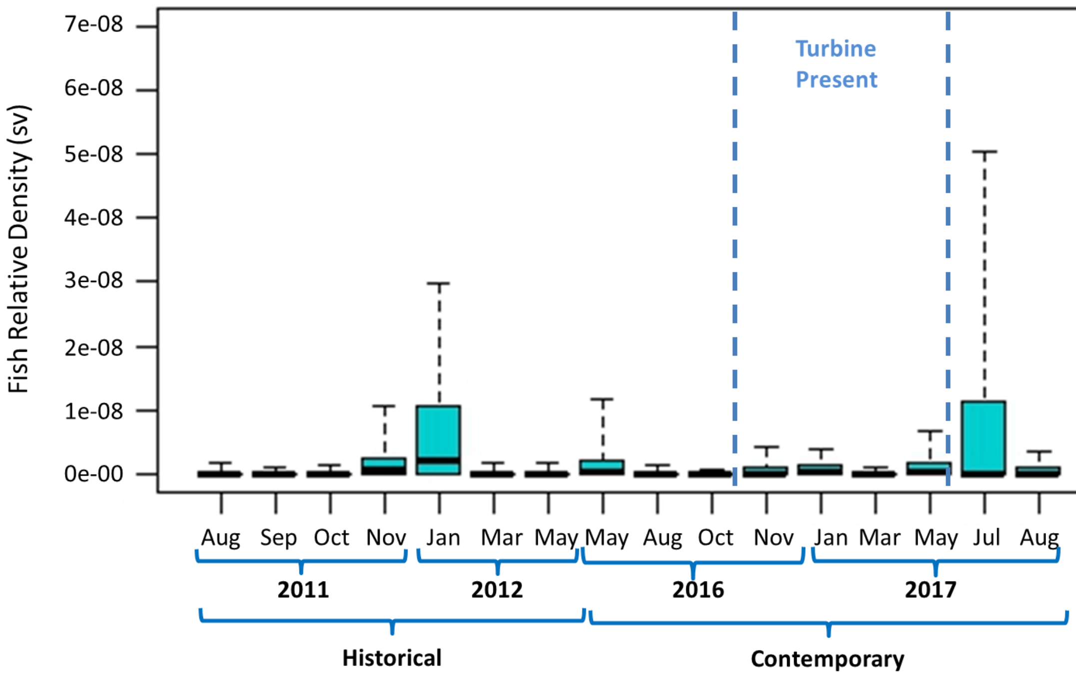


**Figure 4: Boxplot of sv (relative fish density) by survey for the reference site. The dotted blue vertical lines indicate surveys conducted while the turbine was present.**

## C. Seasonal

The contemporary data (Figures 5 and 6, right) had similar fish densities as the historical data (Figure 5 and 6, left) except for May. Relative density was also high in November and January in both dataset, especially in January 2012 (Figure 7 and 8).

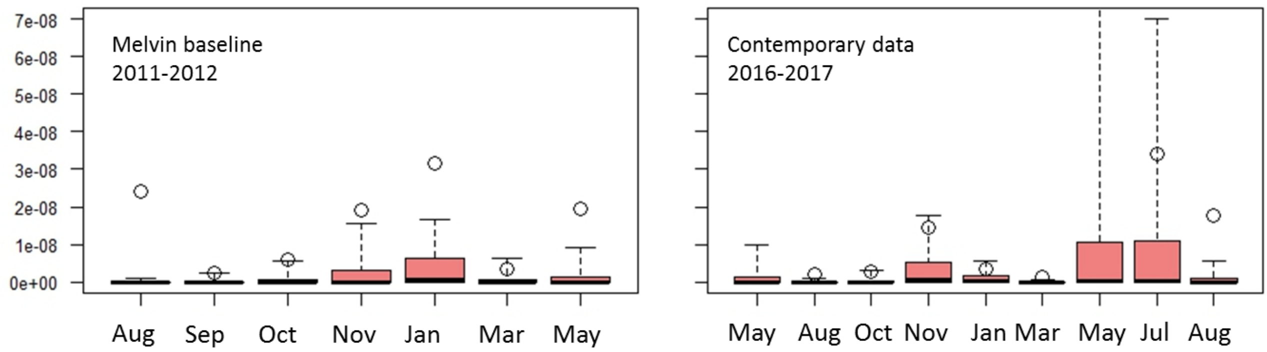


**Figure 5: Boxplot of sv (relative fish density) for CLA site by survey month for historical dataset (2011 and 2012) and contemporary dataset (2016 and 2017). In the contemporary dataset May mean is not represented because the value is too high and couldn't be plotted within the range used here.**

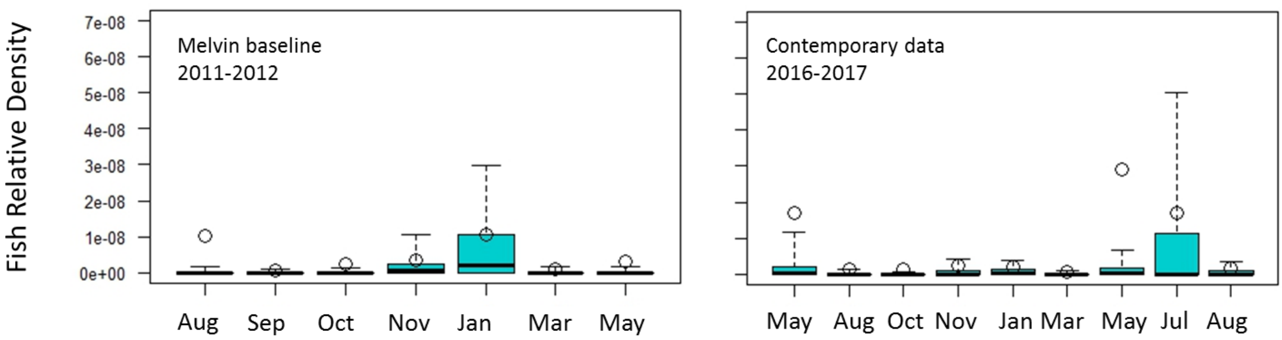


**Figure 6: Boxplot of sv (relative fish density) by survey month for the reference site for historical dataset (2011 and 2012) and contemporary dataset (2016 and 2017)**

As mentioned earlier, variation in relative fish densities could be related to differences in fish aggregation or fishes of different sizes and species being present during different times of year. Seemingly high densities in November could be related to emigration of juvenile clupeids. By late fall, young of the year river herring (*Alosa aestivalus*), alewife (*Alosa pseudoharengus*) and Atlantic herring (*Clupea harengus*) are the abundant clupeid species remaining along the northern coast (Ames and Litcher, 2013; Dadswell, 2013). After that period, they are thought to move to deeper, warmer depths through the winter (Townsend *et al.*, 1989), and return to coastal nurseries in the spring. However, anecdotal data suggest Atlantic herring remain in the passage throughout the winter (Viehman, personal communication).

Higher fish densities in May (especially in 2016) were observed. This may have been associated with adult alewife spring spawning migrations and the presence of Atlantic herring and striped bass (*Morone saxatilus*) (Baker et *al.*, 2014). Striped bass are common in the Minas Passage along the shoreline and they spawn in the head of the tide in May-June (Rulifson and Dadswell, 1995). Spring variation may also be linked to other species migrating into the basin for the summer, e.g. Atlantic sturgeon (*Acipenser oxyrhynchus*), American shad (*Alosa sapidissima*), American mackerel *(Scomber scombrus*), rainbow smelt (*Osmerus mordax*) (Dadswell 2010; Stokesbury *et al.*2016).

## D. Tidal and Diel Cycles

Overall (historical data and contemporary data combined), fish density was different during ebb and flood tides. Relative fish density was higher during ebb tides than during flood tides (Figure 7). Mean sv during ebb tide is the highest, reflecting a higher number of extreme values (outliers), perhaps indicating movement of big fish or aggregations of fish out of the basin with the ebbing tide (Figure 7).

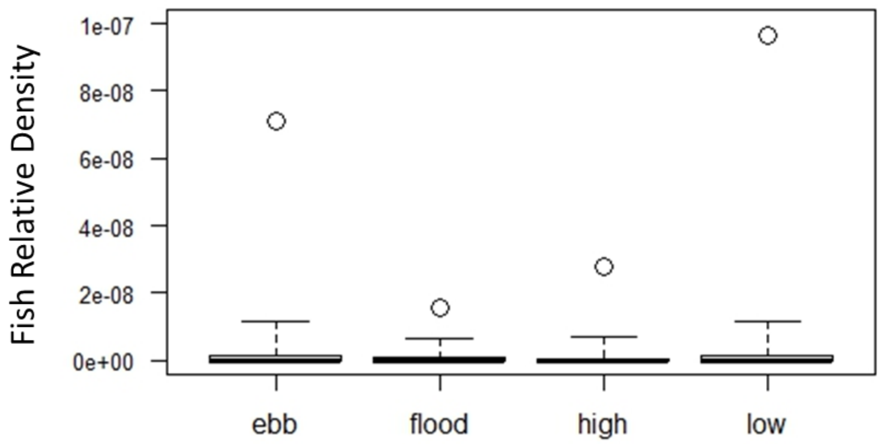


**Figure 7: Boxplot of sv (relative fish density) by tidal stage for historical and contemporary data combined.**

For all data examined, fish density was higher and more variable at night (Figure 8).

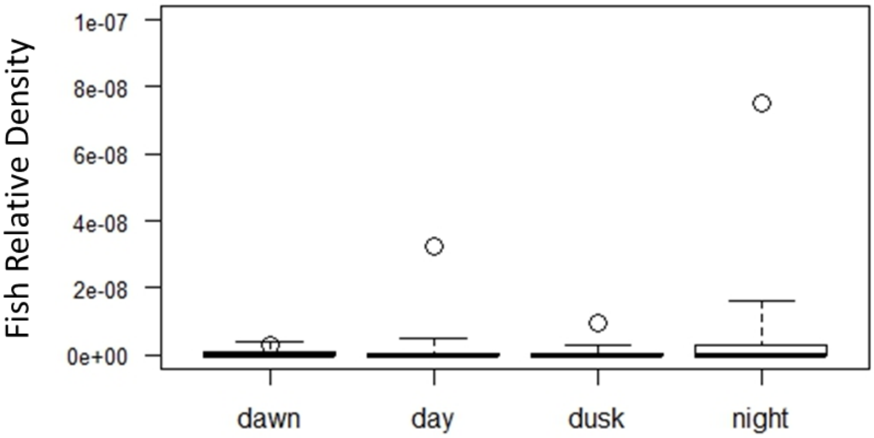


**Figure 8: Boxplot of sv (relative fish density) by diel stage for all the data (left), historical (2011-2012) and contemporary data (2016-2017) separated (right).**

It is well known that fish densities are generally higher at night at similar tidal energy sites (e.g., Cobscook Bay, ME; Viehman *et al.* 2015; Viehman and Zydlewski, 2017) and with up-looking stationary hydroacoustic surveys in the FORCE site (Viehman, personal communication). Furthermore, ebb tide sampling showed higher relative fish densities. Thus, fish behavior has been inferred to result in different densities being observed during different tidal and diel stages (Helfman, 1993; Viehman and Zydlewski, 2017).

## E. Statistical Analyses

The Generalized Linear Models used suggest significant effects of all factors tested (Tables 5, 6 and 7, except the interaction of diel cycle and tidal cycle). These results and the statistical approach are being reviewed by a statistician and this report will be updated according to any suggested recommendations.

**Table 5: Results of the two-stage GLM 2A (factors: fish presence, site and turbine).**

| | Df | Deviance | Resid. Df | Resid. Dev | Pr (>Chi) |
|---|---|---|---|---|---|
| Null model | | | 100731 | 2.6E-07 | |
| Fish | 1 | 2.2E-10 | 100730 | 2.6E-07 | < 2.2E-16 |
| Site | 2 | 7.5E-11 | 100728 | 2.6E-07 | 6.1E-07 |
| Turbine | 1 | 6.9E-11 | 100727 | 2.6E-07 | 2.9E-07 |

**Table 6: Results of the two-stage GLM 2B (factors: fish presence, site and survey month).**

| | Df | Deviance | Resid. Df | Resid. Dev | Pr(>Chi) |
|---|---|---|---|---|---|
| Null model | | | 100731 | 2.6E-07 | |
| Fish | 1 | 2.2E-10 | 100730 | 2.6E-07 | < 2.2E-16 |
| Site | 2 | 7.5E-11 | 100728 | 2.6E-07 | 6.0E-07 |
| Month | 7 | 3.8E-10 | 100721 | 2.6E-07 | < 2.2E-16 |

**Table 7: Results of the two-stage GLM 3 (factors: fish presence, site, survey month, turbine, diel, tide and interaction between site and diel cycle).**

| | Df | Deviance | Resid. Df | Resid. Dev | Pr(>Chi) |
|---|---|---|---|---|---|
| Null model | | | 100731 | 2.6E-07 | |
| Fish | 1 | 2.2E-10 | 100730 | 2.6E-07 | < 2.2E-16 |
| Site | 2 | 7.5E-11 | 100728 | 2.6E-07 | 5.9E-07 |
| Month | 7 | 3.8E-10 | 100721 | 2.6E-07 | < 2.2E-16 |
| Year | 3 | 6.6E-11 | 100718 | 2.6E-07 | 1.5E-05 |
| Turbine | 1 | 3.6E-11 | 100717 | 2.6E-07 | 2.0E-04 |
| Diel | 3 | 4.7E-11 | 100714 | 2.6E-07 | 4.3E-04 |
| Tide | 3 | 2.7E-11 | 100711 | 2.6E-07 | 1.7E-02 |
| Site*Diel | 6 | 4.3E-11 | 100705 | 2.6E-07 | 1.2E-02 |
| Diel*Tide | 7 | 3.2E-11 | 100698 | 2.6E-07 | 9.5E-02 |

The statistical models used address issues with the large volume of zero data. However, the design is unbalanced, 4 turbine samples and 12 not-present, and the data are divided into many 20 m distance bins for each transect, resulting in large sample sizes. While some factors are seemingly more significant than others, their interpretation is difficult and needs to be reviewed with a statistician.

Additional data from the region are likely to improve the fit of the model. As such, monitoring should continue in order to assess changes in fish distribution patterns over time since such patterns have been reported by others in similar environments (Wilson *et al.*, 2006; Copping *et al.*, 2016; Viehman, 2016).

## 2. Fish Vertical Distribution

Relative fish densities in vertical bins of the water column varied among month and between CLA and reference sites (Figure 17 and 18).

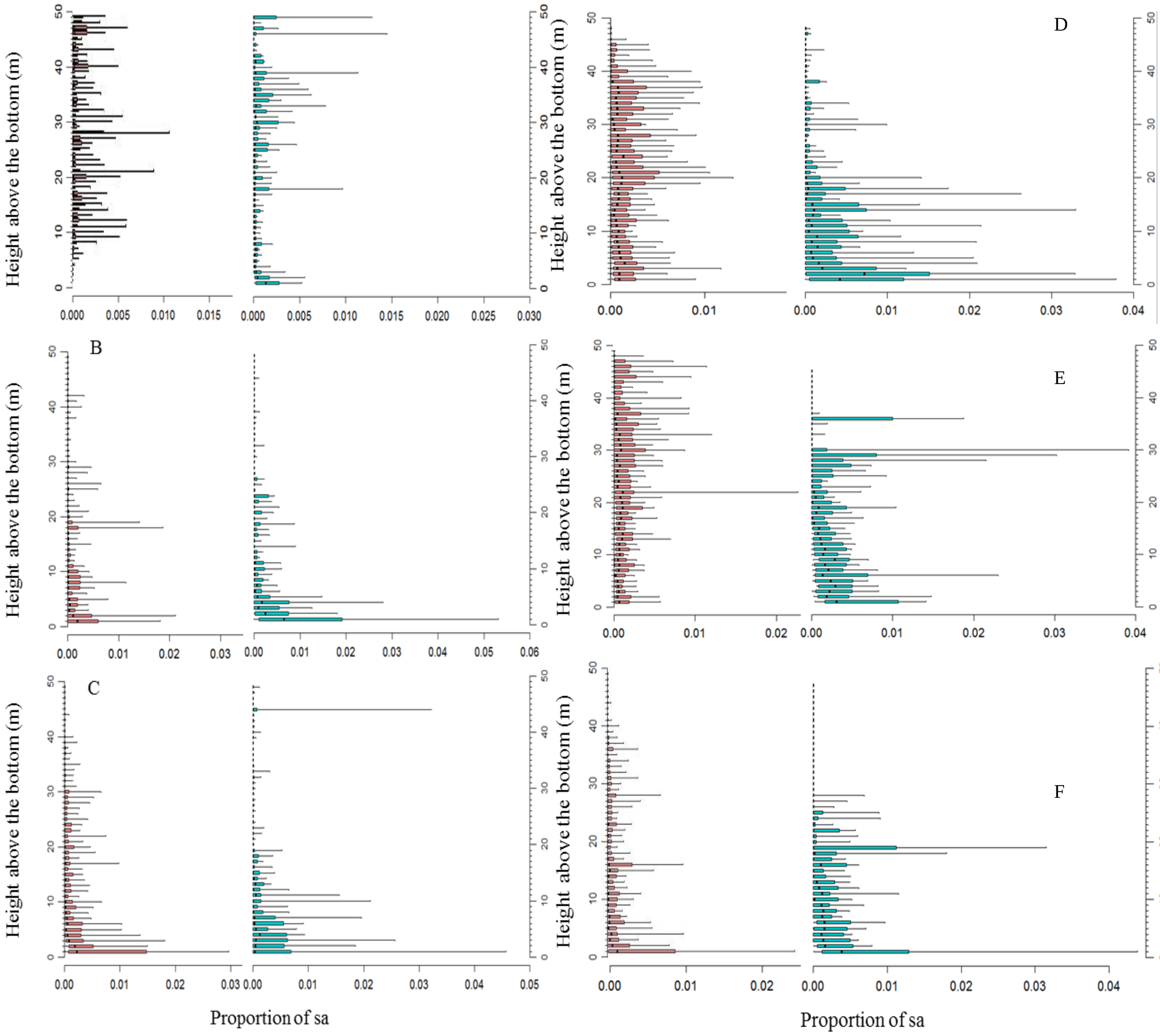


**Figure 17: Boxplot of proportion of backscatter (sa, relative fish density) by layer for May (A), August (B), October (C), November (D) 2016, January (E) and March (F) 2017, by site (CLA in red, left and reference in blue, right). The turbine was present during the November 2016 (D), and January (E) and March (F) 2017 surveys. The proportion of sa (x axis) is very small because numerous outliers have not been plotted to be able to see trends in vertical distributions.**

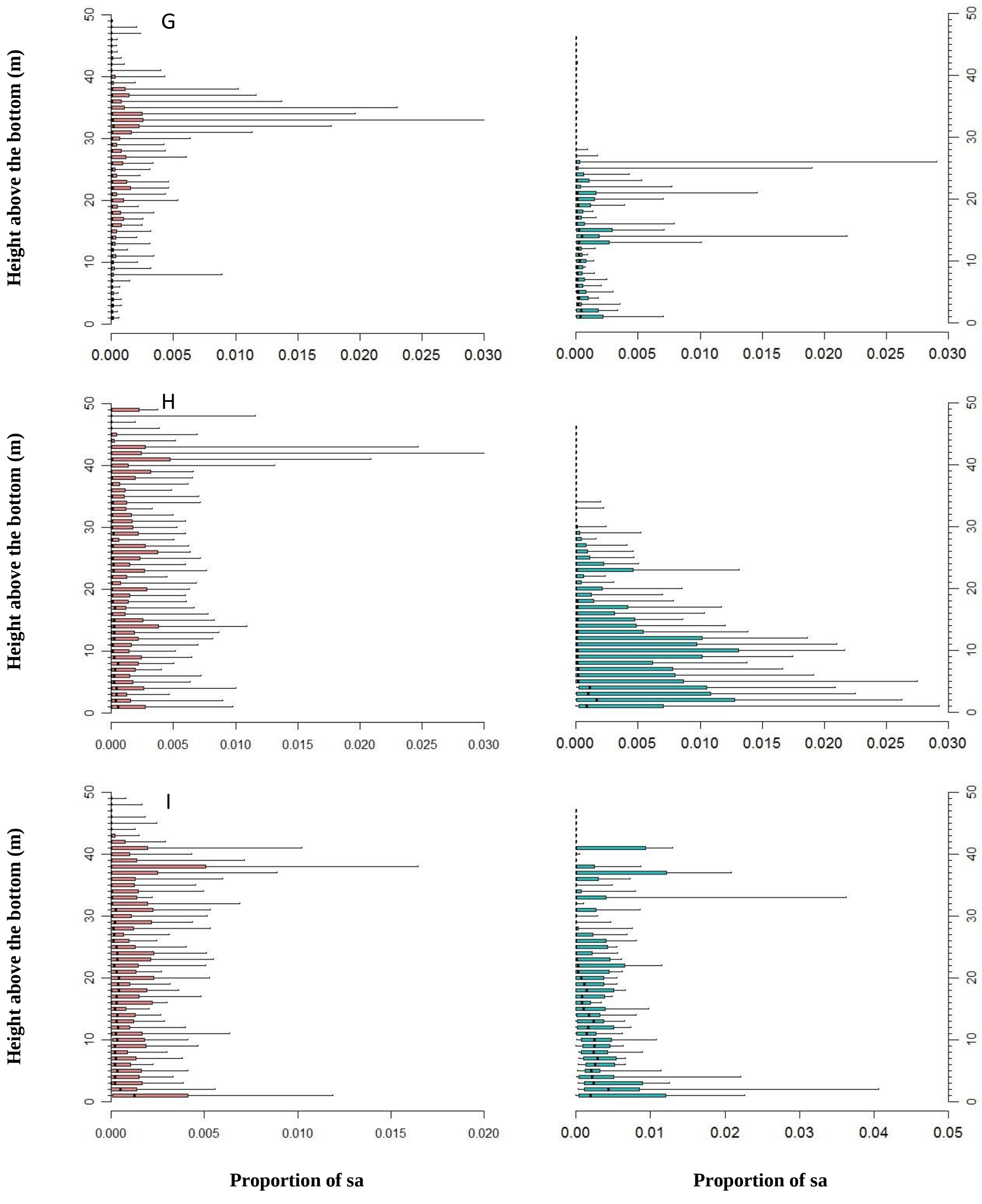


**Figure 18: Boxplot of proportion of backscatter (sa, relative fish density) by layer for May 2017 (G), July 2017 (H), and August 2017 (I) surveys, by site (CLA in red, left and reference in blue, right). The turbine was present during the May 2017 (G) survey. The proportion of sa (x axis) is very small because numerous outliers have not been plotted to be able to see trends in vertical distribution.**

Fish vertical distributions were highly variable within month and sites (Figures 17 & 18). Nevertheless, in August and November 2016 and July 2017, the fish were more concentrated in the first 10 meters above the bottom. These densities could be related to benthic-oriented fish presence. Numerous demersal species occupy the channel, e.g., Atlantic sturgeon (*Acipenser oxyrinchus*), brook trout (*Salvelinus fontinalis*), wolffish (*Anarhichas lupus*), sea raven (*Hemitripterus americanus*), grubby (*Myoxocephalus aeneus*), among others, and can contribute to this higher bottom density concentration (Dadswell, 2013). In May 2017, the vertical distributions between the CLA and the reference site seem different, with a majority of fish located 20 to 40m above the bottom at the CLA and fish distributed more evenly in the first 30m above the bottom at the reference site (Figure 18G). Fish vertical distributions varied in May 2016 and May 2017. This difference may be explained by the different sampling time within the month of May month (last neap tide in 2016 and first neap tide in 2017). Fish species composition and their distribution can be completely different at the beginning and end of May each year. In July and August 2017, CLA and reference site distributions look similar with fish located in the first 20m above the sea floor in July (Figure 18H) and more evenly distributed in both in August (Figure 18I).

## Summary and Conclusions

Three hydroacoustic surveys were conducted by FORCE staff in 2017. The data collected were fully calibrated, reliable and good quality. During two of the three surveys conducted by FORCE, the two along transect (South_CW and North_FM) have been interchanged. This mistake has been reported and corrected during the last survey in August 2017 but needs to be incorporated in the field protocol for future surveys. Entrained air were removed from the data and relative fish density metrics were exported for comparisons within and between surveys, as well as with the surveys conducted 5 years previously, in 2011-2012.

For this three month dataset seasonal variation was high but fish densities were highest in May, probably linked to the presence of migratory species in May like alewife and the presence of Atlantic herring and striped bass. Similarities between historical and contemporary data as well as project and reference site data suggest the need for continued utility of the data and further data collection may provide more insights to patterns emerging from the dataset.

The GLM results revealed significant effects of all factors tested on fish presence and relative density. However, data are not balanced with 12 surveys without a turbine and only three with an operational turbine. As such, monitoring should continue in order to assess changes in fish distribution patterns as the site is further developed.

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