Eastern Charlotte Waterways
Data Report

Jillian Duggan, Emma Carline & Mark Wood
OCEAN SONICS LTD. 110 Parkway Dr. Truro Heights, NS B6L 1N8
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Eastern Charlotte Waterways – Data Analysis

Location: Saint John Harbour, New Brunswick, Canada. South-west of Partridge Island.

Coordinates: 45.2250°N, 66.0693° W


Introduction
Ocean Sonics processed sound monitoring data from the 2016-2017 Eastern Charlotte Waterways (ECW) deployments in Saint John Harbour. The data was collected over the year by Eastern Charlotte Waterways in partnership with Port Saint John to assess underwater noise produced by operations in the Saint John Harbour. The purpose of the report is to provide a fully comprehensive document with information on ambient sound level measurement comparisons, sea mammal detections and vessel noise measurements. Key findings will be listed along with any interesting events.

Baseline ambient sound level measurements were calculated from the existing 2016-2017 deployment data with core processing procedures.

- Third Octave Analysis
- Spectral Probability Density Plots
- Diurnal and Weekly Rhythm Plots

The baseline ambient sound measurements were analyzed and presented in a variety of formats to best view the data. The same third octave bands as in the report by ECW, on this dataset, were used to compare findings (20, 63, 125 & 1000 Hz). The bands were chosen by ECW to assess the noise in baleen whale communication range (20 Hz), industrial vessel traffic (63 and 125 Hz) recommended by the European Union’s Marine Strategy Framework Directive (Vandergraff et al. 2012) and smaller vessel traffic (1000 Hz).

A complete review of the .wav data was done to search for intermittent sound from biological and anthropogenic sources. Detector algorithms were used to search for whales and dolphins. Vessel sound comparison was done using marine Automatic Identification System (AIS) data coupled with the corresponding acoustic data from the hydrophones. Select periods of time with proper AIS data and acoustic sound data were chosen for analysis. A review of select detected vessels is provided. In reviewing the data, it was noted that an increase in the length of the recording time in one duty cycle would provide a more complete view of vessel passes. Observations were presented from the overall dataset as well as future recommendations.
Materials & Methods

Deployment

A mooring system was designed by Eastern Charlotte Waterways to create an underwater sound monitoring system comprised of an Ocean Sonics icListen HF hydrophone (SB2), an Ocean Sonics Gen-2 fiberglass battery pack with 72 D-cell alkaline batteries and a five-meter cat 5 cable attaching the hydrophone to the battery pack. A metal cone-shaped structure housed the equipment stabilizing the mooring and keeping the hydrophone above the seabed. The hydrophone was attached to the inside center bar of the cone structure while the battery pack was attached to the bottom circle structure at the base of the cone. The anchor was attached to a mooring line that connected it to a ‘high-flyer’ surface buoy used for retrieval. The hydrophone was setup to record underwater sound data throughout a year. The project consisted of 5 deployments ranging from 2 to 3 months each. During the deployment an icListen hydrophone, recorded .wav data at a sampling rate of 32kS/s. The hydrophone used a duty cycling setup to record the first 2 out of every 10 minutes. The mooring was deployed south-west of Partridge Island (45.2250°N, 66.0693°W).

Deployment Dates

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date*</th>
<th>Hydrophone Serial Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nov. 3, 2016</td>
<td>Dec. 18, 2016</td>
<td>1370</td>
</tr>
<tr>
<td>2 Jan. 26, 2017</td>
<td>Mar. 8, 2017</td>
<td>1373</td>
</tr>
<tr>
<td>3 Mar. 13, 2017</td>
<td>Apr. 27, 2017</td>
<td>1370</td>
</tr>
<tr>
<td>4 May 24, 2017</td>
<td>Jul. 5, 2017</td>
<td>1373</td>
</tr>
</tbody>
</table>

*Revised dates to reflect continuous and complete data. Toward the end of some deployments the hydrophone stopped recording and then began again (continuing to record for up to a day). For the data analysis, no days of data were used after the data stopped recording the first time because of inconsistent durations.

Figure 1. Image of mooring equipment, courtesy of ECW.
Figure 2. Total days of data recorded each month during the one-year deployment.

Figure 3. Saint John Harbour with coordinates of deployment location.
Core Data Analyses Descriptions

- **⅓ Octave Analysis**
  The Sound Pressure Level (SPL) in ⅓ octave bands (12.5 Hz - 10 kHz) was calculated over each month of data. First, each .wav file was divided into 50% overlapping Hanning windows of length fs (the sample rate) before applying the FFT (Fast Fourier Transform). These spectrum values were averaged over the windows and then the windows were averaged over the .wav files. Finally, the SPL values within each ⅓ band were summed.
  1/3 octave graphs of each month found in Appendix A.

- **Long-term Spectrograms**
  FFTs with a frequency bin width of 3 Hz were calculated. This data was used to create a spectrogram for each week of data, starting with the first recording for each month.
  Long-term Spectrograms are found in Appendix B.

- **Quantiles**
  A ⅓ octave analysis was performed on each recording. Percentiles for each frequency band were then calculated from these values. The 5th, 25th, 50th, 75th, and 95th percentiles were plotted.

- **Cumulative Density Plot**
  For each dB value (in 2 dB steps from the min to the max ⅓ octave values of the dataset) and each of the ⅓ octave bands 25, 63, 125, and 1000 Hz, the percentage of .wav files with ⅓ octave value below that the dB value was calculated.

- **Spectral Probability Density Plots**
  The spectrum for each .wav file was calculated (using a Hanning window of size fs, 50% overlap and averaging the windows after applying the FFT). Using this set of spectrums, a histogram was made for each frequency bin. The histograms were normalized to 1 to give a probability density. In order to plot the histograms side by side in one figure, each consecutive pair of frequency bins was averaged. One spectral probability density plot was made for each season.

- **Weekly Rhythm Plots**
  A ⅓ octave analysis was performed for each .wav file and the median was taken over the entire recording period for each day of the week. The bands 25, 63, 125, 1000 Hz were plotted over the week. These plots are meant to show a “typical” week during the recording period.

- **Daily Rhythm Plots**
  A ⅓ octave analysis was performed for each .wav file and the median was taken over the entire recording period for each 20-minute interval of the day. The median for the bands 25, 63, 125, 1000 Hz were plotted over a day. These plots are meant to show a “typical” day during the recording period.

- **Hourly Mean**
  A ⅓ octave analysis was performed for each .wav file in the data recording period and the mean was taken for each 20-minute interval of the day. This is the same as the Daily Rhythm plot except that it uses the mean instead of the median. Results were restricted to the bands 25, 63, 125, and 1000 Hz.

- **Daily Mean**
  The mean was taken over each day in the ⅓ octave bands 25, 63, 125, and 1000 Hz. These calculated values were then plotted, one plot per month. Note that days with no recordings are left blank.
  Daily Mean plots (one for each month) are found in Appendix C.
Results
Core Processing - Ambient Sound Measurements

Third Octave Analysis

Figure 4. Select 1/3 Octave Bands over the year-long deployment. The 25 Hz and 63 Hz bands contain higher values during the winter months, especially in February.

Figure 5. Third octave values in each month of the deployment.
Quantiles and Cumulative Density

Figure 6. Quantiles (the 5th, 25th, 50th, 75th, and 95th percentiles) for each band were over the entire dataset. This gives an overview of the noise levels in each band over the year.

Figure 7. Cumulative Density.

Spectral Probability Density Plots
Spectral probability density (SPD) plots can be used as a tool for analyzing the statistical distribution of underwater noise levels across the frequency spectrum. These plots show the sound distribution over a
large data set giving more information than conventional spectral averages and percentiles. The SPD plots can reveal multi-modality and other interesting patterns in the data (Merchant et al., 2013).

Figure 8. Spectral Probability Density Plot over the winter months, December 2016 - February 2017. Frequency range: 0 – 12 kHz.

Figure 9. Spectral Probability Density Plot over the spring months, March - May 2017.
Figure 10. Spectral Probability Density Plot over the summer months, June - August 2017.

Figure 11. Spectral Probability Density Plot over the autumn months, September – October 2017 and November 2016.
Rhythm Plots & Hourly Mean

The weekly rhythm plot shows no strong patterns. This demonstrates that the noise is consistent over time and rather than having a significant increase or decrease on certain days of the week. The daily rhythm plot remains consistent in noise levels throughout the day except for several peaks which were found to correlate with the Saint John – Digby ferry passes. The hourly mean plot shows similar levels of amplitude with more noticeable peaks relating to ferry passes. The differences are resulting from outlying data causing the mean levels to shift and differ from the median daily rhythm.

Weekly Rhythm Plot

![Weekly Rhythm Plot](image1)

*Figure 12. Weekly Rhythm Plot. No strong patterns were found.*

Daily Rhythm Plot

![Daily Rhythm Plot](image2)

*Figure 13. Daily Rhythm Plot. Peaks occur during ferry passes.*
Hourly Mean

![Hourly Mean Plot](image)

*Figure 14. Hourly Mean Plot uses the mean noise levels, blue rectangles show peaks in noise levels over the year, this is correlated to the Saint John - Digby Ferry passing the listening station.*

**Noise Source Data Analysis**

A major noise source contributing to the ambient noise measurements at the deployment site was vessel traffic, specifically the pattern of ferry traffic by the deployment site each day. Other contributors included environmental noise such as rain, wind, tidal noise and marine mammal vocalizations. Noise sources were found and identified through a visual and auditory review of the .wav files, a marine mammal detector, and comparing AIS data to the acoustic data. Noises found throughout the recordings are noted below.

**Periodic Noises**

**Knocking & Scraping**

![Audacity spectrogram](image)

*Figure 15. Audacity spectrogram December 4, 2016 at 23:00 UTC. Knocking, sharp impulses from 0-1300 Hz, and scraping 50 - 300 Hz.*
Figure 16. Audacity spectrogram of 2-minute file from December 13, 2016 at 18:50:00. Scraping found from 50 – 300 Hz.

**Associated Tidal Noise**

Figure 17. Audacity spectrogram of 2-minute file from September 1, 2017 at 03:10 UTC. Noise from tidal noise; waves moving water as well as small particles of sand past the hydrophone. Tidal noise found around 2.5 – 13 kHz.

**Rain**

Figure 18. Audacity spectrogram, 1-minute. July 2, 2017, at 07:20:00. Rain noise begins at 1:10. Note: vessel noise continuous in lower 2 kHz and seal calls below 1 kHz at 1:03 and 1:46.
Wind

Measurements from the Saint John Weather Buoy by the Canadian Hydrographic Service of the Department of Fisheries and Oceans were used to compare the spectral data to wind measurements. This showed a correlation between increased wind speeds and increased noise levels throughout the spectrum. The sound

Figure 19. Wind Speed (peak and average) plotted on a spectrogram over the week of February 8 – 14 showing that an increase in wind speed correlates to an increase in noise levels.

Figure 20. Wind Speed (peak and average) plotted on a spectrogram over the week of March 1-7 showing that an increase in wind speed correlates to an increase in noise levels.

Figure 21. Wind Speed (peak and average) plotted on a spectrogram over the week of March 15-21 showing that an increase in wind speed correlates to an increase in noise levels.
Biological Sounds

**Marine Mammals, Fish, Low Frequency Noise.**

A portion of the analysis was focused on detecting marine mammals. A variety of methods were used to detect whale calls, including PAMGuard’s whistle and moan detector and a visual analysis using Lucy.

The data was sampled at 32 kS/s allowing detections of marine mammals vocalizing between 10 Hz – 12 kHz. Fish tags, harbour porpoise and high frequency dolphin whistles occurring above 12 kHz and were not detected.

There was a significant amount of noise in the lower frequencies making it difficult to detect low frequency baleen whale calls such as those of blue whales or fin whales. Potential fin and sei whale detections were made in fall 2016. Additionally, there were a variety of knocking, scraping and tapping. Some of the low frequency knocking was attributed to fish sounds in regular patterns. Some of the knocking and scraping could be from crustacean and seal activity near the mooring. There were knocking sounds attributed to the mooring line as well as potential strumming of the mooring line. The mooring line knocking occurred when there was an increase in vessel traffic and tidal noise, where the motion of the waves would cause the mooring line to move and hit the structure.

Many marine mammals were detected throughout the deployment. The most common marine mammals found were dolphins, detected by their clicks, buzzes and whistles in the data. Harbour seals were also common throughout the entire dataset. Humpbacks were found throughout November, December 2016, as well as, September and October 2017. Birds were also recorded periodically, as sound couples well from the air above the hydrophone. The sea bird calls are believed to be from a type of gull.

**Species Noted:**
- Dolphins
- Humpback Whales
- Harbour Seals
- Fish
- Crustaceans
- Birds (gulls)

**Table 1. Detection of Marine Mammals**

<table>
<thead>
<tr>
<th></th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolphin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humpback Whale</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
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<tr>
<td>Seal</td>
<td>x</td>
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<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
common to the area: Atlantic white-sided (*Lagenorhynchus acutus*), Atlantic white-striped (*Stenella coeruleoalba*) and common dolphin (*Delphinus delphis*).

![Dolphin Clicks](image)

Figure 22. Audacity spectrogram of dolphin buzz. April 4, 2017 at 00:50:45 UTC (hydrophone 1370).

![Zoomed In](image)

Figure 23. Audacity spectrogram of dolphin buzz zoomed in to see individual clicks. April 3, 2017 at 22:11:06 UTC (hydrophone 1370).

![Clicks](image)

Figure 24. Audacity spectrogram of dolphin clicks, April 4, 2017 at 02:30:25 UTC (hydrophone 1370).
Figure 25. Audacity spectrogram of dolphin clicks, April 4, 2017 at 16:10:17 (hydrophone 1370).

Figure 26. Audacity spectrogram of dolphin whistle, April 4, 2018 at 01:11:47 UTC (hydrophone 1370).
[0.1 second of data, amplification 40 dB, window size: 256]

Figure 27. Audacity spectrogram of two dolphin whistles, April 3, 2017 at 04:20:52 UTC (hydrophone 1370).
Whale Calls

Humpback whales were found in the falls of 2016 and 2017. They were most often found calling in repeating patterns referred to as a songs or partial songs. The calls occur most frequently between 300 to 700 Hz. At times, there appears to be multiple whales calling.

PAMGuard was used to look for whale calls in the dataset using the whistle and moan detector. The detector worked well when there were no vessels in the area, no knocking on the mooring, and when there were large amounts of low frequency noise, which masks the calls. When low frequency noises were present an increase in false positive detections occurred. Whale calls were verified by playback of the data on Lucy and Audacity.

![Figure 28. Audacity spectrogram of humpback whale calls (partial song). December 2, 2016 at 14:30 UTC (hydrophone 1370).](image)

![Figure 29. Audacity spectrogram of humpback whale calls (partial song), multiple whales calling. November 8, 2016 at 19:10 UTC (hydrophone 1370).](image)
Figure 30. PAMGuard identifying whale calls in data, notice calls are being found but additional low frequency knocking is also being detected.

Harbour Seals

Harbour seals were noted throughout the year. The calls appear in succession, starting quietly and becoming louder into the end of the call. The calls last between 10-15 seconds and most of the sound occurs between 0-500 Hz.

Figure 31. Audacity spectrogram of harbour seal, long roars at 0-6 s, 32-46 s and 75-93 s. January 31, 2017 at 11:00 UTC (hydrophone 1373).
Figure 32. Audacity spectrogram of harbour seals, long roars at 20-35 s, 57-71 s and 100-106 s. January 31, 2017 at 10:50 UTC (hydrophone 1373).

Figure 33. Audacity spectrogram, short roars at 13-15 s, 60-63 and 100-103 s, with a short grunt at 35-36 seconds. January 31 at 03:00 UTC (hydrophone 1373).

Fish

Many fish produce sound for protection, fright response, while competing for mates or courting. There are various sounds that can be produced by fish including drumming (produced by sonic muscles used near swim bladder), stridulating (striking or rubbing skeletal components) and swimming. Commonly the resulting sounds are knocking, grunting and rumbling (during spawning) which are all below 1000 Hz.

Figure 34. Periodic rhythmic knocking between 150 – 500 Hz, potential fish knocking. April 4, 2017 at 04:31:13 UTC (hydrophone 1370).
**Crustaceans**

Many popping, snapping and scratching noises in the data were attributed to crustacean activity in the area. There could have been lobster or crabs in the area that were attracted to the mooring for protection and the rubbing, knocking and scraping sounds could be from an interest in the mooring frame, battery pack etc. These sounds occur as broadband noise.

**Birds**

Bird calls were found throughout the recordings. The bird calls in Figure 35 were recorded in the spring and appear to be from a type of gull. The reason that bird calls were recorded on the hydrophone is due to the sound in air directly above the hydrophone coupling into the water below. This occurs most often when the sound is close to the water level and the hydrophone is in shallow water.

![Figure 35. Audacity spectrogram with gull calls. April 4, 2017 at 09:10:50 UTC (hydrophone 1370).](image)

**Anthropogenic Noise – AIS Data**

**Vessels**

When a vessel passes the hydrophone there is a temporary increase in noise levels at that location. When the vessel is nearby, higher frequencies are seen because the distance to the boat is small enough that they are not completely attenuated by the water (Wenz, 1962; Hildebrand, 2009). It is important to measure vessel activity and how this impacts ambient noise levels. Specifically, it is important to assess how long vessels increase ambient noise levels in a region, because this potentially masks frequency bands used for marine mammal communication.

AIS data was used to find times when vessels passed by the hydrophone while entering or leaving the port. Times were noted when a vessel passed within 5 km of the hydrophone and had acoustic data associated to the data points (the first 2 minutes of every 10 minutes). Vessels were chosen to compare within hydrophone deployments in the summer and fall of 2017. Larger vessels and common vessels found throughout the year were chosen to give examples of the sound levels associated with each type. Sound levels of passenger vessels, a cargo ship, a tanker and a pilot vessel were all compared at distances of approximately 2.5 – 3 km away from the hydrophone. The larger vessels were travelling
between 6.8 and 10.8 knots, (cargo, tanker, cruise ships), while the smaller vessels (ferry, pilot vessel) were travelling between 15.1 to 18.8 knots. See Appendix D for 1/3 octave analysis on the passes of the vessels in Table 2.

Table 2. Vessel Information passing hydrophone.

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Vessel Type</th>
<th>Gross Tonnage</th>
<th>Speed Over Ground (kts)</th>
<th>Size (length x width (m))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celebrity Summit</td>
<td>Passenger (cruise)</td>
<td>90940</td>
<td>10.8</td>
<td>294 x 32</td>
</tr>
<tr>
<td>Norwegian Gem</td>
<td>Passenger (cruise)</td>
<td>93530</td>
<td>8</td>
<td>294 x 32</td>
</tr>
<tr>
<td>NOR’EASTER</td>
<td>Tanker</td>
<td>23421</td>
<td>6.8</td>
<td>184 x 27</td>
</tr>
<tr>
<td>Irving Hazelnut</td>
<td>Cargo</td>
<td>N/A</td>
<td>6</td>
<td>19 x 5</td>
</tr>
<tr>
<td>Fundy Rose</td>
<td>Passenger (ferry)</td>
<td>10193</td>
<td>15.1</td>
<td>128 x 18.9</td>
</tr>
<tr>
<td>Captain AG Soppitt</td>
<td>Pilot</td>
<td>N/A</td>
<td>18.8</td>
<td>17 x 5</td>
</tr>
</tbody>
</table>

Figure 36. 1/3 octave plot of cruise ships and tanker vessel.
**Figure 37. 1/3 octave plot of pilot, cargo and ferry vessels.**

**Discussion and Conclusion**

**Ambient Sound Measurements**

The core processing showed very similar results to the previous report by ECW, *Assessing Underwater Noise at Port Saint John, 2018*.

Overall, the ambient noise measurements were found to have the greatest variations in the winter of 2017. The low frequency noise was greatest in February and March with visible variations in noise produced at lower frequencies, leading one to believe that it was due to something periodic, such as environmental factors or anthropogenic noise. There does not appear to be more vessels in the area near the hydrophone around that time of increased low frequency noise. The noise could be from increased shipping farther away from the hydrophone location, potential construction noise near the port or dredging. Another possibility is from environmental effects, such as increased wind and wave pressure fluctuation during winter weather in the area. Sea spray, movement of ice and tidal noise can also affect measurements in the lower frequencies used for shipping activity monitoring (Merchant, et al., 2016).

The MSFD defines noise pollution as the occurrence of sound levels above 100 dB in the 63 or 125 Hz third octave bands. It was found that noise pollution occurred in only 5% of the days in this dataset. There were 11 days where the noise at 63 Hz averaged above 100 dB that included February 13th, 16th, 17th, 18th, 26th, 27th and March 1st, 2nd, 5th, 11th 2017. There was only one day where the noise at 125 Hz averaged over 100 dB (March 15, 2017).
Deployment Variability
During the analysis it was noted that different deployments had differing amounts of low frequency noise. It was found that deployments with the hydrophone 1307 had consistently greater amounts of low frequency noise than other deployments. This could be due to the environment during the deployment, the hydrophone itself or the equipment and mooring setup. A mooring line rubbing against the element or the cone structure can cause more noise in this frequency range. True low frequency noise could be amplified by the positioning of the mooring in the shallow water as well. Due to the high amounts of variability in the lower frequencies during the various deployments it is recommended that deployments are kept with the same equipment and positioning.

Low Frequency Noise
The large amounts of low frequency made it difficult to detect low frequency baleen whales using detection software, visual and aural analysis. The high variability of low frequency noise with the large variety of potential sound sources (vessels, crustaceans, equipment and weather) increased the challenges of sound source identification. Sounds such as humpback whale calls and seal calls were easier to identify in frequencies above 400 Hz.

The mooring system and its position could have introduced low frequency noise through the orientation of the hydrophone and geographical features of the region. Because this deployment site was closer to the harbour, additional low frequency noises could have been introduced by various activities around the port such as construction, dredging and vessel activities. Because this deployment site was also relatively shallow, the low frequency noise found throughout February and March 2017 could have been due to wind, sea spray and surface waves. Shallow water can also attenuate low frequency signals such as noise from vessels.

Marine Mammals and Fish
The most common marine mammals found throughout the deployment were seals and dolphins. Additionally, humpback whales were noted in the fall of both years corresponding to migration patterns. Harbour seals were noted throughout the winter near the deployment site. A call that was found year-round (a roar sound), is typically categorized as a mating call and has been primarily documented in recordings during the mating season. Dr. John Terhune noted that most of the work on harbour seal calls has been done during the breeding season so having typical roars in January raises questions related to the behavioural functions of the calls. It was also noted that the distribution and numbers of harbour seals has increased greatly in the Bay of Fundy since 1980. For these reasons it is of interest to study the seal calls in the recordings from all deployments to date for seal call counts. The calls found through the deployments suggest a year-round presence of the seals and further evaluation of the data for call counts would increase knowledge on the species now spending more time near the harbour. Future studies could be performed in parallel with the acoustic data collection monitoring behaviour near the deployment sites and the sounds associated.

The humpback whale calls were primarily partial whale songs. The same repeating pattern was noticed throughout recordings. At times, humpback whales were calling simultaneously, noted in the results. The humpback calls were distinctive above ambient noise levels. Humpback calls were sometimes found at the same time as vessel noise and masking could occur. PAMGuard whistle and moan detector was
used on the data and was found to be useful for finding clear calls without much masking. PAMGuard did detect many knocking and scrapping sounds that did not seem to be whale calls upon further review.

Near Port Saint John there are various fish present throughout the year and so there is an opportunity for recordings of fish noise. This data could be used in the future as more fish noises are described and understood.

No definitive detections of North Atlantic Right Whales were found throughout the analysis. The majority of July and August were not recorded on the hydrophones, this is when the closest sightings of NARW have been noted relative to the monitoring site (NOAA). It is possible that NARW calls were missed because data was not recorded continuously. It is also possibile that the whales were too far away to be detected by the hydrophone.

Vessel Noise
Vessel noise was found in most of the data and came from a variety of sources such as ships entering and leaving the port, the ferry and distant vessels. To look at the noise levels from different sources a range of vessel types were chosen, and sound profiles were extracted from the vessel passes.

Cargo ships, cruise ships, the Saint John to Digby ferry, and a pilot vessel were all measured approximately 2 to 3 km from the hydrophone location. Vessel profiles using third octave graphs show the frequency content of each vessel’s pass. It should be noted that a variety of factors should be regarded while looking at vessel signatures such as the speed, load of cargo, equipment being used such as SONARs, etc. Approximate vessel speed was noted and gross tonnage.

Larger vessels tend to increase noise levels greater and for longer periods of time as the low frequency noises travel further through the water for longer periods. The smaller vessels increase noise in higher frequencies, but attenuation of these frequencies only allows the noise to travel short distances (Wenz, 1962). The larger vessels, especially the NOR’EASTER and the Norwegian Gem show much greater levels of low frequency noise that would lead increased noise at low frequencies for long amounts of time. The smaller vessels such as the pilot vessel and ferry have increased sound levels in higher frequencies from smaller propellers and increased speeds. The noise from these vessels attenuate much faster and do not affect low frequency communication in baleen whales but they can still have an impact on mid-high frequency communication in whales and dolphins as well as many marine organisms close to the vessel.

Because the ferry spends a lot of time in the area, there are increased noise levels in higher frequencies for longer periods of time and this affects marine organisms in the area. Further studies covering frequencies up to 200 kHz are needed to acquire full noise profiles of vessels which can then be used to assess the impact on marine mammals such as dolphins and harbour porpoise.

Future Recommendations
In the future for the best deployments possible the following points are recommended.

- For each deployment use the with same mooring, hydrophone, and placement in order to minimize variations between deployments based on setup of equipment.
- Record data at full bandwidth (512 kS/s, 200 kHz) to detect harbour porpoise, dolphin clicks and whistles. Noise in the higher frequency bands will affect harbour porpoise who use those bands to communicate.
• Minimize low frequency sounds by reducing noise associated with mooring setup – such as crustaceans creating noise at the base. Ensure no lines can rub against the mooring. Use a setup where the hydrophone is mid-column eliminating the base.
• Minimize time between deployments to prevent gaps in the data.

Having a full-time cabled setup near the port would give the ability to create sound profiles for all vessels entering the port. Using multiple hydrophones in one deployment would give more information on the directionality of noise from the vessels, which is especially useful when the port is busy. A cabled setup could also include GPS time synchronization, providing data needed for a direct comparison of the time in the AIS positioning from vessels with the sound levels recorded on the hydrophone.

This type of setup could also provide a potential for real-time monitoring of harbour porpoise, dolphins and whales around the port. Having a cabled setup increases the memory available because it would be possible to switch out hard drives on land and to power the equipment from shore.
References


Appendix A
January 2017

February 2017
Appendix B

November 2016
December 2016

January 2017
September 2017
October 2017
Appendix C
Appendix D