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

FINAL REPORT

prepared by

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for

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1.0 EXECUTIVE SUMMARY

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

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

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

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

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

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

2.0 INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

3.0 METHODS

3.1 C-POD deployments

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

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

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

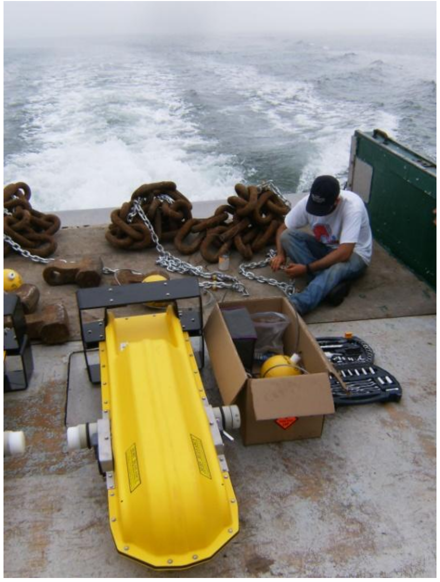


Figure 3.2. Rigging units for deployment of C-PODs. Mooring chain weights can be seen on the stern of the vessel. Photo courtesy of Colin Buhariwalla.

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

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

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

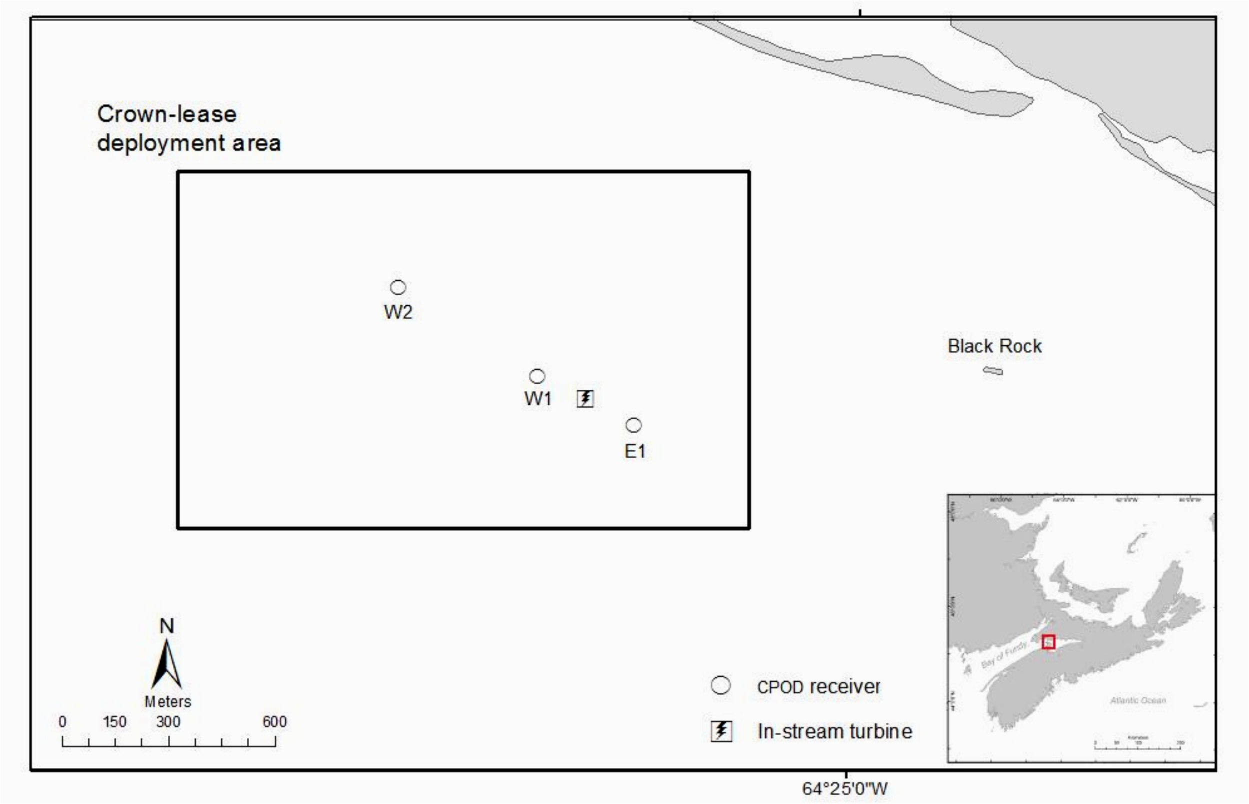


Figure 3.3. C-POD deployment station locations (circles) relative to the NSPI (OpenHydro) turbine and FORCE TISEC demonstration area (large rectangle). Distance between E1 and W1 was ~301m, and between W1 and W2 was ~538m.

3.2 C-POD retrieval

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

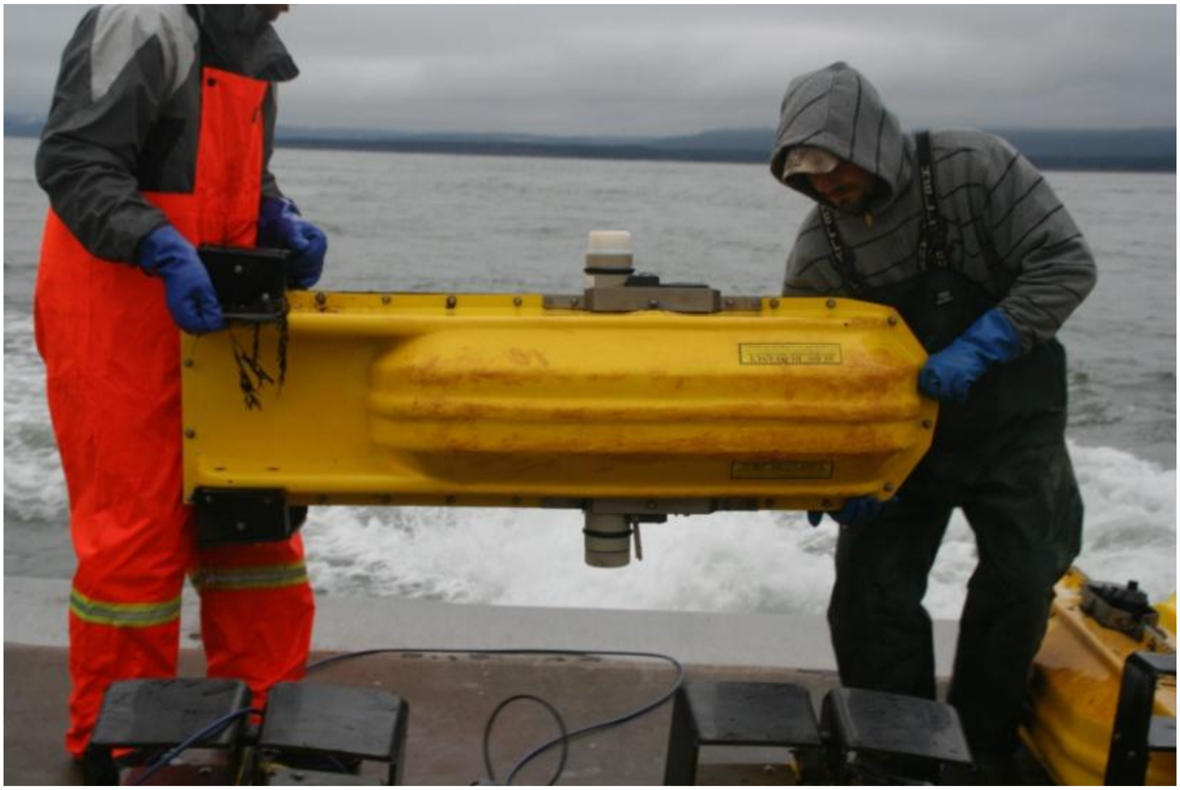


Figure 3.4. C-POD unit W1 immediately following retrieval. Note that part of the tail fin is missing. Photo courtesy of Colin Buhariwalla.

3.3 Instrument performance and data processing

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

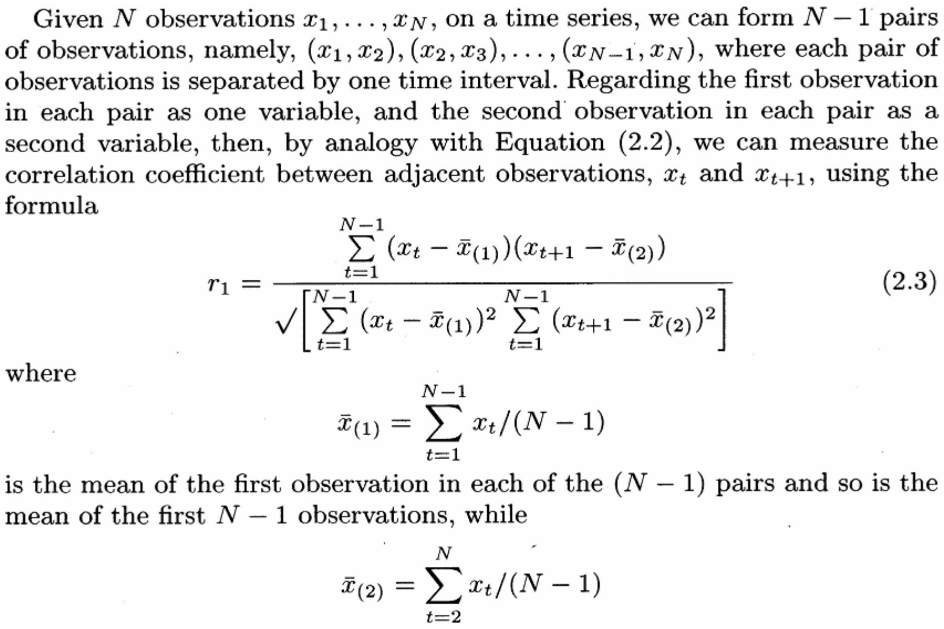
Table 3.2. Summary of data collection success and instrument performance.

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

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

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

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



Given N observations $x_1, \ldots, x_N$, on a time series, we can form $N-1$ pairs of observations, namely, $(x_1, x_2), (x_2, x_3), \ldots, (x_{N-1}, x_N)$, where each pair of observations is separated by one time interval. Regarding the first observation in each pair as one variable, and the second observation in each pair as a second variable, then, by analogy with Equation (2.2), we can measure the correlation coefficient between adjacent observations, x_t and x_{t+1}, using the formula

$$r_1 = \frac{\sum_{t=1}^{N-1}(x_t - \bar{x}_{(1)})(x_{t+1} - \bar{x}_{(2)})}{\sqrt{\left[\sum_{t=1}^{N-1}(x_t - \bar{x}_{(1)})^2 \sum_{t=1}^{N-1}(x_{t+1} - \bar{x}_{(2)})^2\right]}} \qquad (2.3)$$

where

$$\bar{x}_{(1)} = \sum_{t=1}^{N-1} x_t/(N-1)$$

is the mean of the first observation in each of the $(N-1)$ pairs and so is the mean of the first $N-1$ observations, while

$$\bar{x}_{(2)} = \sum_{t=2}^{N} x_t/(N-1)$$

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

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

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

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

3.4 Study plan variance

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

4.0 RESULTS

4.1 Data summary

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

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

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

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

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

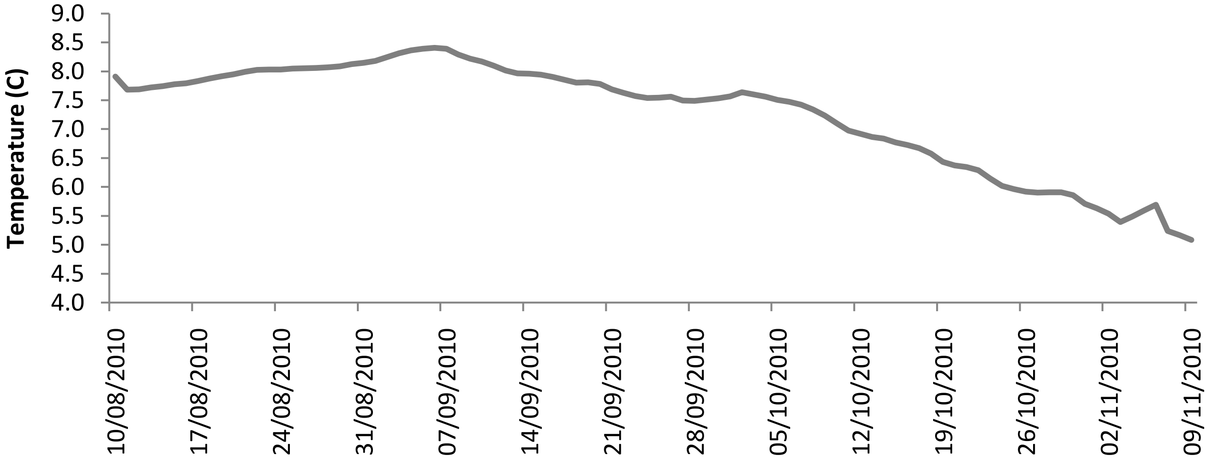


Figure 4.1. Daily temperature averaged across the two C-PODs from 10 Aug – Nov 2010.

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

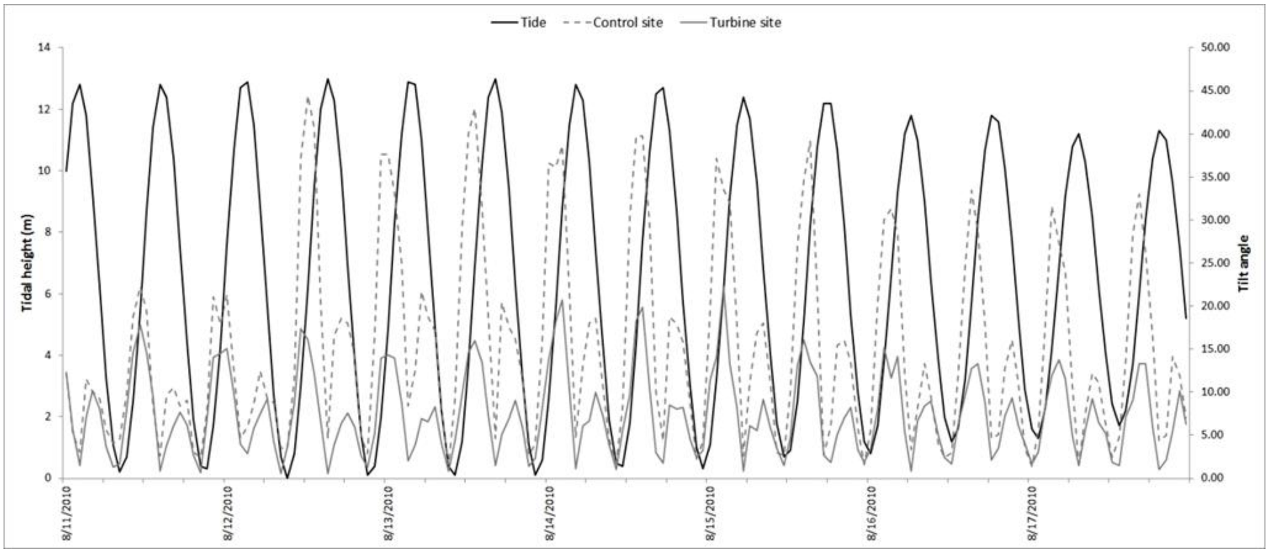


Figure 4.2. One week (Aug 11-17, 2010) plot of tidal height (left axis) in Minas Passage and tilt angle (right axis) from the Turbine and Control site C-PODs.

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

4.1.1 Overall sound scene and unfiltered click detections

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

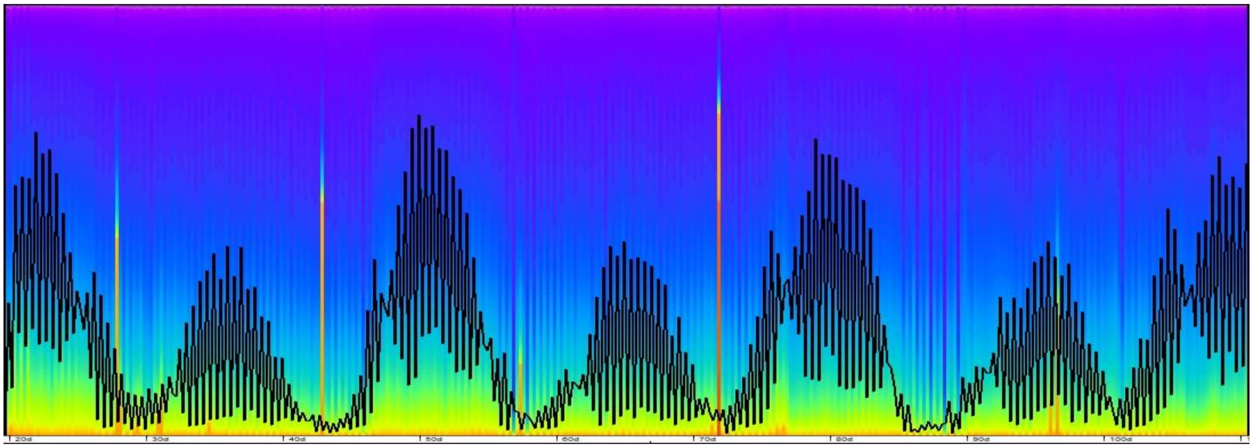


Figure 4.3. Click time series summary information from C-POD 643 (Control). The X-axis depicts the entire 92 days of recording. The Y-axis depicts the overall count of all recorded clicks in six hour bins before post-processing to filter only porpoise clicks. The black line depicts these total click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

4.1.2 Assessment of interference by Vemco acoustic transmitters

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

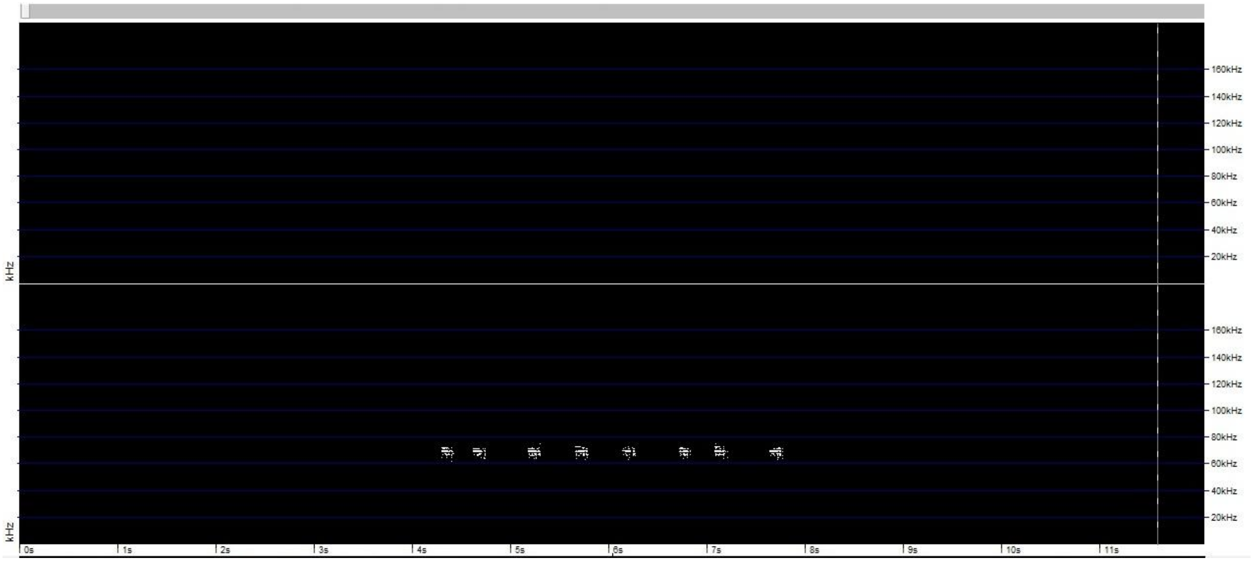


Figure 4.4. Display trace from the C-POD software. X-axis is time in seconds, Y-axis is frequency in kHz. The lower trace displays the raw click data, while the upper trace displays identified click trains. Cleary visible are eight 69 kHz signals from a Vemco tag in the lower trace. The click train filters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

4.1.3 Frequency of porpoise click detections per day

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

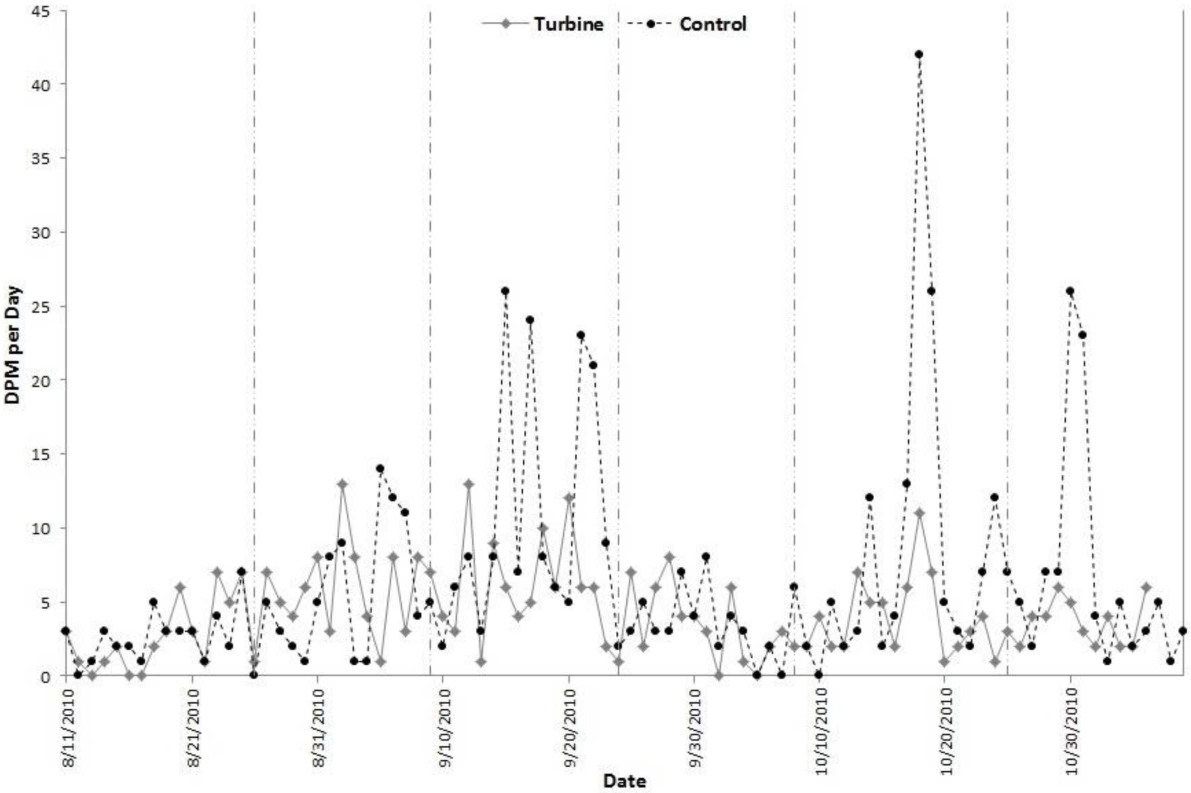


Figure 4.5. Porpoise Detection Positive Minutes (DPM) per day for C-POD 638 (Turbine, grey line and diamonds) and 643 (Control, dashed line and black circles) from August to November 2010. Vertical dashed lines denote time of peak spring tide.

4.2 Analysis of Detection Positive Minutes (DPM) per hour

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

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

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

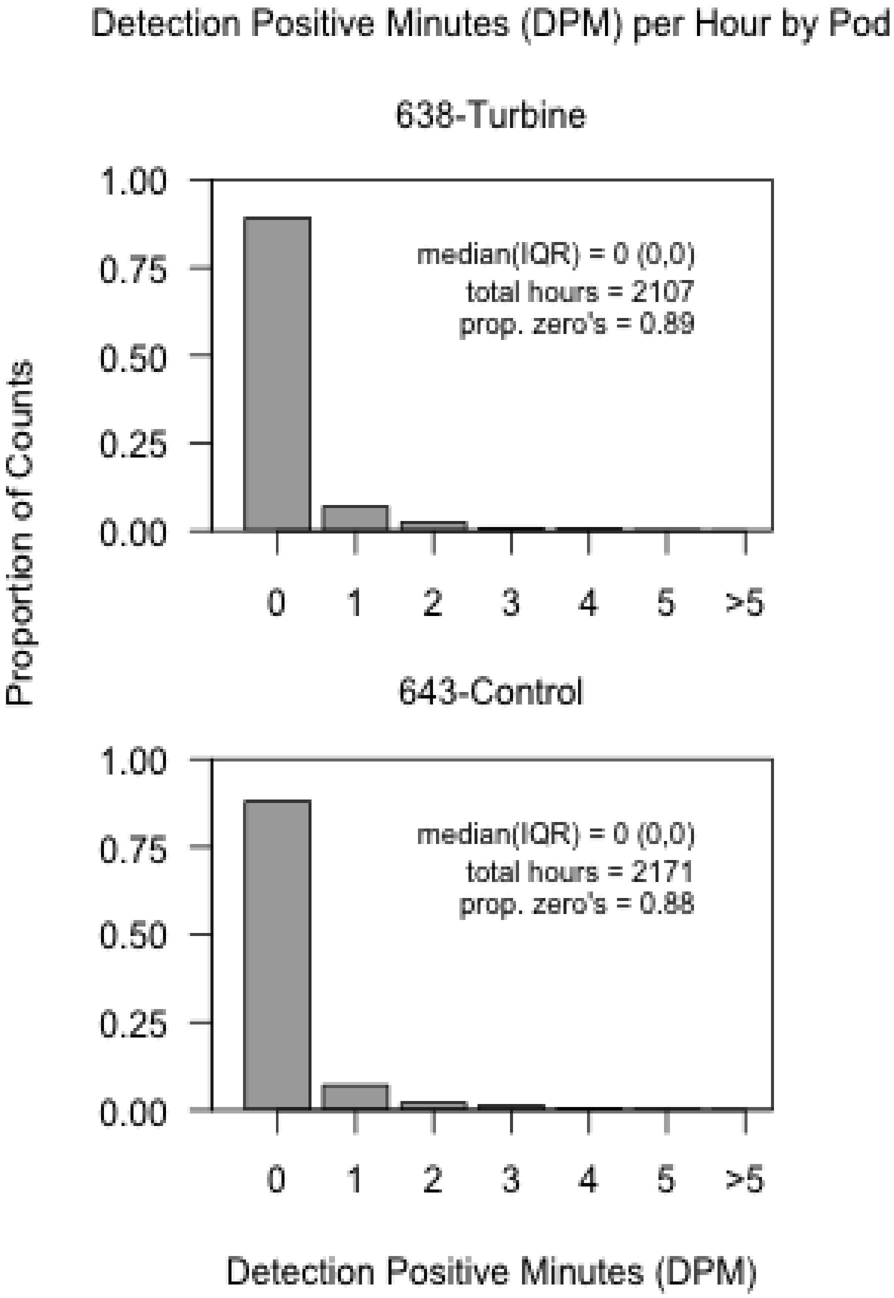


Figure 4.6. Frequency histogram of porpoise Detection Positive Minutes per hour for each POD (site) over the duration of this deployment. For each POD the median (Inter-quartile range or 1st quartile and 3rd quartile), as well as total hours of recording and proportion of time with zero DPM per hour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

4.2.1 Site and month effects on DPM per hour

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

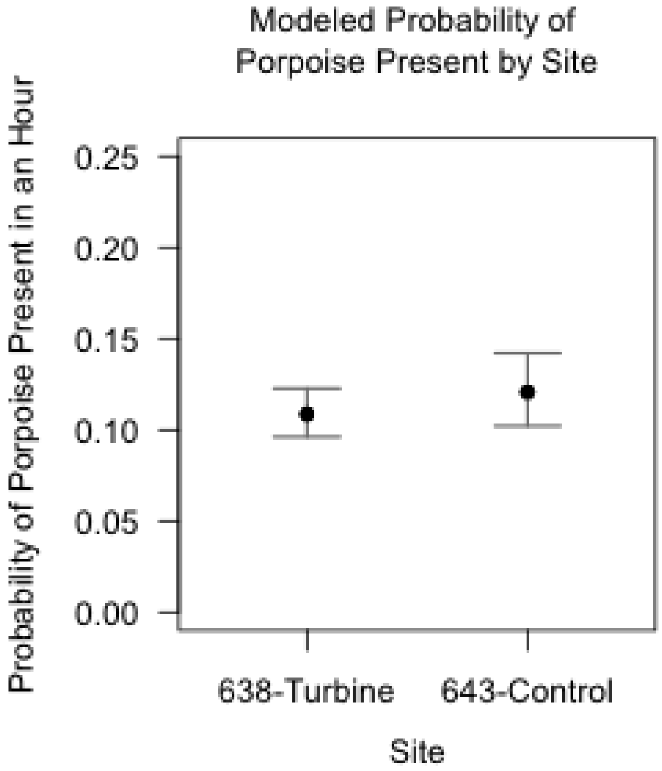


Figure 4.7. Probability of porpoise presence in an hour by site from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

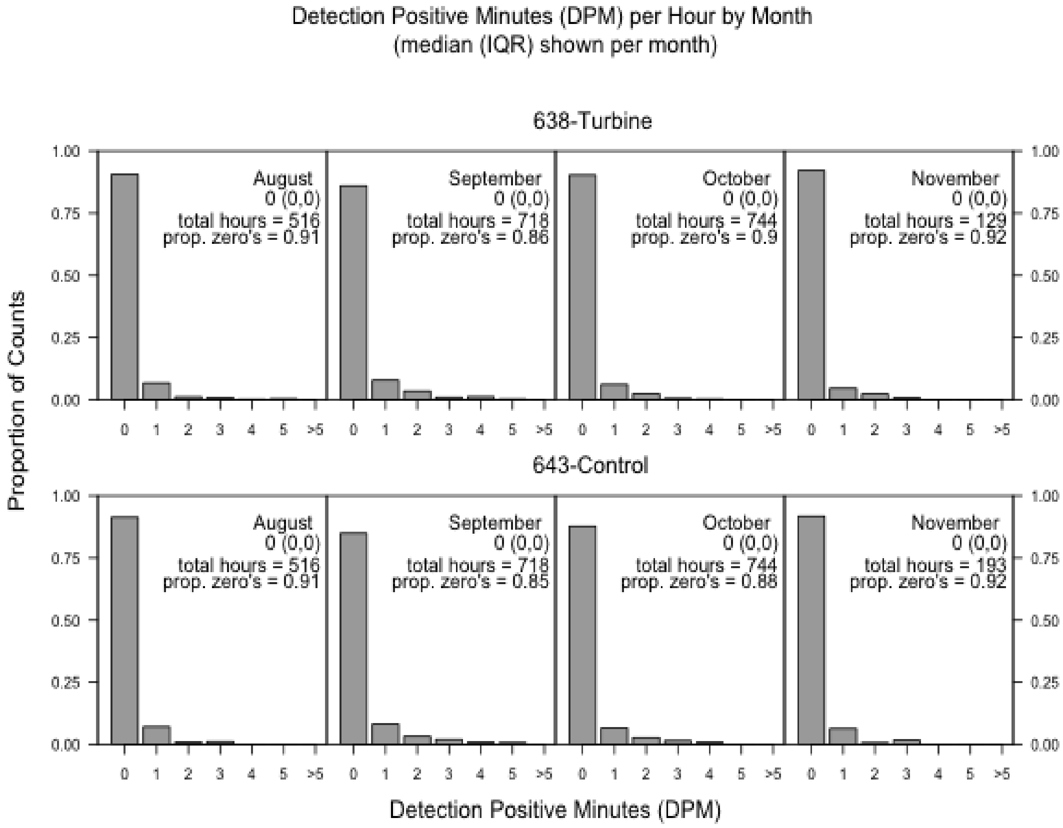


Figure 4.8. Frequency histograms of porpoise Detection Positive Minutes per hour by month and C-POD. For each C-POD the median (Inter-quartile range), as well as total hours of recording and proportion of time with zero DPM per hour are reported.

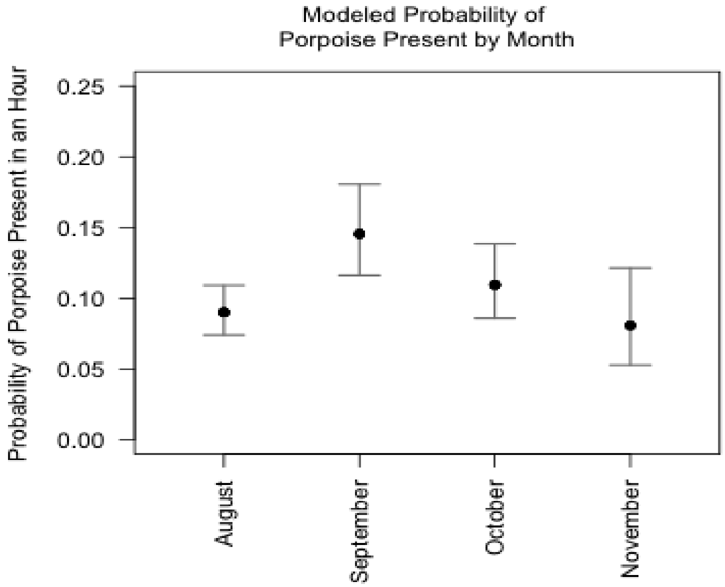


Figure 4.9. Probability of overall porpoise presence in an hour by month from the fit of a Generalized Linear Model. Error bars represent 95% confidence intervals.

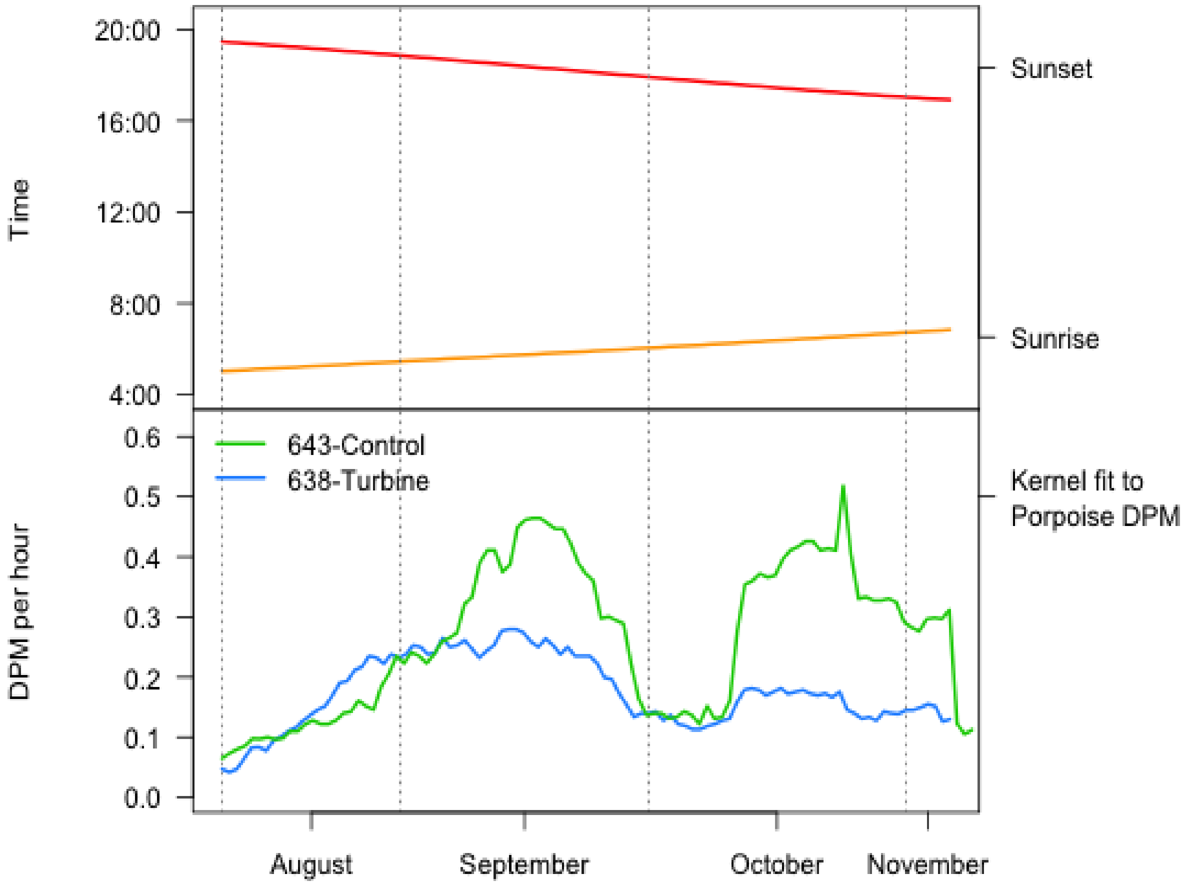


Figure 4.10. Study period variability in day length (top panel) and smoothed DPM per hour at night (bottom panel).

4.2.2 Time of day effects on DPM per hour

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

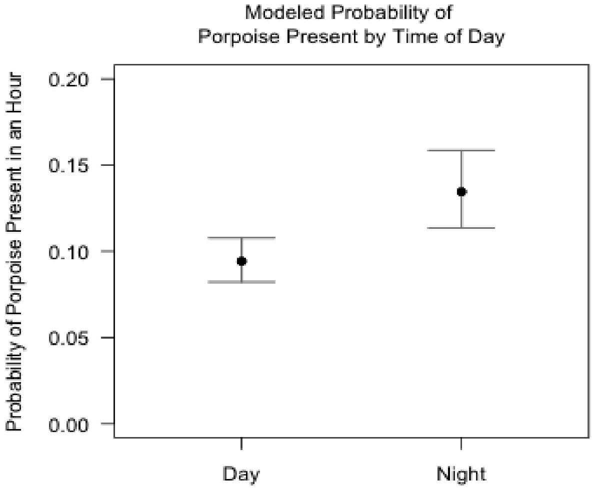


Figure 4.11. Probability of overall porpoise presence in an hour by time of day from the fit of a Generalized Linear Model (sites and days combined). Error bars represent 95% confidence intervals.

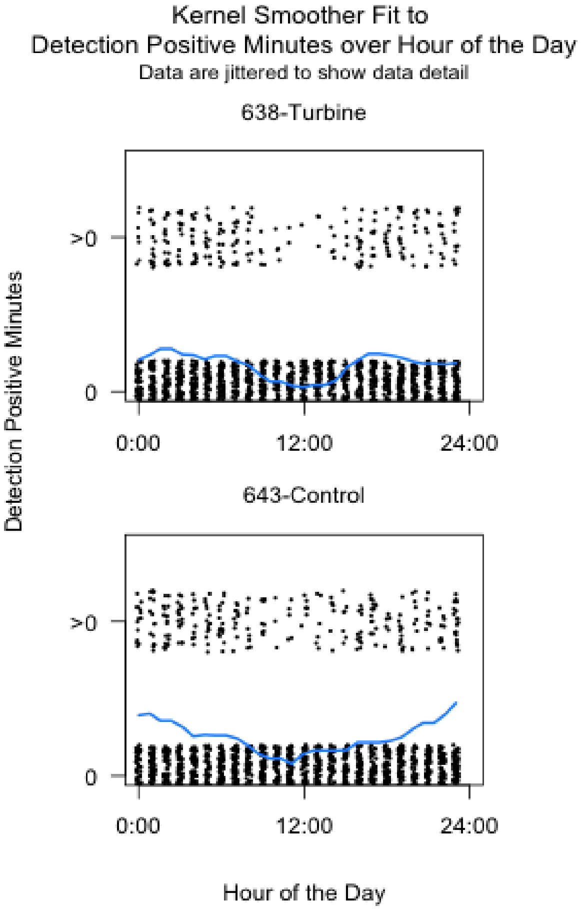


Figure 4.12. Detection Positive Minutes per hour by hour of the day for each C-POD with a kernel smoother (blue line) to depict trends (based on raw data).

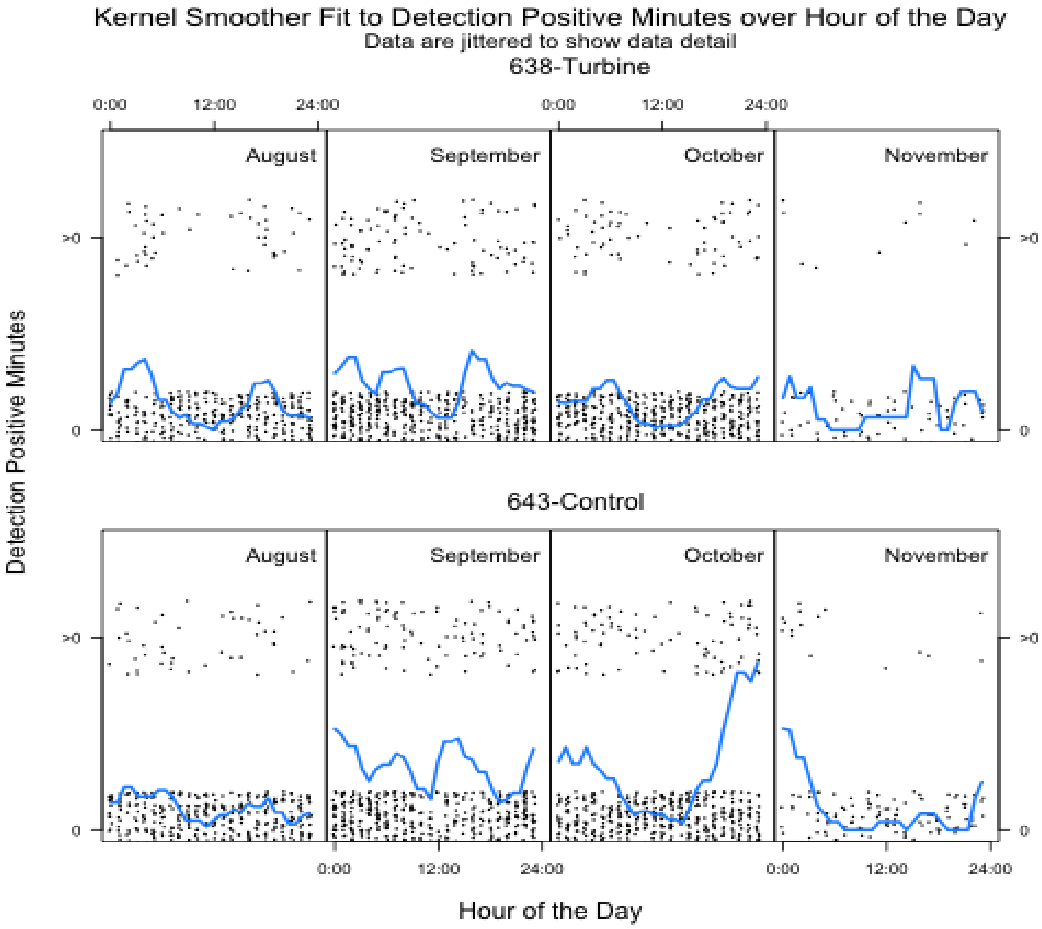


Figure 4.13. Trends in Detection Positive Minutes per hour across hour of the day and by month and site (blue line) to depict trends (based on raw data).

4.2.3 Tidal cycles and DPM per hour

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

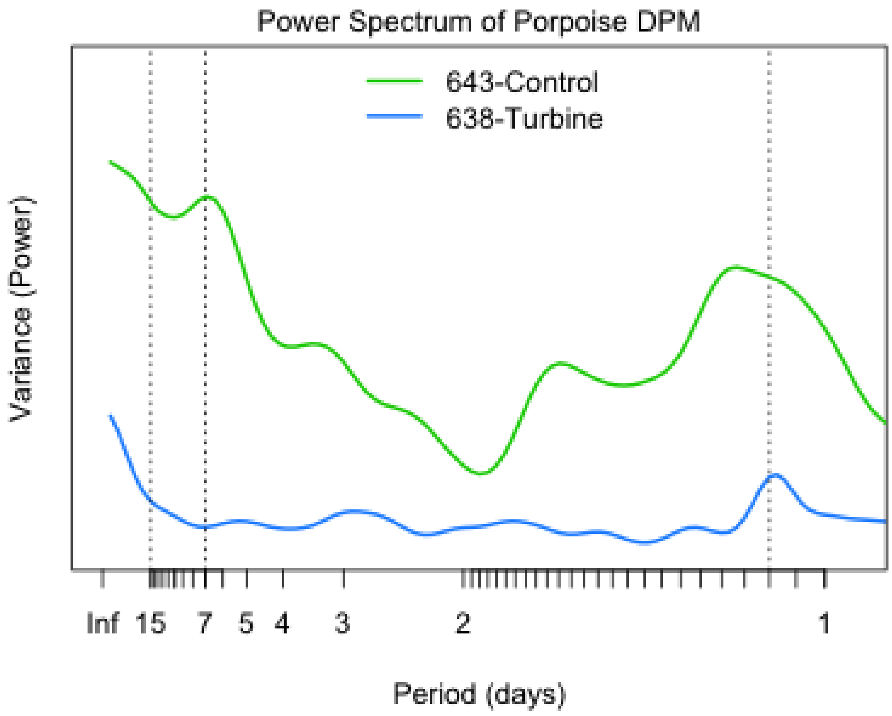


Figure 4.14. Power spectrum of DPM at the two sites at midnight. The x axis marks between 1 and 2 are in hours from 1 to 2 days (e.g. 1 day is 24 hours, the first mark to the left is 25 hours, etc.). The vertical dashed lines illustrate ~daily tidal cycles (~26 hours), a weak cycling at a frequency of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

4.3 Analysis of click train measurements

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

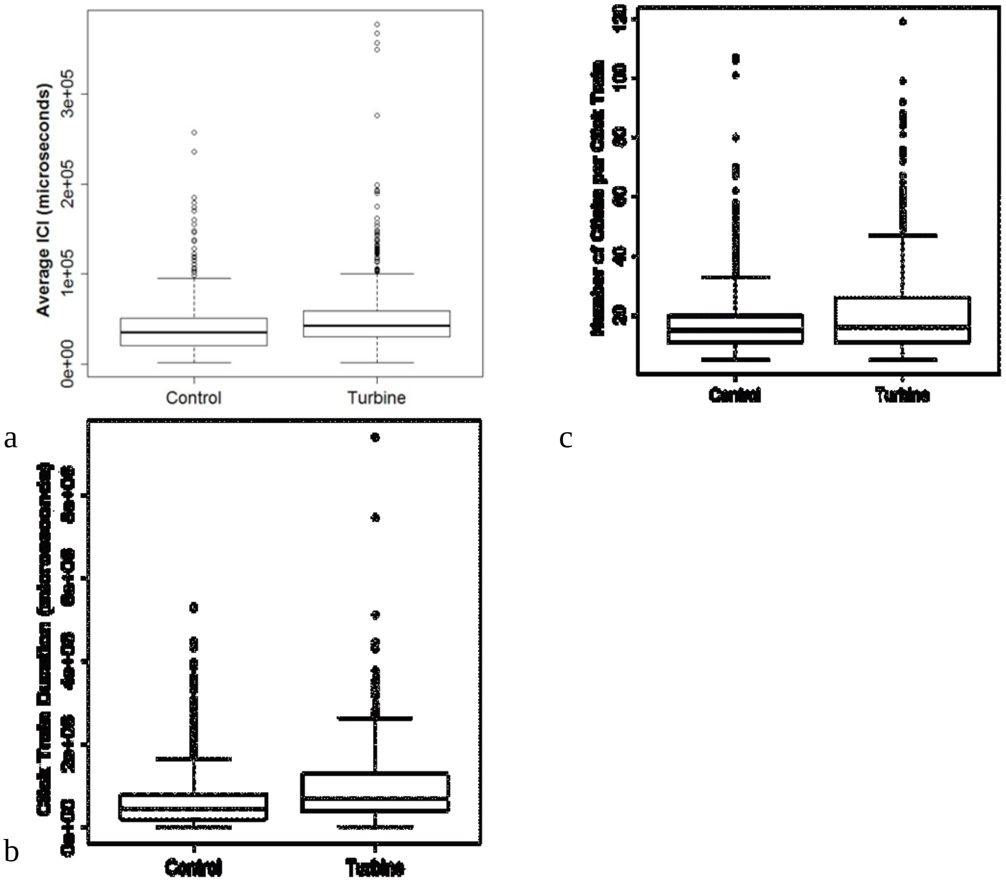


Figure 4.14. Boxplot of a) Average Inter Click Interval (µs), b) Click train duration (µs), and c) Number of clicks per click train (right panel) for each site.

5.0 DISCUSSION

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

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

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

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

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

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

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

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

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

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

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

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

6.0 FUTURE RECOMMENDATIONS

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

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

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