The use of deep-water shipping berths by bottlenose dolphins in the Shannon Estuary

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This report presents results from static acoustic monitoring using C-PODs at Moneypoint, Foynes, Aughinish and Shannon Airport in the Shannon Estuary cSAC between November 2011 and November 2012

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SUMMARY

Long-term Static Acoustic Monitoring (SAM) was carried out at four deep-water jetties (Moneypoint, Foynes, Aughinish and Shannon Airport) in the Shannon Estuary to assess their use by bottlenose dolphins. SAM was carried out using C-PODs, which are self-contained detectors which log the echo-location clicks of dolphins. A total of 368 C-POD days were monitored across each of the four sites. The proportion of days with dolphin detections decreased further up the estuary with 80% of days with detections at Moneypoint compared with just 21% of days at Shannon Airport. Dolphins were detected off Foynes on 47% of days and off Aughinish on 31% of days. Season had a significant effect on dolphin presence at three sites (Moneypoint, Foynes, Aughinish), while diel cycle was significant at Moneypoint, Foynes and Aughinish, with most detections registered during night-time. Tidal cycle only had a significant effect on detections at Aughinish, with most detections during flood tide. The Shannon Estuary is a very important site for bottlenose dolphins and deep-water berths are important habitats which they use as part of their daily activities and on a regular basis throughout the year. Any future development or operation at these sites must take into account the use of these sites by dolphins.

INTRODUCTION

The Shannon Estuary is one of the most important habitats in Ireland, if not Europe, for bottlenose dolphin (*Tursiops truncatus)*. It is the only protected site for this species in Ireland and is designated as a candidate Special Area of Conservation (SAC), which is one of around twenty such sites for this species throughout Europe. Research on the Shannon dolphins started in 1993, when a feasibility study to assess the potential of commercial dolphin-watching was carried out (Berrow *et al.* 1996). This study showed individual dolphins were resident and that it was an important calving area. A more detailed study from 1995-1998 confirmed these initial findings and estimated a population of around 120 dolphins used the estuary (Ingram 2000). Since this study five abundance estimates have been carried out which have shown the population to be stable (Berrow *et al.* 2012).

Bottlenose dolphins are not evenly distributed throughout the Shannon Estuary, however survey effort has largely been restricted to the outer and middle estuary Berrow *et al.* 1996; Ingram 2000; Ingram and Rogan 2003; Englund *et al.* 2007; 2008; Berrow *et al.* 2010). Survey effort upriver of Tarbert, Co Kerry is restricted to one short winter study by Berrow (2009). Ingram and Rogan (2002) attempted to describe the dolphins' habitat requirements and suggested they preferentially used areas with the greatest benthic slope and depth for foraging. These sites in the Shannon estuary are characterised by strong currents, especially on ebb tides which are thought to influence the distribution and movement of fish, especially salmon (*Salmo salar)* which is thought to be a preferred prey item of the Shannon dolphins. Preference for deep-water with a strong seabed gradient by bottlenose dolphins for foraging has been shown elsewhere (Hastie *et al.* 2004)

There have been a number of studies which have attempted to monitor bottlenose dolphins acoustically in the estuary sometimes over a number of years. Acoustic monitoring devices used to date include a static hydrophone (Berrow *et al.* 2006; Hickey *et al.* 2009) and self-contained click detectors called T-PODs and C-PODs (Philpott *et al.* 2007; O'Brien *et al*. 2012; Hansen *et al*. in prep). A recent ongoing study has deployed a hydrophone at Tarbert with the acquired signal streamed live through the internet (see www.monitoringoceannoise.com). These studies have shown significant tidal and diel patterns to the occurrence of dolphins at monitored sites but potentially large differences in these patterns over relatively short distances.

As part of the Shannon Integrated Framework Plan, static acoustic monitoring of bottlenose dolphins was carried out at deep-water berths. This study will provide high quality temporal data on the use of these sites by bottlenose dolphins and information on the presence and movement patterns of dolphins in a previously poorly surveyed part of the estuary. It is hoped this study can inform managers on the implications of developing these, and potential new sites, and be used to prepare mitigation measures to minimise disturbance to dolphins.

METHODS

This was carried out through the deployment of self-contained click detectors (C-PODs) which log the echolocation clicks of porpoises and dolphins (Fig. 1). A single C-POD can monitor both porpoise and dolphins simultaneously through identifying characteristic click parameters which can be assigned to either group. Once deployed, the C-POD operates in a passive mode and is constantly listening for tonal clicks within a frequency range of 20-160 kHz. When a tonal click is detected, the C-POD records the time of occurrence, centre frequency, intensity, duration, bandwidth and frequency of the click. Internally, the C-POD is equipped with a Secure Digital (SD) flash card, and all data are stored on this card. Dedicated software (CPOD.exe) is used to process the data and allows for the extraction of data files under pre-determined parameters as set by the user. Additionally, the C-POD also records temperature. It must be noted that the C-POD does not record actual sound files, only information about the tonal clicks it detects. Using the dedicated software, a train detection algorithm is run through the raw data to produce a CP.3 file. Through this process of train detection, C-PODs record a wide range of click types but the train detection searches for coherent trains within them. Recent detection distance trials carried out in the Shannon Estuary suggests a maximum detection distance of 797m for bottlenose dolphins (O'Brien *et al.* 2012).

Figure 1. C-POD unit by Chelonia Ltd.

Deployments

A single C-POD was deployed on jetties at each of the four locations, Moneypoint, Foynes, Aughinish and Shannon Airport (Fig. 2). Each of these locations are deep-water shipping berths for loading and unloading cargo vessels of up to 200,000 DWT. These berths and the area monitored (c800m from the unit) were used by ships entering and exiting the berths and travelling in the adjacent shipping channel.

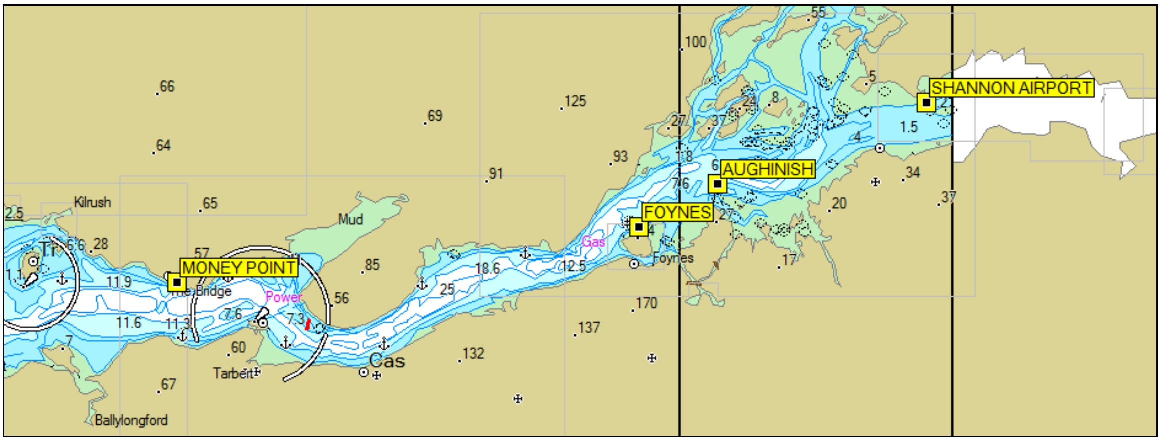


Figure 2. Locations of C-PODs at four deep-water berths in the Shannon Estuary

Light weight mooring designs were used at each of the sites by attaching to existing structures e.g. jetties. A roped line was hung from the top of the jetty with a 20kg weight attached to the end. At approximately mid-water a loop was etched in the line and the C-POD units were shackled secure. The units are positively buoyant, but salmon floats are attached to them to ensure they stay upright even in heavy seas and strong currents (Fig. 3).

Figure 2. Photograph of mooring used to deploy C-PODs during SAM monitoring in the Shannon Estuary using fixed structures

C-PODs were deployed at each site between 5 November 2011 and 4 November 2012, a total of 368 days. Full temporal coverage was not recorded at each site due to equipment malfunction or battery wastage but this did not impact on the models run for each dataset using the four factors selected.

C-POD calibration

Calibration of C-PODs is important in order to compare results across units. The manufacturers of C-PODs (Chelonia Ltd.) calibrate all units to a standard prior to dispatch. However, these calibrations are carried out under controlled conditions and they highly recommend that further calibrations are carried out in the field prior to their use in monitoring programmes. Field calibration aims to identify differences in sensitivity between units, and also enables better comparisons between datasets from different locations when multiple loggers are used or several units are used across a number of sites (O'Brien *et al*. 2012). If units of differing sensitivities are used, then the data do not accurately reflect the activity at a site. For example, a low detection rate may be caused by a less sensitive C-POD, with a lower detection threshold, which in turn leads to a lower detection range rather than a decline in use of the site by dolphins. It is essential that differences between units are determined prior to their deployment, to allow the use of correction factors to the data. Field trials should be carried out in high density areas in order to determine the detection function (O'Brien *et al.* 2012). Calibration trials were carried out off Moneypoint prior to start of present survey.

Four separate units were used during the present project and all were deployed off Moneypoint for calibration with 12 other units (Fig. 4). C-PODs 173, 947, 547 and 548 were deployed with a reference unit (C-POD 169) and deployed simultaneously, strapped together for 23 days (Fig. 5). This allowed enough time to establish if sensitivity would be a confounding factor between units before deployment in the present study.

Following calibration the data were extracted under two categories, 1) NBHF (porpoise band) and 2) Other (dolphin band) using the C-POD.exe software (Version 2.013, June 2011).

These data were in the form of Excel.xlsx files using C.POD.exe software and analysed as Detection Positive Minutes (DPM) within hourly segments.

Statistical analysis

Statistical analyses were carried out using the program R (R Development Core Team, 2011). All combinations of C-POD pairs were modelled using an orthogonal regression of DPM across hourly segments. This was compared to a null model, assuming no variation in C-POD detections, a = 0 and b = 1, and used to assess C-POD performance. An error margin of ±20% DPM per hour was plotted along the null model to distinguish between an acceptable level of variation in C-POD performance and problematic variation due to faulty or highly sensitive unit. From these graphs it was possible to determine successful or unsuccessful C-POD combinations. The mean intercept and gradient values of the orthogonal model for each C-POD pair were extracted and used to create centipede plots where, deviation from 0 on the horizontal axis, of mean intercept values and deviation from 1 on the horizontal axis, of mean gradient values indicated deviations from the null model. This was also used to identify if only one or two POD combinations were unsuccessful and also the extent of variability within the intercept and gradient values. Results were then used to highlight poor performing units or very sensitive units, if they existed and a correction factor could be generated and applied to the data.

Long-term data analyses

The long-term dataset was categorised into the following factors season, diel, tidal phase and tidal cycle in order to explore potential factors influencing the presence of dolphins and porpoises at the site. Season was categorised as spring (February to April), summer (May to July), autumn (August to October) and winter (November to January). Diel cycle was split into four phases (morning, day, evening and night) following the methods described by Carlström (2005). Morning began at the onset of civil twilight, and the length was calculated as twice the duration between the beginning of civil twilight and sunrise. Evening ended at the end of civil twilight and lasted twice the duration of the time between sunset and end of civil twilight. Information on sunset and sunrise was obtained from http://aa.usno.navy.mil/data/docs/RS_OneDay.php. As data were extracted from the C-POD units by hour, times between 12:30 and 13:29 were classified as 13:00, times between13:30 and 14:29 were classified as 14:00 etc. Tidal phase was categorised according to the phases of the moon using admiralty data (WXTide 32). Spring tide was calculated as 24 hours either side of the highest high water and neap tide lowest low water (O'Brien, 2009). Data were further classified by tidal cycle. One hour before and after high water was termed slack high, while one hour before and after low water was termed slack low. Hours that fell between slack high and slack low were deemed an ebbing tide. Similarly hours that fell between slack low and slack high were deemed as flood.

The dataset was then converted to the binomial Detection Positive Hours (DPH), where 1=detection(s) recorded and 0=no recorded detections in order to reduce the amount of zeros in the dataset. C-POD ID number was included as a random factor and a binomial generalized linear mixed-effect model (GLMM) was fitted using R statistical software (R Development Core Team, 2011). Akaike's information criterion (AIC), log likelihood and a histogram of fitted residuals were used as diagnostic tools for model selection. Wald chi-squared tests were computed for each variable and predicted proportions of DPH were extracted across all levels.

RESULTS

Calibration trials

There were some discrepancies between units (Fig. 4) but C-POD performance was within the acceptable error margin of ±20% DPM per hour (Fig's 5 and 6) and therefore no correction factor was applied to the data to make it comparable.

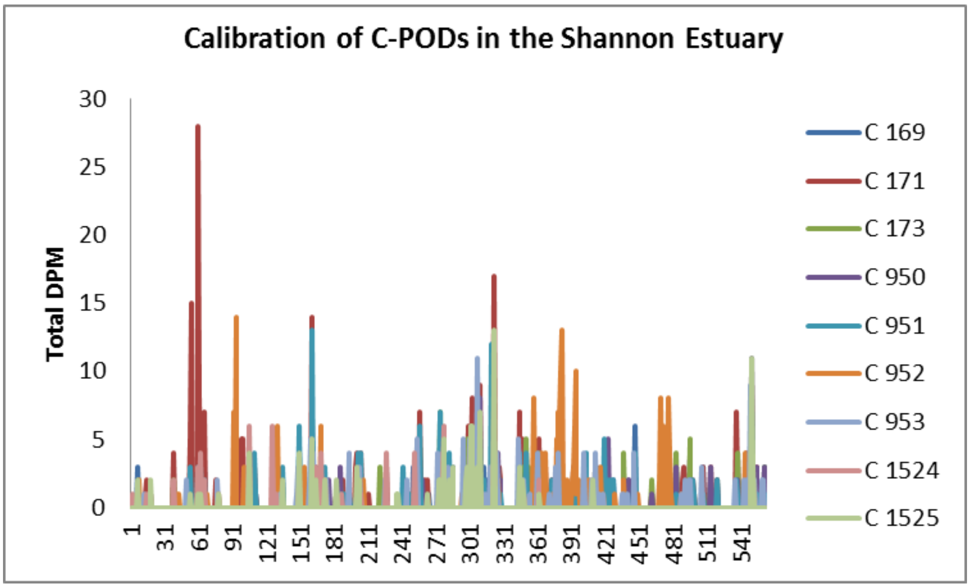


Figure 4. Detection Positive Minutes from units used during the present study, C-PODs 169, 171, 173, 950, 951, 952, 953, 1524, and 1525. C-169 is the reference unit. No correction factor (*cf*) required.

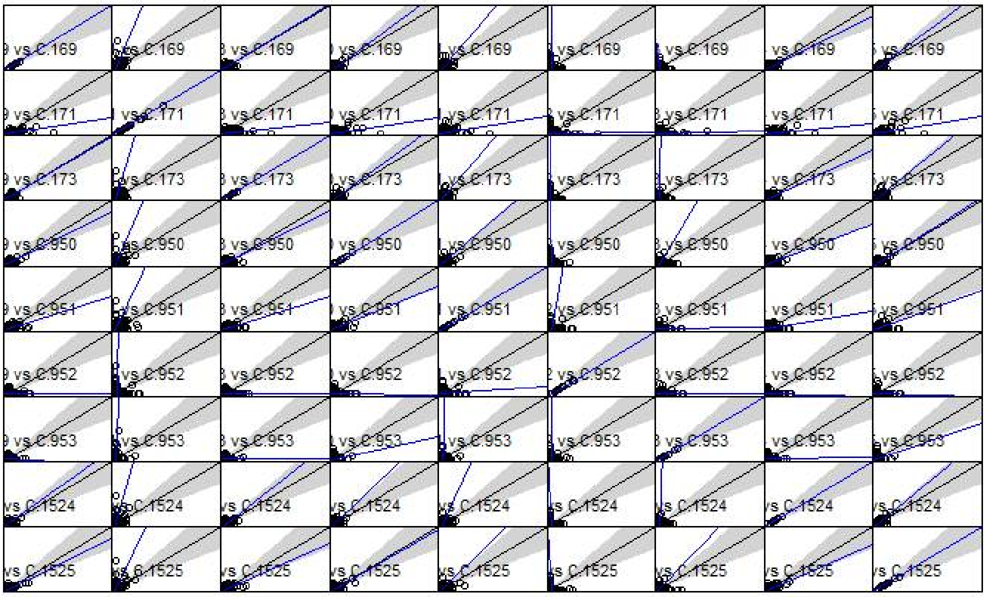


Figure 5. Orthogonal regression plot of C-POD comparisons in calibration trial, in blue, with a null model where each unit performs exactly the same, in black and an acceptable error margin of ±20%, in grey.

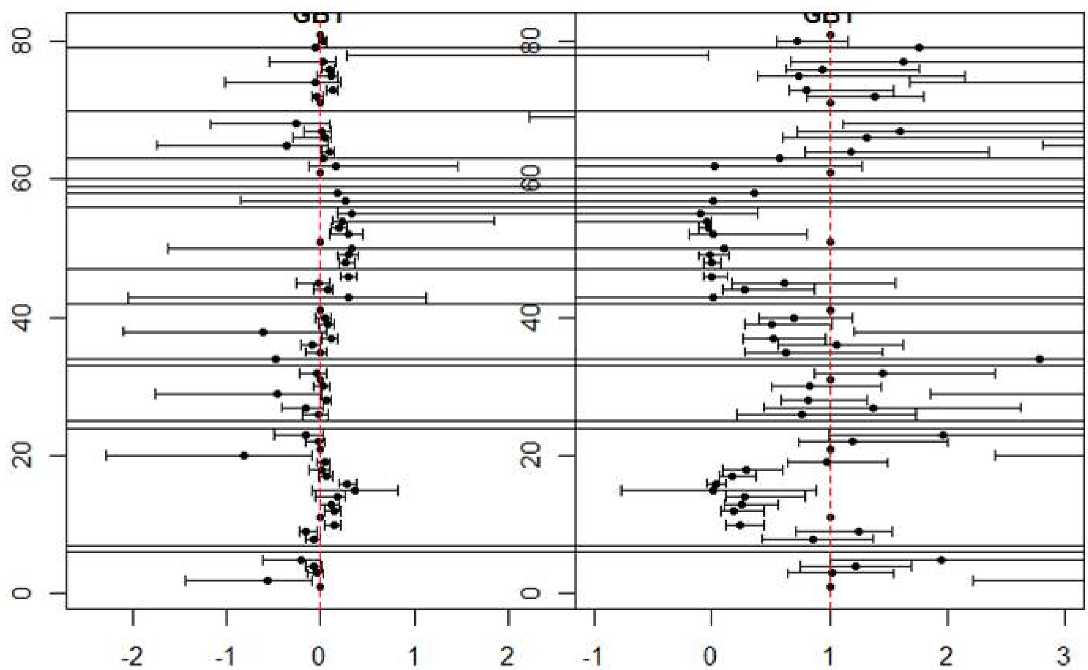


Figure 6. Centipede plot of the intercept and slope values (±std), of the orthogonal regression plots, for each pod performance comparison in calibration trails at Moneypoint 2011. Deviation from the red dotted lines, 0 on the intercept plot and 1 on the gradient plot, indicates deviation from the null model assuming no variation. Plot indicates that a greater extent of variation is found within the gradient values.

Static Acoustic Monitoring

A total of 368 days were monitored at the four sites with detections recorded on an average of 45% of days across all sites (Tables 1 and 2). The mean number of number of Detection Positive Minutes per day across all sites was 3.5 (Fig. 7). Harbour porpoise clicks can be distinguished from dolphins through the high frequency clicks generated by the porpoise, but on occasion dolphins in the estuary are found to produce clicks of a similar frequency and inter click interval, hence both categories are used in analyses even though bottlenose dolphins are the only species known to occur here.

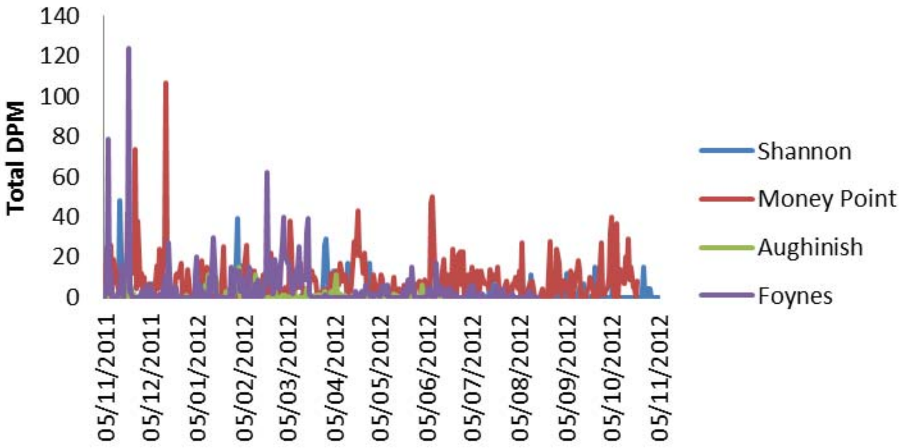


Figure 7. Total Dolphin Positive Minutes (DPM) recorded per day over the deployment peroiod at four sites

The proportion of days with dolphin detections decreased further up the estuary with 80% of days with detections at Moneypoint compared with just 21% of days at Shannon Airport (Table 1 and Fig. 8). An average monitoring index of 0.3% DPM was calculated across the four sites. Moneypoint had the greatest index at 1.0% DPM, while Aughinish had the least with 0.08% DPM. Mean number of DPM at each site showed a similar trend with a slight increase at Shannon Airport compared to Aughinish but both these sites were much less than Moneypoint and Foynes.

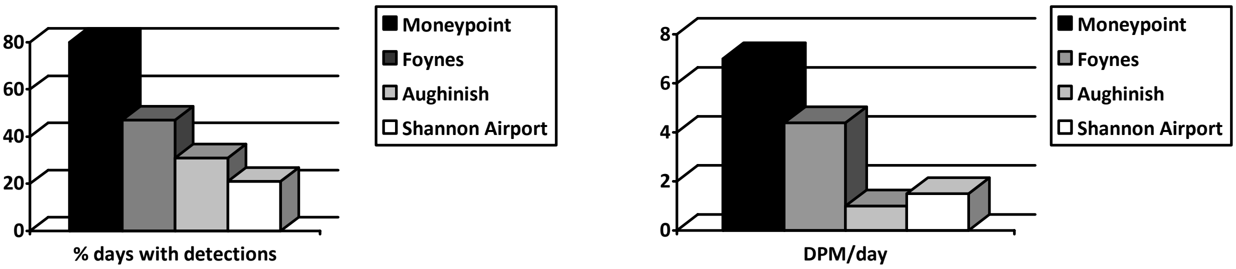
Table 1. Summary of results from SAM at four sites in the Shannon Estuary

Location	Duration (days)	% of days with detections	Detection Positive Minutes	Porpoise Positive Minutes	Dolphin Positive Minutes	Mean DPM/day (porpoise)	Mean DPM/day (dolphin)
Moneypoint	351	80	2737	244	2493	1.00	7.0
Foynes	288	47	1266	27	1239	0.09	4.4
Aughinish	225	31	252	28	224	0.12	1.0
Shannon	368	21	588	41	547	0.11	1.5
Totals	**1232**	**179**	**4843**	**340**	**4503**	**1.32**	**13.9**

Table 2. Results of C-POD deployments in the Shannon Estuary, including the calculation of a monitoring index %DPM

Location	Total Days	Total Hours	Total Min	DPD	Total DPM	% DPD	% DPM
				Dol	Dol	Dol	Dol

Moneypoint	351	8424	505,440	281	2737	80	0.50
Foynes	288	6912	414,720	134	1266	47	0.30
Aughinish	225	5400	324,000	70	252	31	0.08
Shannon	368	8832	529,920	77	588	21	0.10



Proportion of days with detections **Dolphin Positive Minutes (DPM)**

Figure 8. Summary of detection postive days and minutes at each of the four sites

Generalized linear mixed-effect model (GLMM) analyses

<u>Moneypoint</u>

Results from the generalized linear mixed-effect model (GLMM) analyses (Fig. 8) show that season had a significant effect on the presence of dolphins at the site with a peak in detections during the winter (χ^2= 788.8, p<0.0001). Most dolphin detections were recorded during the night (χ^2= 132.4, p<0.0001) showing they are more active at the site during this period. Tidal cycle and tidal phase were not found to be significant factors influence dolphin presence at the site.

<u>Foynes</u>

Results from the GLMM analyses showed that season had a significant effect on the presence of dolphins at the site (Fig. 9). A significant peak in detections was recorded during the spring (χ^2= 82.5, p<0.0001) and at night (χ^2= 82.5, p<0.0001). Tidal cycle and tidal phase were not found to be significant factors influencing dolphin presence at the site.

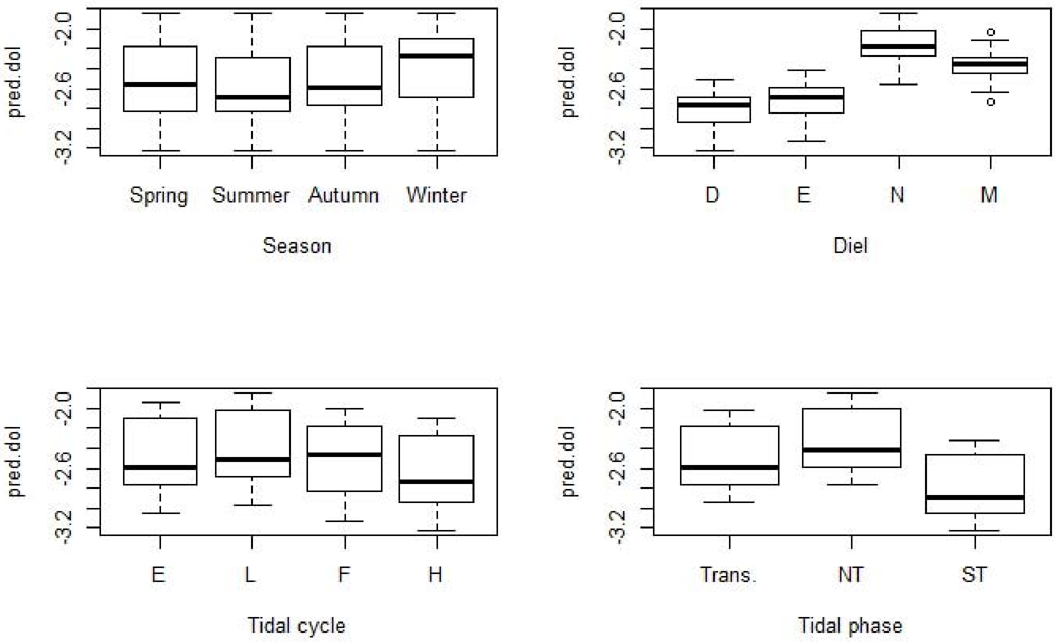


Figure 8. Predicted proportion of porpoise detection positive hours, in the narrow band high frequency channel from Moneypoint across season, diel (where D = day, E = evening, M = morning and N = night), tidal phase (where Trans. = transitional phase, NT = neap tide and ST = spring tide) and tidal cycle (where E = ebb, L = slack low, F = flood and H = slack high).

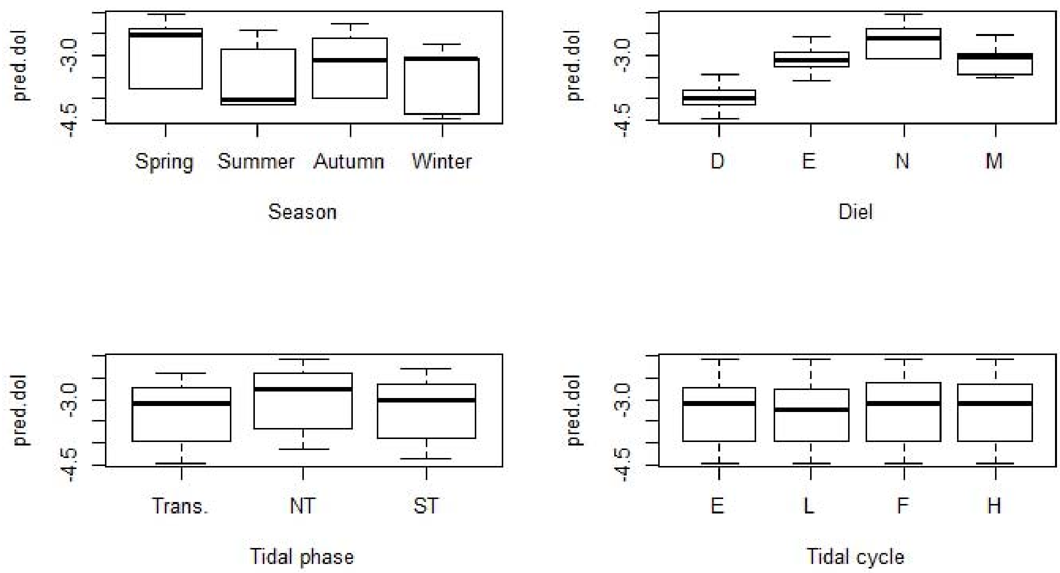


Figure 9. Predicted proportion of porpoise detection positive hours, in the narrow band high frequency channel from Foynes across season, diel (where D = day, E = evening, M = morning and N = night), tidal phase (where Trans. = transitional phase, NT = neap tide and ST = spring tide) and tidal cycle (where E = ebb, L = slack low, F = flood and H = slack high).

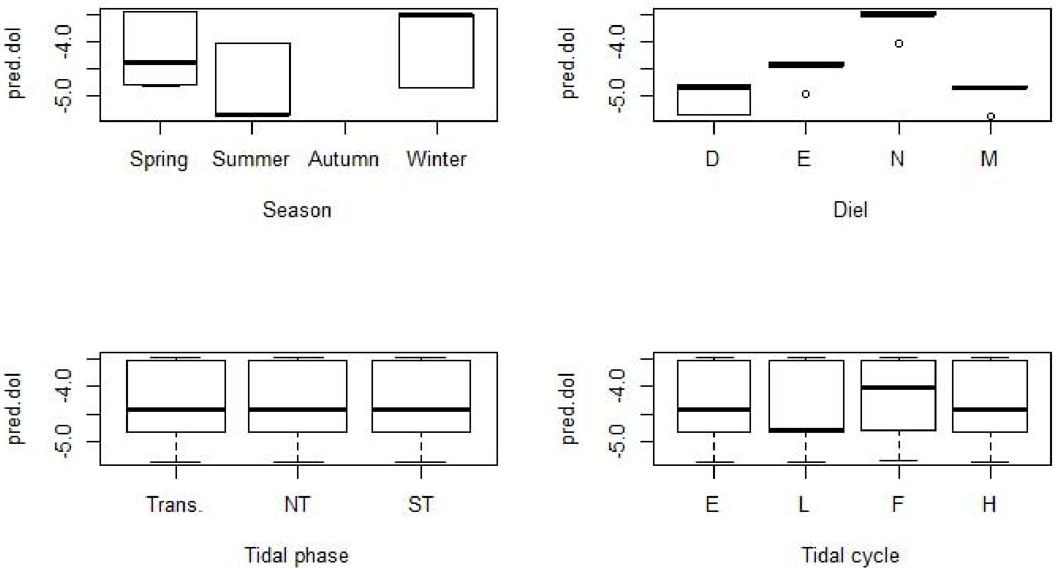


Figure 10. Predicted proportion of porpoise detection positive hours, in the narrow band high frequency channel from Aughinish across season, diel (where D = day, E = evening, M = morning and N = night), tidal phase (where Trans. = transitional phase, NT = neap tide and ST = spring tide) and tidal cycle (where E = ebb, L = slack low, F = flood and H = slack high).

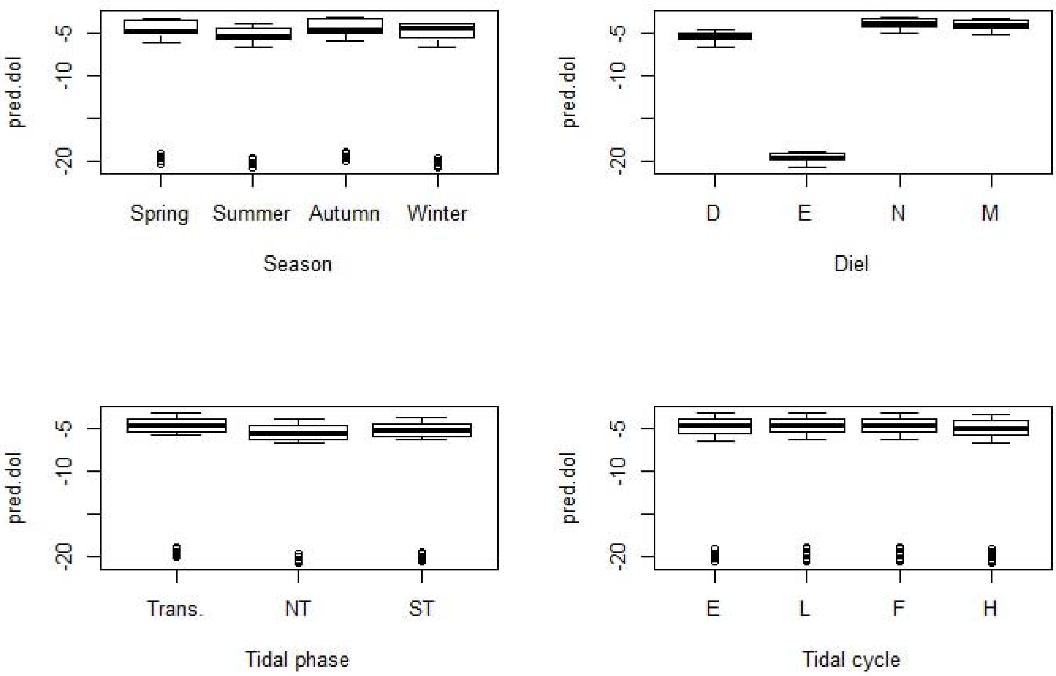


Figure 11. Predicted proportion of porpoise detection positive hours, in the narrow band high frequency channel from Shannon Airport across season, diel (where D = day, E = evening, M = morning and N = night), tidal phase (where Trans. = transitional phase, NT = neap tide and ST = spring tide) and tidal cycle (where E = ebb, L = slack low, F = flood and H = slack high).

Aughinish

Season had a significant effect on the presence of dolphins at Aughinish with more detections during the winter months (χ^2= 237.5, p<0.0001) (Fig. 10). A monitoring gap exists during the autumn, hence this season could not be tested. Similar to Moneypoint and Foynes, most dolphin detections were recorded during the night (χ^2= 253.6, p<0.0001) and during the flood tide (χ^2= 287.2, p<0.0001).

Shannon Airport

Season did not have a significant effect on the presence of dolphins at Shannon Airport (Fig. 11). There was no significant effect on detections on diel, tidal phase or tidal cycle.

DISCUSSION

In order to evaluate the importance of an area for dolphins, it is essential that their presence at the site is fully understood. Cetaceans live in an acoustic world and increasingly acoustic monitoring techniques have been developed rather than relying on visual methods, whose efficiency is hugely dependent on light, weather conditions and sea-state. Static Acoustic Monitoring (SAM) involves the recording or detection of cetacean vocalisations or echolocation clicks and is a very useful tool for exploring fine scale habitat use by dolphins. The main advantage of SAM is that is can provide information on species that can go undetected visually for the majority of their lives and can operate day and night and in all sea conditions. For example, bottlenose dolphins are thought to be underwater for up to 87% of the time (Mate *et al.,* 1995). Patterns of cetacean presence have been described using SAM over seasonal scales (Canning *et al*., 2008, Bolt *et al*., 2009; Simon *et al*., 2010; Gilles *et al*., 2011), diel cycles (Cox and Read 2004; Carlström, 2005; Todd *et al*., 2009; Phillpot *et al*., 2007) and tidal cycles (Philpott *et al*., 2007; Marubini *et al*., 2009). Visual monitoring of cetaceans can provide numbers for density and abundance estimation but will be biased due to factors such as observer effect and unfavourable sea conditions. Therefore, to obtain a complete dataset SAM is required to evaluate fully the importance of a site and can be more rapid and cost effective than visual means.

The aim of the present study was to explore the use of deep-water berths in the Shannon Estuary cSAC by bottlenose dolphins. During this study dolphins were recorded at all sites for periods ranging from 80% to 21% of days monitored. This is the first extensive monitoring of dolphins in the inner estuary and it shows they are using these habitats much more than was previously thought. The occurrence of dolphins as far up river as Shannon Airport on 21% of days monitored is much greater than expected. More detections were recorded at night at three of the four sites and thus visual techniques would have greatly under-estimated the dolphins use of these sites.

Season was found to be significant influence of dolphin presence at three of the four sites. At Moneypoint and Aughinish peak detections occurred during winter with peak detections at Foynes during spring. There was no significant seasonal trend at Shannon Airport. This was previously reported at Moneypoint and Foynes by O'Brien *et al.* (2012) during 600 days monitoring between 2009 and 2011. This study shows this trend is consistent and seasonal, and diel patterns also occur further upriver. Additionally, the influence of diel phase, with most detections recorded at night has also been previously described by O'Brien *et al.* (2012) from at Moneypoint and Foynes. There was however no previous data from Aughinish and Shannon Airport. Most dolphin detections at Aughinish were during flood tides while there was no significant influence of tide at the only three sites. This suggests the use of Aughinish by dolphins is different compared to the other three sites and needs further exploration. It might reflect more limited foraging opportunities at Aughinish and dolphins are passing through this site.

Concentrations of dolphins around deep, narrow channels were demonstrated in the Moray Firth, Scotland a site of another resident group of bottlenose dolphins (Hastie et al. 2003) and the use of this habitat was consistent over a ten year period. Hastie et al. (2004) showed this was linked to foraging and peaked in June and July. Although the identity of the preferred prey could not be determined but suspected it was salmonids. Fury and Harrison (2011) showed bottlenose dolphins in estuaries in Australia were more abundant in the spring and during a flood tide which they associated with access to their preferred prey of mullet and whiting. This is different to the use of the Shannon as dolphins occur in the Shannon throughout the year but exhibit seasonal preferences in the use of habitats within the estuary.

A monitoring index comprising %DPM was generated for each site and facilitated comparison with previous work carried out in the estuary but can also be used to compare with other sites outside the Shannon (O'Brien *et al.* 2012; O'Brien, 2009).

Clearly the Shannon Estuary is a very important site for bottlenose dolphins and the deep-water berths are important habitats which they use as part of their daily activities and on a regular basis. Although there was a trend with declining detection rates the further up-river monitoring was carried out, the presence of dolphins at Shannon Airport on 21% of days show that dolphins do use the inner estuary on a near daily rate and throughout the year. Any development of deep-water berths in the Shannon Estuary must take into account the use of these sites by bottlenose dolphins and ensure mitigation measures are in place during development and operation. The continued Static Acoustic Monitoring is recommended as it is a very cost-effective and will determine the long-term use of these sites.

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