Harbour porpoise surveys in Roaringwater Bay and Islands SAC, 2015

Joanne O'Brien and Simon Berrow

Irish Whale and Dolphin Group, Merchants Quay, Kilrush, County Clare

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Survey team:

Joanne O'Brien	**(Primary, LOGGER)**
Simon Berrow	**(Primary, LOGGER)**
Padraig Whooley	**(Primary)**
Paddy Dwyer	**(LOGGER, Primary)**
Mairéad O'Donovan	**(LOGGER)**

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Cover image: Harbour Porpoise in the Roaringwater Bay and Islands SAC; by Padraig Whooley

Executive Summary

A visual survey of harbour porpoises (*Phocoena phocoena*) was carried out in 2015 in Roaringwater Bay and Islands SAC in order to derive local density and abundance estimates. Single platform line-transect surveys were carried out according to a standardised design across six days between June and September 2015. Static Acoustic Monitoring (SAM) through the deployment of C-PODs was carried out at two sites within the SAC using a randomised sampling design. Distance sampling was used to produce a detection function based on the observed distribution of harbour porpoise sightings. Abundance estimates were calculated using the survey day as the sample and the sighting as the observation:

(i) for all survey days,
(ii) stratified by sea state and
(iii) for all surveys combined.

The total survey effort in Roaringwater Bay and Islands SAC per survey ranged from 53-55 km and was 324 km overall. Surveys were carried out in very favourable weather conditions on all six surveys, with sea-state 0 for 34%, sea-state 1 for 50% and sea-state 2 for 16% of overall survey effort.

The number of porpoise sightings per survey ranged from 6 to 18 and from 5 to 23 individuals with a total of 75 sightings of 141 individual porpoises overall. Other notable species recorded included minke whale, common dolphin, grey seal and basking shark. Sightings were made throughout the survey area. Density estimates ranged from 0.76 porpoises per km^2 to 3.03 porpoises per km^2 and this was equated overall to 2.02 porpoises per km^2. The coefficients of variation around the estimates were quite high (0.25-0.68) and 0.28 overall. Mean group size varied between 1.26-2.14 porpoises over the survey duration and showed a slight trend towards increasing group size over the June-September period. The overall pooled density estimate from all survey days combined gave an abundance estimate of 289±80 with 95% Confidence Intervals of 155-541.

The effect of sea-state on density estimates was investigated by running DISTANCE software models on data derived from sea-state 0, sea-state 0+1 and sea-state 0+1+2. The highest density estimate of porpoises was collected in sea-state 0+1 (2.41 porpoises per km^2) but was quite similar for all sea-states suggesting there was a limited effect of sea-state and hence the estimates using all sea-states combined are robust. The proportion of young porpoises and calves to all porpoises (including adults) was calculated for each survey and ranged from 8% to 27% and was 14.2% overall.

The density estimate recorded during the current survey was higher than previous estimates from Roaringwater Bay and Islands SAC in 2008 and 2013, where densities of 1.18 and 1.24 porpoises per km^2 respectively were calculated. Whether this reflects an increase in the local population size or an increase in the use of the SAC by porpoises is not clear and this will require a longer time series of comparable data to elucidate.

Autonomous porpoise click detectors (C-PODs) were successfully used to compile a continuous acoustic dataset from two locations within the SAC over the survey duration. Significant temporal trends were evident in the acoustic data acquired, showing porpoise presence (as indicated by vocal activity) to be influenced by time of day and night, and the tidal cycle. These patterns were different between the two sites at Gascanane Sound and Baltimore, situated ca. 5 km apart, demonstrating a degree of variability in site usage across small spatial scales.

We recommend repeating survey track-lines using the same methodology during future surveys in order to improve the data time series within the site. Given the variability in density estimates per survey via distance sampling, consideration should also be given to developing acoustic indices from which to monitor population status. It is likely that acoustic datasets, when put into appropriate models, will be able to identify changes at a higher resolution than visual surveys but these indices will require data replication over a number of years.

Introduction

The harbour porpoise (*Phocoena phocoena*) is the most widespread and abundant cetacean species in Irish waters (Berrow, 2001). It has been recorded off all Irish coasts, including over the continental shelf but is thought to be most abundant off the southwest coast (Wall *et al.,* 2013). It is also consistently one of the most frequently recorded species stranded on the Irish coast (O'Connell and Berrow, 2015).

There have been a number of dedicated surveys which have estimated absolute abundances of harbour porpoises in Irish waters. In July 1994, an abundance estimate of 36,280 harbour porpoises was calculated for the Celtic Sea as part of an international project called SCANS (Small Cetacean Abundance in the North Sea) (Hammond *et al.,* 2002). This survey was repeated in July 2005 (SCANS-II) when it covered all waters overlying the continental shelf, including the Irish Sea (Hammond *et al.,* 2013). Ship-based double platform line-transect surveys were carried out in the Celtic Sea and in offshore Ireland, while aircraft were used for coastal Ireland and in the Irish Sea. Harbour porpoise abundance estimates were generated for three areas; the Celtic Sea (80,613, CV=0.50), Irish Sea (15,230, CV=0.35) and Atlantic coastal Ireland (10,716, CV=0.37). The offshore Ireland survey area included Scotland and an estimate of 10,002 porpoises (CV=1.24) was generated for both areas combined. Hammond *et al.* (2013) reported a doubling of harbour porpoise density in the Celtic Sea between the SCANS and SCANS II survey years.

In 2007 and 2008, the National Parks and Wildlife Service (NPWS) commissioned surveys of harbour porpoise at eight sites including Roaringwater Bay, Dublin Bay and North County Dublin (Berrow *et al.,* 2007; 2008a; 2008b; 2014). Six single platform surveys were carried out at each site between July and October with density estimates calculated for each survey day and for all surveys combined (i.e., pooled estimates). These showed that density estimates were highest for the Blasket Islands SAC, North County Dublin and Dublin Bay with estimates for Roaringwater Bay SAC also among the highest recorded for all sites. It was recommended that an SAC for harbour porpoise should be designated off the east coast due to the elevated densities recorded. Single platform line-transect surveys using distance sampling and acoustic monitoring were also carried out in summer at a further six regional sites around Ireland between 2010 and 2012 (Ryan *et al.*, 2010; Berrow *et al.,* 2011; 2012). These sites were generally situated between 6-12 nm offshore and the surveys recorded all cetacean species encountered. Harbour porpoises were recorded at all sites but densities were highest in the Irish Sea with 1.58 ± 0.22 porpoises per km^2 recorded and with an associated CV of 0.14 (Berrow *et al.,* 2011).

Harbour porpoises rely on sound production through the use of echolocation signals for foraging, orientation and communication. These signals are characterised as being narrow-band, high frequency clicks peaking between 110 and 150kHz, while the average click has a duration of 2µs with a mean source level of 150dB re 1µPa @ 1m (Møhl and Andersen 1973; Goodson and Sturtivant, 1996; Au *et al.,* 1999; Carlström, 2005; Villadsgaard *et al.,* 2007; Verfuß *et al.,* 2007). The reliance on sound by these animals, coupled with the fact they seem to continuously echolocate, producing a click train every 12.3 seconds (Akamatsu *et al*., 2007) makes static acoustic monitoring (SAM) a very valuable tool for determining the presence of and assessing fine scale habitat use by the species. The main advantage of SAM is that it can provide information on harbour porpoises that can go undetected visually for up to 95% of the time (Read & Westgate, 1995). Patterns of cetacean presence have been described over seasonal scales (Canning *et al*., 2008, Bolt *et al*., 2009; Simon *et al*., 2010; Gilles *et al*., 2011; O'Brien *et al.,* 2013), diel cycle (Cox & Read 2004; Carlström, 2005; Todd *et al*., 2009; Philpott *et al*., 2007; O'Brien *et al.,* 2013) and tidal patterns (Philpott *et al*., 2007; Marubini *et al*., 2009; O'Brien *et al.,* 2013). In order to evaluate the importance of an area, it is fundamental that the presence of small cetaceans at a site is fully understood and this requires monitoring over varying time scales depending on monitoring methods. SAM provided a means to gather data from a number of random sites continuously during the 2015 survey season and therefore assess if temporal factors which could not be picked up on during intermittent visual surveys, influenced the presence of the species at the site.

EU Member States are required to designate Special Areas of Conservation (SACs) for species listed under Annex II of the EU Habitats Directive, one of which is the harbour porpoise. The Blasket Islands SAC and Roaringwater Bay and Islands SAC were designated as candidate SACs for the species in 2000. More recently in 2012 a third SAC (Rockabill to Dalkey Island SAC) was designated with harbour porpoise as a qualifying interest. In order to contribute to the Department of Arts, Heritage and the Gaeltacht's (DAHG) site management and surveillance, visual and static acoustic monitoring of harbour porpoises was carried out in Roaringwater Bay and Islands SAC during the summer of 2015. This was the third dedicated line transect survey of harbour porpoises within this SAC which enabled ongoing trends in summer density estimates to be explored. The objectives of the survey in 2015 were to:

i) derive updated summer density and population estimates for harbour porpoises within the Roaringwater Bay and Islands SAC using robust sampling methods for small cetacean density/population estimation;
ii) estimate associated Coefficients of Variation and 95% Confidence Intervals;
iii) deploy SAM units (C-PODs) to continuously monitor the site acoustically over the entire survey duration (June to Sept).

Methods

<u>Survey site and platform</u>

The survey site and line-transect survey design is shown in Figure 1. The area of Roaringwater Bay and Islands SAC is approximately 143 km^2. A series of 10 track-lines spaced 1nm apart were provided by DAHG and these were chosen randomly in order to provide equal coverage probability within the SAC.

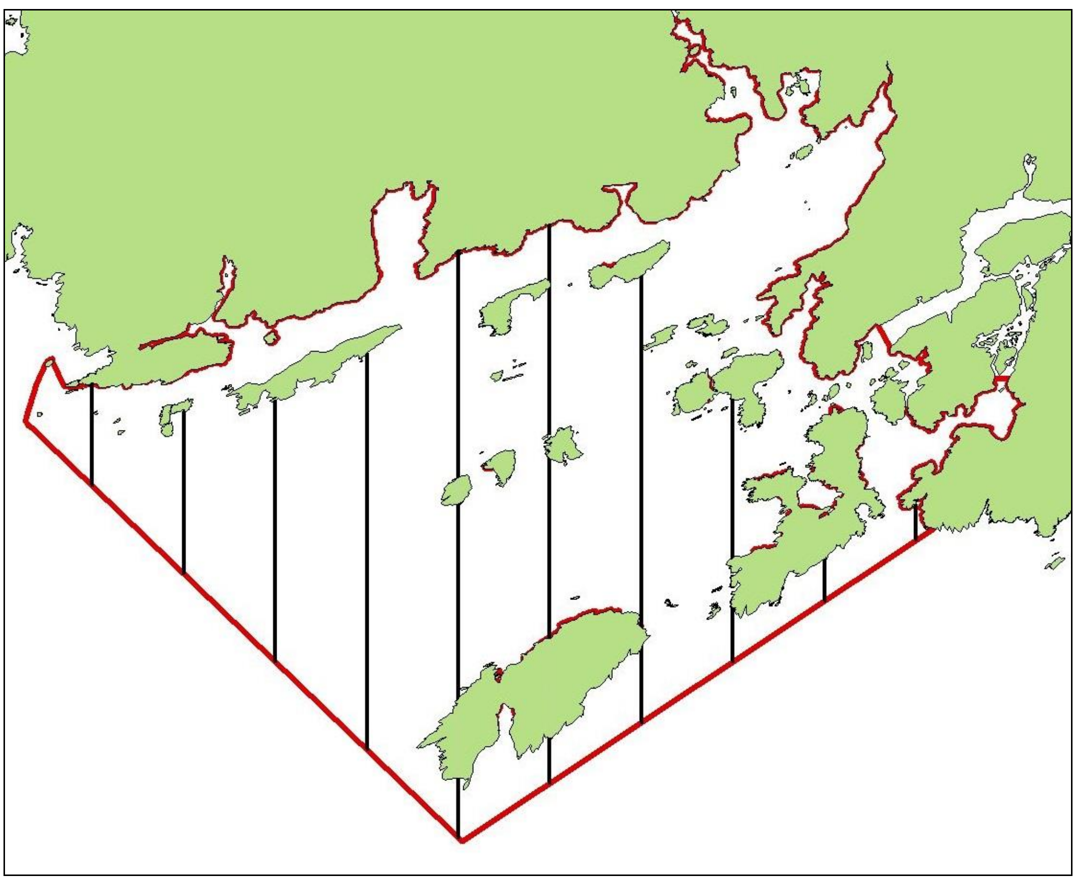


Figure 1. Roaringwater Bay and Islands SAC showing DAHG survey track lines selected for coverage in 2015.

Survey platform

The same vessel was used on each survey, the MV Holly-Jo, skippered by Colin Barnes of Cork Whalewatch. The primary observation platform offered a height of 3.2m above the waterline (Figure 2).

Figure 2. MV Holly-Jo with flying bridge suitable for line-transect surveying.

Survey methodology

Conventional single platform line-transect surveys were carried out within the boundaries of the site along the pre-determined track-lines. Transect lines were designed to try and get full coverage of the site over the study period to ensure that no potentially important porpoise concentrations were overlooked and to provide equal coverage probability. The survey conditions prescribed by DAHG in which surveys were to be carried out included Beaufort Force/Sea state 2 or less and good light conditions with a visibility of 6km or more.

The survey vessel travelled at a speed of 12-16 km hr^{-1} (7-9 knots), which was 2-3 times the average speed of the target species (harbour porpoise) as recommended by Dawson *et al.* (2008). Two primary observers were positioned on the flying bridge, which provided an eye-height above sea-level of between 4-5m depending on the height of each individual observer. Primary observers watched with the naked eye from dead ahead to 90^{o} to port or starboard depending on which side of the vessel they were stationed. All sightings were recorded but sightings more than 300m from the track-line were not used in the distance sampling model. Calves/juveniles were defined as porpoises ≤ half the length of the accompanying animal (adult) and in very close proximity to it. Small animals seen alone were also classified as juveniles. Sightings off-effort while transiting between track-lines or to the study site were recorded but not included in further data analysis.

During each transect the position of the survey vessel was tracked continuously through a GPS receiver connected to a laptop computer, while survey effort including environmental conditions (sea-state, wind strength and direction, glare, etc.) were recorded every 15 minutes using LOGGER software (© IFAW). When a sighting was made the position of the vessel was recorded immediately and the angle of the sighting from the track of the vessel and the estimated radial distance of the sighted animal(s) from the vessel were recorded. These data were communicated to the recorder in the wheelhouse via VHF radio. The angle was recorded to the nearest degree using an angle board attached to the vessel immediately in front of each observer. Accurate distance estimation is essential for distance sampling. Measuring sticks (Heinemann, 1981) were made by each primary observer to assist in distance estimation.

Density and abundance estimation

Distance sampling was used to derive a density estimate and to calculate a corresponding abundance estimate for each individual survey where possible. The software programme DISTANCE (Version 5, University of St Andrews, Scotland) was used for calculating the detection function, which is the probability of detecting an object a certain distance from the track-line. The detection function was used to calculate the density of animals on the track-line of the vessel. During this survey we assumed that all animals on the track-line were observed, i.e., that g(0) = 1, given the strict operational and environmental conditions under which surveys took place. The DISTANCE software allows the user to select a number of models in order to identify the most appropriate for the data. It also allows truncation of sighting outliers when estimating variance in group size and testing for evasive movement prior to detection.

To calculate density, “day” was used as the sample regime with sightings used as sampling observations. Estimates of abundance and density obtained via the DISTANCE modelling process were calculated and presented for each survey day. An overall pooled abundance/density estimate was derived from all track-lines surveyed combined across all survey days. This was necessary in order to obtain sufficient sightings for a statistically robust estimate using the DISTANCE model (the minimum required is 40—60; Buckland *et al.,* 2001). In conducting this pooled analysis, we assumed that there were no significant changes in distribution within the site between sample days or any immigration into or emigration out of the site.

The data were fitted to a number of models available in the DISTANCE software. The Half-Normal model with cosine adjustments was found to provide the best fit according to the Akaike Information Criterion delivered by the model. The recorded sighting data were grouped into equal distance bands of 0-30m, 30-60m, etc up to 300m. The DISTANCE model determines the influence of cluster size on variability by using a size-bias regression method with the log(n) of cluster size plotted against the corresponding estimated detection function g(x). A Chi-squared test associated with the estimation of each detection function was provided by the DISTANCE model. If found to be statistically significant it indicated that the detection function was a good fit and that the corresponding estimates were robust. The proportions of the variability accounted for by the encounter rates, detection probability and group size (cluster size) were presented with each detection function. Variability associated with the encounter rate reflects the number of sightings on each track-line. The detection probability reflects how far the sightings were from the track-line and cluster size reflects the range of estimated group sizes recorded on each survey.

<u>Mapping cetacean survey and encounter data</u>

Maps of the study area and associated survey data were created in Irish Grid (TM65_Irish Grid) with ArcMap 10.2 while maps of the prescribed survey area, surveytrack-lines and coordinates were obtained from DAHG. Data concerning transects, effort, sightings, abundance and density were stored in a single MS Access database, which was queried and processed via GIS to produce sighting distribution maps.

<u>Static acoustic monitoring</u>

Random selection of SAM locations

A map of Roaringwater Bay and Islands SAC was plotted in ArcMap 10.2 and a 1km^2 grid overlain on the base map. Four of these 1km^2 grids were then combined and assigned a “site number” (sites 1-21; Figure 3). These were then plotted in Excel and assigned random numbers which were subsequently sorted from lowest to highest values; the first two site numbers in the sorted sequence were chosen as the locations for the first SAM deployment (early season). The third and fourth site numbers were then selected as the locations for the second deployment (mid-season). The mid-point of each box was chosen as the approximate deployment location and C-POD deployment took place as close as possible to that point, depending on depth and proximity to vessel traffic. Deployment of the C-PODS took place at the first two locations (sites 16 & 18) during the first survey in June 2015, while retrieval and re-deployment of these units at the remaining two sites (sites 19 & 20) was planned for early August (Figure 3).

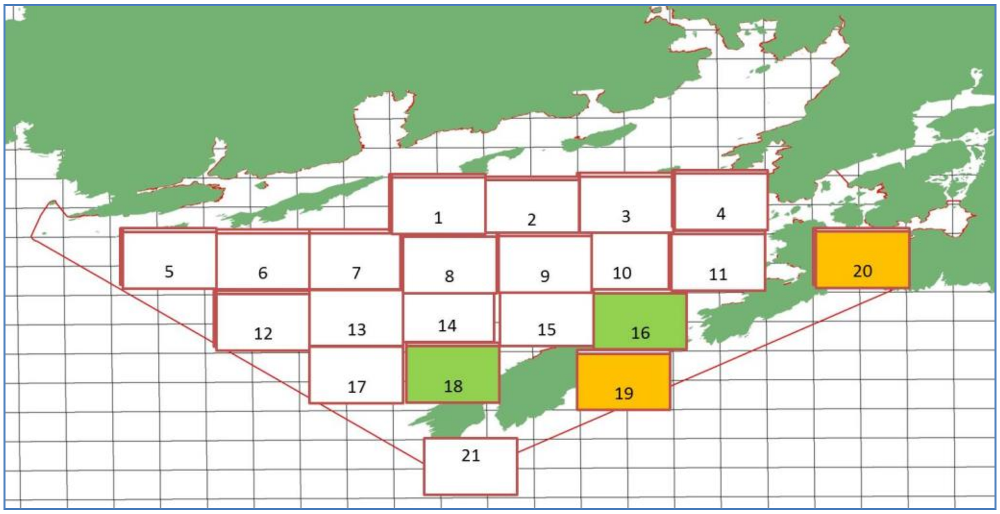


Figure 3. Map of Roaringwater Bay and Islands SAC where four 1km^2 squares were combined and assigned a site number (21 in total). Sites 18 and 16 (green background) were the locations for SAM deployment 1 and sites 19 and 20 (orange background) were the locations for deployment 2.

Moorings

Light weight moorings were constructed using polypropylene rope and mooring blocks weighing 20kg each. A maximum of 60kg was used per mooring depending on the site. A single line ran from the mooring blocks to two surface buoys. A single loop was made on the main line three quarters of the way down and all monitoring units were shackled into that loop which was lined with a metal thimble to protect the rope from fraying (Figure 4). A second safety line was threaded through the lid of the C-POD and also shackled onto the main line. This light weight mooring design was used as it has proved successful at a number of other sites around the country, even in adverse weather conditions.

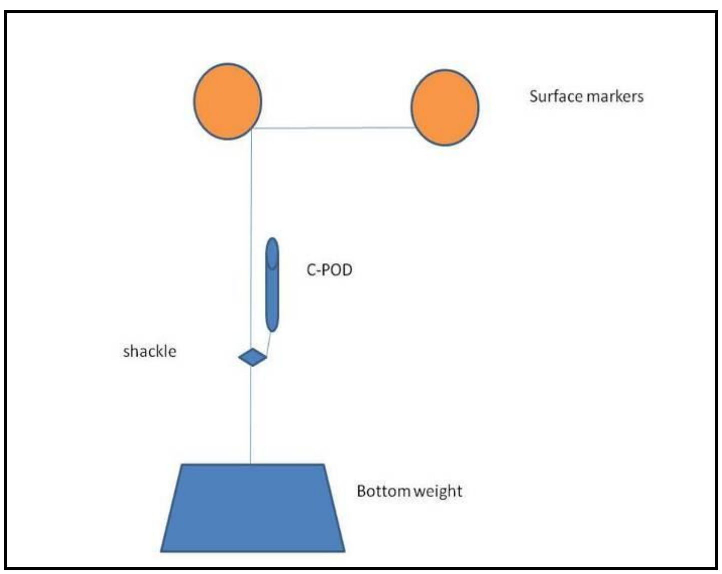


Figure 4. Light-weight mooring design used during the study

C-PODs

Once deployed at sea the C-POD (Chelonia Ltd; www.chelonia.co.uk) operates in a passive detection mode and is constantly listening for tonal clicks within a frequency range of 20 to 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, provided by the manufacturer, is used to process the data from the SD card when connected to a PC via a card-reader. This allows for the extraction of data files under pre-determined parameters as set by the user. Additionally, the C-POD also records temperature over its deployment duration. It must be noted that the C-POD does not record actual sound files, only information about the tonal clicks it detects. The C-POD is a sound pressure level detector with a detection threshold of 114.5 ±1.2 dB re. 1µPa peak-to-peak at 130 kHz, with the frequency response shown below (Figure 5). A recorded detection distance of 441 ±42m (92% <400m) was derived previously for the Harbour porpoise in Galway Bay (O'Brien *et al.,* 2013) while bottlenose dolphins in the Shannon Estuary have been detectable acoustically at ranges of ca. 700-850m (75% of groups recorded at <400m distance).

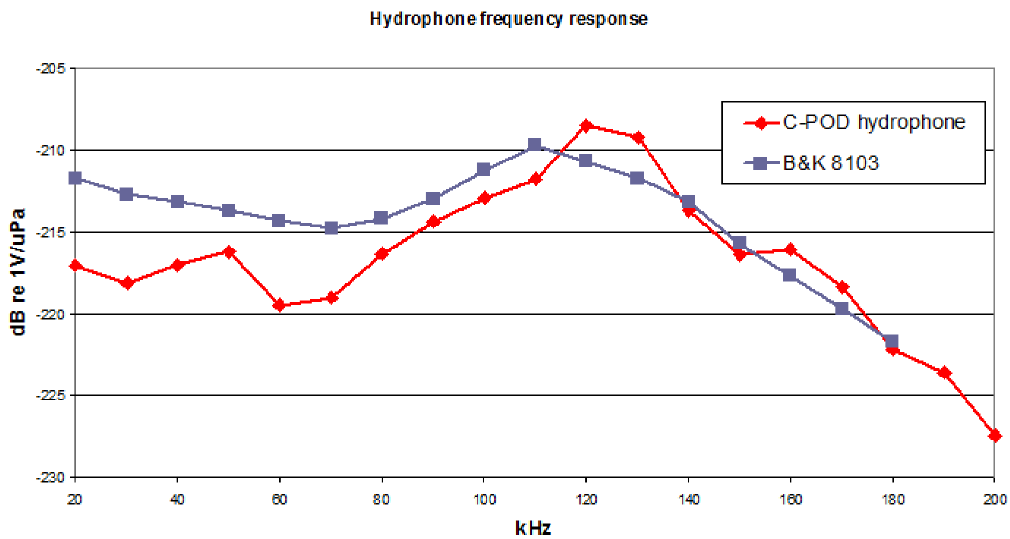


Figure 5. Frequency response by C-POD hydrophones (www.chelonia.co.uk)

Calibration

Calibration of the C-PODs is important in order to facilitate the comparison of acoustic detection results across different units. Chelonia Ltd calibrates all units to a standard prior to dispatch. These calibrations are carried out in the lab under controlled conditions and thus Chelonia highly recommends that further calibrations are carried out in the field prior to their employment in monitoring programmes instead of through further tank tests (Nick Tregenza, Chelonia Ltd., *pers. comm.*). Both C-PODs deployed during the present study were calibrated during field trials in the Shannon Estuary in January 2015.

Data analysis

All C-POD data were extracted using CPOD.exe as detection positive minutes (DPMs) per day and per hour. Detections logged by the devices were extracted as NBHF (porpoise detections) and Dolphins (only to species level in the absence of visual confirmation). Data were analysed using the software package R. R is a language and environment for statistical computing and graphics. It is free software, available at www.r-project.org/index.html. The software compiles and runs on a wide range of UNIX platforms, Windows and MacOS. R provides a wide variety of linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering and graphical techniques (R Development Core Team, 2011). R is designed around a true computer language, similar to the S language. The effective programming language includes conditionals, loops, user-defined recursive functions and input and output facilities.

Only high probability clicks were used in the analysis of C-POD data. Both dolphin and porpoise detections extracted per hour were classified into the following categories: *diel cycle* (day and night-time) and *tidal state* (ebb, flood, slack high, slack low). The term *PPM (porpoise-positive minutes)* was given to represent the number of minutes in a day or hour that harbour porpoises were acoustically detected, while *DPM (dolphin-positive minutes)* represented the number of minutes dolphins were detected. Data format *PPM/h* and *DPM/h* were divided into day and night-time categories using local times of sunrise and sunset obtained from the U.S. Naval Observatory (www.aa.usno.navy.mil/data/docs/RS). Hourly data segments were further categorised into each of the four prescribed tidal states, where three hours was assigned to each state (one hour either side of the hour using admiralty data (WXTide 32).

All data were analysed statistically using the programme R. In order to overcome zero inflation, the data were transposed into a binomial format of Detection Positive Hours (DPH), where 1=detection(s) recorded and 0=no recorded detections. This was also the rationale behind the use of a generalized linear mixed-effect model (GLMM), where the binomial data was analysed using the glmer function in the lme4 package developed for R. C-POD ID number was included as a random factor to take into account variability between units. The Akaike information criterion (AIC) 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 and displayed as box plots using the HH package developed for R.

Results

Six survey days were completed in Roaringwater Bay and Islands SAC during the present study. Favourable conditions, defined as sea-state ≤2 with good light and visibility to at least 6km, were recorded during all six (Table 1). Sea-state can be influenced by wind and tide and can change throughout the survey. In Roaringwater Bay sea-state 0 predominated for two of the six surveys (23 June and 15 July) and sea-state was ≤ 1 for three other surveys (14 July, 7 and 12 August) (Table 2). Only on one survey (7 September) was sea-state 2 the predominant condition for the majority (58.4%) of survey effort, amounting to 31 km of track-line. On 14 July, 27% of effort was carried out in sea-state 2, but for three of the surveys all effort was in sea-state ≤1 (Table 2). No survey effort on any of the six survey days was carried out in sea-state 3.

Table 1. Environmental conditions during the surveys of Roaringwater Bay and Islands SAC in 2015.

Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
23 June	None	11-15km	4	S	7/8	None
14 July	None	11-15km	5	N	7/8	None
15 July	None	11-15km	3	-	3/8	None
7 August	None	11-15km	4	S	5/8	None
12 August	None	11-15km	3	NE	7/8	None
7 September	None	16-20km	4	N	8/8	None

The total survey effort in Roaringwater Bay and Islands SAC per survey day was very consistent ranging from 53-55km per survey (Table 2). The small differences were due to restrictions in accessing some areas due to tide exposing shallow rocks, which affected the safe distance to which the survey vessel could approach islands; this made some track-lines less accessible, and lead to slight deviations from the original track provided by DAHG.

Table 2. Sea-state and on-effort sighting data for harbour porpoises recorded in Roaringwater Bay and Islands SAC, 2015.

Sample Day	Date	Total effort (km) in sea-state ≤2	Sea-state (% of total survey time)			Number of sightings	Total no. of animals
			0	1	2		
1	23 June	53.6	79.1	20.8	0.0	23	38
2	14 July	54.1	23.7	49.5	26.9	5	11
3	15 July	53.0	54.1	45.9	0.0	18	30
4	7 August	55.0	09.2	79.6	11.1	6	11
5	12 August	55.3	37.2	62.8	0.0	17	36
6	7 September	53.1	4.14	37.5	58.4	7	15
Total		**324**	**34.8**	**50.1**	**16.1**	**75**	**141**

The number of sightings per survey ranged from 5 to 23 with a total of 75 overall (Table 2). The highest numbers of sightings were recorded on surveys 1, 3 and 5 (in months June, July and August) suggesting there was not a monthly trend in detection rates but days with a good number of detections spread throughout the survey period. Sighting rates on two consecutive days in July (Surveys 2 and 3) reported quite different numbers of sightings (5 and 18) and individuals (11 and 30) despite very favourable sea conditions. The total number of individual porpoises recorded per survey also varied from 11 to 38 with a total of 141 overall.

Track-lines undertaken and sightings recorded in Roaringwater Bay and Islands SAC during each survey day are shown in Figures 6a-f. Harbour porpoises were evenly distributed throughout the track-lines with no obvious clusters (Figures 6a-f). Within the overall study area the survey was always started from east to west but this occurred at different states of the tide, which may have biased results if there was a consistent movement of porpoises through the day; but this does not appear to be the case.

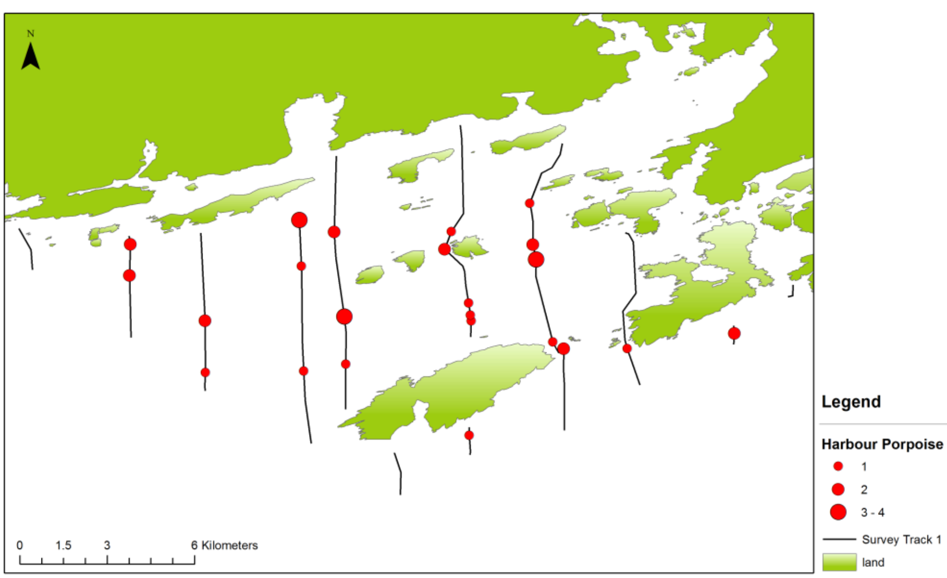


Figure 6a. Track-lines and distribution of harbour porpoise sightings on 23 June 2015

Figure 6b. Track-lines and distribution of harbour porpoise sightings on 14 July 2015

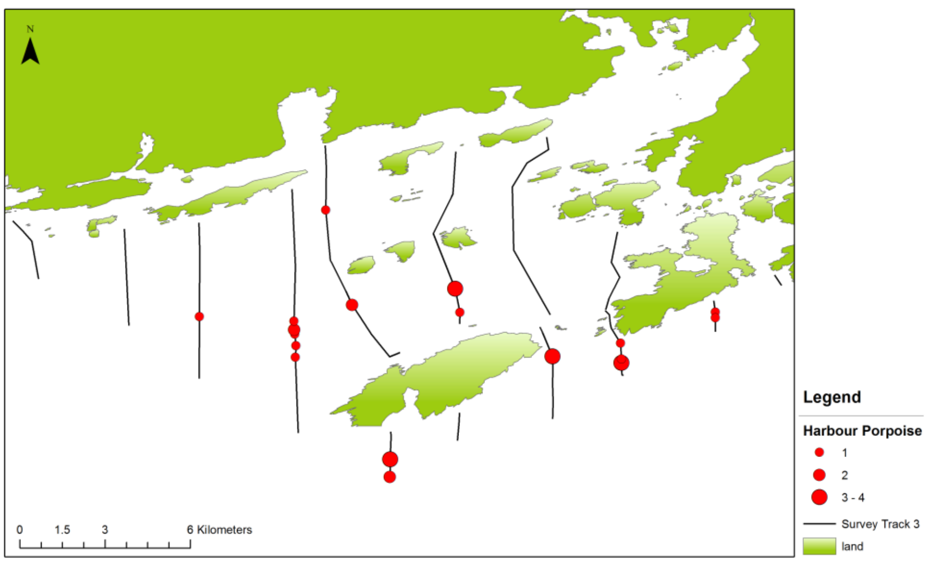


Figure 6c. Track-lines and distribution of harbour porpoise sightings on 15 July 2015

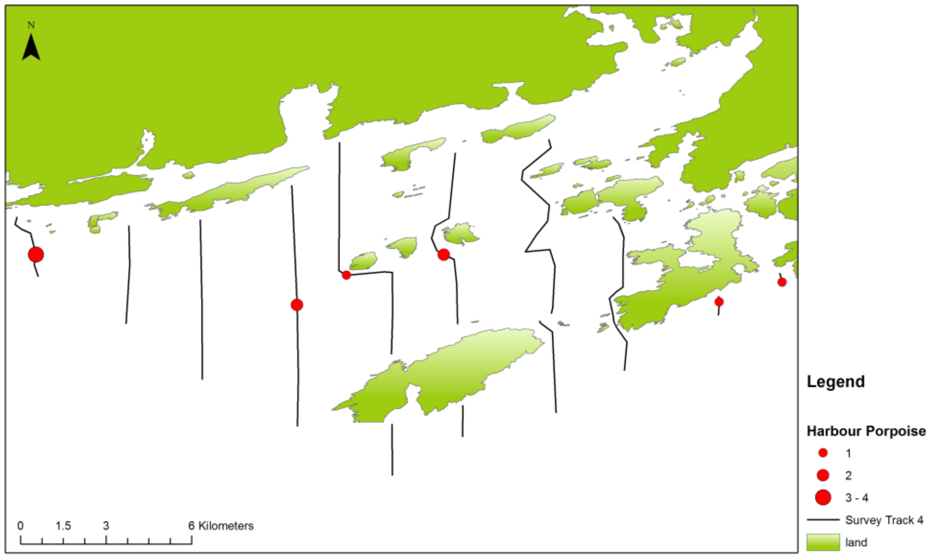


Figure 6d. Track-lines and distribution of harbour porpoise sightings on 7 August 2015

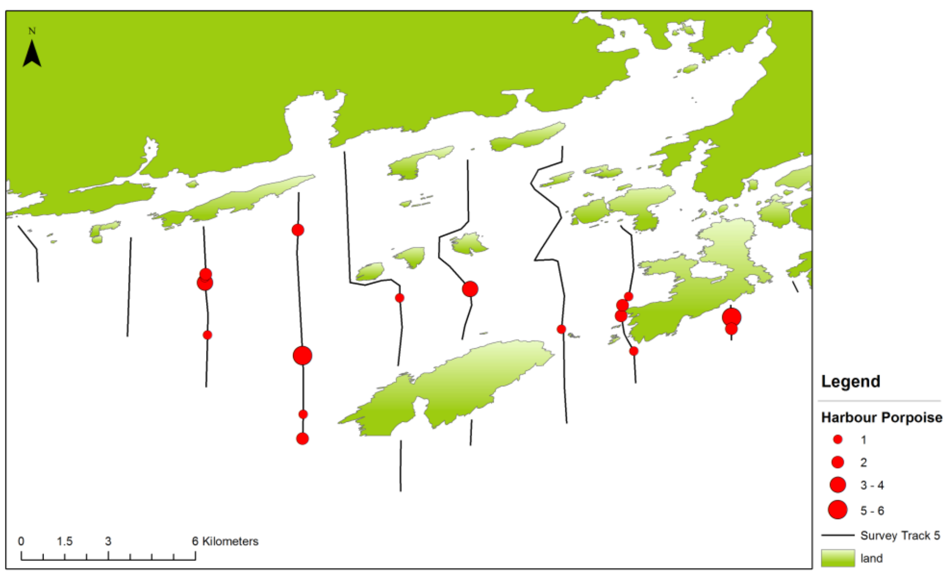


Figure 6e. Track-lines and distribution of harbour porpoise sightings on 12 August 2015

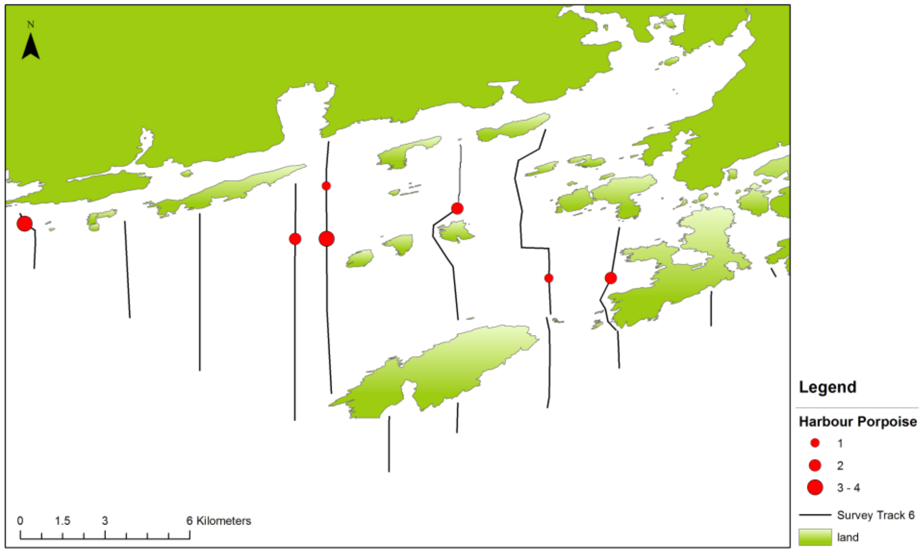


Figure 6f. Track-lines and distribution of harbour porpoise sightings on 7 September 2015

Density and abundance estimation

Density estimates for harbour porpoises within the SAC were calculated for all survey days but it should be noted that for three days (14 July, 7 August and 7 September) the total number of sightings recorded was ≤7 and the results of the analysis for these dates should be treated with caution (Table 3). The detection functions for harbour porpoise during all surveys are shown graphically in Figure 7. Using the Chi-squared test for goodness of fit to the DISTANCE model data for the first survey were good (P=0.91) but for others less so (P≤0.62). Evasive reactions of porpoises from the survey vessel were most evident on survey 1, with a peak in sightings some 60-90m from the track-line (Figure 7), most likely resulting in an underestimate of animal density. The DISTANCE model could be adjusted to account for this movement but this was not carried out in the current analysis. Evidence for evasive movement was less pronounced for all other survey days (Figure 7). Mean group (cluster) size was greatest on surveys 5 and 6 (2.14 and 2.12) and lowest on survey 1 (1.65), suggesting a trend of increasing group size with month.

Table 3. Model data used in the harbour porpoise abundance and density estimation process for each survey of Roaringwater Bay and Islands SAC in 2015 (Note: A half-normal model with cosine series adjustments and sightings data truncated at 300m was used).

Sample Day	Chi^2 P value	Effective Strip Width (m)	Mean Cluster size ± SE	Variability (D)		
				Detection	Encounter	Cluster
1	0.909	182.9	1.65±0.17	50.1	35.3	14.6
2	0.229	88.1	2.00±0.45	25.5	50.2	24.3
3	0.156	82.4	1.75±0.25	28.6	50.1	21.3
4	0.622	82.8	1.83±0.48	36.8	56.3	6.8
5	0.448	110.1	2.12±0.33	29.6	55.3	15.1
6	0.557	198.9	2.14±0.62	60.3	15.2	24.5

Overall	**0.774**	**109.8**	**1.87±0.12**	**16.8**	**77.9**	**5.3**

The proportion of variability in the data accounted for by the detection probability was highest for only two surveys (surveys 1 and 6; Table 3) while variability associated with encounter rates was greatest for the other 4 surveys. Variability associated with cluster size was only significant for surveys 2, 3 and 6 with >21% variability associated with this parameter.

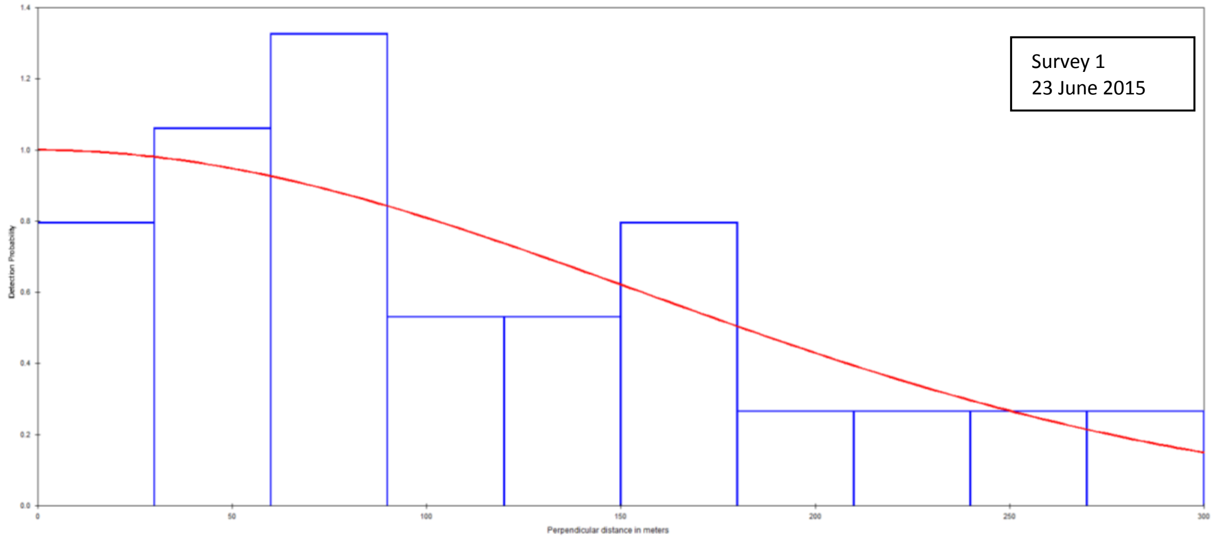
Density and abundance estimates for harbour porpoise in Roaringwater Bay and Islands SAC are shown in Table 4. The density estimates varied quite considerably between surveys with highest densities on surveys 1, 3 and 5, correlating to surveys with the greatest number of sightings. Lowest densities were estimated on surveys 4 and 5 with only 0.76 harbour porpoises per km^2 recorded on each of these days (Table 4). The highest density was recorded on survey 3 (15 July) with 3.03±1.01 porpoises per km^2. This produced an abundance estimate of 434±144 porpoises with 95% Confidence Intervals=223-843 porpoises. A similar abundance was estimated on 12 August but with higher variance, with 424±187 porpoises with 95% Confidence Intervals=178-1013 porpoises. The lowest animal densities of 0.76 porpoises per km^2 resulted in abundance estimates of 109 individuals (Table 4).

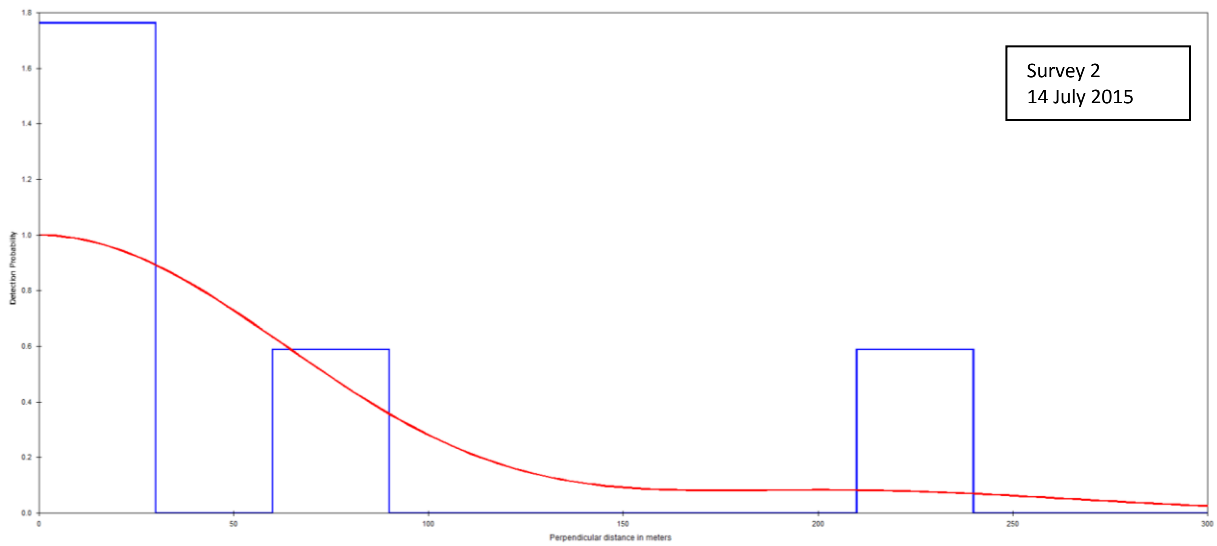
The overall pooled density estimate for all six survey days combined was 2.02±0.56 porpoises per km^2 (CV=0.28), providing a corresponding abundance estimate of 289±80 harbour porpoises (95% CI = 155-541)**.**

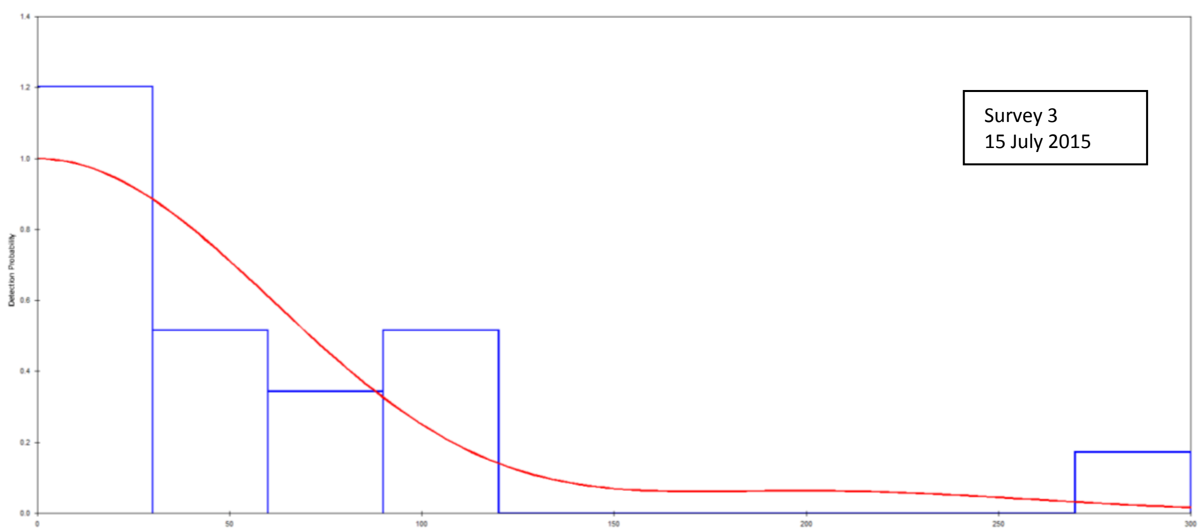
Table 4. Estimated density, abundance (N) and group sizes of harbour porpoise recorded during surveys of Roaringwater Bay and Islands SAC, 2015.

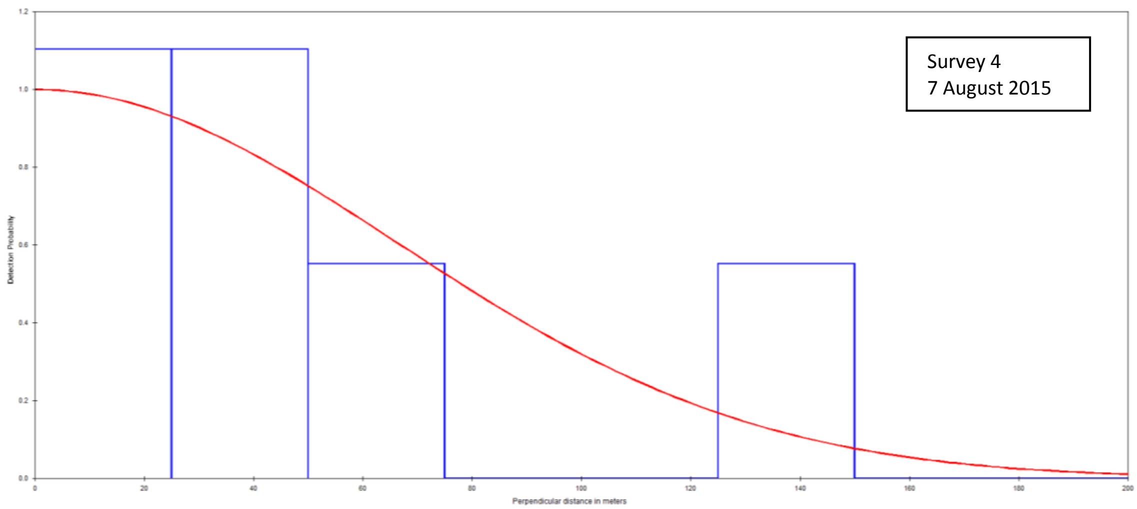
Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Mean group size (95% CI)
1	330 (198-549)	59	0.25	2.31	1.65 (1.32-2.05)
2	194 (51-731)	133	0.68	1.35	2.00 (1.08-3.69)
3	434 (223-843)	144	0.33	3.03	1.75 (1.29-2.37)
4	109 (40-298)	55	0.50	0.76	1.83 (1.00-3.54)
5	424 (178-1013)	187	0.44	2.96	2.11 (1.52-2.94)
6	109 (36-327)	59	0.55	0.76	2.14 (1.35-3.38)
Overall[1]	**289 (155-541)**	**80**	**0.28**	**2.02**	**1.87 (1.64-2.12)**

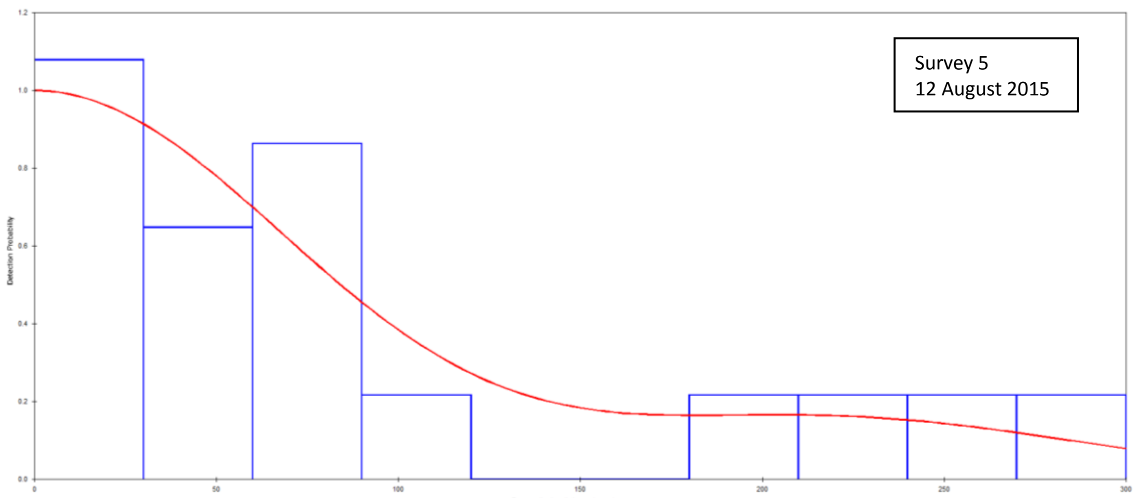
[1] – includes combined sightings and effort data from all six surveys of Roaringwater Bay and Islands SAC.

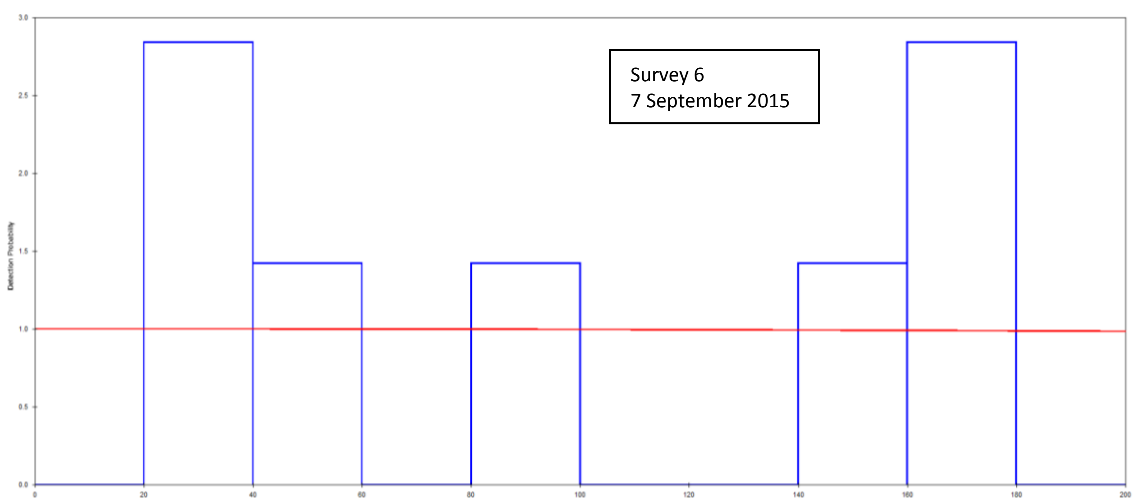

Survey 1
23 June 2015
Detection Probability
Perpendicular distance in meters


Survey 2
14 July 2015
Detection Probability
Perpendicular distance in meters


Survey 3
15 July 2015
Detection Probability
Perpendicular distance in meters


Survey 4
7 August 2015
Detection Probability
Perpendicular distance in meters


Survey 5
12 August 2015
Detection Probability
Perpendicular distance in meters


Survey 6
7 September 2015
Detection Probability
Perpendicular distance in meters

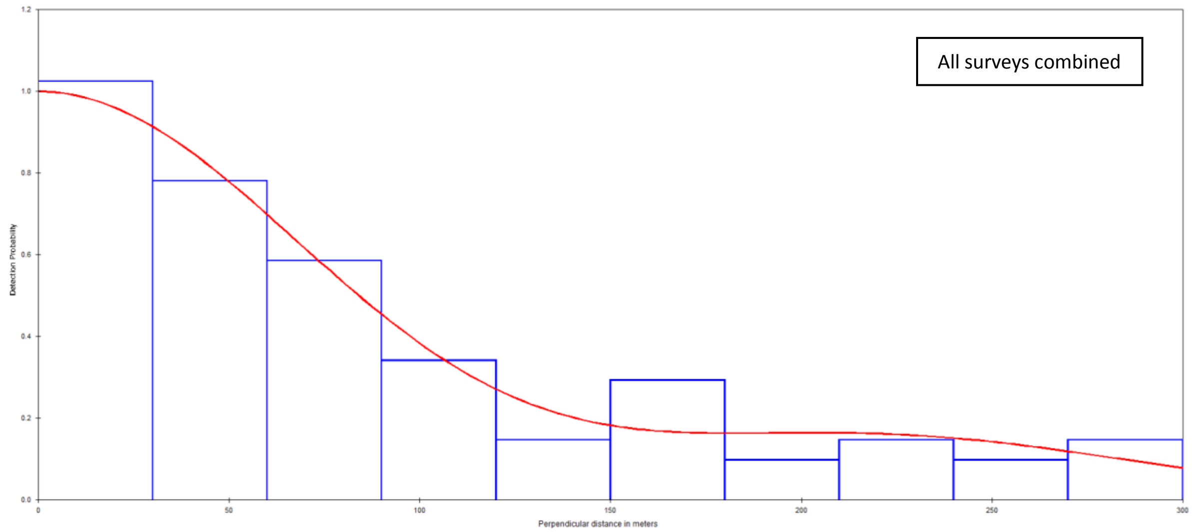


Figure 7. Detection function plots for each survey of harbour porpoises in Roaringwater Bay and Islands SAC, 2015.

Density and abundance estimates in different sea-states

In order to explore the potential effect of sea-state on density estimates, the data for surveys 1-3 were pooled and detection functions calculated for increasing sea-state (Table 5). A detection function was determined for all sightings and effort in sea-state 0 over the six surveys combined, followed by a similar analysis for sea-state 0+1 and sea-state 0+1+2 (Figure 8). Total sighting effort (in km) was calculated for each sea-state class and subsequently used in the distance sampling analysis.

Density estimates classified by sea-state provided the highest figure for sea-state 0+1 (2.41 porpoises per km^2), which was slightly higher than for sea-state 0 (2.05 porpoises per km^2) and sea-state 0+1+2 (2.03 porpoises per km^2, but were quite consistent throughout changing sea-states. The CV for the estimate in sea-state 0 (0.30) was lower than for the other two categories. These data suggest it is appropriate to pool the survey data from all survey days and in all sea-states.

Table 5. Density, abundance (N) and group size estimates of harbour porpoise in Roaringwater Bay and Islands SAC across different sea-state classes.

Sea-state Class	Effort (km)	Chi^2 P value	Mean group size ± SE	Density (per km^2)	SE	CV	N (95% CI)
0	111.8	0.86	1.58±0.11	2.05	0.30	0.15	293 (218-394)
0+1	272.5	0.97	1.84±0.12	2.41	0.43	0.18	345 (213-556)
0+1+2	324.0	0.81	1.87±0.12	2.03	0.48	0.24	289 (155-541)

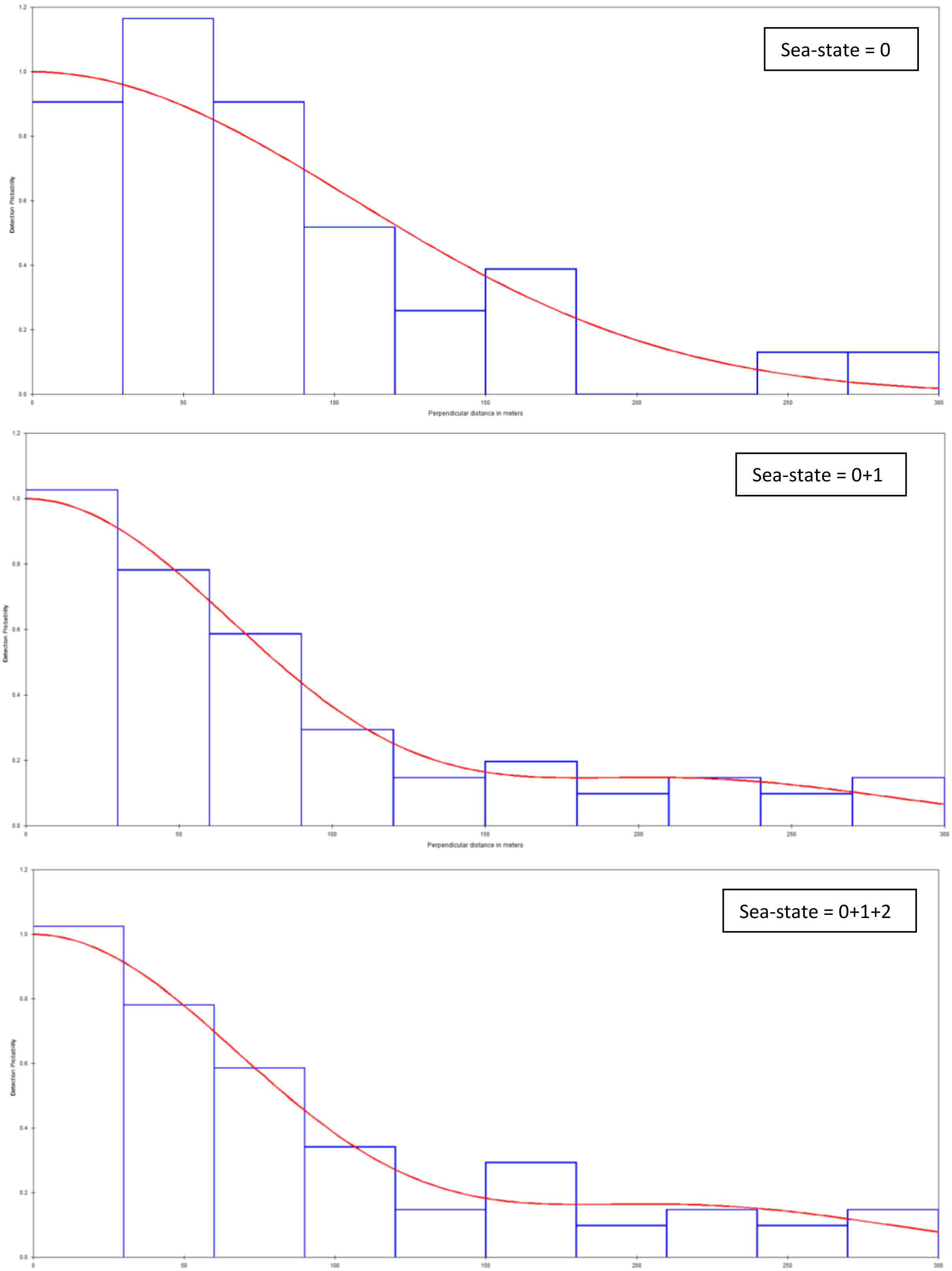


Figure 8. Detection function plots for harbour porpoise surveys of Roaringwater Bay and Islands SAC, 2015 according to different sea-state classes.

Proportion of young porpoises to adults

The proportion of young porpoises and calves to all porpoises (including adults) was calculated for each survey within Roaringwater Bay and Islands SAC in 2015 (Table 6). The proportion of young porpoises (juveniles and calves combined) recorded on survey days ranged from 8% to 27% and was 14.2% overall. The observed proportion of calves to adults was significantly lower at 3.5% overall, but reached a maximum of 8.3% on the fifth survey on 12 August.

Table 6. The numbers and proportions of adult harbour porpoises, juveniles and calves recorded during surveys in Roaringwater Bay and Islands SAC, 2015.

Survey	Number of sightings	Number of Individuals	Adults	Juveniles	Calves	% young	% calves
1	23	38	35	2	1	7.9	2.6
2	5	11	9	2	0	18.2	0.0
3	18	30	22	6	1	23.3	3.3
4	6	11	8	3	0	27.2	0.0
5	17	36	31	2	3	13.9	8.3
6	7	15	14	1	0	6.7	0.0
Overall	**76**	**141**	**119**	**16**	**5**	**14.2**	**3.5**

Additional sightings

Grey seals (*Halichoerus grypus*) were the most frequently recorded additional species recorded during the study with sightings logged during every survey day (Table 7). Short-beaked common dolphins (*Delphinus delphis*) were the most abundant ancillary species recorded with totals each day ranging from 8 to 53 individuals and these were recorded on four of the six survey days. Minke whales (*Balaenoptera acutorostrata*) were also frequently recorded in Roaringwater Bay and Islands SAC during the survey period with greatest abundance in July (Table 7). Common dolphins and minke whales were mainly recorded south of Cape Clear (Clear Island) and Sherkin Island (Appendix 1) with grey seals mainly recorded around Gascanane Sound. Three probable basking shark (*Cetorhinus maximus*) sightings were made in July and September. Maps of the location of all these sightings are shown in Appendix 1.

Table 7. Sighting records of additional species other than harbour porpoise that were recorded in Roaringwater Bay and Islands SAC, 2015.

Species	Date	Total number of sightings	Total number of individuals
Common dolphin	14 July	4	53
	15 July	2	8
	12 August	2	17
	7 September	6	27
Minke whale	14 July	4	4
	15 July	2	2

	12 August	1	1
	7 September	1	1
Grey seal	23 June	13	23
	14 July	8	10
	15 July	9	13
	7 August	3	3
	12 August	6	10
	7 September	4	4
Basking shark	14 July	1	1
	24 September	2	2

Static Acoustic Monitoring (SAM)

Field calibrations

Field testing of the detection abilities of individual C-PODs took place in January 2015 off Money Point power station in the Shannon Estuary (Co. Clare) for a total of 13 days. The total DPMs on both PODs were very similar, 137 and 147 respectively. As the variation between units was so low (Figure 9), data recorded from either C-POD was not adjusted but the potential variability between devices was nevertheless accounted for in the explanatory models by incorporating POD ID as a variable.

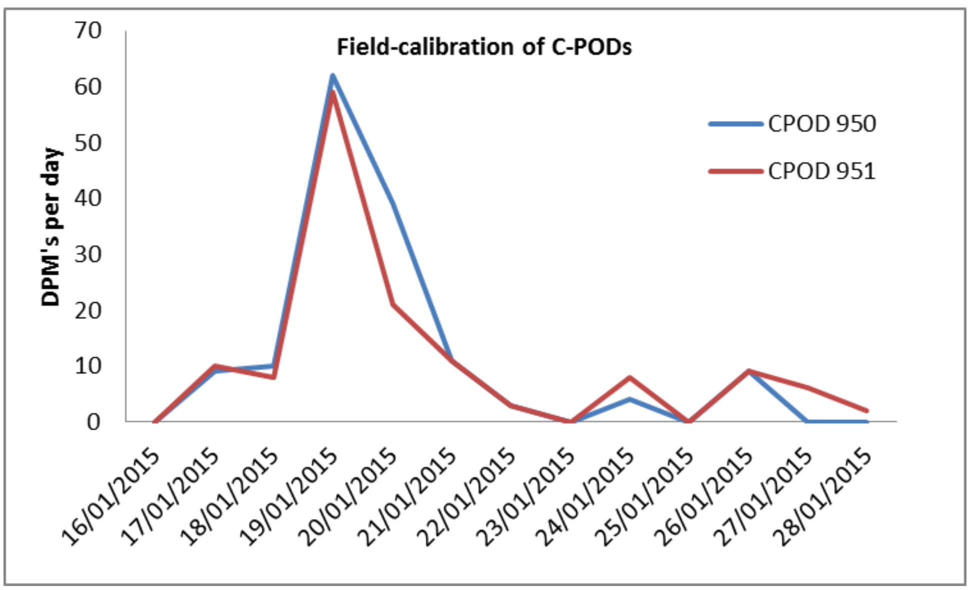


Figure 9. Calibration results for C-PODs used in Roaringwater Bay, from trials in the Shannon Estuary, January 2015.

SAM Deployments

On recovery of the moored C-POD devices in Roaringwater Bay, all data were downloaded, processed and exported using cpod.exe (version 2.044). Two deployments at four distinct, randomly selected sites were scheduled to take place during the study. The first two deployments took place on 23 June, at locations to the east and north-west of Cape Clear Island (Figure 3, sites 16 and 18). Recoveries took place on 7 August (46 days later). The C-POD deployed in Gascanane Sound (box 16) was successfully retrieved; however the second C-POD deployed at site 18 was missing. The data from the C-POD recovered in Gascanane Sound was downloaded, and the device re-deployed in Baltimore Harbour (site 20) where it remained until 7 September (32 days later). However upon retrieval of this unit it was found that the C-POD had worked normally until 18 August, after which it was turned into an off position, probably due to it being lifted and then put back incorrectly; hence no data were recorded between that and the 7 September when it was retrieved (Table 8).

Table 8. Details of C-POD deployment locations over the duration of the study in 2015.

Location	Name	Deployment date	Recovery date	C-POD No.	Deployment duration
Site 16	Gascanane Sound	23.06.15	07.08.15	951	46 d
Site 18	W of Cape	23.06.15	*Missing*	952	N/A
Site 20	Baltimore Harbour	07.08.15	07.09.15	951	32 d

Datasets from two out the planned four locations were available for analysis. These consisted of Gascanane Sound (site 16, June to August, 46 days) and Baltimore Harbour (site 20, August to September, 12 days) (Table 9; Figure 10).

Table 9. Detection details from C-POD deployments in Roaringwater Bay, 2015

Details			***Porpoise detections***		***Dolphin detections***	
Location	**Month**	**No. days deployed and operational**	**% of days with porpoise detections**	**Total PPM**	**% of days with dolphin detections**	**Total DPM**
Gascanane	June	8	100	225	0	0
	July	31	100	2406	39	377
	Aug	7	100	699	4	98
Baltimore	Aug	12	100	1641	100	603

Data are presented for both harbour porpoise and dolphin detections from both locations (Table 9; Figure 10 and 10). Results show that porpoises were detected in Gascanane Sound on 100% of days monitored, while dolphins were detected on 39% of days monitored in July and 4% of days in August. These detections were most likely of common dolphins as they were the only dolphin species detected visually over the duration of the survey. Due to the position of the C-POD off Baltimore, the detection range was not obstructed by islands which could have led to the greater number of dolphin detections than previous locations.

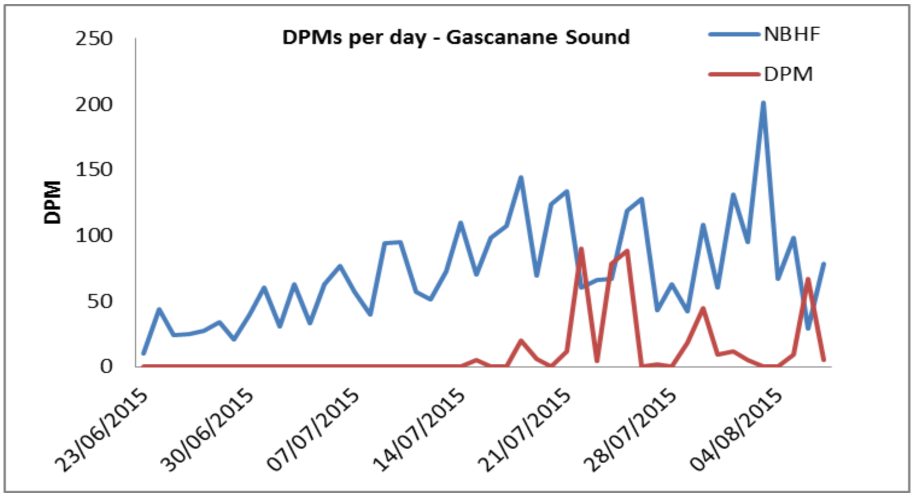


Figure 10. Detection positive minutes for porpoises (NBHF) and dolphins (DPM) recorded from Gascanane Sound in 2015 (N=46 days).

Results from Baltimore showed that both porpoises and dolphins were detected on 100% of days monitored but only 12 days of data were logged due to the POD switching to an off position on the 18 August (Figure 11), most likely due to human interference with the moored device.

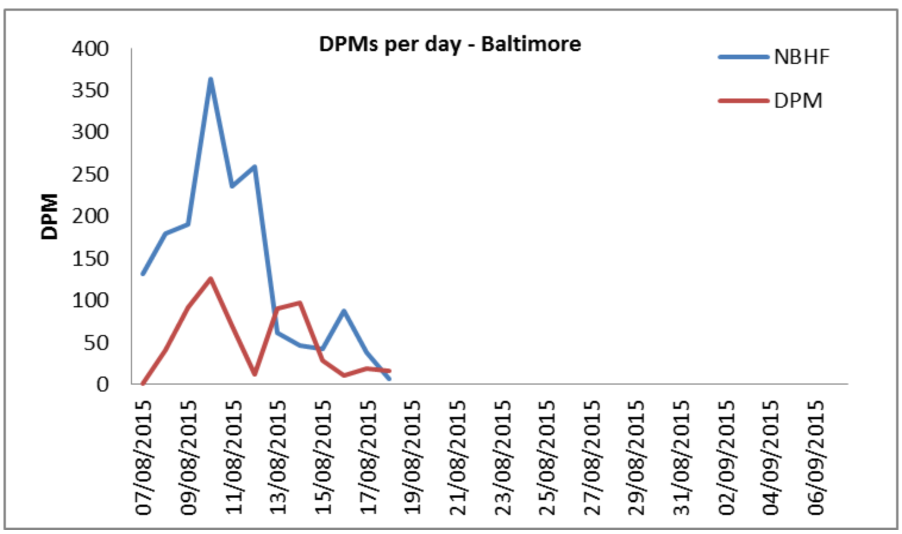


Figure 11. Detection positive minutes for porpoises (NBHF) and dolphins (DPM) recorded from Baltimore in 2015 (N=32 days, but only logging for 12).

The comparatively short datasets were not ideal for data modelling but attempts were made to look for significant patterns in porpoise/dolphin detections across diel and tidal state as these factors offered the greatest replication over the monitoring period. Results from the model run on Gascanane Sound data (site 16) showed that diel state (χ^2= 54.4, df=2, p<0.0001) and tidal state (χ^2= 33.4, df=2, p<0.0001) were strongly linked with the variation in porpoise detections (Figure 12) with night (N) and morning (M) recording a higher detection rate, as well as during an ebb (E) and slack low tide (SL). The box plots below show the distribution of the data or each of the variables, with the usual box plot format, representing the median, quartiles and outliers.

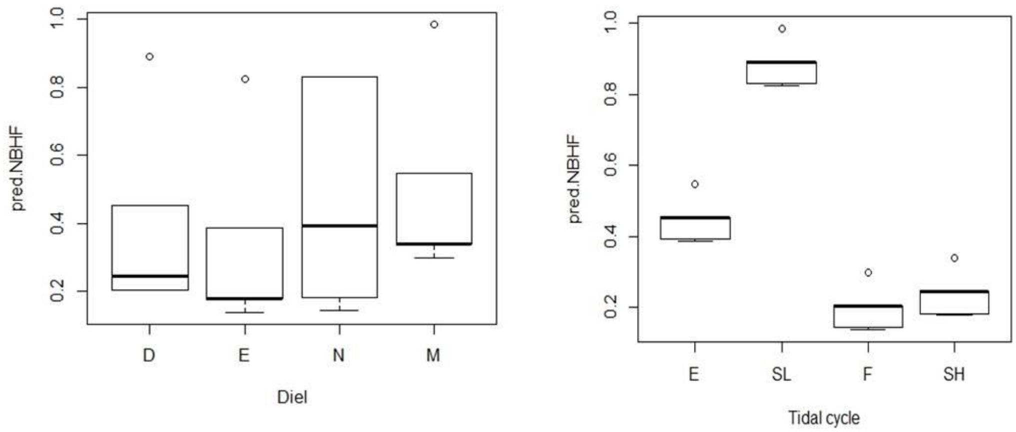


Figure 12. NBHF detection rates from Gascanane Sound in 2015, modelled by diel and tidal states.

The Gascanane Sound dataset was further explored for trends in dolphin presence and results showed significant variation during the day (D) and morning (M) (χ^2= 198.5, p<0.000) and during flood (F) and slack high tides (SH) (χ^2= 313.2, p<0.001; Figure 13).

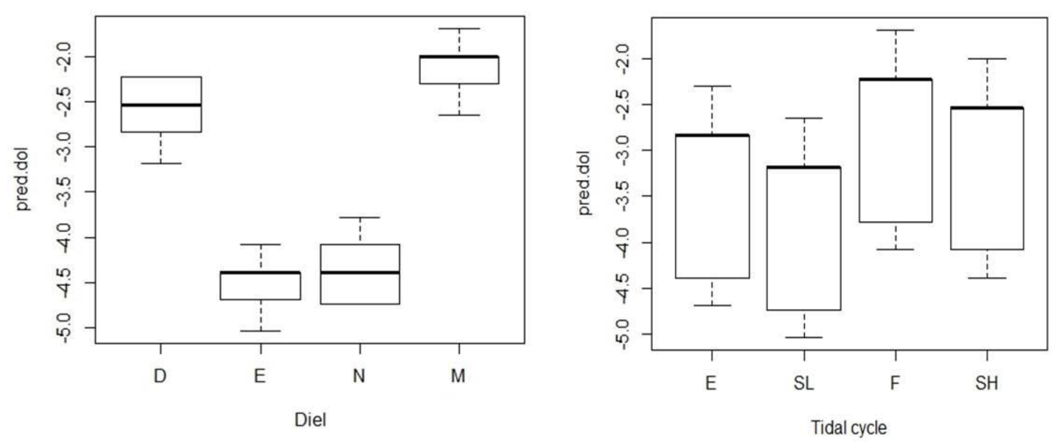


Figure 13. Dolphin detections from Gascanane Sound in 2015, modelled by diel and tidal states.

The Baltimore dataset was short at only 12 days but still significant trends were evident, with more porpoise detections logged over the diel categories morning (M) and evening (E) (χ^2= 3.4, p<0.000), with flood (F), slack low (SL) and ebb tides (E) having similar levels of detections but significantly higher than detections during slack high tides (SH) (χ^2= 9.3, p<0.000; Figure 14).

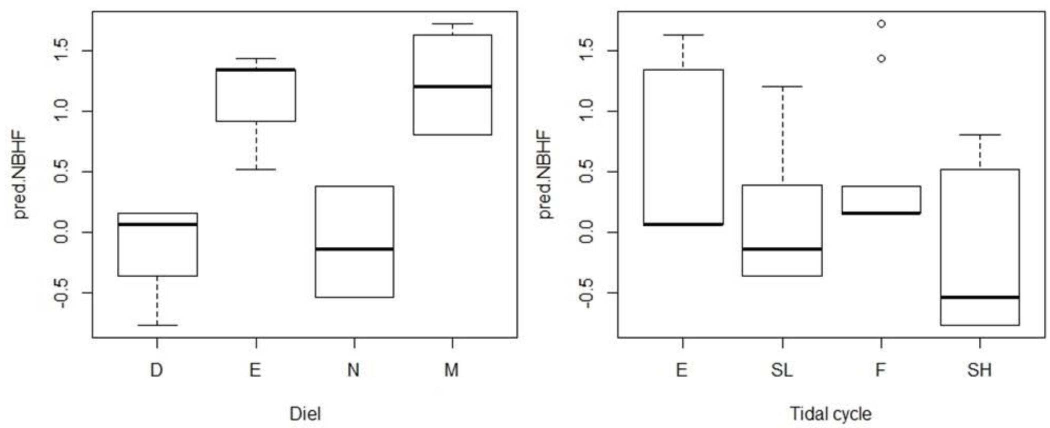


Figure 14. NBHF detections from Baltimore in 2015, modelled by diel and tidal states.

Dolphin detections from Baltimore were also analysed and these showed significant variation across diel cycle with considerably more detections during the night (N) (χ^2= 36.9, p<0.000) and during slack tides (SH, SL), (χ^2= 68.1, p<0.000; Figure 15).

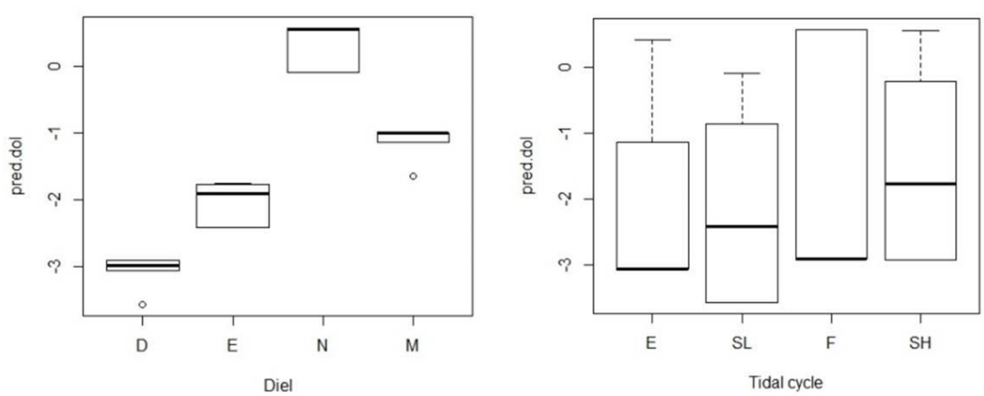


Figure 15. Dolphin detections from Baltimore in 2015, modelled by diel and tidal states.

Discussion

This is the third dedicated survey of harbour porpoises in Roaringwater Bay and Islands SAC since it was designated with harbour porpoise as a qualifying interest. Similar single platform line transect surveys carried out in 2008 and 2013 now provide some measure of inter-annual comparison in the density and status of this qualifying interest. The survey carried out in 2015 was successful in that sea conditions were favourable throughout all six surveys and porpoises were recorded on all surveys albeit with a noticeable range of observations. In addition, SAM using C-PODs was carried out at three sites within the SAC, thereby starting a baseline acoustic dataset which can inform on site usage by small cetaceans, and indicate spatial and temporal patterns in occurrence that are not feasible through visual monitoring alone.

Distance sampling was used to derive density and abundance estimates for harbour porpoise within the site in 2015. Statistical inference using distance sampling rests on the validity of several assumptions (Buckland *et al.,* 2001). These include the assumption that objects are spatially distributed according to some stochastic process. If transect lines are randomly placed within the study area we can safely assume that objects are uniformly distributed with respect to the perpendicular distance from the line in any given direction. During the current survey randomised pre-determined track-lines were provided by DAHG which provided equal coverage probability within the SAC. Another assumption is that objects on the track-line are always detected (i.e., g(0)=1) and are detected at their initial location prior to any movement in response to the observer. Finally, if objects occurring on or near to the track-line are not detected the resulting density estimate will be an underestimate.

To minimise the effect of animal movement on the detection rate and detection function it is recommended that the speed of the observation platform is at least twice the speed of the object, as performed in this study. If this is the case, then movement of the object causes few problems in line-transect sampling (Buckland *et al.,* 2001). Typically for broad-scale surveys of harbour porpoise g(0)= 0.30-0.40 (Hammond *et al.,* 2002), or even as low as 0.21 (Hammond *et al.,* 2013). Thus less than half of the animals on the track-line may only be detected. If this was the case during the present survey then we could perhaps double the density estimate to obtain a truer density estimate. Without a double-platform line-transect methodology it is not possible to accurately determine the number of porpoise detections on the track-line that were missed. The detection functions derived for individual surveys in the current analysis also suggested that there was some evasive movement relative to the survey boat on two of the six surveys, which caused a poor fit to the DISTANCE model. Such factors will tend to lower the density estimates and increase the CVs delivered via the modelling process. However these sources of variability were consistent throughout the present survey and are also consistent with previous surveys carried out at the site (Berrow *et al.,* 2008a; Berrow and O'Brien, 2013).

The ability to visually detect harbour porpoises at sea, and thus the accuracy of density and abundance estimates, is extremely dependent on sea-state. During the present study all transect lines were carried out in sea-state 2 or less (as per contractual obligations), since the ability to detect harbour porpoises decreases significantly in sea-states ≥3 (Teilmann, 2003). In the present study, when the data were stratified by sea-state there was little difference in the density estimates which supports the decision to survey sites in conditions up to and including sea-state 2. Although overall detection function and density estimates when data were analysed per survey day or per sea-states were the same, the CV and other statistics around the estimates were slightly different. These differences are attributed to the number of factors entered into the models when classed according to sea-state (n=3) and per day (n=6). The DISTANCE model pools the data during analysis resulting in a change in CV. This is the first survey of Roaringwater Bay and Islands SAC in which all 6 survey days produced enough sightings on each survey day to combine in the model providing the most robust estimate to date. In addition this was the first year where segments of track did not have to be excluded as all survey effort was completed in sea-state 2 or less.

<u>Harbour porpoises density estimates in Roaringwater Bay and elsewhere in Ireland</u>

Roaringwater Bay and Islands Special Area of Conservation was designated as a candidate SAC in 2000 with harbour porpoise as one of its qualifying features. An abundance estimate was carried out in 2008 via six zig-zag line-transect surveys spanning roughly the same area (Berrow *et al.,* 2008a), and again in 2013 using a DAHG survey design comprising 10 randomly set parallel track-lines (Berrow and O'Brien, 2013). A breakdown of the density and abundance estimates and associated statistics derived by the three surveys to date is given in Table 10.

Table 10. Density, abundance and group size estimates for harbour porpoise within Roaringwater Bay and Islands SAC from 2008 to 2015.

Year	Area (km^2)	Survey effort (km)	No. of sightings	Mean group	Density (per	Abundance ± SE (95% CI)	CV	Reference

			(animals)	size	km²)			
2015	143	324	75 (141)	1.86	2.02	289±80 (155-541)	0.28	This survey
2013	143	250	67 (107)	1.56	1.18	151±18 (119-192)	0.12	Berrow and O'Brien (2013)
2008	128	331	47 (110)	2.21	1.24	159±42 (95-689)	0.27	Berrow *et al.* (2008a)

Line-transect designs were notably different in 2008 to recent years, but the survey effort carried out across all three surveys are similar, with a total of 324 km of track-line surveyed in 2015, compared to 250km in 2013 and 331 in 2008 (Table 10). The number of sightings per survey are similar for 2013 and 2015, but the total number of individuals in 2015 shows at least a 20% increase when compared with 2013 and 2008 respectively. Mean group size in 2015 was also greater than that recorded in 2013 or 2008 (Table 10). Thus there does seem to have been a real increase in the density of harbour porpoises recorded in Roaringwater Bay and Islands SAC during 2015.

The density estimate recorded during the present survey was high compared to similar surveys elsewhere in Ireland and within Europe. The highest density recorded at small scale sites in Ireland prior to this survey was from North County Dublin in 2008, when a density of at 2.03 porpoises per km^2 was recorded (Berrow *et al.,* 2008b). The density recorded in Roaringwater Bay and Islands SAC in 2015 compares favourably with the two other SACs in Ireland with harbour porpoise as a qualifying interest. Harbour porpoise densities in the Blasket Islands SAC ranged from 0.64 to 1.65 porpoise per km^2 (O'Brien and Berrow, 2014) and Rockabill to Dalkey Island SAC at 1.44 porpoise per km^2 (Berrow and O'Brien, 2013). These densities were much greater than other sites surveyed around the Irish coast since 2008 (Berrow *et al.,* 2014). Elsewhere in Europe, densities of between 0.21 and 2.35 porpoise per km^2 were reported during the summer period in the German Bight by Gilles *et al.* (2011) from aerial surveys.

<u>Proportion of young to adult harbour porpoise</u>

The proportion of young recorded in 2015 was very consistent with 2013 but greater than in 2008 (Table 11). The proportion of calves at around 3-4% is quite low compared to that reported by Sonntag *et al.* (1999) who calculated up to 18% calves at the Isle of Sylt in Germany, which is considered an important calving area in the North Sea. However, the proportion is consistent with other studies at around 3-5% (Hammond *et al.,* 2002; Evans and Hammond, 2004).

Table 11. The numbers and/or proportions of adult harbour porpoises, juveniles and calves recorded during surveys in Roaringwater Bay and Islands SAC from 2008 to 2015.

Survey	Number of sightings	Number of Individuals	Adults	Juveniles	Calves	% young	% calves
2015	76	141	111	15	5	14.2	3.5
2013	67	107	93	10	4	13.1	3.7
2008	47	110	102	8	0	7.3	0.0

<u>Trends in raw density estimates for harbour porpoise in Roaringwater Bay and Islands SAC</u>

The results from the present survey demonstrate an apparent increase in density overall in 2015 compared to 2013 and 2008 (Figure 16, Table 11). This increase may be due to a number of factors and not necessarily simply due to an increase in population size, but continued monitoring will be able to determine this.

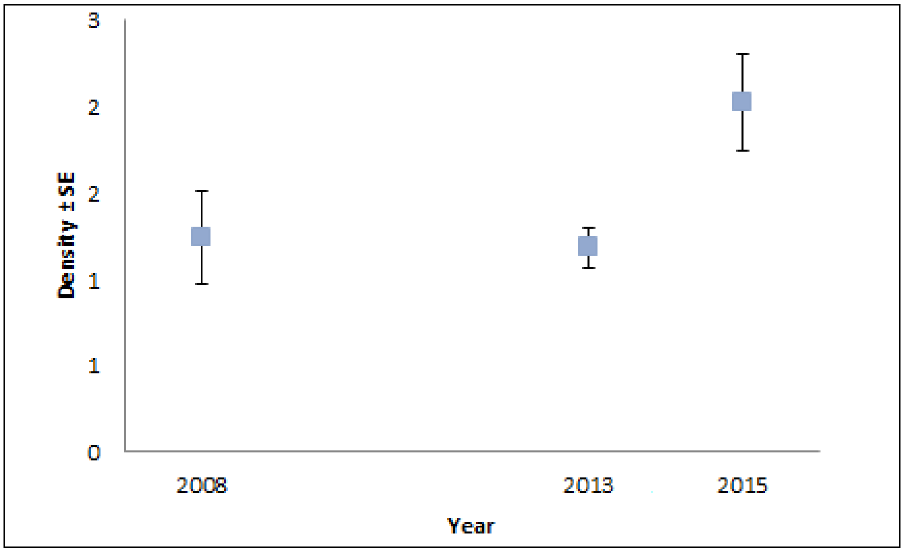


Figure 16. Changes in the recorded density of harbour porpoises in Roaringwater Bay and Islands SAC over time.

It is not likely that the higher pooled density recorded in 2015 was due to the survey design as similar track-lines were surveyed in 2013 and all three surveys undertaken to date provided good coverage of the site. An increase in porpoise density cannot be attributed to sea conditions as similar effort was carried out in sea-states 0, 1 and 2 in 2015 compared to 2013, although there was 30% more track-line surveyed in 2015 compared to 2013. The main differences between the survey years was the total number of survey days that were used to compile the overall estimate for that year. 2015 is the first year that all 6 survey days completed could be used to generate the overall estimate, in comparison to 2013 and 2008, when only 3 of the survey days per year yielded enough sightings to be used in the model.

The CV of the 2015 pooled density estimate (0.28) is much higher than the 2013 estimate but similar to the 2008 one (Table 12), reflecting significant variability in the porpoise data recorded between individual survey days in spite of a standardised design, survey protocol, and an experienced survey team. As the process of building baseline data on the abundance of harbour porpoises at individual sites is in its early stages, appropriate caution must be taken when carrying out inter-site and inter-annual comparisons. In the case of all three SACs, effective long-term monitoring of these important sites for harbour porpoises will allow for such trends in porpoise occurrence to be recorded and to establish whether the estimates are consistent, or whether they increase or decrease over time.

Table 12. Abundance estimates of harbour porpoises within SACs designated for the species in Ireland.

Location	Year	Area (km^2)	Mean group size	% young	Density (per km^2)	Abundance ± SE(95% CI)	CV	No. of surveys	Reference
Rockabill to Dalkey Island SAC	2013	271	1.47	5	1.44	391±25 (344-445)	0.09	5	Berrow and O'Brien (2013)

North County Dublin	2008	104	1.41	8	2.03	211±47 (137-327)	0.23	4	Berrow *et al.* (2008a)
Dublin Bay	2008	116	1.19	6	1.19	138±33 (86-221)	0.24	4	Berrow *et al.* (2008a)
Blasket Islands SAC	2007	227	2.32	2	1.33	303±76 (186-494)	0.25	5	Berrow *et al.* (2009)
	2008	227	1.76	18	1.65	372±105 (216-647)	0.28	3	Berrow *et al.* (2008a)
	2014	227	2.09	6	0.64	146±53 (41-516)	0.36	3	O'Brien and Berrow (2014)
Roaringwater Bay and Islands SAC	2008	128	2.21	7	1.24	159±42 (95-689)	0.27	3	Berrow *et al.* (2008a)
	2013	128	1.56	13	1.18	151±18 (119-192)	0.12	3	Berrow and O'Brien (2013)
	2015	128	1.86	14.2	2.02	289±80 (155-541)	0.28	6	This survey

Static Acoustic Monitoring

When the SAM and visual datasets from Roaringwater Bay and Islands SAC are compared, it is evident that the two datasets provide unique but different information for the site over the study period. The SAM dataset is more complex when providing information on temporal trends influencing the presence of porpoises, but fails to provide information on abundance. Results showed that harbour porpoises were present at the monitored sites on 100% of days, with significant trends in their presence such as at Gascanane Sound, where porpoises were more active during the night-time hours and during a flood and slack high tide. At Baltimore, the opposite was found where porpoises were more active during the morning and evening and flood, ebb and high tides. A considerable amount of visual surveying would have to be carried out at the site before we could identify similar trends and would be of little value in identifying peak porpoise activity if this was occurring during night-time hours.

When the visual data are compared with the C-POD data it is evident they are not consistent (Figure 17). For example on the 14 July, a total of 110 PPM's were recorded for the day but no visual sightings were recorded on the survey line through Gascanane Sound where the C-POD was positioned. On the 15 July, a single sighting was recorded on the transect line but a total of 70 PPMs were recorded over the entire day. Similarly from Baltimore, the site of the second deployment, a peak in detections was recorded on 12 August (240 PPM), the day when the fifth visual survey was carried out, but no sightings were recorded on this transect line closest to the C-POD. It would be interesting to compare these trends with simultaneous deployments but this was not possible due to the loss of equipment.

It is difficult to compare SAM results with previous acoustic data collected from the site as it was collected on T-PODs, the precursor to C-PODs and previous research by O'Brien *et al.* (2013) found significant differences between datasets from both equipment types during simultaneous deployments. Table 13 below shows results from previous years over the same deployment period but using T-PODs. When the data are presented as mean detection positive minutes per hour, it is evident that values over the present study are higher than in previous work; these differences are not necessarily due to differences in porpoise detections but may be due to the differences in the sensitivity of the recording equipment used and so must be treated with caution. However, when compared with previous SAM results from the Blasket Islands SAC over a similar timeframe and using C-PODs, the positive detection results overall are much higher during the present study. Additionally, values are greater during the present study when compared with a similar timeframe in Galway Bay (O'Brien *et al*., 2013). At this stage results should be treated with caution but with continued monitoring, more comprehensive conclusions could be established. As with the visual data, these first deployments will serve as background data and over time would contribute to a knowledge base on the factors influencing porpoise presence at the site and a better understanding of habitat use within the SAC.

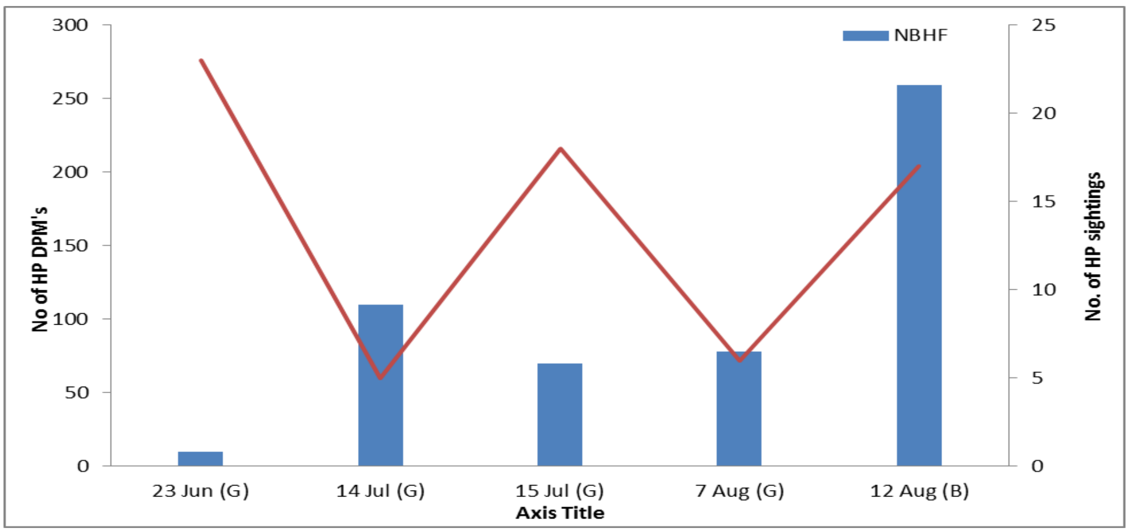


Figure 17. Total PPM (porpoise positive minutes) recorded per day from the SAM site active during the same day of visual survey (*G denotes data from Gascanane Sound (site 16), while B denotes Baltimore, (site 20)).

Table 13. Acoustic detection parameters recorded for harbour porpoises within SACs across Ireland.

County	Location	Unit type	Month	No. days deployed	% of days with porpoise detections	% Porpoise Positive Hours	Total Porpoise Positive Minutes	Mean PPM per hour	References
Dublin	Howth Hd	T-PODs	July	19	100	81	3891	8.9	Berrow *et al.* (2008a)
			Aug	12	100	79	4336	15.6	
			Sept	16	100	74	5491	13.5	
Cork	Castlepoint	T-PODs	Jul	22	100	33	540	1	Berrow *et al.* (2008a)
			Aug	31	100	29	667	0.9	
			Sept	10	100	24	172	0.8	

Cork	Sherkin Island	T-PODs	July	9	100	48	109	0.6	Berrow *et al.* (2008a)
			Aug	14	71	39	598	2.1	
			Sept	-	-	-	-	-	
Cork	Galley Head	T-PODs	July	22	100	25	372	0.8	Berrow *et al.* (2008b)
			Aug	20	100	32	550	1.2	
			Sept	21	100	34	692	1.4	
Cork	Old Head of Kinsale	T-PODs	July	-	-	-	-	-	Berrow *et al.* (2008b)
			Aug	11	100	27	130	0.5	
			Sept	11	100	39	266	1.0	
Kerry	Inishtooskert	C-PODs	Aug	31	77	9.3	130	0.2	O'Brien *et al.*, 2013
			Sept	30	80	8.6	123	0.2	
Kerry	Wildbank	C-PODs	Aug	31	61	7.3	87	0.1	O'Brien *et al.*, 2013
			Sept	30	94	18.7	224	0.3	
Galway	Spiddal	C-PODs	Aug	25	100	46	1702	2.8	O'Brien *et al.*, 2013
			Sept	30	100	38	1959	2.7	
Cork	Gascanane		June	8	100	51	225	1.3	*This study*
			July	31	100	59	2406	3.2	
			Aug	7	100	65	699	4.4	
	Baltimore		Aug	12	100	51	1641	6.1	

Recommendations

Arising from the current study, the following recommendations are made for future harbour porpoise surveys in Roaringwater Bay and Islands SAC:

1. Density estimates obtained in 2015 were different to those obtained in 2013 despite similar track-lines. It is recommended to repeat these track-lines using the same methodology during future surveys to improve the time series.

2. Due to the small area of the SAC relative to the range of this highly mobile species, large variations in densities within the SAC would be expected. These short term variations are most likely to be driven by local prey availability in addition to overlying environmental or seasonal changes, for example. A power analysis on the current datasets should be carried out to explore how long it would take to measure changes in population within the site given the within year variability demonstrated so far.

3. The replacement of towed passive acoustic monitoring (PAM) with the static approach (SAM) provided more robust data on spatial and temporal patterns in porpoise presence at a number of random locations within the SAC. Over time such data could inform survey design for density estimation by contributing information on habitat use and night-time presence at particular sites. Based on the loss of equipment during the present study, future deployments should take place using acoustic release mechanisms in order to eliminate the possibility of human interference and to keep moored devices out of the way of vessel traffic.

4. Given the variability in density estimates derived from the distance sampling approach, consideration should also be given to developing acoustic indices through which population status could be monitored. It is likely that acoustic datasets, when put into appropriate models, would be able to identify changes in occurrence and distribution at a quicker rate and possibly at a higher resolution than visual surveys, but these indices would also require data replication over a number of years.

Acknowledgements

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Appendix 1: Distribution maps for additional species that were recorded during surveys within Roaringwater Bay and Islands SAC in 2015.

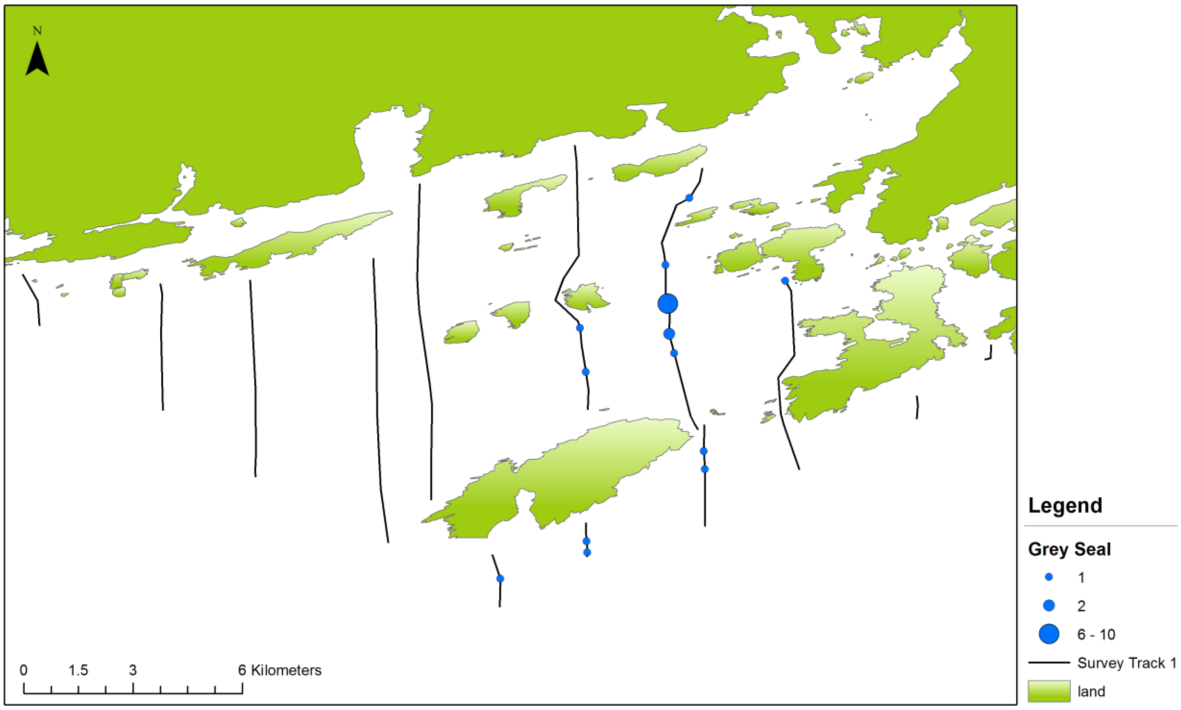

Figure 18. Grey seal sightings during survey 1.

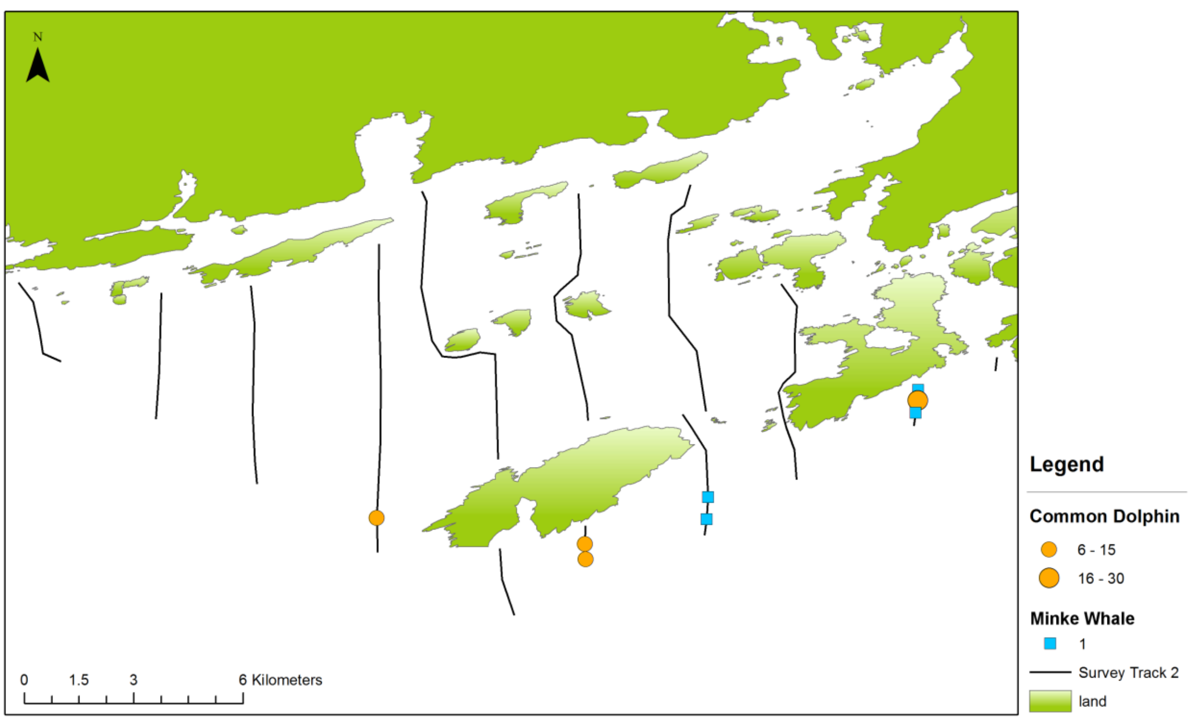

Figure 19. Common dolphin and Minke whale sightings during survey 2

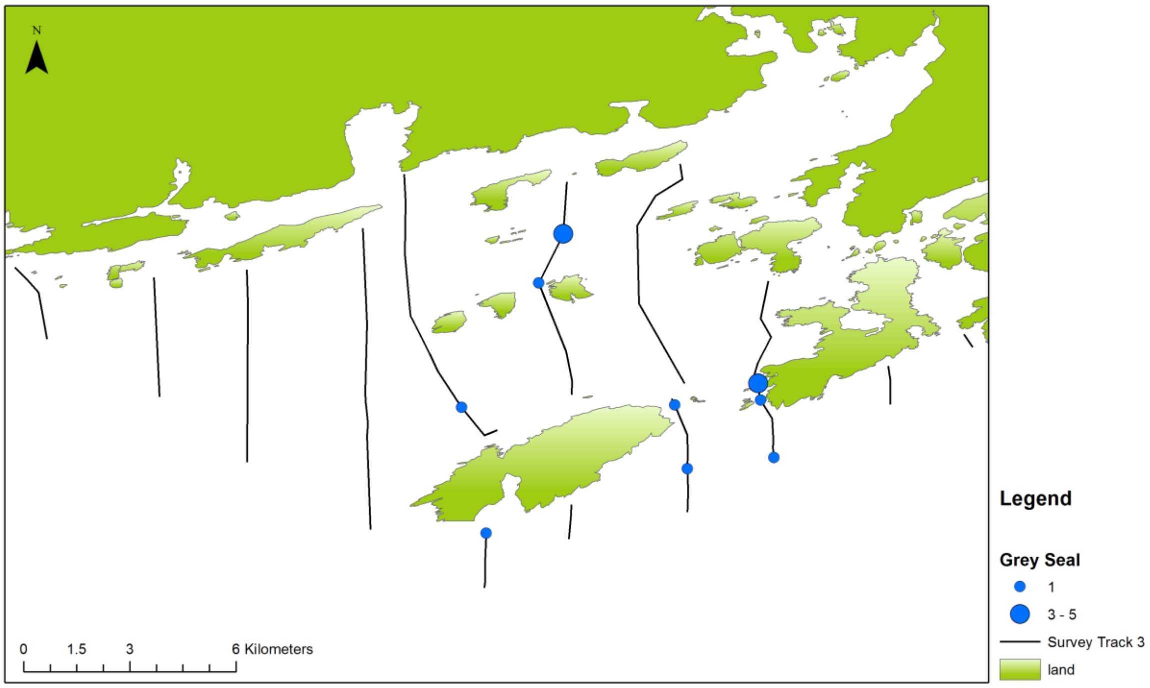

Figure 20. Grey seal sightings during survey 3.

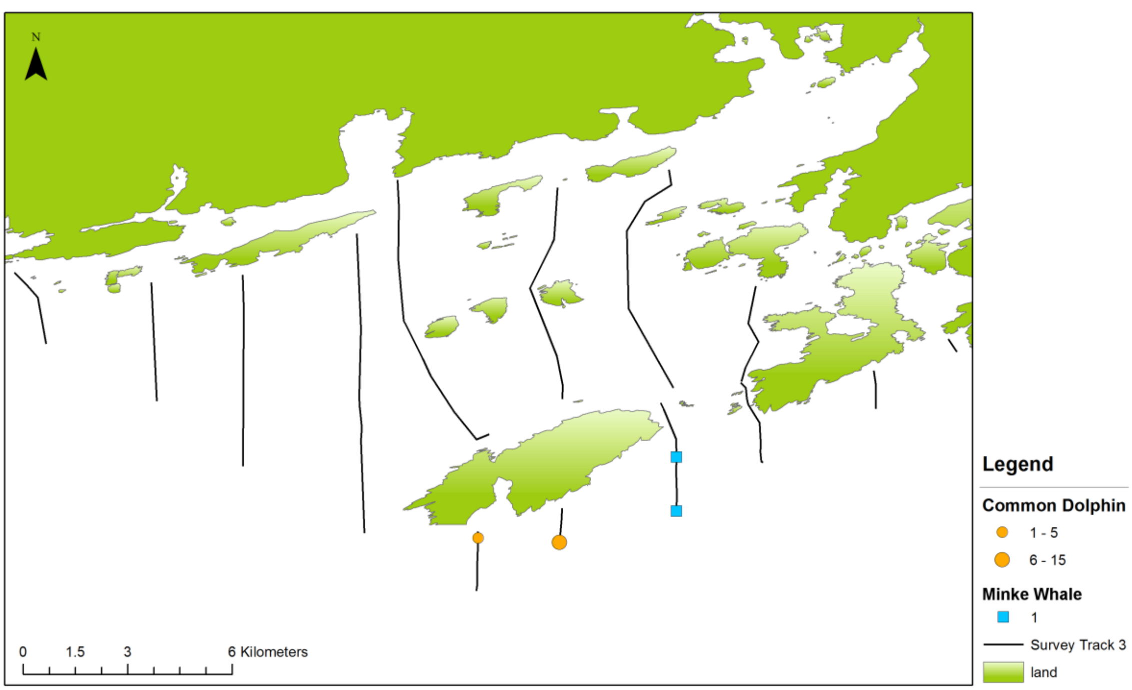

Figure 21. Common dolphin and Minke whale sightings during survey 3.

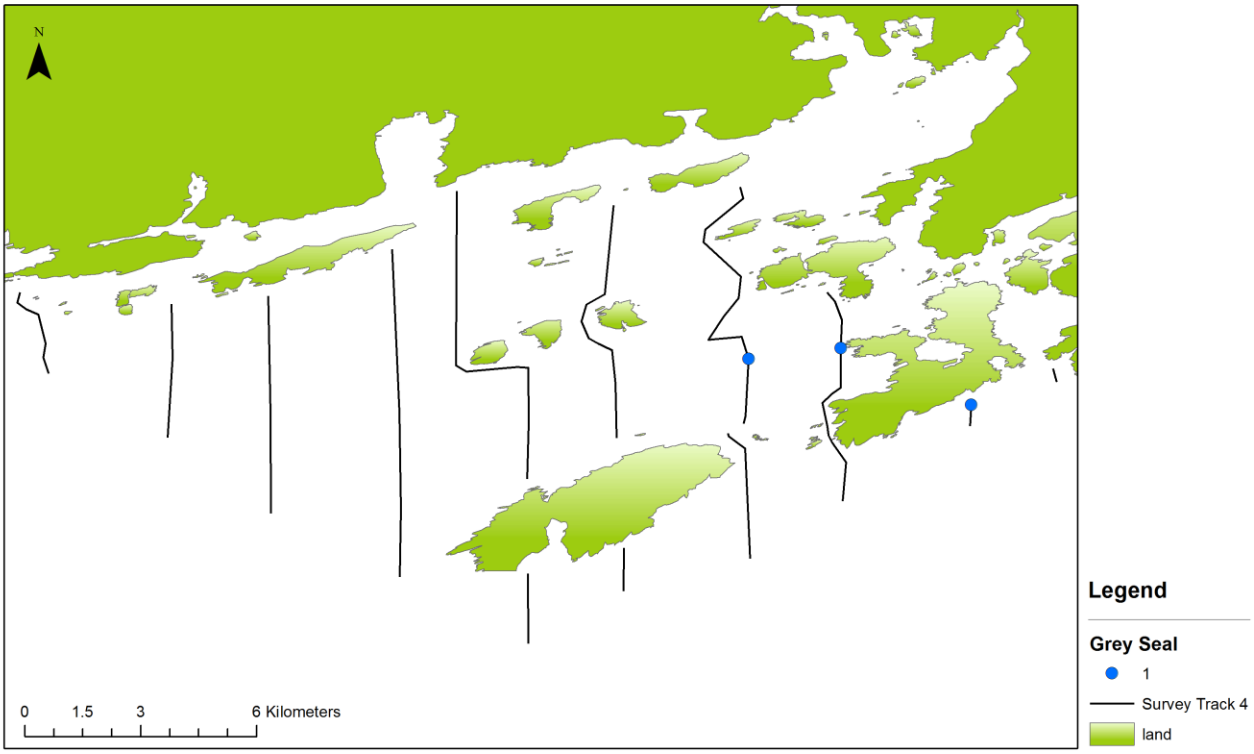

Figure 22. Grey seal sightings during survey 4.

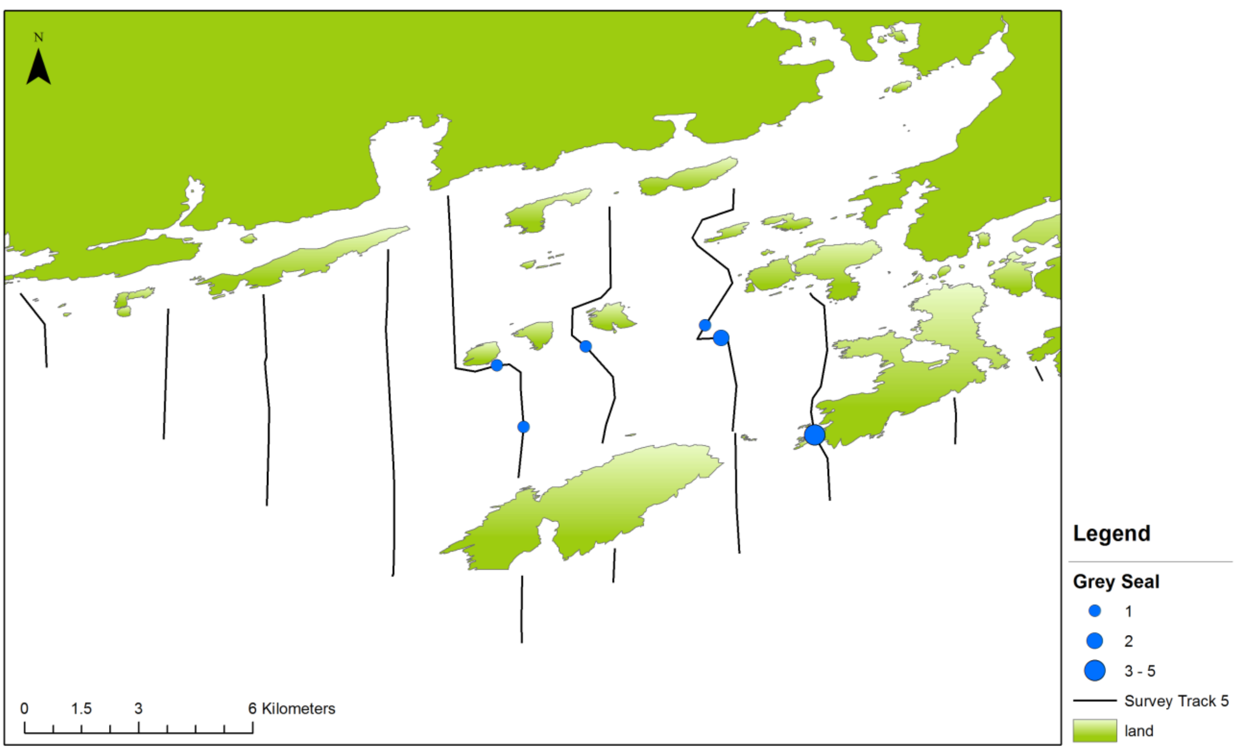

Figure 23. Grey seal sightings during survey 5.

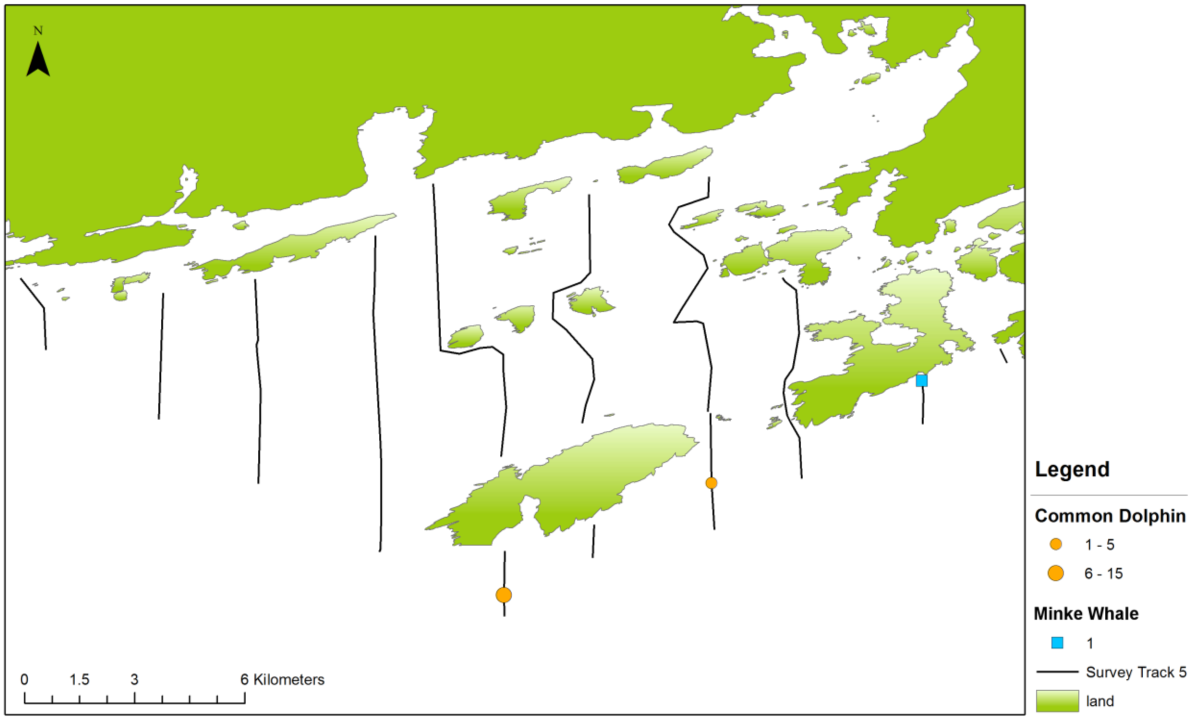

Figure 24. Common dolphin and Minke whale sightings during survey 5.

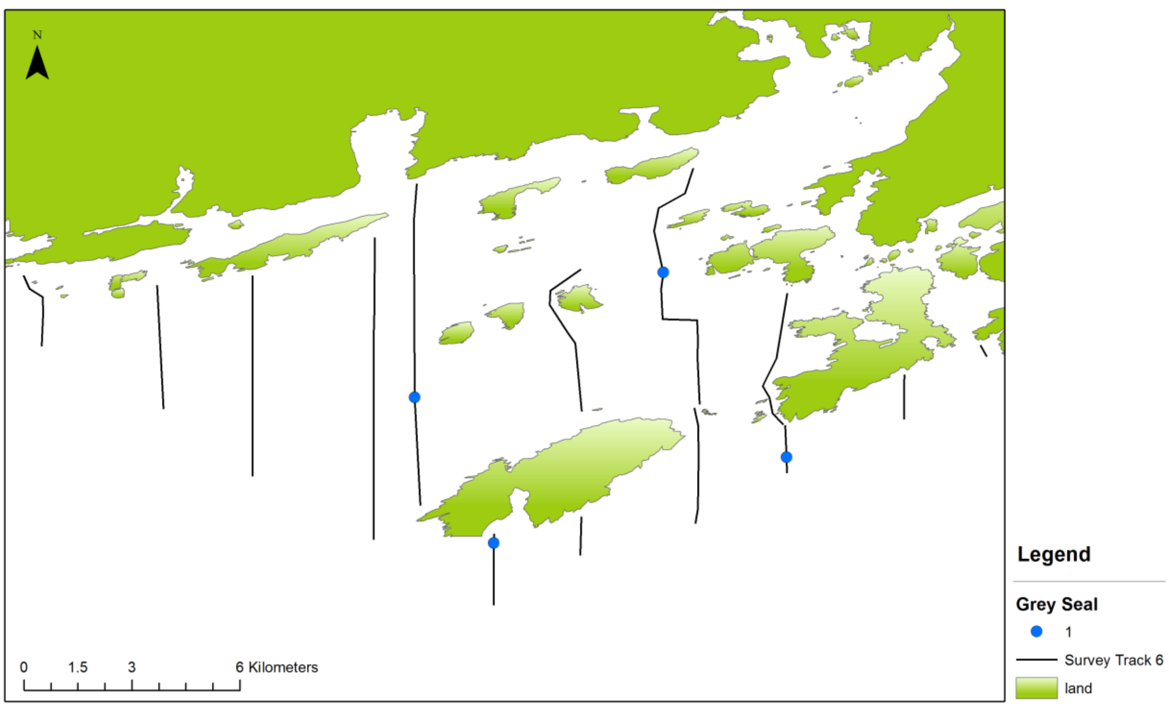

Figure 25. Grey seal sightings during survey 6.

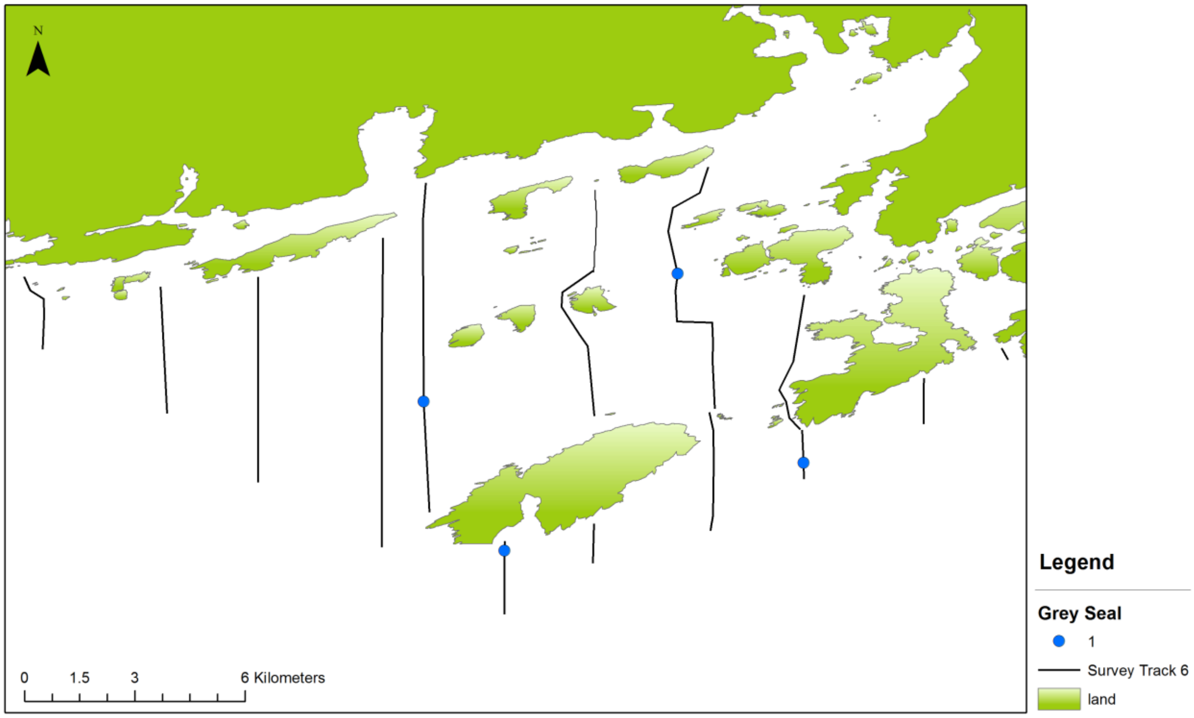

Figure 26. Grey seal sightings during survey 6.

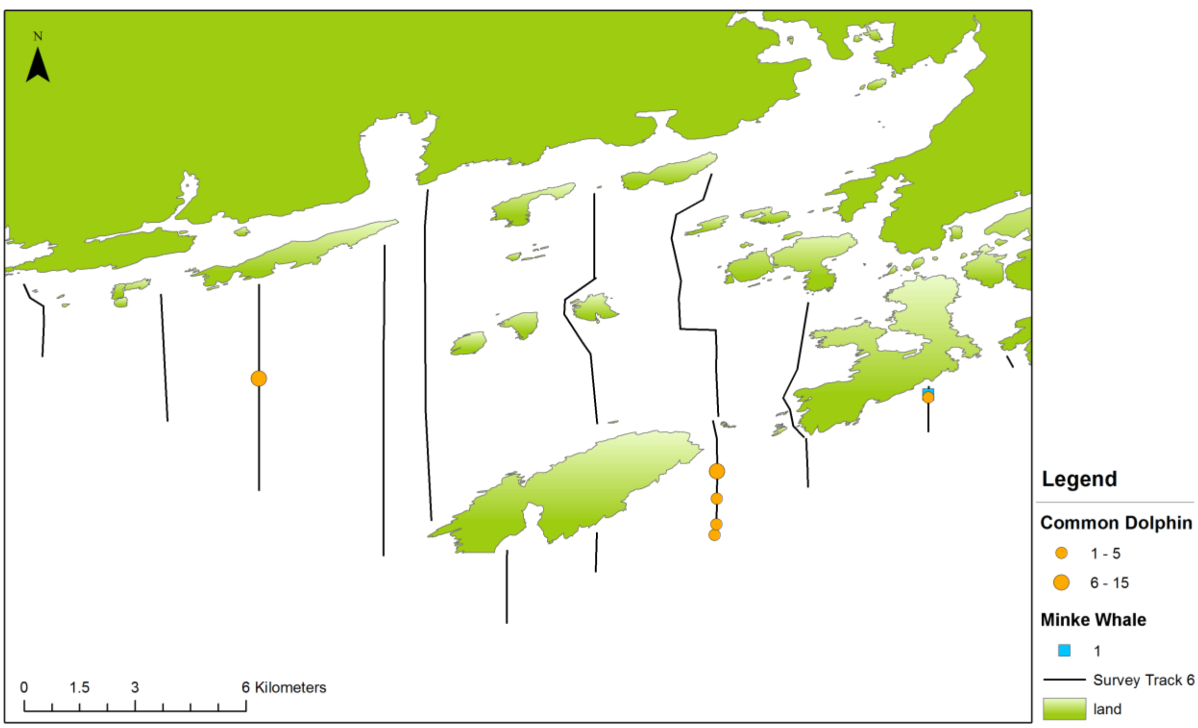

Figure 27. Common dolphin and Minke whale sightings during survey 6.

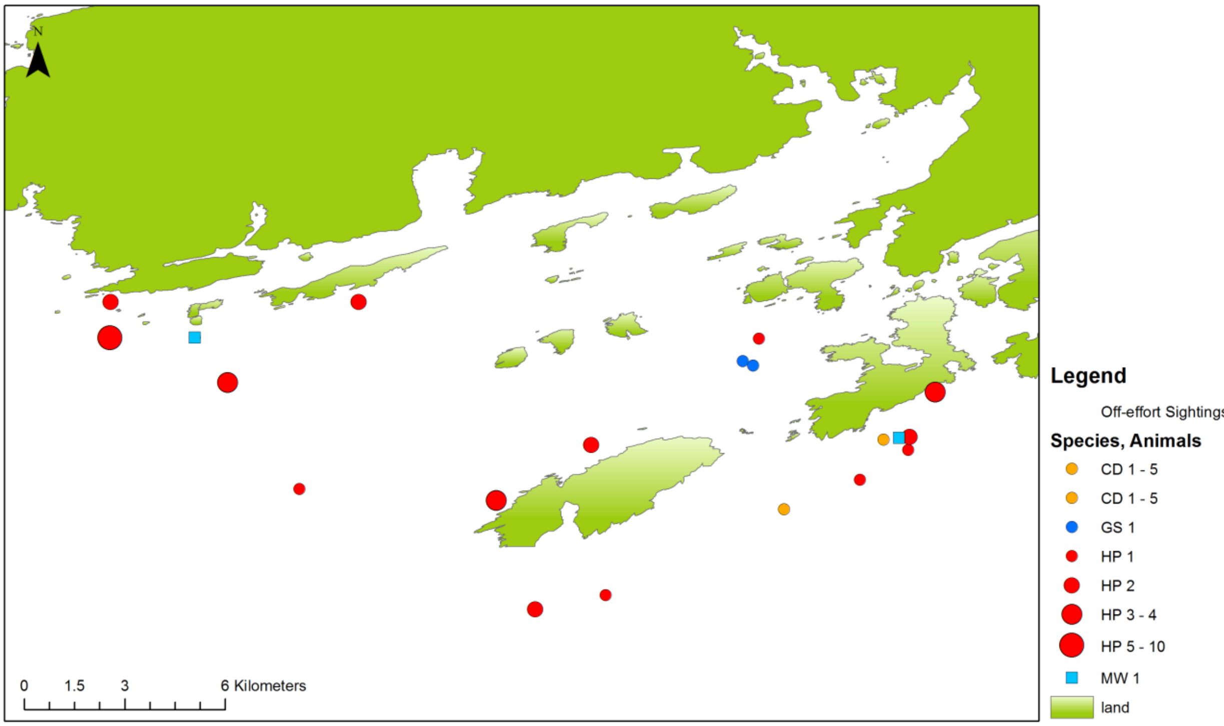

Figure 28. All off-effort sightings recorded across all surveys in 2015.