Harbour Porpoise
SAC Survey 2013

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Cover image: Harbour Porpoise in Rockabill to Dalkey Island SAC © Isabel Baker/DAHG

Executive Summary

A visual and Passive Acoustic Monitoring (PAM) survey of harbour porpoises (*Phocoena phocoena*) was carried out in 2013 at two Special Areas of Conservation (Rockabill to Dalkey Island SAC, Co Dublin and Roaringwater Bay and Islands SAC, Co Cork) in order to derive local density and abundance estimates. Single platform line-transect surveys were carried out according to a standardised design on six days at each site between July and October 2013, and a towed hydrophone array was deployed during all surveys to collect ancillary passive acoustic data. Distance sampling was used to produce a detection function based on the observed distribution of harbour porpoise sightings. Abundance estimates were calculated using the day as the sample and the sighting as the observation (i) for all survey days with sufficient sightings and (ii) for each site overall using pooled survey effort and sightings information.

Surveys were carried out in favourable weather conditions (sea-state ≤2, with visibility of at least 6km) whenever possible. These conditions were achieved on five of the six surveys of Rockabill to Dalkey Island SAC and all of the Roaringwater Bay and Islands SAC surveys, although fog was reported on two survey days in September which reduced visibility. Data from the first survey of Rockabill to Dalkey Island SAC was not used since sea-state increased during the second half of the survey.

A combined total of 640km of track-line effort was carried out in Rockabill to Dalkey Island SAC over five surveys. This resulted in a total of 201 sightings comprising at least 292 individual harbour porpoises. One sighting of a single minke whale (*Balaenoptera acutorostrata*) was recorded in the SAC but there were also two acoustic detections of dolphins in the absence of corresponding visual sightings. Sightings were made throughout the survey area. Abundance recorded in Dublin Bay was a little lower than the rest of the site, which may have been due to high vessel activity in this area. The PAM carried out during five surveys of Rockabill to Dalkey Island SAC resulted in a total of 23 harbour porpoise acoustic detections (in comparison to 201 visual sightings), with a detection rate of 0.04 detections per km. Within this site in 2013 the observed proportion of young porpoises (juveniles and calves combined) to adults was 7% and the proportion of calves to adults was 2%.

A total of 67 sightings comprising at least 107 individual harbour porpoises were recorded in Roaringwater Bay and Islands SAC during six surveys and 250km of track-line effort. In addition to harbour porpoise sightings, common dolphins (*Delphinus delphis*) were also recorded in every month surveyed with minke whales recorded in July and August in good numbers and sunfish (*Mola mola*) also recorded from July to September. Harbour porpoises were observed during every survey at the site, however there was great variation in the number of sightings per survey which ranged from 23 sightings in early July to only one sighting on 24th September. Overall there was a huge difference in sightings between early in the survey period compared to later where the number of sightings per survey declined from 16-23 during July and August to only 1-3 per survey in September and October. The number of sightings of other cetacean species within Roaringwater Bay also declined into the autumn, suggesting that food availability had declined leading to animals leaving the bay. PAM was carried out during all six surveys of Roaringwater Bay and Islands SAC. A total of six harbour porpoise detections (compared to 67 visual sightings) were recorded at a detection rate of 0.02 detections per km. All but one acoustic detection in Roaringwater Bay and Islands SAC had simultaneous visual sightings. The proportion of young porpoises (juveniles and calves combined) to adults was 13% and the proportion of calves to adults was 4%.

Density estimates at both sites varied between surveys. The effect of sea-state on density estimates was investigated by running distance models on data derived from sea-state0, seas-state 0+1 and sea-state 0+1+2 at both sites independently. This showed there was no effect of including sightings and effort recorded in sea-state 2 to that recorded in sea-states 0+1 suggesting it was appropriate to survey harbour porpoise in up to sea-state 2. Estimates in Rockabill to Dalkey Island SAC were more consistent ranging from 1.13 porpoises per km^2 to a maximum of 2.61, with an overall density of 1.44±0.09 porpoises per km^2 with a very low CV of 0.06. Harbour porpoise abundance for Rockabill to Dalkey Island SAC was around 400 individuals (391±25 with 95% CI of 344-445). Density estimates during the first three surveys in Roaringwater Bay and Islands SAC were high at 1.86, 1.97 and 2.61 porpoises per km^2 but the overall density estimate was depressed by very low densities on the last three

surveys in 2013. The overall density of 1.18±0.14 porpoises per km^2 provided an abundance estimate of 151±18 with 95% CI of 119-192.

Density estimates were compared to similar surveys carried out in 2008. North County Dublin encompassed the northern sector of the present survey site and Dublin Bay encompassed the southern sector. Density estimates in North County Dublin in 2008 were 2.03 porpoises per km^2 and 1.19 porpoises per km^2 in Dublin Bay. If we take the average of the overall densities at these sites it equates to 1.61 which is similar to the 1.44 porpoises per km^2 pooled estimate from the present survey. Overall density estimates in Roaringwater Bay and Islands SAC between 2008 and 2013 were very similar with 1.24 porpoises per km^2 in 2008 and 1.18 porpoises per km^2 in 2013 giving a consistent abundance estimate of 150-160 individuals.

We recommend that the survey period for future surveys of this kind is extended to include June to increase the number of suitable days available for surveying. We also suggest that PAM did not contribute significantly to the survey as sighting surveys are only carried out in optimal weather conditions. Under these circumstances the numbers of acoustic detections which are not also observed visually were few and most harbour porpoise sightings were not detected acoustically. We recommend that Static Acoustic Monitoring (SAM), through the use of CPODs, is carried out in preference to PAM. This could provide valuable additional information on the habitat use of the target species at the site during an entire period of survey (e.g., during the summer months).

Rockabill Island, off the Co. Dublin coast.

Boat traffic in Dublin Bay.

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 coasts and 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 2012).

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) but encompassed all Irish waters 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; 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, (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). 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 carried out at a further six regional sites around Ireland between 2010 and 2012. These sites were 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 (Verfuß *et al.* 2005). These signals are characterised as being narrow-band, high frequency 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). Variations in inter-click intervals (ICIs) can be used to identify different acoustic behaviours such as feeding, approach behaviour and communication (Koschinski *et al.* 2008). Harbour porpoises also have a lower frequency component to their click (2kHz) which Møhl and Andersen (1973) suggested may have communication function. Harbour porpoises seem to continuously echolocate, producing a click train every 12.3 seconds (Akamatsu *et al*., 2007) making them ideal candidates for acoustic monitoring if they are within the range capabilities of the recording equipment.

EU member states are required to designate Special Areas of Conservation (SAC) 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 have already been designated as candidate Special Areas of Conservation (SAC) for the species. In 2012 an area to the east of County Dublin was proposed as a further candidate SAC for harbour porpoise: Rockabill to Dalkey Island SAC. In order to contribute towards the Department of Arts, Heritage and the Gaeltacht's (DAHG) site management and monitoring obligations, a set of visual and acoustic harbour porpoise surveys were carried out in this new SAC and in Roaringwater Bay and Islands SAC during the summer of 2013. The objectives of the surveys were to:

i) derive updated summer density and population estimates for harbour porpoises within each SAC using robust sampling methods for small cetacean density/population estimation;

ii) estimate associated Coefficients of Variation and 95% Confidence Intervals;
iii) collect ancillary data during all surveys, including acoustic data using Passive Acoustic Monitoring (PAM).

Methods

Survey sites

The survey sites and DAHG line-transect survey designs (black lines) are shown in Figures 1a and 1b. The area of Rockabill to Dalkey Island SAC is an estimated 273.3 km^2 while Roaringwater Bay and Islands SAC in Co. Cork is almost half this area at approximately 142.6 km^2. In each case track-line coordinates were provided by DAHG.

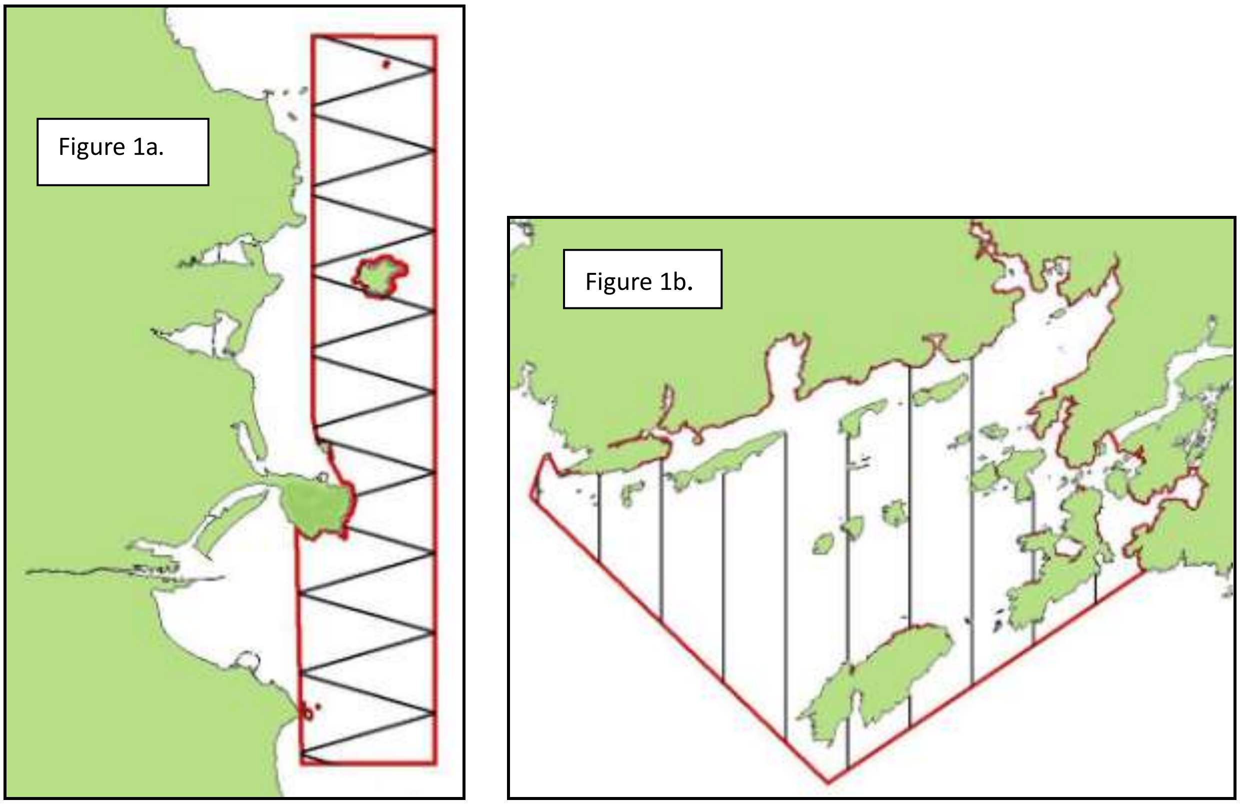


Figure 1a. Rockabill to Dalkey Island SAC, Co. Dublin. Figure 1b. Roaringwater Bay and Islands SAC, Co. Cork.

Survey platforms

The same vessel was used at each site: MV Beluga at Rockabill to Dalkey Island SAC, and MV Holly Jo at Roaringwater Bay and Islands SAC. The observation platform height on each vessel was greater than 3m, with MV Beluga at 3.1m and MV Holly Jo at 3.2m.

Survey methodology

Conventional single platform line-transect surveys were carried out within or in close proximity to the boundaries of the survey sites along the pre-determined track-lines provided by DAHG. Transect lines were plotted from a random starting position within each site and the designs were orientated to cross depth gradients and provide equal coverage probability following the recommendations of Dawson *et al.* (2008) who concluded that a systematic pattern of line spacing resulted in better precision than randomised line spacing. The 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. 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 visibility 6 km or more.

Each 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 4-6m depending on the height of the platform and 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 200m from the track-line (300m if sea-state 0 predominated) were not used in the distance sampling model. This followed the recommendations of Buckland *et al.* (2001) since values beyond this truncation distance do not contribute much to the density estimate and they make it difficult to fit the detection function. 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 was also recorded but not included in 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 on each vessel 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 site 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 is used to calculate the density of animals on the track-line of the vessel. In 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.

All sightings including those reported in sea-state ≤2 are listed in each site's summary tables below. To calculate density we used "day" as the sample regime with sightings used as sampling observations. Estimates of abundance and density obtained via the DISTANCE modelling process are presented for each survey day provided that there were sufficient sightings to generate an estimate. The overall pooled abundance/density estimates for each site were derived from all track-lines surveyed in sea-state 2 or less combined across all survey days. This was necessary in order to obtain sufficient sightings for a 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 each site between sample days or any immigration into or emigration out of the site.

We fitted the data to a number of models available in the DISTANCE software. We found that a Half-Normal model with cosine adjustments best fitted the data according to the Akaike Information Criterion delivered by the model. The recorded data were grouped into equal distance intervals of 0-20m, 20-40m up to 180-200m for most sites and 0-30m, 30-60m up to 300m for surveys carried out if the majority of effort was carried out in a sea-state ≤1. 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 is delivered 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) are presented with each detection function. Variability associated with the encounter rate reflects the number of sightings on each track-line, which varied substantially and ranged from zero to twelve sightings (Figs. 2, 6). The detection probability reflects how far the sightings were from the track-line and cluster size reflects the range of estimated group sizes recorded at each site.

Mapping cetacean survey and encounter data

Maps of the respective study areas and associated survey data were created in Irish Grid (TM65_Irish Grid) with ArcView 9.3 while maps of the prescribed survey areas 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 distribution maps.

Acoustic monitoring

The collection of acoustic data during visual surveys can add an extra dimension to the survey dataset especially for mid-frequency dolphin species whose vocalisations can be detected over several hundred metres or more. Acoustic monitoring may also detect cetaceans which are beyond the visual observers view and therefore increase the capacity of the survey. As part of the survey programme a towed hydrophone array was deployed during visual surveys. This array consisted of a 200m-long cable with two hydrophone elements (HP-03) situated 25cm apart in a fluid-filled tube at the end of the cable. The cable and hydrophone array were connected to the vessel with a bungee cord to avoid excessive tension on the main line. The equipment is designed to be negatively buoyant in order to tow the hydrophone elements under the surface at a depth of 2-5m depending on the speed of the vessel.

The cable contains wires that conduct power from the battery attached at the dry end (MAGREC Ltd HP-27st buffer box) to preamplifiers in the fluid-filled tube at the wet end of the array. The buffer box and an attached dedicated soundcard (National Instruments DAQ-6255) were linked into a laptop computer. The soundcard allows for the detection of sounds which lie outside the processing capability of the computer's own soundcard. Two sound channels were sampled via the hydrophone array at a 192 kHz sampling rate. This allowed the detection and logging of acoustic encounters occurring within a 2-96 kHz frequency range. The open-source software PAMGUARD (ver.1.11.02 Beta) was used for on-board laptop-based data acquisition. PAMGUARD is a fusion of the IFAW suite and *Ishmael* acoustic detection and analysis software and it contains applications such as click detectors, tonal whistle detectors, a spectrogram viewer, in-built sound filters and the capability to calculate bearings on maps, to record a track log and several other functions.

During each line-transect survey the hydrophone was deployed behind the survey vessel and its real-time output was monitored on the laptop by a single observer to ensure the optimal operation of the software and to maintain an operating log to assist in later analyses. Track-lines of acoustic survey effort were recorded using an external GPS receiver which provides NMEA data through the laptop for use by the PAMGUARD software. The "user-input" facility in PAMGUARD was used by the PAM operator to record all relevant information throughout the survey, such as when detections were recorded, the presence of passing vessels which might interfere with recordings, changes in track, etc. Acoustic recordings were made when the PAM operator recognised detections either visually on the spectrogram or aurally through headphones. Recordings consisted of raw .*wav* files and these were stored on the laptop and later backed up to a 2 TB hard drive for post-survey analysis.

Results

Rockabill to Dalkey Island SAC

Six surveys were carried out in Rockabill to Dalkey Island SAC between July and September 2013 (Table 1). Environmental conditions on the first survey (5 July) deteriorated as wind speed increased during the day and therefore survey effort had to be cut short. Apart from that first survey day, environmental conditions were favourable during the remaining five surveys (Table 1).

Table 1: Overall environmental conditions during the surveys of Rockabill to Dalkey Island SAC in 2013.

Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
5-6 July	0	16-20	5	S	1/8	No
12 July	0	16-20	1	S	1/8	No
7 August	0	16-20	0	S	2/8	No
26 August	1	6-10	0	S	3/8	No
27 August	0	6-10	2	W	8/8	No
13 September	<1	11-15	6	NW	7/8	No

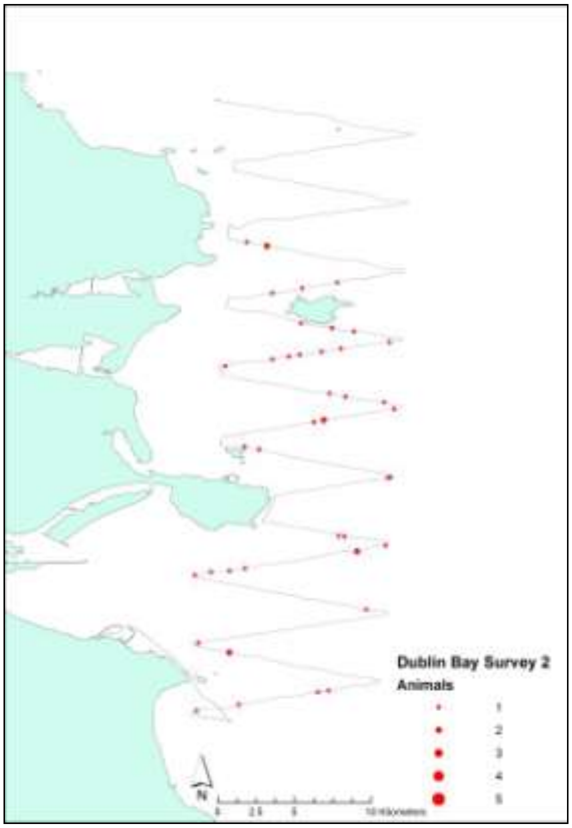
The proportion of effort (time) surveyed in different sea-states is shown in Table 2. Sea-state 0 predominated for one survey (survey 5) and sea-state ≤1 for three surveys. Survey effort was carried out exclusively in sea-state ≤2 on three of the six surveys. A small proportion of survey effort on 12 July and 26 August was carried out in sea-state 3 (Table 2). Sea-state on 5 July (survey 1) increased to sea-state ≥3 after 7 hours, after about two-thirds of the full survey length had been completed. The survey was subsequently abandoned. The northern half of the study area was surveyed in sea-state ≤2 on the following day (6 July) but since the area had been covered over two days and not in a single day the associated data could not be treated as one sample day or strictly compared with subsequent surveys within the site. Following consultation with DAHG it was decided that the data from 5-6 July while of value should not undergo the distance sampling analysis as performed on other complete datasets.

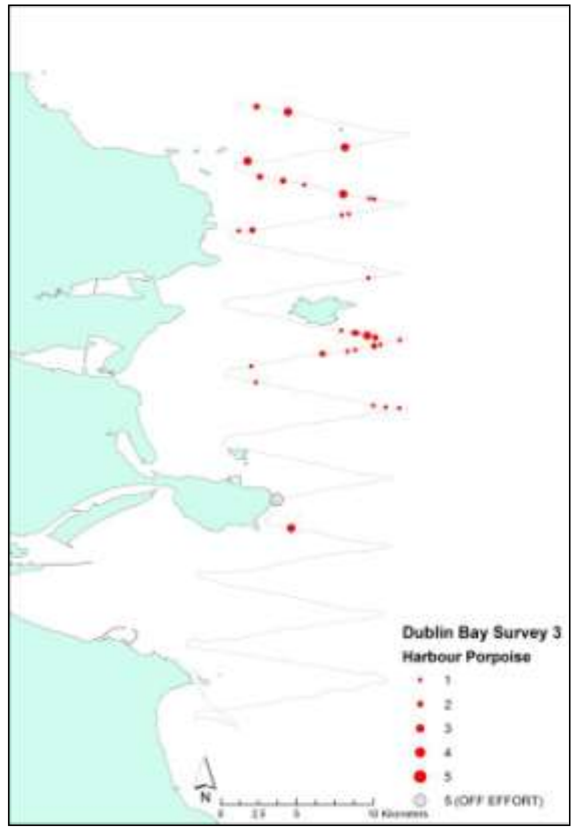
Table 2. Sea-state and on-effort sightings data for harbour porpoises recorded within Rockabill to Dalkey Island SAC.

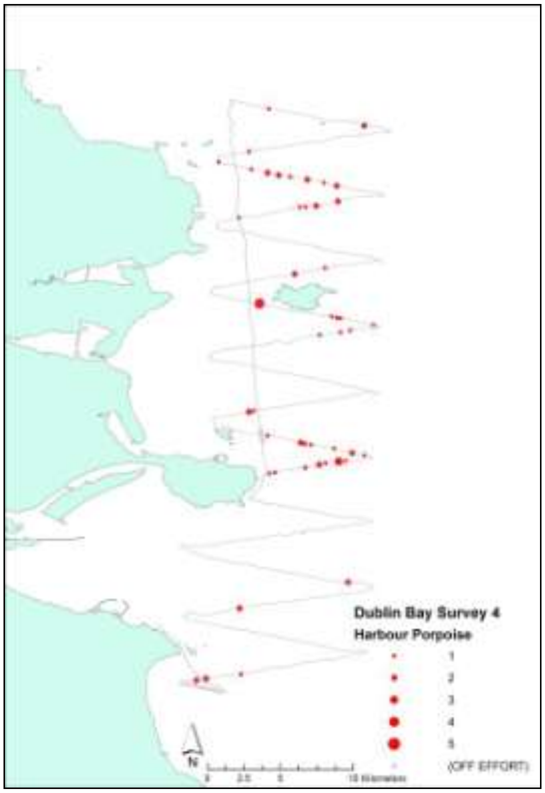
Sample Day	Date	Total effort (km) in sea-state ≤2	Sea-state (% of total survey time)				Number of sightings	Total no. of animals
			0	1	2	3		
1	5-6 July	-	0.0	58.1	35.2	6.7	(21)[1]	(30)[1]
2	12 July	129.3	44.1	25.3	26.0	4.6	39	43
3	7 August	128.5	39.2	50.2	10.6	0	27	48
4	26 August	122.2	0	27.3	68.6	4.1	48	69
5	27 August	130.8	53.0	26.3	20.7	0	78	116
6	13 September	130.4	15.8	26.4	57.7	0	9	16
Total		**641.2**					**201**	**292**

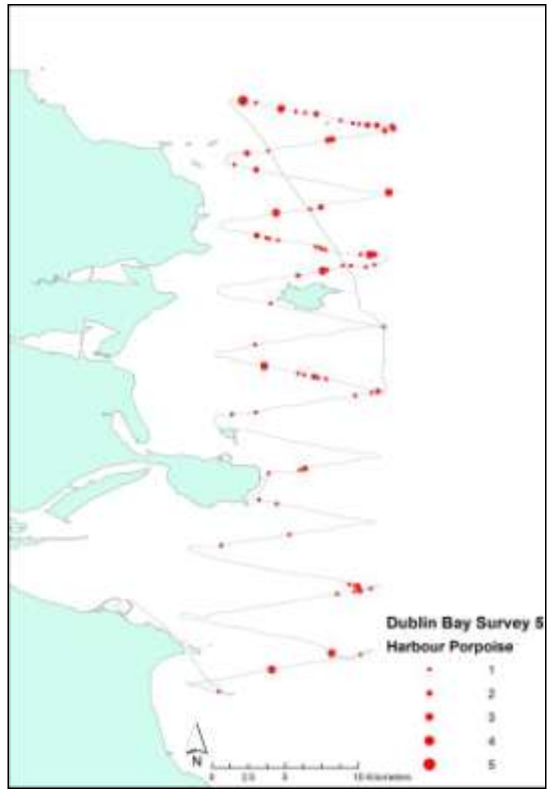
[1] – sightings from the first two-part sample coverage are not included in the totals for site

A total of 201 sightings of harbour porpoise were recorded during the five one-day surveys, delivering an estimated total of 292 individual animals (Table 2). Track-lines and individual sighting locations within each survey are shown in Figure 2 with the exception of data from 5-6 July. Harbour porpoises were distributed throughout the study area. A lower incidence of harbour porpoise sightings was apparent in outer Dublin Bay by comparison with waters lying off and to the north of Howth Head. There were only four sightings off-effort during the five surveys, three during survey 4 on 26 August.









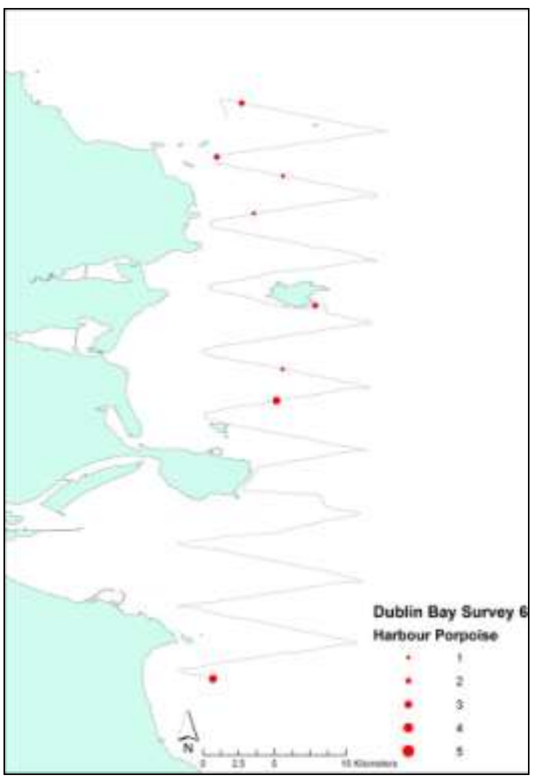


Figure 2a-e. Maps showing the locations of harbour porpoise sightings and corresponding group sizes recorded during each one-day survey of Rockabill to Dalkey Island SAC in 2013.

Density and abundance estimation

Density estimates for harbour porpoise within the SAC were calculated from sightings data obtained on five of the six surveys and also for all surveys combined into one sample (i.e., pooled density estimate). The sightings dataset was truncated at 300m from the track-line, apart from the last survey which was limited at 200m since there were few sightings overall and no sightings beyond 200m. A summary of the data from the DISTANCE model is shown in Table 3. Chi-squared values delivered by the model were favourable (P>0.5 for four of the five surveys) indicating that the detection functions were a good fit and the resulting estimates robust. The effective strip width data were quite consistent across sample days and most variability was attributed to the detection probability rather than cluster size. Such features are typical of harbour porpoise surveys as group sizes tend to be small (i.e., in single figures) and comparatively consistent in time. Mean cluster (group) size did vary a little between surveys however, between 1.10 and 1.78 (Table 3).

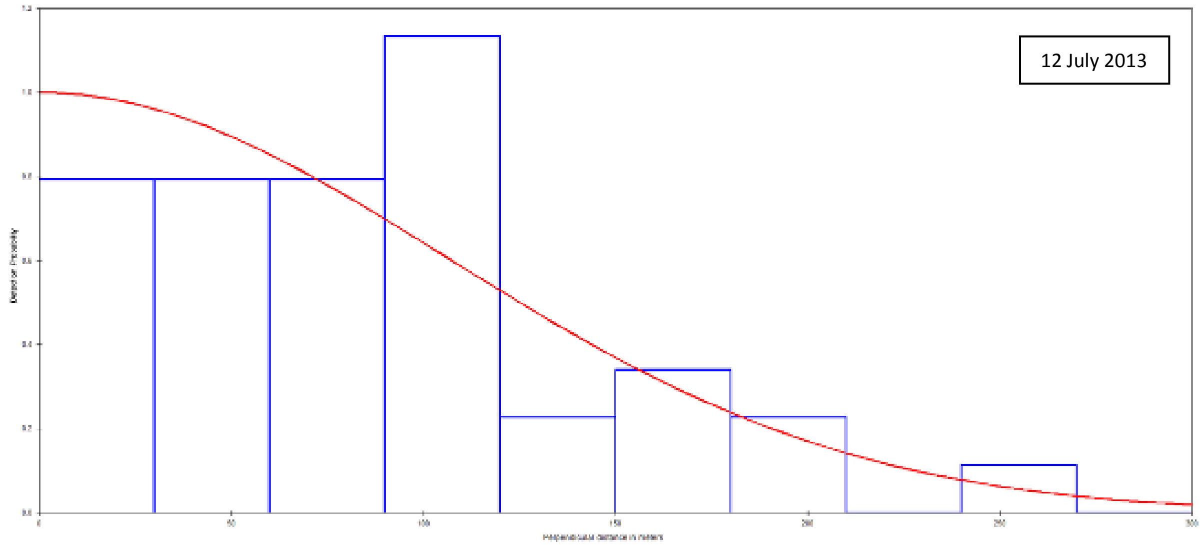
The detection functions for harbour porpoise in Rockabill to Dalkey Island SAC are shown graphically in Figure 3. There was evidence of evasive movement by harbour porpoises on 7 August with a peak in sightings 60m from the track-line and this was reflected by a poor goodness of fit in the Chi-squared test (P=0.297; Table 3). On the last survey (13 September), although there were only nine sightings in total the modelled detection function was a good fit (P=0.769; Table 3) but the effective strip width was quite narrow (i.e., 58m; Table 3).

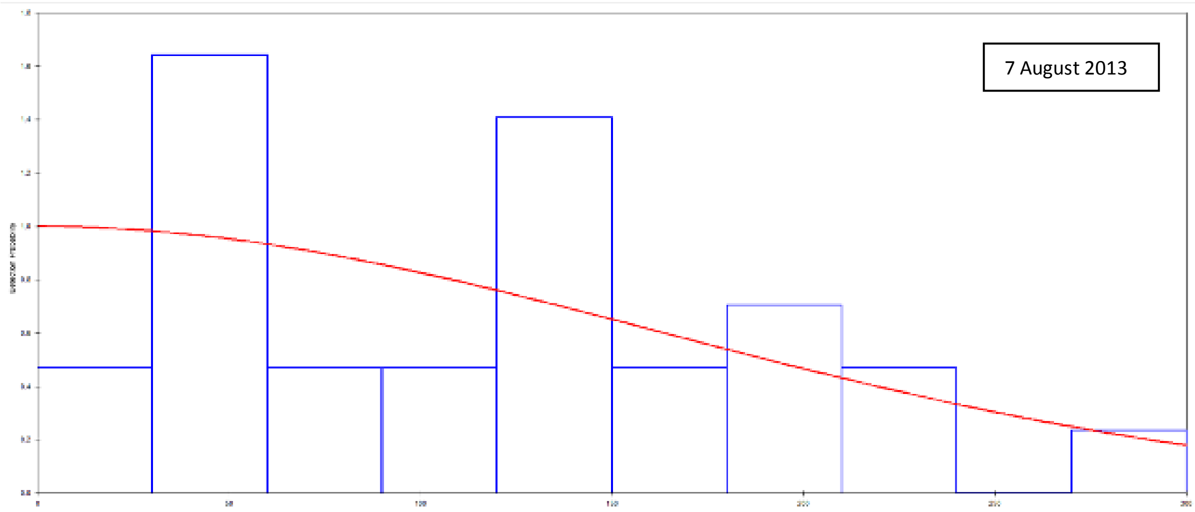
Table 3. Model data used in the harbour porpoise abundance and density estimation process for each survey of Rockabill to Dalkey Island SAC. Note: A half-normal model with cosine series adjustments and sightings data truncated at 300m was used unless otherwise stated.

Sample Day	Chi^2 P value	Effective Strip Width (m)	Mean Cluster Size ±SE	Variability (D)	
				Detection	Cluster
2	0.523	132.6	1.10±0.49	92.0	8.0
3	0.297	190.1	1.74±0.19	74.2	25.8
4	0.552	170.9	1.44±0.93	80.8	19.2
5	0.644	160.2	1.50±0.84	76.8	23.2
6	0.769	58.12[1]	1.78±0.28	73.2	26.8
OVERALL	**0.320**	**156.9**	**1.45±0.50**	**78.0**	**22.0**

[1] – sightings data were truncated at 200m

Density and abundance estimates for harbour porpoise in Rockabill to Dalkey Island SAC are shown in Table 4. Density estimates ranged from 1.13 animals per km^2 on 7 August to 2.61 per km^2 on 27 August. Although only nine sightings totalling 16 individuals were recorded on the last survey (13 September) the density estimate derived from the DISTANCE model was similar to previous survey days. However the coefficient of variation around the estimate was comparatively high (CV=0.28). Abundance estimates delivered by each survey ranged from 309 to 442 porpoises (Table 4). Mean group size varied between surveys with peaks in early August and September. The overall pooled density estimate from all survey days combined was 1.44 porpoises per km^2 which gave an abundance estimate of 391±25 (95% Confidence Intervals [CI] = 344-445) and a low CV (0.06).


12 July 2013
Perpendicular distance in meters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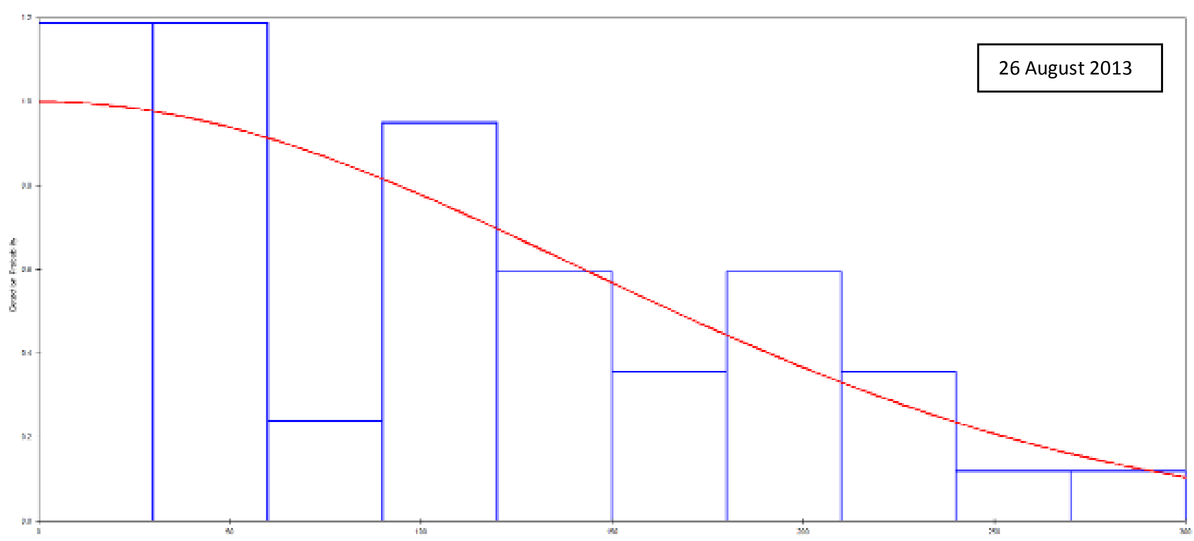

26 August 2013
Perpendicular distance in meters

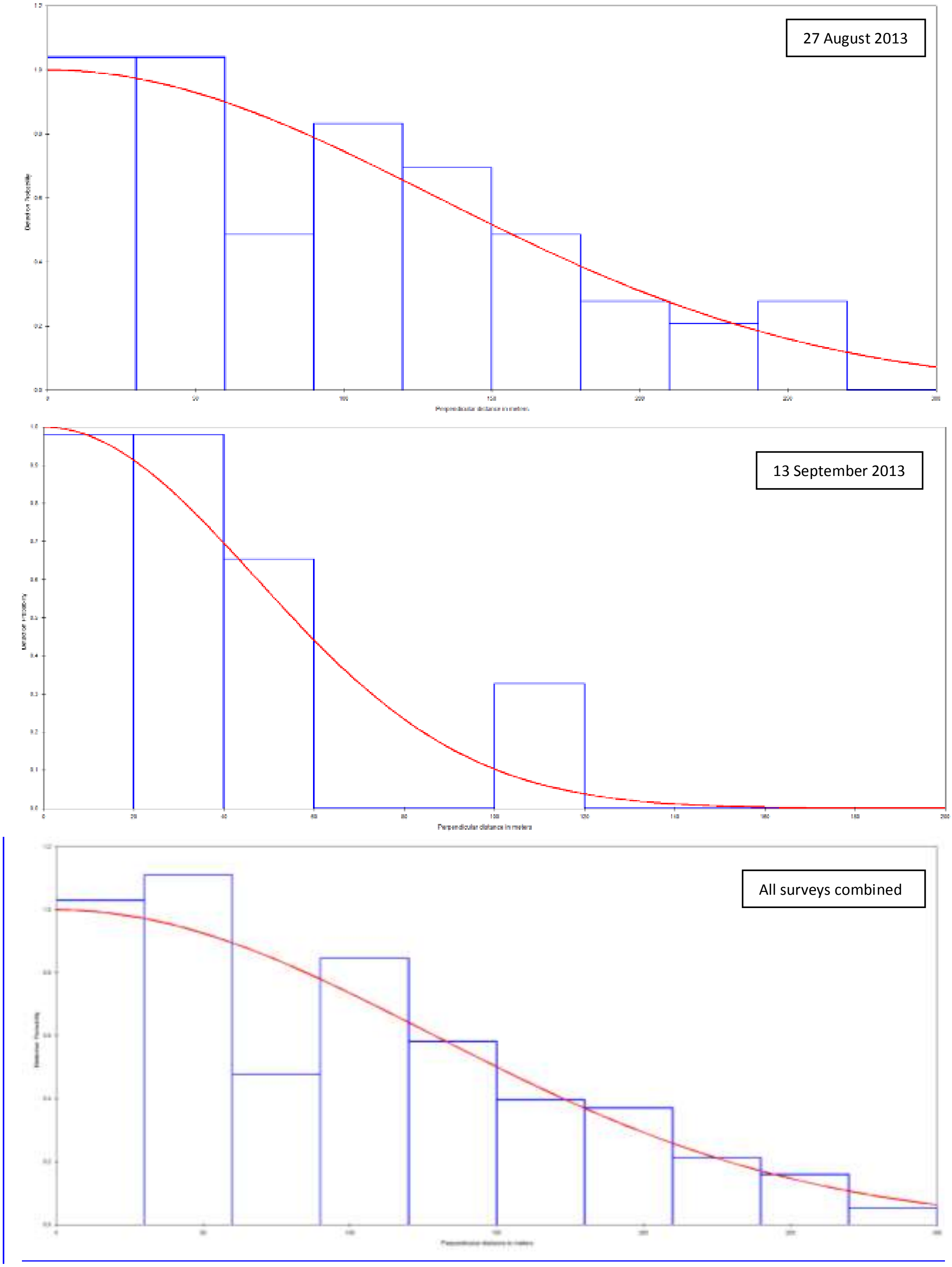


Figure 3. Detection function plots for each survey of harbour porpoises in Rockabill to Dalkey Island SAC.

Table 4. Estimated density, abundance (N) and group sizes of harbour porpoise recorded during each survey of Rockabill to Dalkey Island SAC in 2013.

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Mean group size (95% CI)
2	349 (271-450)	44.1	0.13	1.29	1.10 (1.00-1.21)
3	309 (208-438)	61.2	0.20	1.13	1.74 (1.39-2.17)
4	442 (338-579)	59.7	0.13	1.63	1.44 (1.26-1.64)
5	346 (173-689)	75.2	0.10	2.61	1.50 (1.34-1.68)
6	382 (211-692)	106.9	0.28	1.41	1.77 (1.24-2.54)
Overall	**391 (344-445)**	**25.4**	**0.06**	**1.44**	**1.45 (1.36-1.56)**

Density and abundance estimates in different sea-states

In order to determine whether sea-state may have had an influence on the estimates produced by the modeling process, the data for all surveys were pooled and detection functions calculated for increasing sea-state (i.e., sea-state 0, sea-state 0+1, sea-state 0+1+2). Total sighting effort (in km) was calculated for each sea-state class and subsequently used in the distance sampling analysis. The model's best fit was generated from data collected in sea-state 0 (P=0.89) but the highest density of porpoises was recorded in sea-states 0+1 (1.66 animals per km^2; Table 5). There was little change in either the density estimate or other model data when data collected in sea-state 2 was included, while the CV decreased further. This suggested that within Rockabill to Dalkey Island SAC it was appropriate to survey in conditions up to and including sea-state 2.

Table 5. Density, abundance (N) and group size estimates of harbour porpoise in Rockabill to Dalkey Island 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	206.1	0.89	1.43±0.01	1.31	0.15	0.11	355 (284-445)
0+1	425.0	0.43	1.45±0.05	1.66	0.12	0.07	449 (388-520)
0+1+2	641.1	0.32	1.46±0.05	1.45	0.09	0.06	394 (347-448)

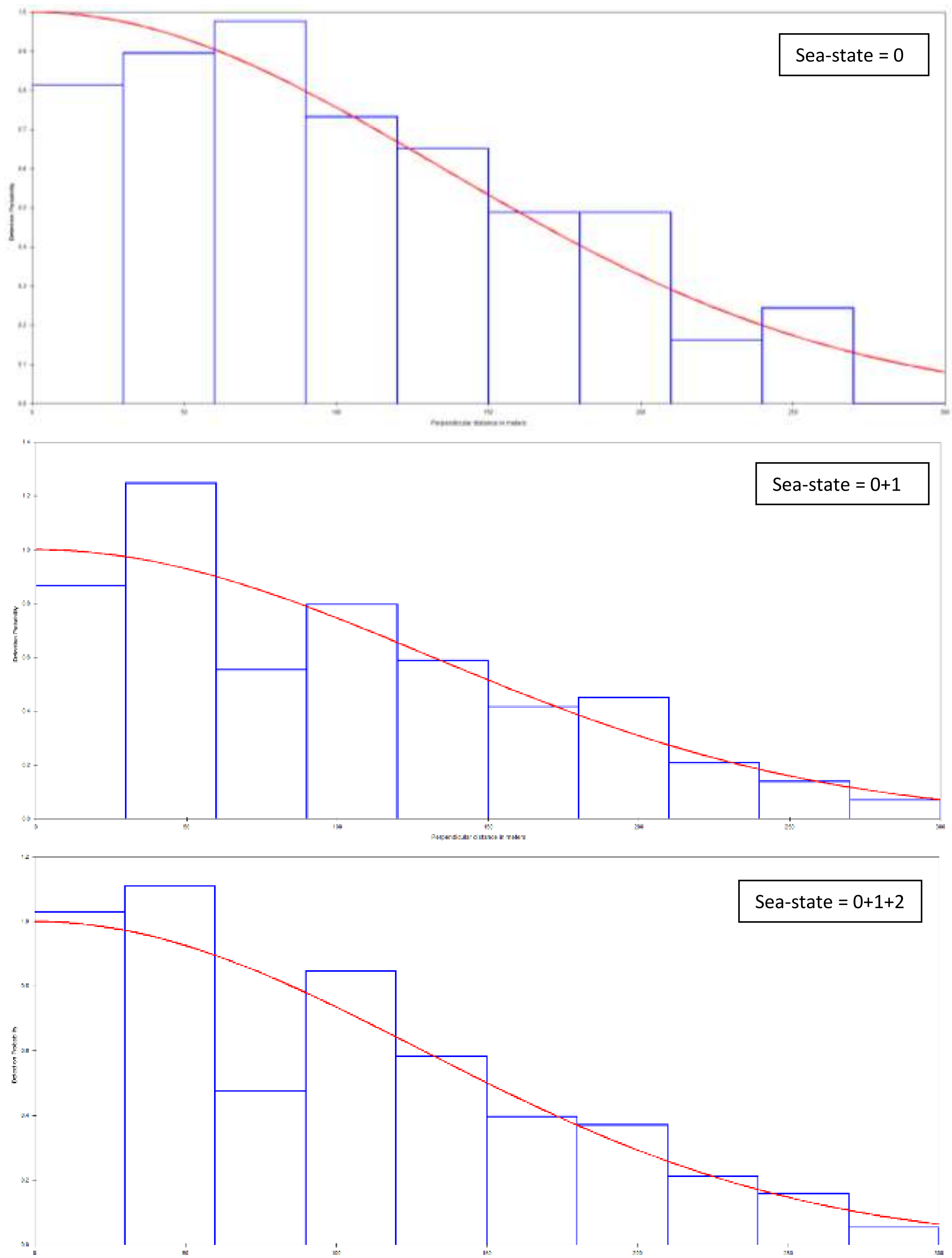


Figure 4. Detection function plots for harbour porpoise surveys of Rockabill to Dalkey Islands SAC according to different sea-state classes.

Proportion of young porpoises to adults

The numbers and/or proportions of young porpoises and calves to all porpoises (including adults), for each survey and for all surveys combined, are shown in Table 6. The proportion of young harbour porpoises (i.e., juveniles + calves) recorded on survey days ranged from c. 4-19% of all animals seen and was c. 7% overall using the combined dataset. The proportion of calves recorded on each survey ranged from 0 to c. 8% of all animals seen and was c. 2% overall using the combined dataset.

Table 6. The numbers and/or proportions of adult harbour porpoises, juveniles and calves recorded during surveys in Rockabill to Dalkey Island SAC in 2013.

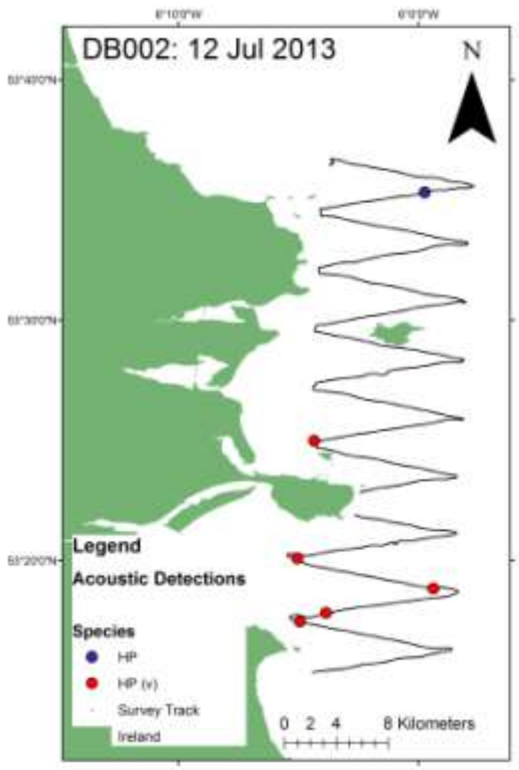
Survey	Number of Sightings	Number of Individuals	Adults	Juveniles	Calves	% young	% calves
2	39	43	43	2	0	4.4	0.0
3	27	48	42	2	4	12.5	8.3
4	48	69	65	3	1	5.8	1.4
5	78	116	111	5	0	4.3	0.0
6	9	16	13	2	1	18.8	6.3
Overall	**201**	**292**	**272**	**14**	**6**	**6.8**	**2.0**

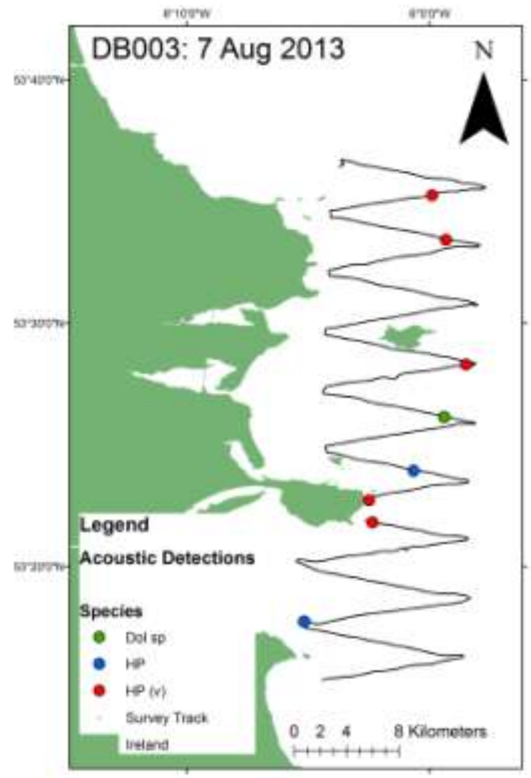
Acoustic detections

A total of five full PAM surveys were completed within Rockabill to Dalkey Island SAC survey in parallel with the visual survey effort (Fig. 5). PAM data were also collected for survey 1 (5-6 July) but were not analysed or presented further for reasons stated above. A total of 25 acoustic detections were logged of which 92% were of harbour porpoise (23 detections) and 80% (20 detections) of these had simultaneous visual sightings (Table 7; Figure 5). On two occasions (7 and 27 August) acoustic detections (i.e., whistles) of an unidentified dolphin species were recorded but no corresponding visual sightings were recorded. In addition, on two survey days (27 August, 13 September) no acoustic detections of harbour porpoise were made in spite of numerous sightings recorded on each day (Figure 5; Table 2).

Table 7. Summary of acoustic detections of small cetaceans recorded in Rockabill to Dalkey Island SAC in 2013.

Species	Clicks	Whistles	Total no. of detections	Detection duration min-max (secs)	Mean encounter duration (secs)	Detections/km
Harbour porpoise	Y	N	23	2-62	5	0.04
Dolphin spp.	Y	Y	2	300-1080	690	0.0015


DB002: 12 Jul 2013
N
Legend
Acoustic Detections
Species
HP
HP (v)
Survey Track
Ireland
0 2 4 8 Kilometers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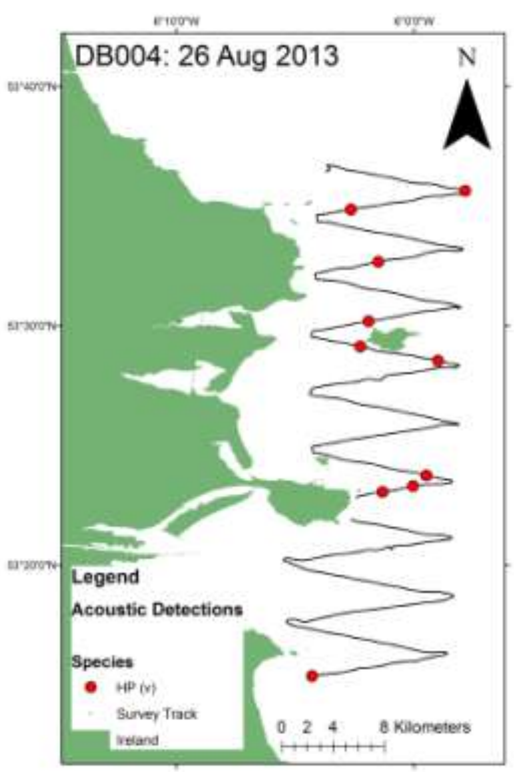
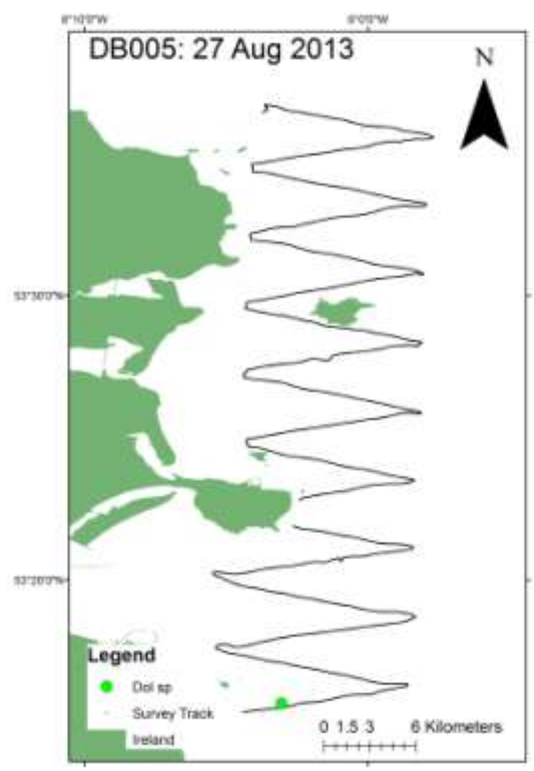
N
Legend
Acoustic Detections
Species
Dol sp
HP
HP (v)
Survey Track
Ireland
0 2 4 8 Kilometers


DB004: 26 Aug 2013
N
Legend
Acoustic Detections
Species
HP (v)
Survey Track
Ireland
0 2 4 8 Kilometers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N
Legend
Dol sp
Survey Track
Ireland
0 1.5 3 6 Kilometers

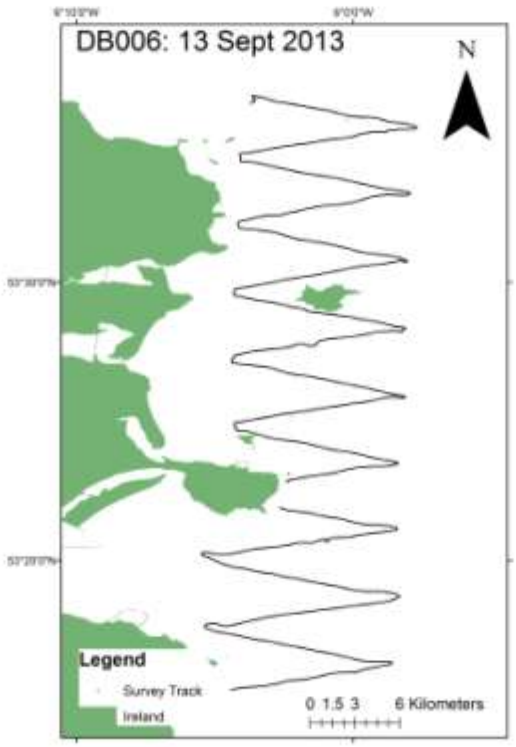


Figure 5a-e. Acoustic survey track-lines (solid line) and the locations of acoustic detections (circles) obtained during surveys in Rockabill to Dalkey Islands SAC in 2013.

<u>Additional sightings</u>

There was only one additional cetacean sighting other than harbour porpoise recorded in Rockabill to Dalkey Island SAC. This was of a single minke whale (*Balaenoptera acutorostrata*) on the first survey (5-6 July).

Roaringwater Bay and Islands SAC

Six survey days were carried out 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 on four of the six survey days (Table 8). Restricted visibility, through fog, was reported on 24 and 25 September at the beginning of each survey but this improved during the survey and was always >500m from the vessel. Since this was greater than the distance within which sightings of harbour porpoise were truncated (0-300m; see distance sampling analysis) the survey team considered that the data collected were suitable for further analytical use and for reporting.

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 (10-11 July) and was predominantly ≤ sea-state 1 for all surveys (Table 9). Only on one survey (11 July) was sea-state >2 for around 8.8% of survey effort, which amounted to 6.3km of track-line. In this case the southern margins of track-lines 9 and 10 (total length of 1.6km) off the south coast of Sherkin Island were not surveyed due to the unacceptably high sea-state which would make the visual detection of harbour porpoises more difficult. Total survey effort in Roaringwater Bay and Islands SAC ranged from c. 37-46km per survey (Table 9). This was influenced by the tide which, when low, increased the safe distance to which the survey vessel could approach islands and made some track-lines less accessible, e.g., adjacent to Horse Island in the northern part of the study area.

Table 8. Overall environmental conditions during the surveys of Roaringwater Bay and Islands SAC in 2013.

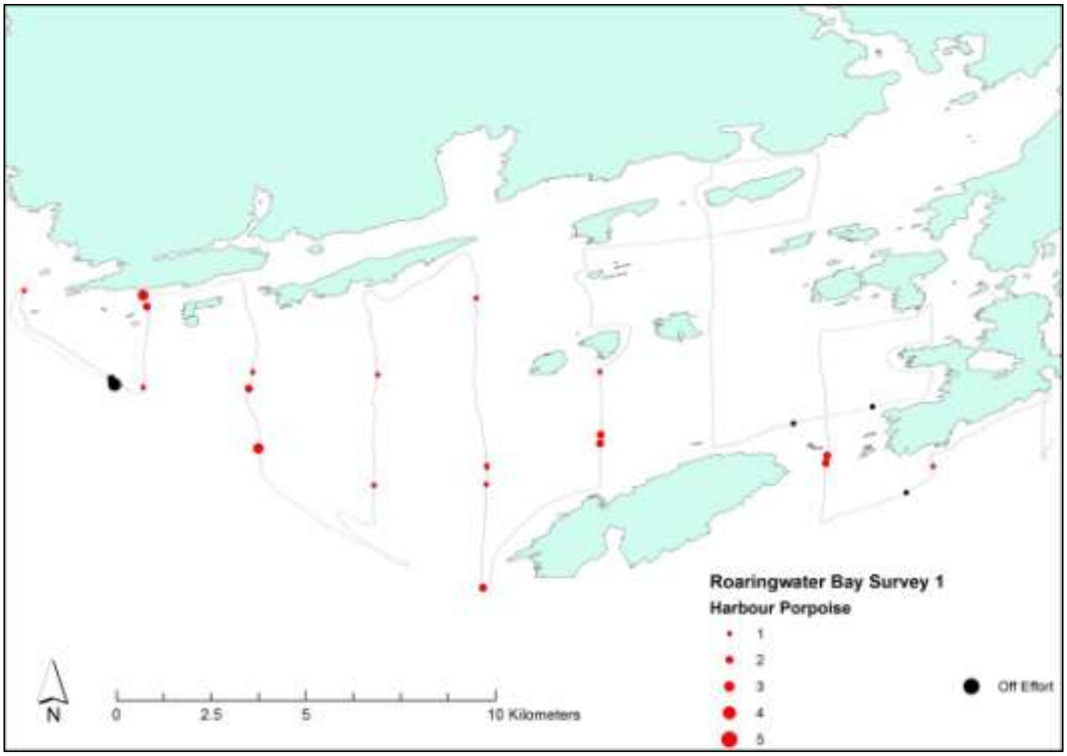
Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
10 July	None	>20km	2	E	1/8	No
11 July	None	>20km	3	E	1/8	No
28 August	None	11-15km	1	N	7/8	No
24 September	<1	1-5km	3	S	8/8	Fog
25 September	<1	1-5km	3	E	8/8	Fog
10 October	None	16-20km	4	N	3/8	No

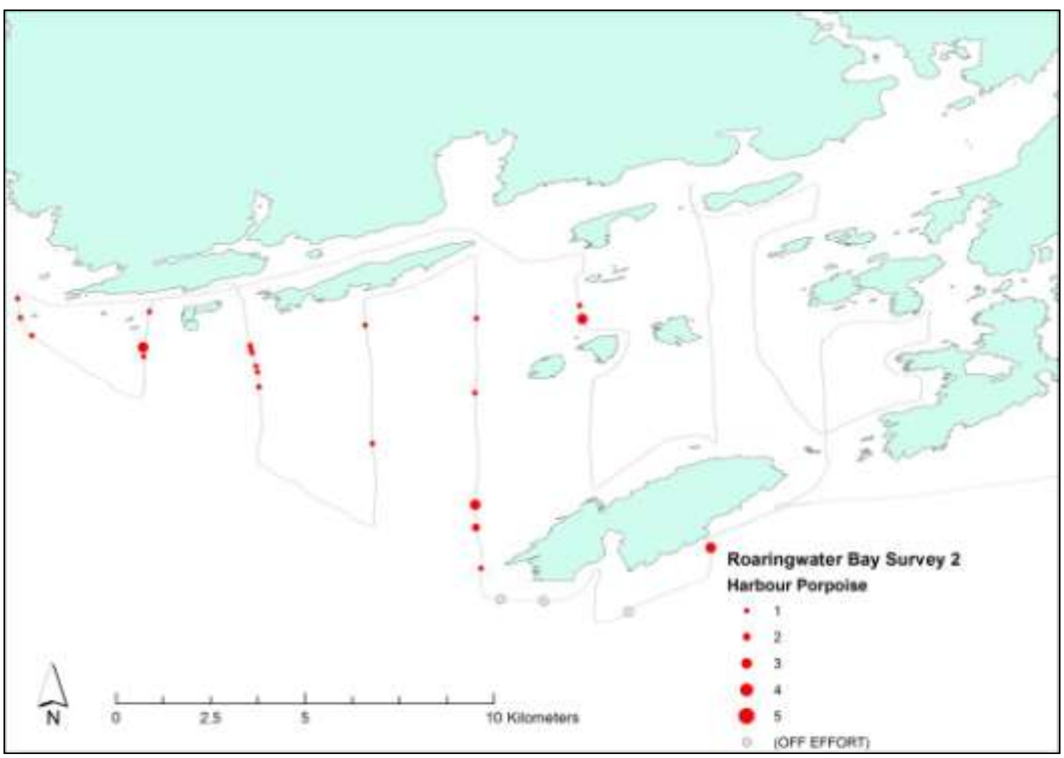
Table 9. Sea-state and on-effort sightings data for harbour porpoises recorded within Roaringwater Bay and Islands SAC.

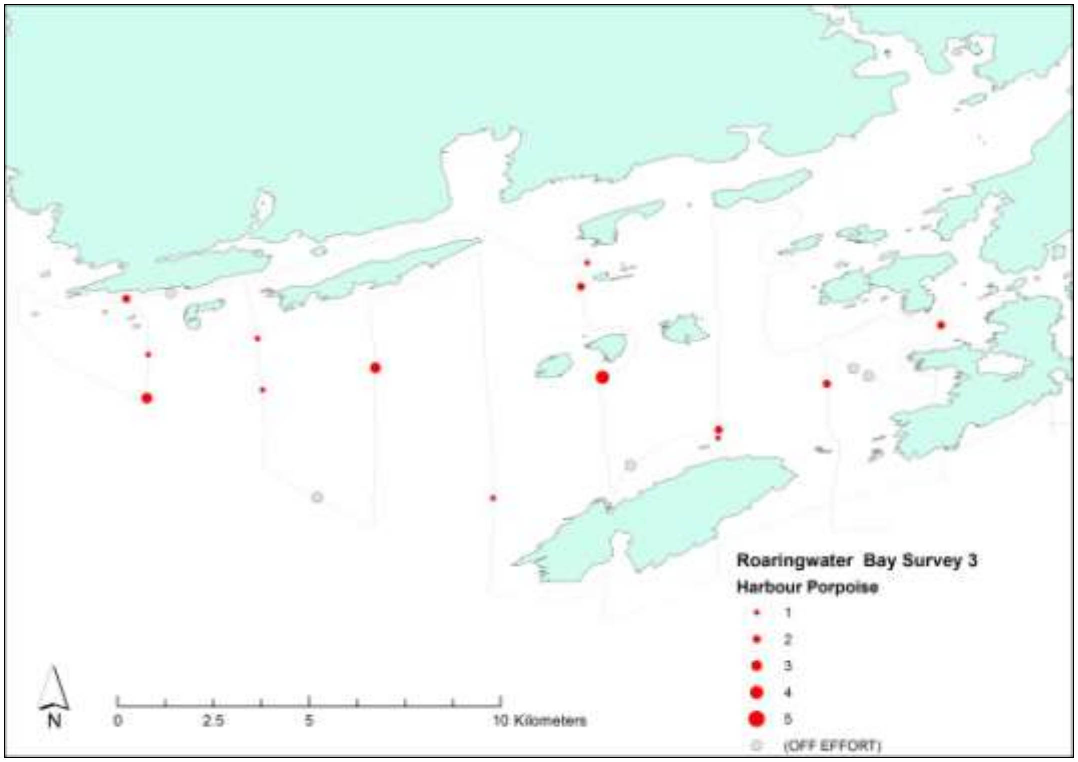
Sample Day	Date	Total effort (km) in sea-state ≤2	Sea-state (% of total survey time)				Number of sightings	Total no. of animals
			0	1	2	3		
1	10 July	46.22	43.5	32.5	12.9	11.1	22	33
2	11 July	40.97	51.0	17.3	23.6	8.8	23	33
3	28 August	43.54	34.7	38.0	27.2	0.0	16	30
4	24 September	40.77	29.1	62.3	8.5	0.0	1	1
5	25 September	37.41	9.8	85.5	4.6	0.0	3	6
6	10 October	41.29	0.0	50.3	49.7	0.0	2	4
Total		**250.02**					**67**	**107**

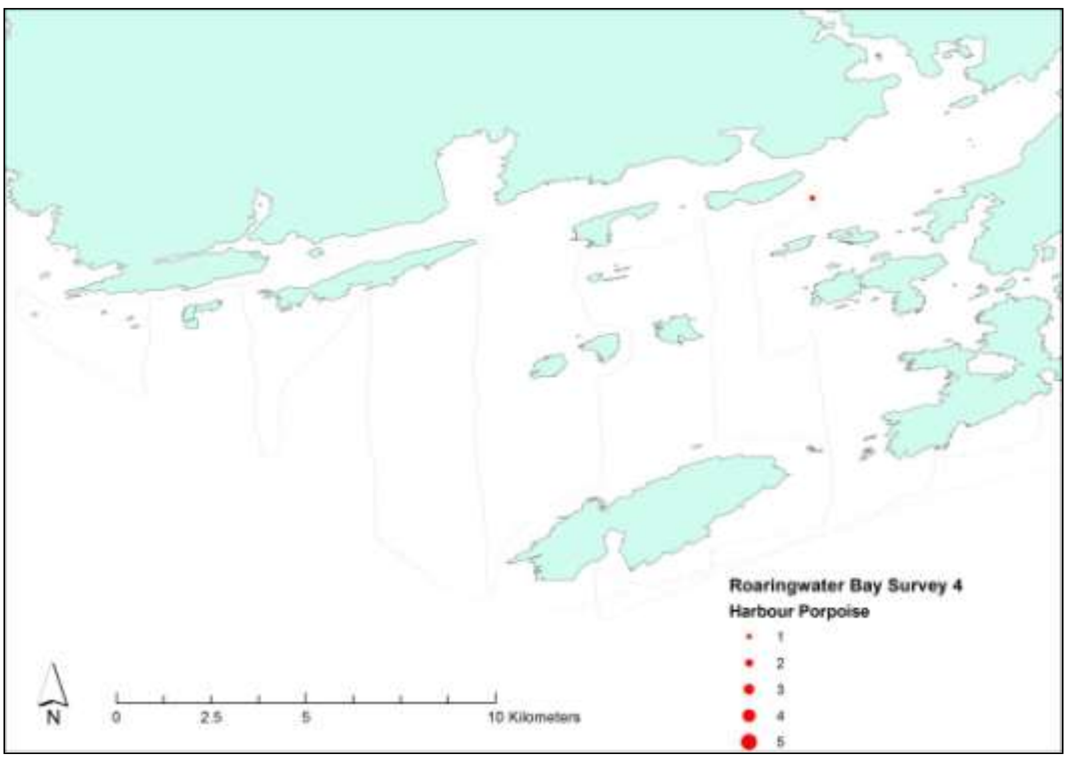
The number of sightings per survey ranged from 1 to 23 with a total of 67 overall (Table 9), 91% of which were recorded during the first three surveys in July and August. The total number of individual porpoises recorded per survey also varied considerably from 1 to 33 with a total of 107 overall. The low number of sightings recorded within Roaringwater Bay and Islands SAC in September and October was not as a consequence of sighting conditions (Table 9) but instead reflected a considerable change in the numbers of harbour porpoise within the bay during the autumn sample period. In this regard it is interesting to note the apparent consistency in sightings during the first three surveys conducted in July and August and the latter three conducted in September and October. There were more harbour porpoise sightings off-effort in Roaringwater Bay and Islands SAC than in Rockabill to Dalkey Island SAC (up to 30% for some surveys), which was due to the greater transit passages between track-lines at the Co. Cork site.

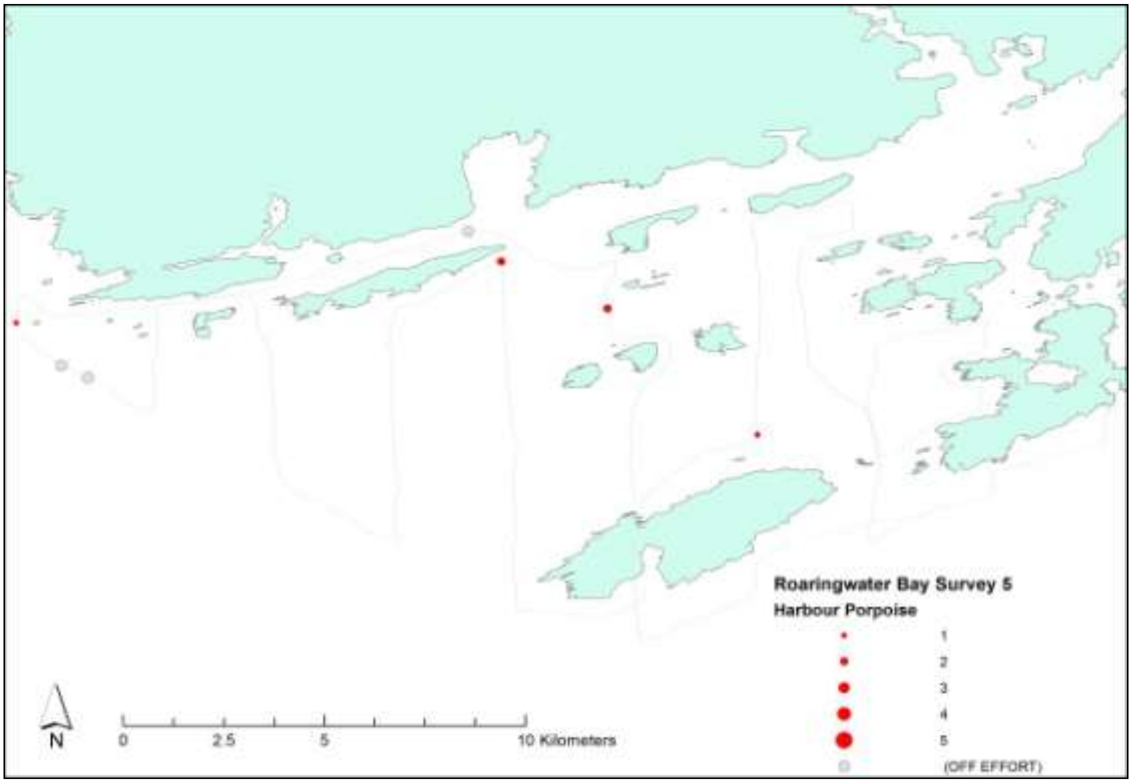
Track-lines undertaken and sightings recorded in Roaringwater Bay and Islands SAC during each survey day are shown in Figure 6a-f. Sightings were distributed throughout the survey area for the first three surveys with lower numbers of encounters reported to the east and north of the site near Sherkin Island, Hare Island and Horse Island.


Roaringwater Bay Survey 1
Harbour Porpoise
1
2
3
4
5
Off Effort
N
0
2.5
5
10 Kilometers


Roaringwater Bay Survey 2
Harbour Porpoise
1
2
3
4
5
(OFF EFFORT)
N
0
2.5
5
10 Kilometers


Roaringwater Bay Survey 3
Harbour Porpoise
1
2
3
4
5
(OFF EFFORT)
N
0
2.5
5
10 Kilometers


Roaringwater Bay Survey 4
Harbour Porpoise
1
2
3
4
5
N
0
2.5
5
10 Kilometers



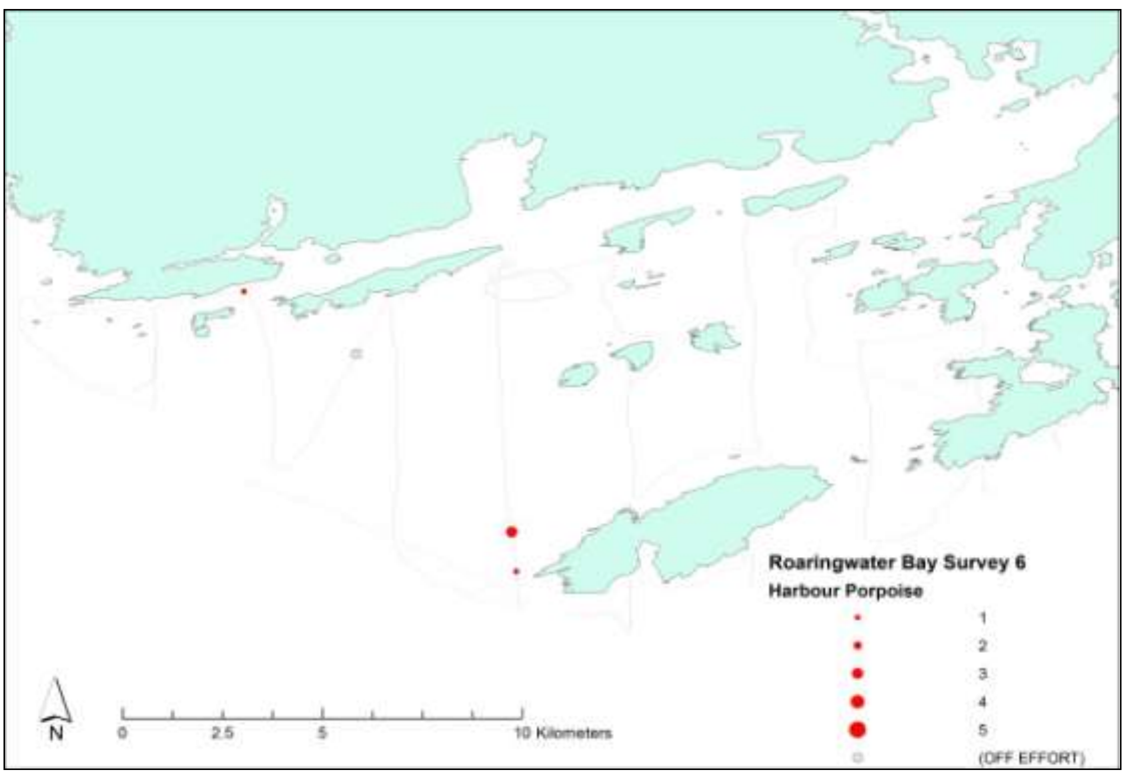


Figure 6a-f. Maps showing the locations of harbour porpoise sightings and corresponding group sizes recorded during each one-day survey of Roaringwater Bay and Islands SAC in 2013.

Density and abundance estimation

Density estimates for harbour porpoises within the SAC were calculated for the first three survey days conducted during July and August (Table 10) since too few porpoises were recorded during the latter three surveys in September and October. The detection functions for harbour porpoise during surveys 1-3 are shown graphically in Figure 7. Using the Chi-squared test good fits to the DISTANCE model were shown by the sightings data for surveys 1 and 3 but a poor fit was provided by the data from survey 2 (P=0.212; Table 10). This was probably due to the evasive reactions of porpoises to the survey vessel which saw a peak in sightings some 60-120m from the track-line (Fig. 7) and which could result in an underestimate of animal density. The DISTANCE model could be manipulated to account for this movement but this was not carried out in the current analysis.

Mean group (cluster) size was greatest in survey 3 (1.87) and lowest in survey 2 (1.39). The proportion of variability in the data accounted for by the detection probability was quite consistent for each survey with most of the variability attributed to this feature rather than group size. The increase in variability associated with group size in survey 3 was due to an increase and broader spread in group sizes recorded on this survey day.

Table 10. Model data used in the harbour porpoise abundance and density estimation process for each survey of Roaringwater Bay and Islands SAC. 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	Cluster
1	0.822	193.1	1.50±0.14	79.1	20.9
2	0.212	201.0	1.39±0.16	77.4	22.6
3	0.956	153.1	1.87±0.24	65.6	34.4
4	-	-	1.00	-	-
5	-	-	1.67	-	-
6	-	-	2.00	-	-
Overall	**0.942**	**183.5**	**1.62±0.09**	**76.3**	**23.7**

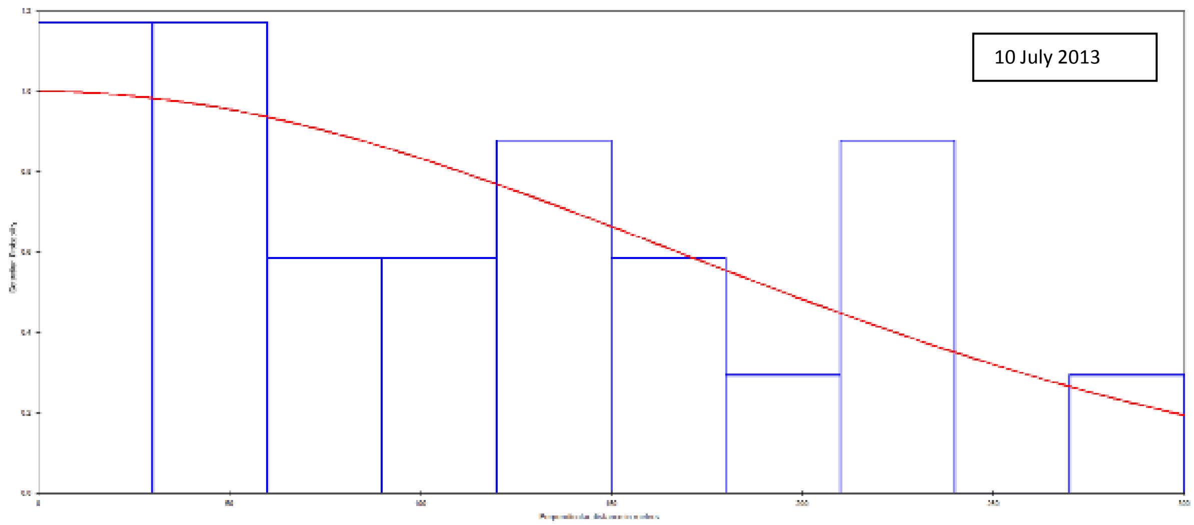
Density and abundance estimates for harbour porpoise in Roaringwater Bay and Islands SAC are shown in Table 11. The figures were quite consistent across all three survey replicates for which the data were sufficient to undergo distance sampling (i.e., survey samples 1-3). The highest density was recorded on survey 3 (28 August) with 2.61±0.64 porpoises per km^2. This produced an abundance estimate of 324±80 porpoises with 95% Confidence Intervals=196-533 porpoises. The lowest animal density of 1.86±0.40 porpoises per km^2 on survey 1 (10 July) resulted in an abundance estimate of 244±53 with 95% Confidence Intervals=158-377 porpoises.

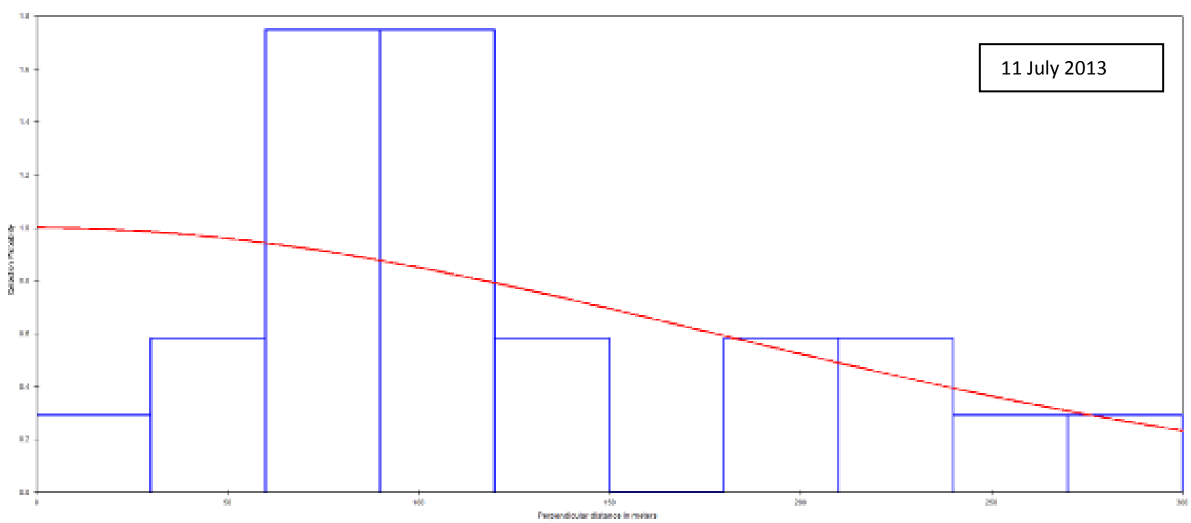
The overall pooled density estimate for all six survey days combined was 1.18±0.14 porpoises per km^2 (CV=0.12) delivering a corresponding abundance estimate of 151±18 harbour porpoises (95% CI = 119-192)**.** These figures were lower than those reported separately for the first three surveys; this is because the pooled estimates were strongly influenced by the last three surveys in late September and October during which comparatively few porpoise sightings were recorded within the SAC.

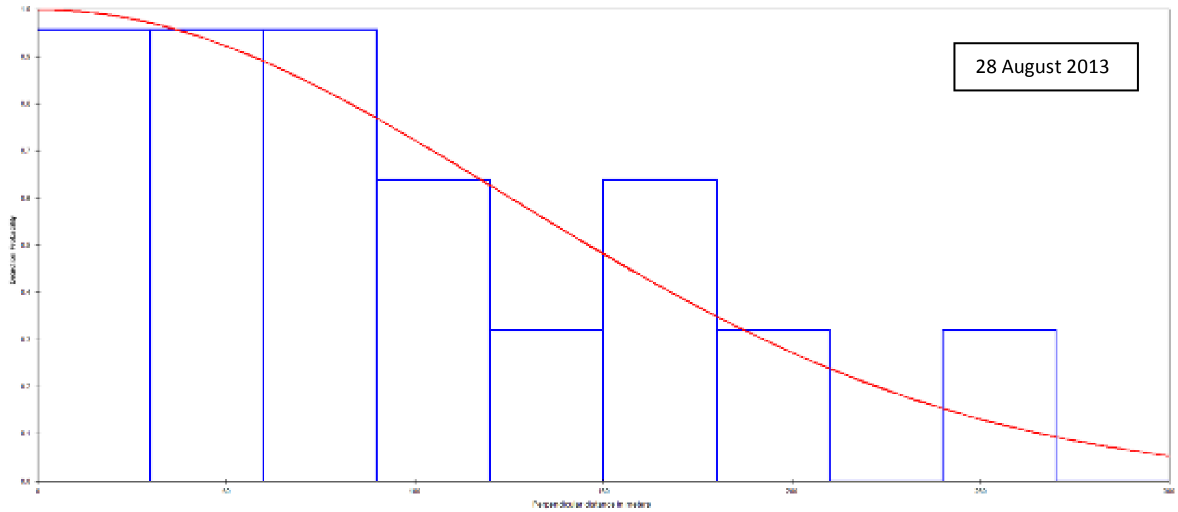
Table 11. Estimated density, abundance (N) and group sizes of harbour porpoise recorded during surveys of Roaringwater Bay and Islands SAC in 2013.

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Mean group size (95% CI)
1	238 (155-367)	50.9	0.21	1.86	1.50 (1.23-1.83)
2	244 (158-377)	52.7	0.22	1.97	1.39 (1.09-1.77)
3	324 (196-533)	79.9	0.25	2.61	1.87 (1.43-2.46)
Overall[1]	**151 (119-192)**	**18.3**	**0.12**	**1.18**	**1.56 (1.38-1.77)**

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







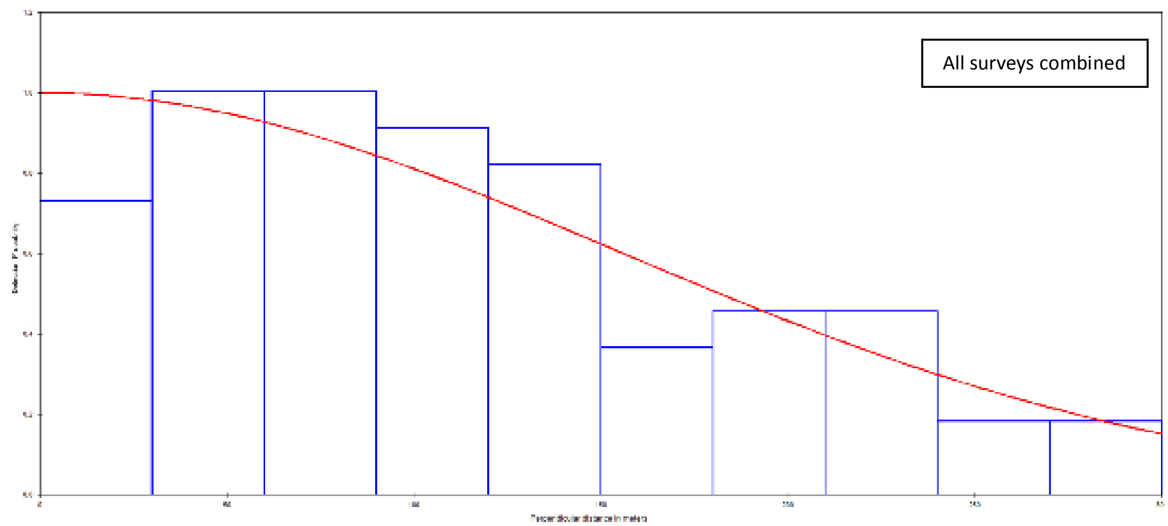


Figure 7. Detection function plots for each survey of harbour porpoises in Roaringwater Bay and Islands SAC.
(Note: There were insufficient sightings during the last three surveys to carry out the distance sampling analysis).

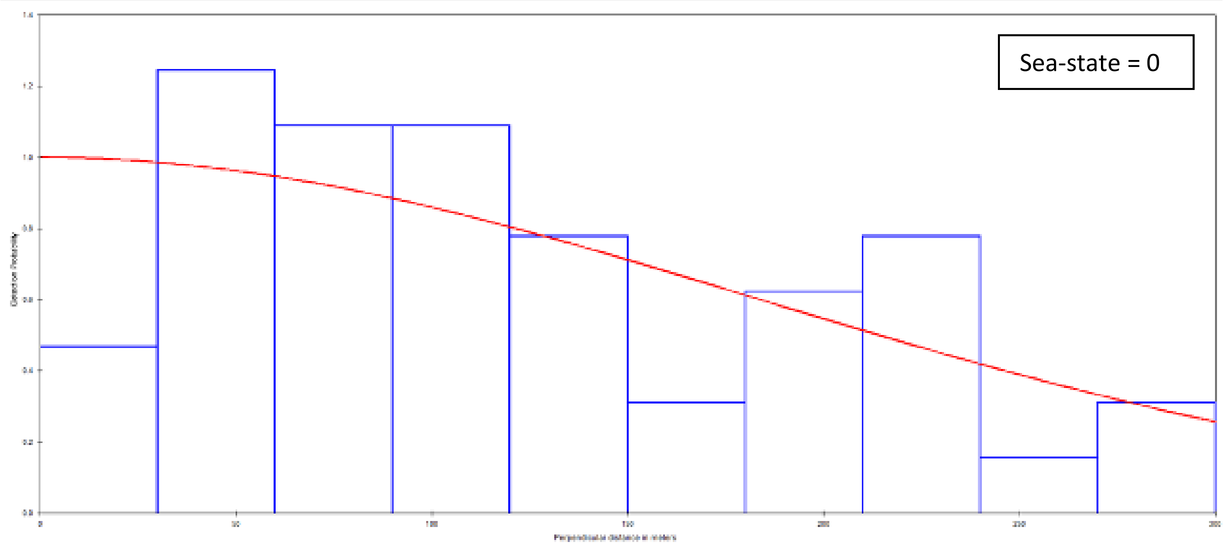
Density and abundance estimates in different sea-states

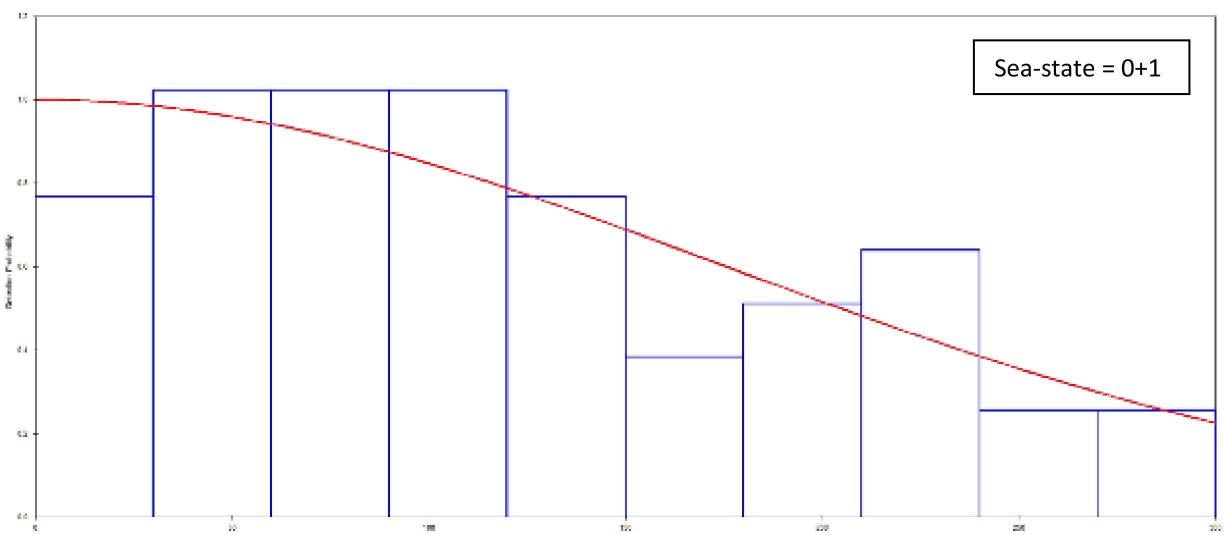
In order to explore the potential effect of sea-state on density estimates the data for surveys 1-3 were pooled and detection functions calculated for increasing sea-state (Table 12). Sightings in sea-state 0 were used to determine a detection function. Sightings in sea-state 0+1 and sightings in sea-state 0+1+2 were also then pooled as appropriate to determine the corresponding detection functions. 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 (2.06 porpoises per km^2) which may have been expected since these are normally perfect conditions for visual observation. However overall survey effort carried out in such conditions was quite low (i.e., c. 78km) and the CV for the estimate was also slightly higher (0.16) than that derived for the remaining two sea-state classes (Table 12). When sightings data for sea-state 0 and 1 were combined, the density estimate was similar to that for sea-states 0-2 (1.09 porpoises per km^2; Table 12) and the CV for the estimate was the lowest of all three classes, suggesting that it was appropriate to survey within Roaringwater Bay and Islands SAC in conditions up to and including sea-state 2.

Table 12. 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	77.89	0.60	1.50±0.11	2.06	0.32	0.16	256 (188-350)
0+1	204.67	0.96	1.50±0.10	0.97	0.14	0.14	120 (91-159)
0+1+2	247.03	0.91	1.55±0.10	1.09	0.14	0.13	136 (106-175)





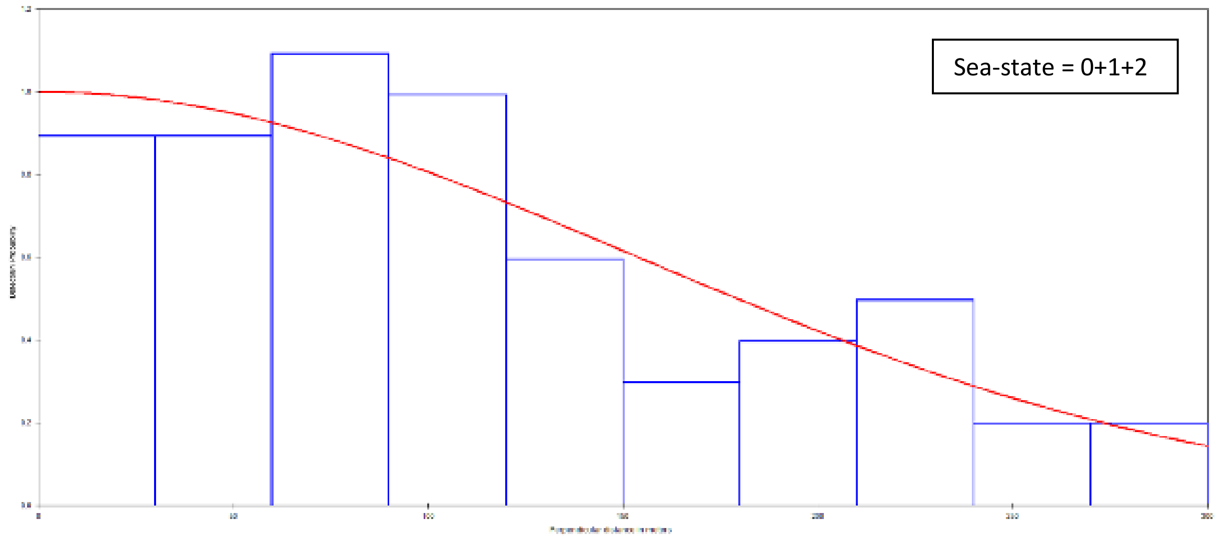


Figure 8. Detection function plots for harbour porpoise surveys of Roaringwater Bay and Islands SAC according to different sea-state classes.

<u>Proportion of young porpoises to adults</u>

The proportion of young porpoises and calves to all porpoises (including adults) was calculated for each survey within Roaringwater Bay and Islands SAC (Table 13). The proportion of young porpoises (juveniles and calves combined) recorded on survey days ranged from c. 9% to c. 15% on the first three surveys which had the majority of sighting records, and it was 13.1% overall. The observed proportion of calves to adults was significantly lower at 4% overall but reached a maximum of c. 9.1% on the first survey of the SAC (10 July; Table 13). Interestingly, the following day no calves were recorded during the survey even though the number of sightings and individuals were almost identical between both survey days.

Table 13. The numbers and/or proportions of adult harbour porpoises, juveniles and calves recorded during surveys in Roaringwater Bay and Islands SAC in 2013.

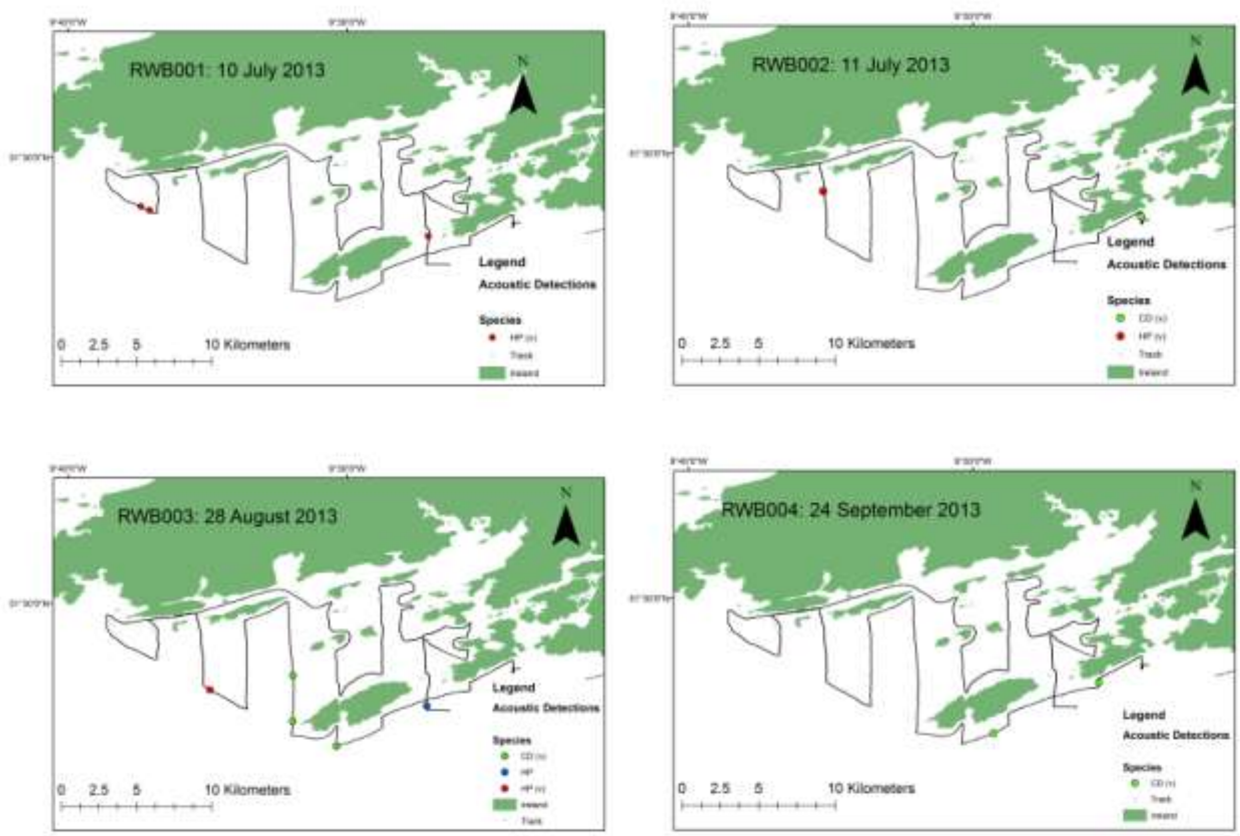
Survey	Number of sightings	Number of Individuals	Adults	Juveniles	Calves	% young	% calves
1	22	33	28	2	3	15.2	9.1
2	23	33	30	3	0	9.1	0.0
3	16	30	26	3	1	13.3	3.3
4	1	1	1	0	0	0.0	0.0
5	3	6	5	1	0	16.7	0.0
6	2	4	3	1	0	25.0	0.0
Overall	**67**	**107**	**93**	**10**	**4**	**13.1**	**3.7**

Acoustic Detections

A total of six full PAM surveys were carried out within Roaringwater Bay and Islands SAC in parallel with the visual survey effort and also during transits between track-lines (Fig. 9). A total of 14 acoustic detections were logged of which 43% were of harbour porpoise (6 detections, in comparison with 67 visual sightings) and 57% (8 detections) were of common dolphins (Table 15). On all but one occasion the acoustic detections were not accompanied by visual sightings within 10 minutes of the acoustic encounter.

Table 15. Summary of acoustic detections of small cetaceans recorded in Roaringwater Bay and Islands SAC in 2013.

Species	Clicks	Whistles	Total no. of detections	Detection duration min-max (secs)	Mean encounter duration (secs)	Detections/km
Harbour porpoise	Y	N	6	2-12	4.75	0.02
Dolphin spp.	Y	Y	8	180-2160	833	0.03



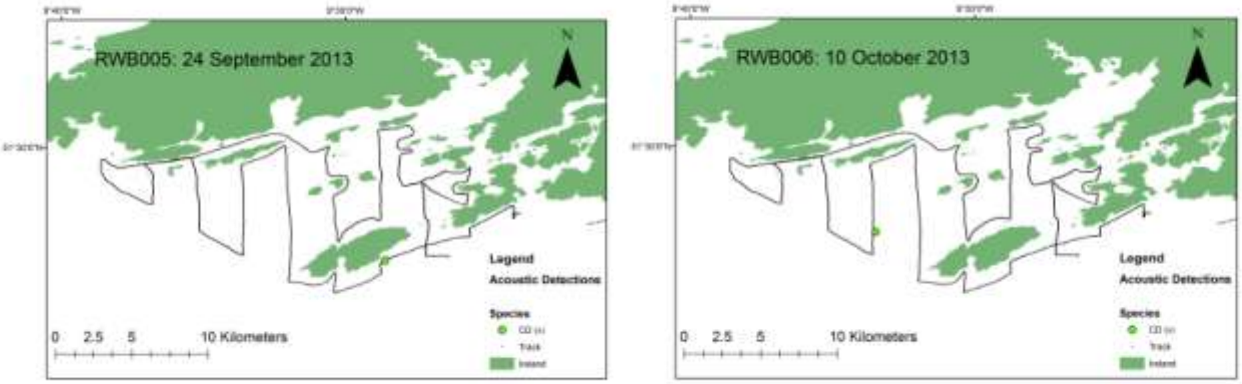


Figure 9a-f. Acoustic survey track-lines (solid line) and the locations of acoustic detections (circles) obtained during surveys in Roaringwater Bay and Islands SAC in 2013.

Additional sightings

Minke whales and short-beaked common dolphins (*Delphinus delphis*) were frequently recorded in Roaringwater Bay and Islands SAC during the survey period (Table 14; Fig. 10). Minke whales were abundant in July and August and absent in September and October, while common dolphins were present throughout the survey period from July to October. Both species were mainly recorded south of Cape Clear (Clear Island) and Sherkin Island and in the outer margins of Roaringwater Bay (Fig. 10). A total of six sunfish were recorded among three surveys within the survey period and they showed a similar distribution to the above cetaceans.

Table 14. Sighting records of additional species other than harbour porpoise that were recorded in Roaringwater Bay and Islands SAC in during surveys in 2013.

Species	Date	Total number of sightings	Total number of individuals	Comments
Common dolphin	10 July	1	1	
	11 July	1	10	
	28 August	4	27	
	24 September	2	13	
	10 October	4	20	
Unidentified dolphin	11 July	1	1	
Minke whale	10 July	2	2	off effort
	11 July	12	12	+ 2 off effort
	28 August	13	14	
Unidentified whale	10 October	1	1	
Sunfish	10 July	3	3	
	28 August	1	1	
	24 September	2	2	

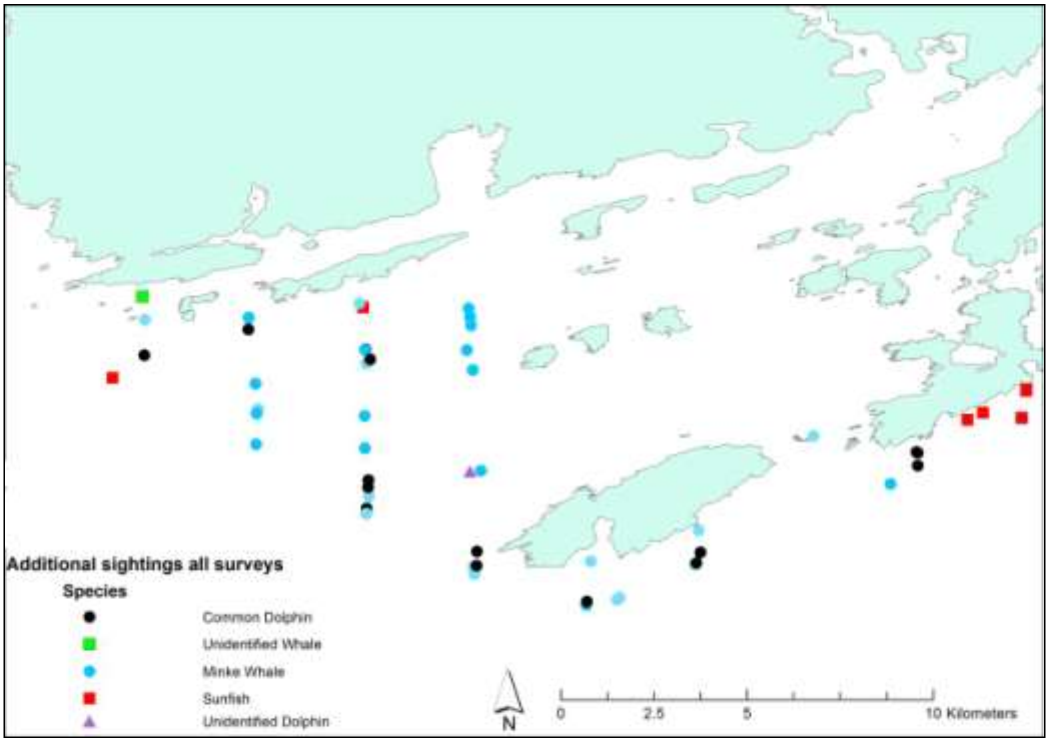


Figure 10. Sighting locations of several additional species in Roaringwater Bay and Islands SAC recorded during surveys in 2013.

Discussion

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. 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. 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) i.e., less than half of the animals on the track-line are detected. If this was the case with the present survey then we could perhaps double the density estimates at both study sites. Without a double-platform line-transect methodology it is not possible to accurately determine the number of porpoise detections missed on the track-line. The detection functions derived in the current analysis also suggest that there was some evasive movement from the survey boat which caused a poor fit to the DISTANCE model on a few occasions. Such factors will tend to lower the density estimates delivered via the modelling process. However these sources of variability were consistent throughout the 2013 survey. Furthermore the single-platform line-transect methods used in 2013 were consistent with those used by Berrow *et al.* (2007; 2008a; 2008b; 2010; 2012) and Ryan *et al.* (2011), which facilitates a comparison between these surveys. It should be remembered however that in the case of each SAC the 2013 randomised survey design was different to those used in previous surveys mentioned above.

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 commissioned to be carried out in sea-state 2 or less 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 obtained for each SAC when data collected in sea-state 2 were included, compared to using data collected only in sea-states 0 and 1. This finding supports the methodological decision to survey within these sites in conditions up to and including sea-state 2.

Acoustic monitoring is much less weather-dependent than visual monitoring, particularly for small species such as harbour porpoise. But as results from the current surveys have shown, PAM detections of harbour porpoise do not necessarily correlate with visual sightings. This is due to the limitations of towed PAM methods for this species. Harbour porpoises tend to avoid boats and larger motorised vessels. They echolocate at high frequencies (centre frequency = 130 kHz) and this energy attenuates quickly in the sea and is extremely directional. Consequently a PAM acoustic detection requires their narrow-band echolocation signal to reach the recording equipment over a distance less than 200m (approximately).

Where a PAM array is deployed behind a moving vessel and animals react to the oncoming vessel by moving away the likelihood of a positive detection decreases unless the animals maintain or shorten their position with respect to the vessel's track-line until they are within the detection range of the array. The data obtained during surveys in 2013 show that this rarely occurs. Since the harbour porpoise surveys carried out in 2013 took place in excellent sea conditions in order to facilitate visual observation, it is concluded that the use of a towed PAM array added little extra information to these surveys. In addition, towing a hydrophone array made manoeuvring around islands more difficult and increased the risk of damaging the array in areas of high vessel areas activity, as was experienced in Dublin Bay. The future use of static acoustic monitoring equipment such as CPODs throughout the survey area could provide a more useful acoustic dataset to inform on porpoise distribution and habitat use within such sites, and to facilitate the investigation of temporal/environmental variability and trends such as seasonal, diel and tidal influences.

Rockabill to Dalkey Island SAC

Within this site the number of sightings of harbour porpoise per survey was high and quite consistent, apart from the last survey in September. Porpoises were distributed throughout the survey area but there were large changes in distribution between surveys, with abundance higher in the northern section during the second half of the survey period. Harbour porpoise records from outer Dublin Bay also varied between surveys but were generally low compared to other areas. This initial observation in 2013 could be a consequence of heavy vessel traffic when ferries and cargo ships approach Dublin Port and Dun Laoghaire Ferry Terminal. Such activity might cause harbour porpoises, or indeed their prey resources, to alter their distribution during periods of higher vessel activity.

Harbour porpoise density estimates were previously generated for two Dublin sites and for Roaringwater Bay in 2008. A comparison of key results from these surveys and the present survey is provided in Table 16. "North County Dublin" was within the northern sector of Rockabill to Dalkey Island SAC and "Dublin Bay" was within the southern sector. Density estimates in North County Dublin in 2008 varied very considerably and the highest density of porpoises recorded at any site in Ireland so far was recorded in August 2008 (i.e., 6.93 porpoises per km^2). However other individual survey estimates during 2008 were much lower, so this single survey had a strong influence on the overall pooled density estimate of 2.03 animals per km^2. Densities in Dublin Bay in 2008 were also comparatively high with three surveys recording 1.49, 1.51 and 2.05 porpoises per km^2 respectively. However density recorded at this site was also as low as 0.48 porpoises per km^2 on one survey. These estimates gave an overall pooled density estimate of 1.19 porpoises per km^2 for Dublin Bay. If we take the average of the overall density estimates in 2008 for the two sites it equates to 1.61 which is quite similar to the 1.44 porpoises per km^2 from the present survey. The CV of the 2013 density estimate for Rockabill to Dalkey Island SAC was very low (CV=0.06) and considerably lower than those derived in 2008, indicating that the density/abundance estimation was robust and that the survey design and methods used within the site were effective. A previous wider-scale line-transect survey in the north Irish Sea, to the east and north of the current SAC, delivered a density estimate of

1.59±0.22 porpoises per km^2 (Berrow *et al.* 2011). This was also of a similar magnitude to that derived from surveys in 2013.

Table 16. Density, abundance and group size estimates for harbour porpoise within the two study sites in 2008 and 2013.

Location	Year	Area (km^2)	Mean group size	Density (per km^2)	Abundance ± SE (95% CI)	CV	Reference
Rockabill to Dalkey Island SAC	**2013**	**273**	**1.47**	**1.44**	**391±25 (344-445)**	**0.06**	**This survey**
North County Dublin	2008	104	1.41	2.03	211±47 (137-327)	0.23	Berrow *et al.* (2008a)
Dublin Bay	2008	116	1.19	1.19	138±33 (86-221)	0.24	Berrow *et al.* (2008a)
Roaringwater Bay and Islands SAC	**2013**	**143**	**1.56**	**1.18**	**151±18 (119-192)**	**0.12**	**This survey**
Roaringwater Bay and Islands SAC	2008	128	2.21	1.24	159±42 (95-689)	0.27	Berrow *et al.* (2008a)

Roaringwater Bay and Islands SAC

Roaringwater Bay and Islands Special Area of Conservation was designated a candidate SAC in 2000 with harbour porpoise as one of its qualifying features. An abundance estimate was carried out in 2008 via six line-transect surveys of the same area (Berrow *et al.* 2008a). A comparison of density and abundance estimates and associated statistics between 2008 and the present survey are shown in Table 16. The survey effort in 2008 was around one-third greater with a total of 330km of track-line surveyed compared to 240km in the present survey. However surveys in 2008 were carried out in sea-states ≤3 compared to sea-state ≤2 in the present survey. Although the line-transect designs were notably different in each case and the number of sightings per survey in 2008 was lower than in 2013, the total number of animals recorded visually was very similar (i.e., 110 in 2008 and 107 in 2013).

Harbour porpoises have historically been recorded off the south and south-west coasts of Ireland in comparatively high numbers but their occurrence appears to be quite variable. In recent years porpoises were recorded during a regional line-transect survey conducted off the south-west coast in the summer of 2010. Survey effort was mainly carried out in good sea conditions (i.e., sea-states 1 and 2) but the number of porpoise sightings was too low for use in any distance sampling analysis (Ryan *et al.* 2010). However, regarding Roaringwater Bay and Islands SAC, Berrow *et al.* (2008a) reported densities within individual surveys of 0.72, 2.13 and 2.70 porpoises per km^2. Density estimates during the first three surveys in 2013 were also comparatively high at 1.86, 1.97 and 2.61 porpoises per km^2. But the overall description of harbour porpoise density within this site was influenced downward by very low densities recorded during the last three surveys in 2013 (and one survey in 2008): overall pooled density estimates were very similar between years with 1.18 porpoises per km^2 in 2013 and 1.24 porpoises per km^2 in 2008, giving an approximate abundance estimate of 150-160 individuals. It is clear that harbour porpoise occurrence in Roaringwater Bay and Islands SAC can be greater than is described by the density estimates pooled from individual surveys conducted across several months.

There was also a notable difference in monthly occurrence of porpoises between 2008 and 2013. In 2008, abundance and group size increased in September while it declined dramatically in 2013. The highest number of sightings in 2008 was achieved in September with 23 sightings of a total of 58 animals giving a density estimate of 2.70 animals per km^2. Similarly a survey also in September provided a density estimate of 2.13. The highest estimates in 2013 were 2.61 and 1.97 animals per km^{2}which are quite similar. To achieve low CVs for harbour porpoise surveys there must be a sufficient number of sightings with which to undertake the distance sampling analysis. The CVs at both Roaringwater Bay and Islands SAC and off County Dublin in 2008 were over twice as high as those from the present study, indicating that the earlier estimates were not as robust as those from 2013.

Proportion of young to adult harbour porpoise

The proportion of young porpoises (both to juveniles and calves and just calves) within the two sites was presented above. At both sites there was great variation in this parameter between surveys, although when the number of sightings was high around 10-15% of all animals recorded were juveniles and 5-10% were calves. This was similar to similar surveys carried out at these sites in 2008 where young accounted for 6-8% of individuals in Dublin and 7% in Roaringwater Bay. Sonntag *et al*. (1999) suggested that the proportion of calves (9.6-17.9%) off the Isle of Sylt in Germany indicated that it was a preferred calving ground for harbour porpoise in the southern North Sea. Our proportions of adults to calves certainly show that both sites are important for calving but these proportions could be consistent around the whole Irish coast.

Acoustic Monitoring

PAM offered little to the Dublin surveys (low relative detection rate of 0.04 per km), except for two dolphin detections recorded on separate days in the absence of visual sightings to confirm species or group size. Whistles were detected for a duration of 5 minutes on 7 August and on the 27 August whistles were recorded for a total of 18 minutes. A sighting of "Dolphin species" was reported to the Irish Whale and Dolphin Group on 9 and 10 August off Howth Head but these sightings could also have been harbour porpoise (accessed from www.iwdg.ie). However, as the main aim of the survey was to estimate abundance of harbour porpoise, the data contribution from acoustic monitoring was very limited.

The Baily Lighthouse, Howth Head.

Dublin Bay.

Recommendations

Arising from the current study, the following recommendations are made for future harbour porpoise surveys:

1. The survey period should be extended to include June, to increase the number of days available to survey during favourable conditions (sea-state ≤2).

2. Harbour porpoise surveys should be carried out in sea-state ≤2 as per this survey.

3. Track-lines should be staggered each survey day to ensure full survey coverage of all available habitats within each SAC. By moving waypoints 1 km each day would ensure complete coverage of the site over the course of the six surveys

4. Track-lines running up to islands or shallow and submerged rocks at both sites pose great difficulties to the survey vessel, resulting in uneven coverage as differences in tidal states can make some areas not possible to survey. This should be taken into account when determining track-lines.

5. Passive Acoustic Monitoring does not provide much ancillary data to the visual dataset, therefore Static Acoustic Monitoring using C-PODs are considered a better option. As large monthly variations in visual detections were reported at both sites, SAM would provide high resolution temporal data to validate whether these large differences between months are consistent, or investigate environmental or other factors that might drive the presence of porpoises at these important sites.

6. Rockabill to Dalkey Island SAC is a large area with around 9-10 hours required to survey all track-lines. Day length can be a limiting factor when surveying into September at this site and this can becoming limiting towards the end of the month if surveys are required.

7. Ship traffic is considerable at times within Rockabill to Dalkey Island SAC, including passenger vessels and yachts. A traffic separation zone exists in the approaches to Dublin port which can compromise survey effort with track-lines shortened or survey vessel speed reduced to avoid these vessels.

8. Track-lines in Roaringwater Bay and Islands SAC should be reviewed as there is a considerable ship time used transiting between track-lines and individual survey effort (km per day) within the site was comparatively low (≈53km per survey).

9. Density estimates obtained in 2013 were consistent with and more accurate than those obtained in 2008. A power analysis of these datasets should be carried out to inform managers on the number of surveys (and sightings required) to determine changes in density and abundance at different resolutions.

10. These survey results provide very useful data on the use of these sites by harbour porpoise. More information could be obtained from the data, including habitat preferences, feeding area etc. with more analysis, especially if combined with datasets collected in 2008 at these sites.

11. These surveys should be repeated for a number of years to provide a measure of variability between years and to explore trends. Static acoustic monitoring could provide robust data on temporal patterns of use over a number of years with which to inform survey design for a density estimates. Clearly it will take a number of surveys to establish reference values for density and abundance from which to monitor population status.

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