Harbour porpoise surveys in the Blasket Islands SAC, 2014

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Executive Summary

A visual and acoustic survey of harbour porpoises (*Phocoena phocoena*) in the Blasket Islands SAC was carried out in 2014 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 between June and September 2014, 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 (i) day for three of the survey days as not enough sightings were achieved on the remaining days and (ii) using pooled survey effort and sightings information for those three surveys. The effect of seas-state on density estimates was also investigated.

Surveys were carried out in favourable weather on all six surveys (95%). However, during the fifth survey on 8 September, sea-state 3 persisted for 30% of the survey effort (31.3 km). This was attributed to strong tides at the time occurring in areas which experience strong currents.

A combined total of 592km of track-line effort was surveyed over the six surveys throughout the survey area. Sightings per survey ranged from 6 to 18 and from 6 to 57 individuals with a total of 68 sightings of 134 individual porpoises overall. Other species recorded included minke whale (43 sightings, 33% of total sightings) and common dolphin (18 sightings, 14% of total sightings). Harbour porpoise density estimates ranged from 0.59 animals per km^2 to 2.20 per km^2. The coefficient of variation around the estimates generated was quite high. Mean group size increased throughout the survey period from June to a peak on the last survey on 9 September. The proportion of young porpoises (juveniles and calves combined) to adults was 8.2% and the proportion of calves to adults was 2.2%. The overall pooled density estimate from all survey days combined was 0.64 porpoises per km^2 which gave an abundance estimate of 146±53 (95% Confidence Intervals [CI] = 41-516) with a CV of 0.36. The effect of sea-state on density estimates was investigated by running distance models on data derived from sea-state 0, seas-state 0+1 and sea-state 0+1+2. The highest density estimate of porpoises was collected in sea-state 0 (1.20 animals per km^2) and decreased considerably in increasing sea-states showing sea-state is an important factor when surveying harbor porpoise in the Blasket Islands SAC.

PAM was carried out during the six surveys resulting in a total of 28 harbour porpoise acoustic detections (in comparison to 68 visual sightings), with a detection rate of 0.05 detections per km. Of the 28 harbour porpoise detections, only five were simultaneous to visual sightings (18%). A total of nine acoustic detections of common dolphins were logged with four of these corresponding to simultaneous visual sightings (44.4%). On this occasion PAM did contribute additional information on porpoise presence outside of the visual dataset but does not add value to density estimation.

Density and abundance estimates generated during the 2014 survey were compared with previous surveys carried out in the same site during summers 2007 and 2008. Despite recording more sightings (68) during the present survey compared to 2007 (44) and 2008 (30), the density estimate during 2014 (0.64/km^2) was less than half of those estimates from 2007 (1.33/km^2) and 2008 (1.65/km^2). This was due to the greater length of track-line surveyed in 2014. Mean group size recorded during 2014 was greater than 2008 (1.76) and less than 2007 (2.32). Adult to calf ratios in 2014 were greater than 2007 but less than in 2008 but were similar to results from sites elsewhere. A strong seasonal shift in density occurred in 2014, with porpoise abundance increasing from the start of the survey in June, peaking in September.

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 habitat of harbour porpoises at the site during the summer months providing an acoustic monitoring index as well as validate seasonal changes. The Blasket Islands is a very dynamic and exposed site and favourable survey conditions are rare. During the period June to September 2014, there were only two days outside of the six days surveyed where sea conditions were suitable for harbour porpoise surveys. On one of these days a heavy fog persisted throughout which would not have permitted surveying and on the other day favourable conditions was not forecasted, making it not possible to mobilise a team in time. Therefore, to increase the chances of surveying in favourable conditions, we recommend that the survey period be extended to include all of June and September.

Tearaght Island during harbour porpoise surveys

Survey conditions in June 2014

Introduction

The harbour porpoise (*Phocoena phocoena*) is the most widespread and abundant cetacean species found 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 (Wall *et al.* 2013). The harbour porpoise is consistently one of the most frequently recorded species stranded on the Irish coast (O'Connell and Berrow 2012). Harbour porpoise are listed on Annex II of the EU Habitats Directive and thus Special Areas of Conservation are required in order to protect a representative range of the habitats for this species in the member state. These sites are designated as Special Areas of Conservation (SACs) and must be surveyed regularly to ensure favourable conservation status of the qualifying interest is achieved.

The first dedicated survey of harbour porpoises in Ireland, where abundance was estimated took place in the Celtic Sea in July 1994, as part of an international project called SCANS (Small Cetacean Abundance in the North Sea) (Hammond *et al.,* 2002). It was estimated that 36,289 porpoises were present. A repeat of this survey in July 2005 (SCANS-II) targeted all Irish waters including the Celtic and Irish Seas (Hammond *et al.* 2013). Harbour porpoise abundance estimates were generated for three areas, 1) Celtic Sea (80,613, CV=0.50), 2) Irish Sea (15,230, CV=0.35) and 3) 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. Between 1994 and 2005, harbour porpoise abundance estimates for the Celtic Sea doubled, and the authors suggested that part of the difference could be attributed to inter-annual variation in the spatial distribution of harbour porpoises with a shift from the northern North Sea to the southern North sea and into the Celtic Sea (Hammond *et al.* 2013).

Previous abundance estimates of harbour porpoise have been carried out in the Blasket Island SAC in 2007 and 2008 on contract to the National Parks and Wildlife Service (NPWS) (Berrow *et al.* 2007; 2008). Six single platform surveys were carried out at each site between July and October each year with density estimates calculated for each survey day and for all surveys combined (i.e. pooled estimates). In 2007, density estimates ranged from 0.71 to 3.39 porpoises per km^2, with the most robust estimate using all the data from each track-line combined, giving an estimate of 1.33 porpoises per km^2 resulting in an abundance of 303±76 (CV=0.25: (186-494)). In 2008, the overall density estimate at the site was 1.65 porpoises per km, equating to an abundance of 372±105.3 (CV=0.28; (216-647)). During previous surveys at the site, a strong seasonal increase in density was recorded from July through to September (Berrow *et al*. 2007; 2008).

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 Sturivant 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 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 was designated for the species in 2000. In order to contribute towards the Department of Arts, Heritage and the Gaeltacht's (DAHG) monitoring obligations, a set of visual and acoustic harbour porpoise surveys were carried out during the summer of 2014, the first since 2008. The objectives of the surveys were to:

i) derive updated summer density and population estimates for harbour porpoises within the Blasket Islands SAC using robust sampling methods for small cetacean density/population estimation;
ii) estimate associated Coefficients of Variation and 95% Confidence Intervals;

iii) collect ancillary information that is readily available during surveys concerning ecological/life history parameters of scientific interest (e.g., the presence of porpoise calves, estimated group sizes, behavioural ecology) and other marine mammal species;
iv) collect ancillary acoustic data using Passive Acoustic Monitoring (PAM).

Methods

Survey site and platform

The survey site and line-transect survey designs is shown in Figure 1. The area of the Blasket Island SAC is 227 km^2. Track-lines were provided by the DAHG and were chosen to provide equal coverage of the SAC.

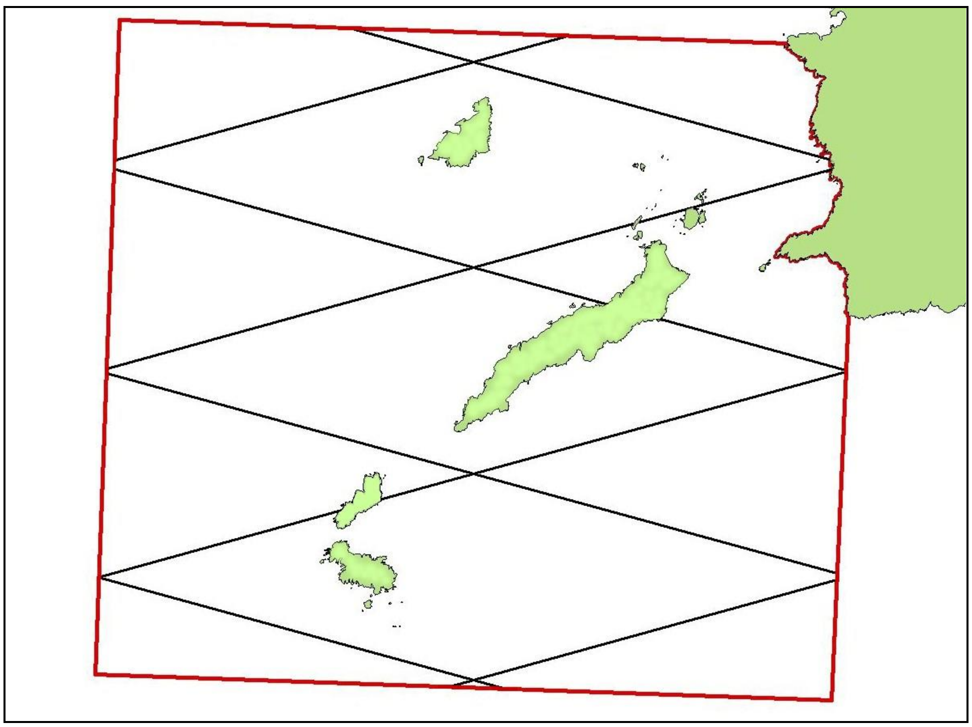


Figure 1. Blasket Islands SAC and track lines.

Fig. 2. MV An Blascaod Mór with flying bridge suitable for line-transects

Survey platform

The same vessel was used on each survey, the MV An Blascaod Mór, skippered by Mick Sheeran of Blasket Islands Marine Tours. The observation platform offered a height of 3.5m above the waterline (Fig 2).

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 visibility 6 km 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° to port or starboard depending on which side of the vessel they were stationed. All sightings were recorded but sightings more than 500m 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 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 0-30m, 30-60m up to 300m and 0-50m, 50-100m up to 500m 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. 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.

Mapping cetacean survey and encounter data

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 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 concurrent with visual surveys can add an extra dimension to the survey 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 detection and therefore increase the capacity of the survey. As part of this survey 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 250 kHz sampling rate. This allowed the detection and logging of acoustic encounters occurring within a 2-125 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

Six surveys were carried out in the Blasket Islands SAC between June and September 2014 (Table 1). Environmental conditions were favourable during all six surveys (Table 1).

Table 1: Overall environmental conditions during the surveys of Blasket Islands SAC 2014.

Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
17 June	0	16-20	5	S	1/8	No
18 June	0	16-20	1	S	1/8	No
24 June	0	16-20	0	S	2/8	No
28 August	1	6-10	0	S	3/8	No
8 September	0	6-10	2	W	8/8	No
9 September	<1	11-15	6	NW	7/8	No

A total of 592.2km of track line was sampled over 6 days from June to September (Table 2). Sightings per survey ranged from 6 to 18 and from 6 to 57 individuals with a total of 68 sightings of 134 individual porpoises overall. Most of this effort (94.7%) was carried out in sea-state 2 or less as per the DAHG requirements, with 31.3km of track-lines surveyed at sea-state 3 on one day (8 September).The proportion of effort (time) surveyed in different sea-states is shown in Table 2. At least 62% of the total survey effort was carried out in a sea-state 1 or less.

Table 2. Sea-state and on-effort sightings data for harbour porpoises recorded within the Blasket Islands SAC in 2014

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	17 June	99.8	12	72	16	0	8	10
2	18 June	100.1	18	38	44	0	6	6
3	24 June	98.5	82	18	0	0	19	28
4	23 August	96.5	39	30	32	0	18	27
5	8 September	68.4	0	0	69	31.4	3	6
6	9 September	97.6	14	52	35	0	14	57
Total		**560.1**					**68**	**134**

Harbour porpoises were evenly distributed throughout the track-lines with no obvious clusters (Fig's 3a-f). The survey was always started from south to north but 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.

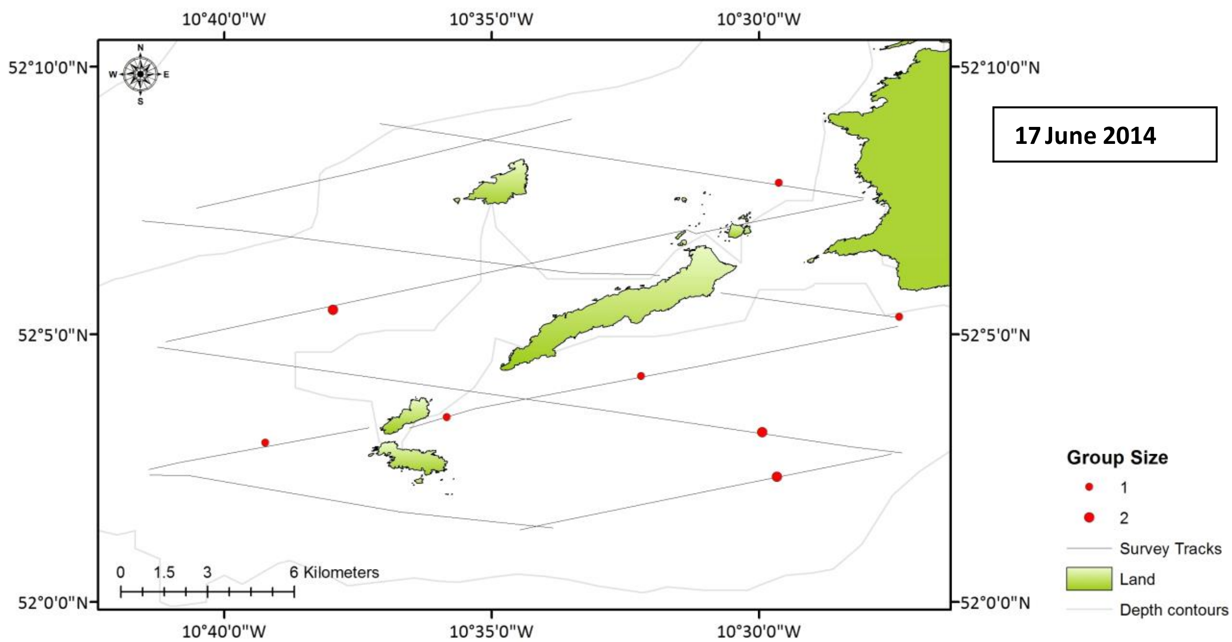


Figure 3a. Track-lines and distribution of harbour porpoise sightings on 17June, 2014

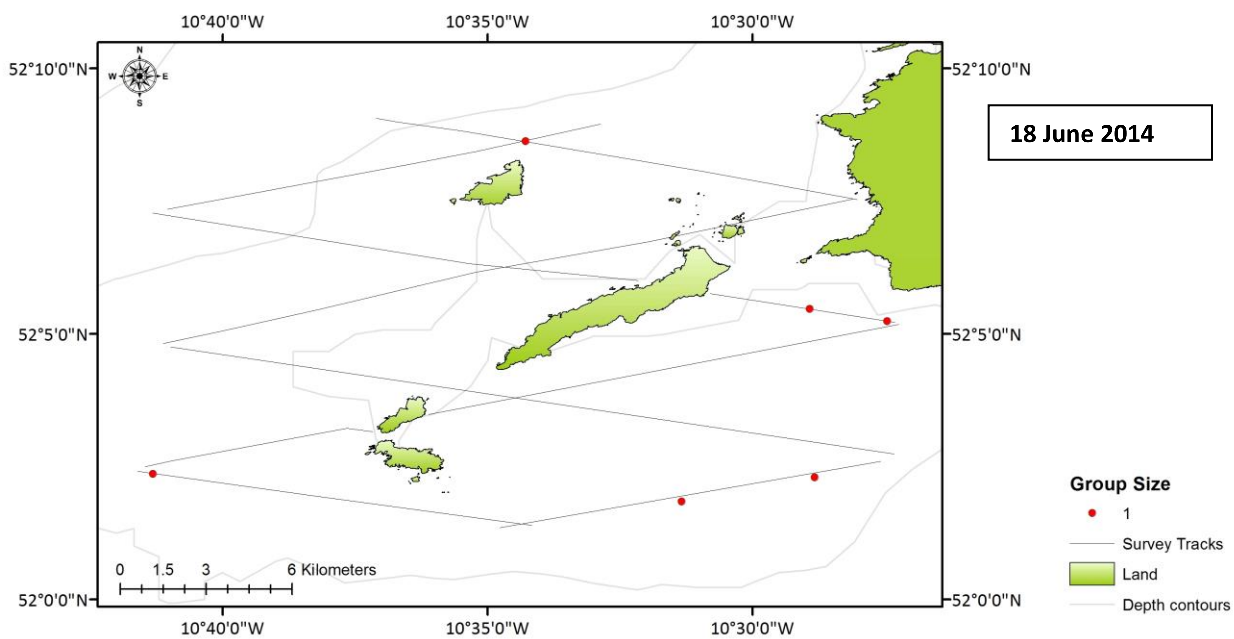


Figure 3b. Track-lines and distribution of harbour porpoise sightings on 18 June, 2014

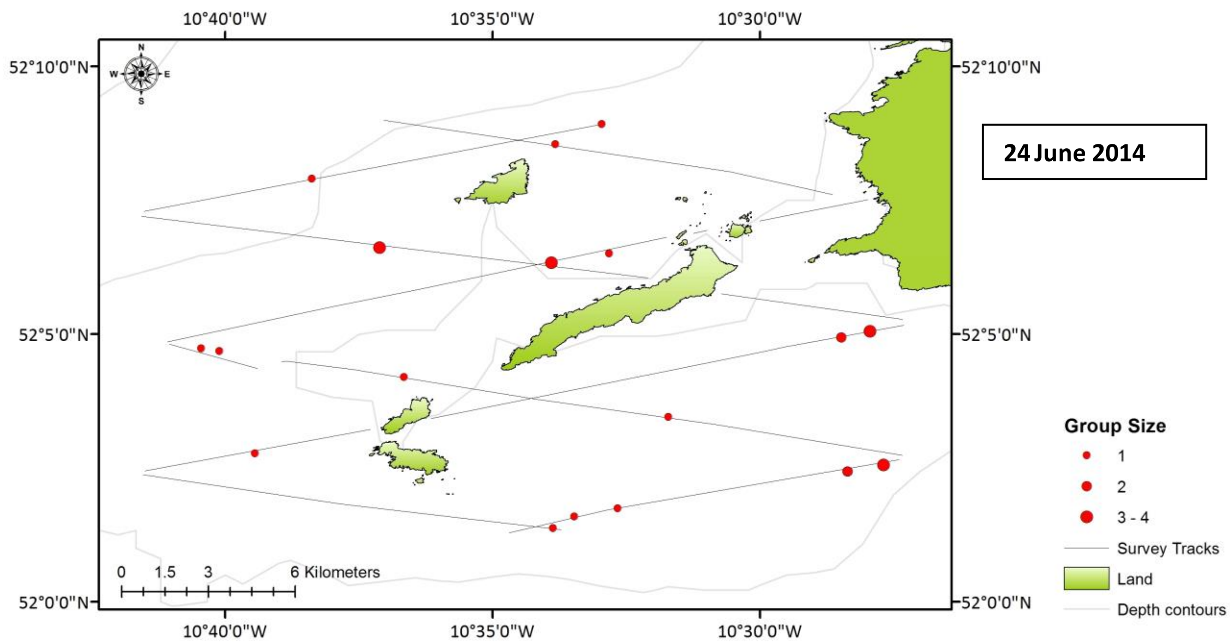


Figure 3c. Track-lines and distribution of harbour porpoise sightings on 24 June, 2014

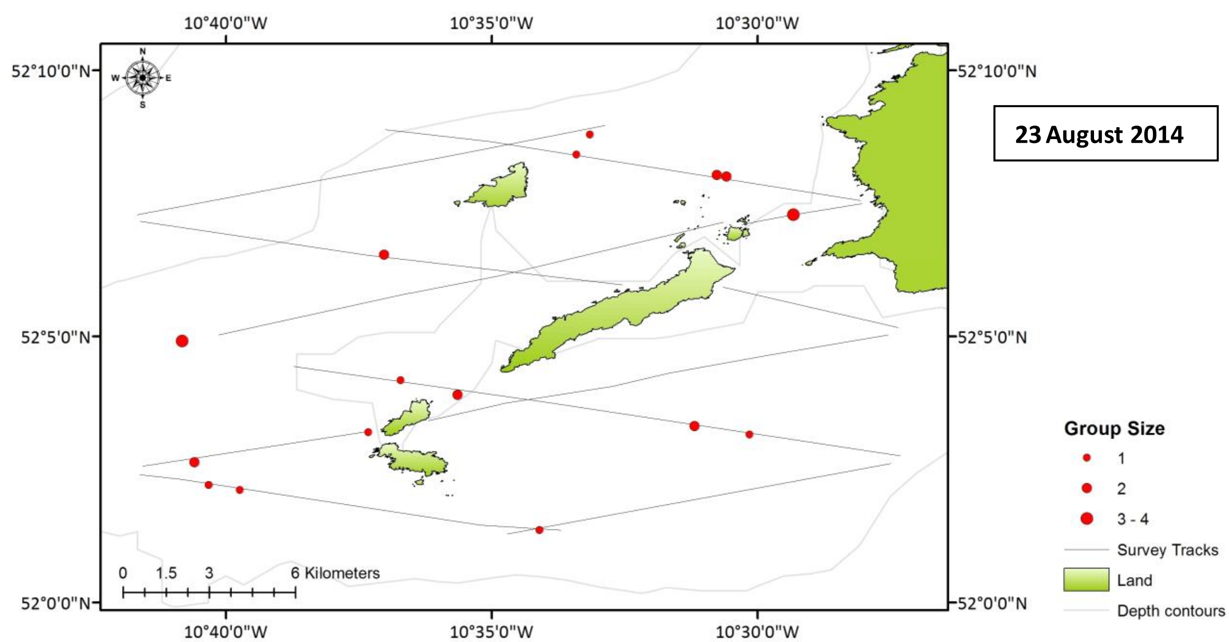


Figure 3d. Track-lines and distribution of harbour porpoise sightings on 23 August 2014

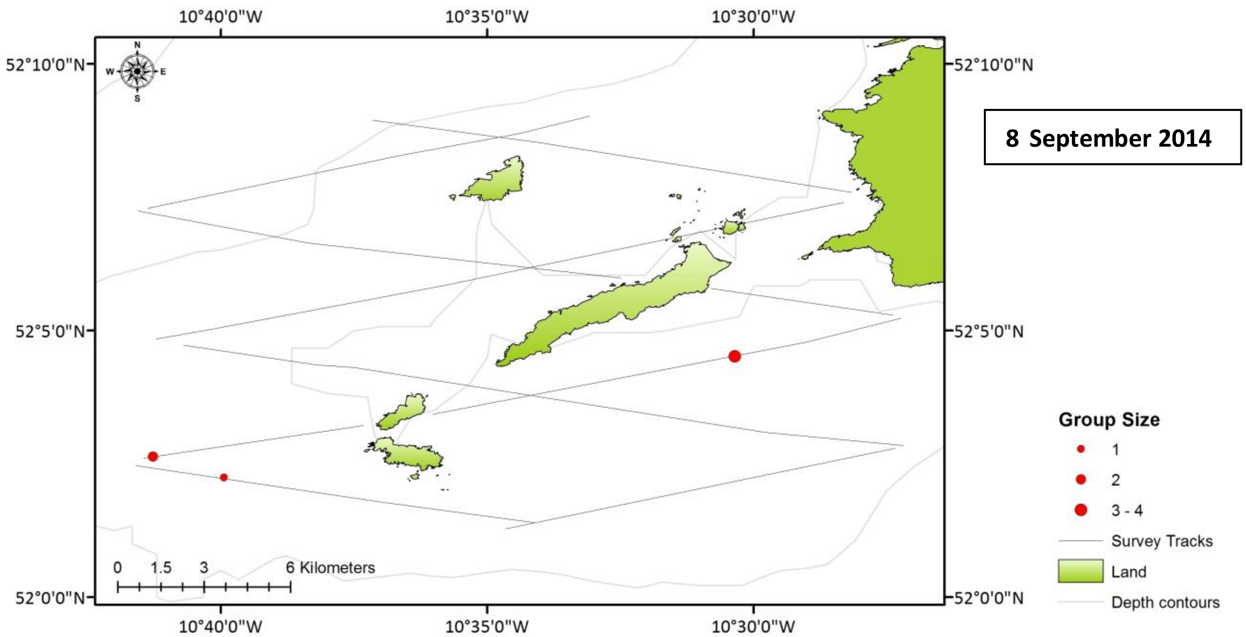


Figure 3e. Track-lines and distribution of harbour porpoise sightings on 8 September 2014

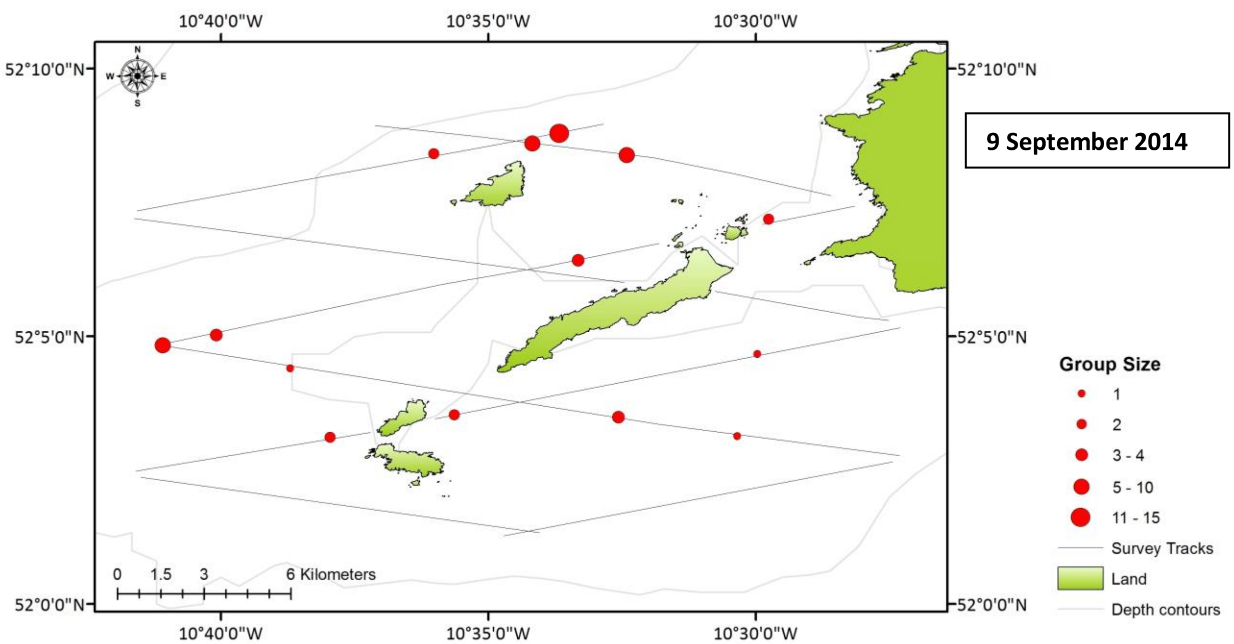


Figure 3f. Track-lines and distribution of harbour porpoise sightings on 9 September 2014

<u>Density and abundance estimation</u>

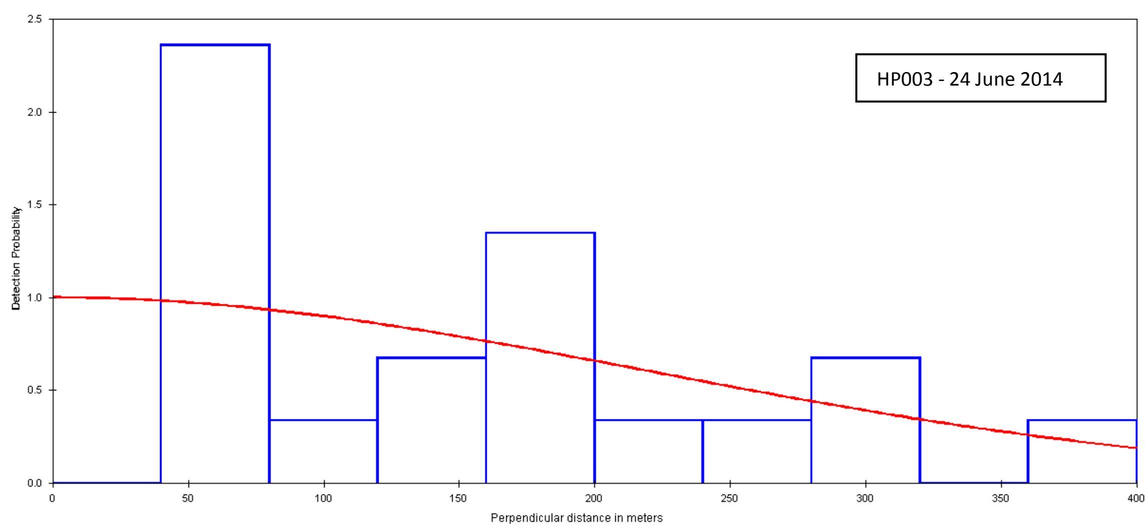
Density estimates for harbour porpoise within the SAC were calculated from sightings data obtained for three of the six survey days, during which enough sightings were recorded. All data from all six surveys for survey effort in sea-state ≤2 (i.e. omitting effort in sea-state 3) were combined into one sample (i.e. pooled density estimate) to provide an overall density. The sightings dataset for each analysis were truncated at 300m from the track-line for reach survey day. A summary of the data from the DISTANCE model is shown in Table 3 and the detection functions are shown graphically in Figure 4a-c and 5. Chi-squared values delivered by the model were not generally favourable with a P value of <0.05 for only one of the six surveys (Survey 3: Table 3). This suggests that the detection functions were not a good fit and the resulting estimates are to be treated with caution. Even the overall estimate returned a P value of 0.609. This was attributed to evasive movement of the porpoises before they were sighted resulting in a peak in sightings 50-100m from the track-line, and in the case of the survey on 24 August up to 150m from the track of the vessel.

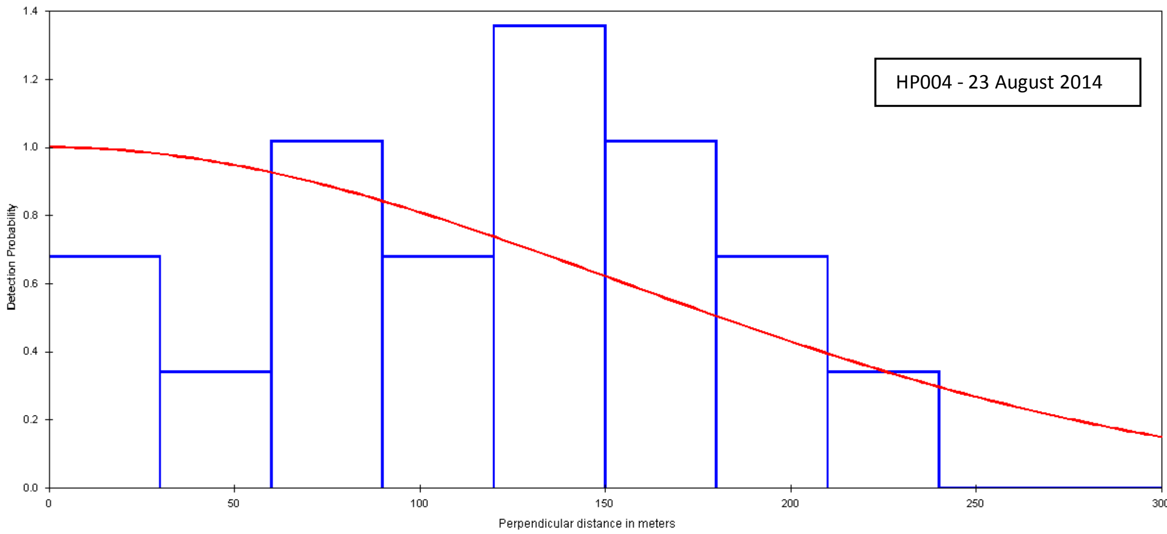
Table 3. Model data used in the harbour porpoise abundance and density estimation process for each survey of the Blasket Islands SAC.

Note: A half-normal model with cosine series adjustments and sightings data truncated at 300m.

Sample Day	Chi^2 P value	Effective Strip Width (m)	Mean Cluster Size ±SE	Variability (D)		
				Detection	Encounter	Cluster
1	0.643	-	1.50±0.19	-	-	-
2	0.671	-	1.00±0.00	-	-	-
3	0.056	256.1	1.63±0.22	69.9		30.1
4	0.456	183.1	1.55±0.17	78.6		21.4
5	-	-	2.00±0.58	-		-
6	0.582	168.1	4.81±1.25	44.6		55.4
OVERALL	**0.609**	**211.8**	**2.09±0.26**	**6.7**	**88.0**	**5.3**

The effective strip width ranged across sample days and was 212m for the overall estimate. Most variability was attributed to the encounter probability rather than cluster size although on the last survey (9 September) cluster size was variable with groups of 10 and 15 recorded. Usually group sizes tend to be consistently quite small (i.e., in single figures) for harbour porpoises and comparatively consistent in time. Mean cluster (group) size was quite consistent for surveys 3 and 4 but was much higher in survey 6 (Table 3).





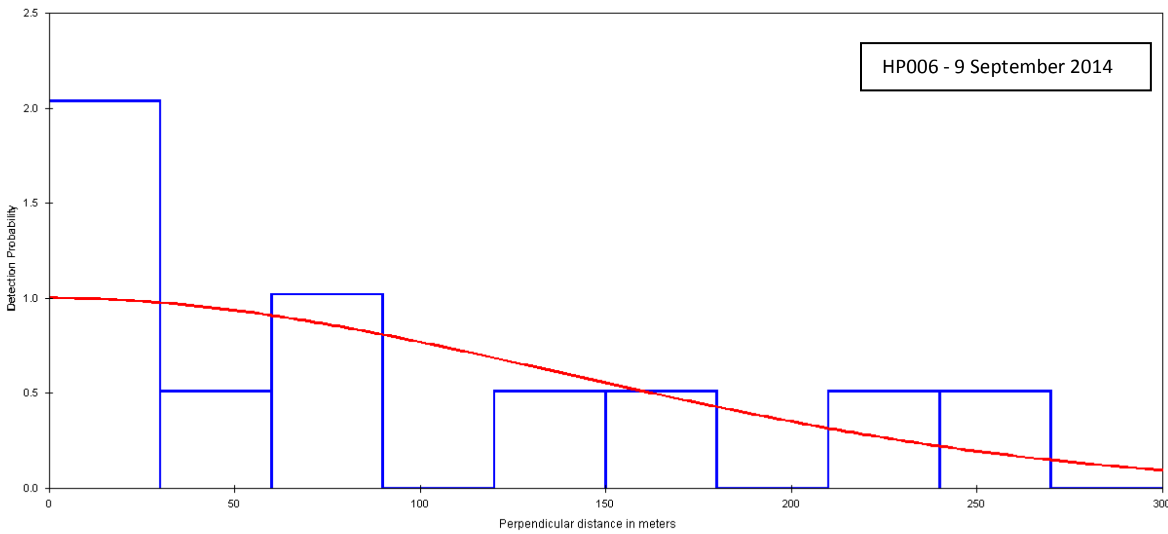


Figure 4a-c. Detection function plots for three surveys of harbour porpoises in the Blasket Islands SAC

Density and abundance estimates for harbour porpoise in the Blasket Islands SAC are shown in Table 4. Density estimates ranged from 0.59 animals per km^2 on 24 June to 2.20 per km^2 on 9 September. For three survey days no density estimates were calculated as the numbers of sightings were too few despite the same track-lines being surveyed in very favourable conditions. The coefficients of variation around the estimates were quite high with the lowest recorded at 0.23 for 24 August. Abundance estimates from each survey ranged from 133 to 499 porpoises (Table 4). Mean group size increased throughout the survey period from June to a peak on the last survey in September. The overall pooled density estimate from all survey days combined was 0.64 porpoises per km^2 which gave an abundance estimate of 146±53 (95% Confidence Intervals [CI] = 41-516) with a high CV (0.36).

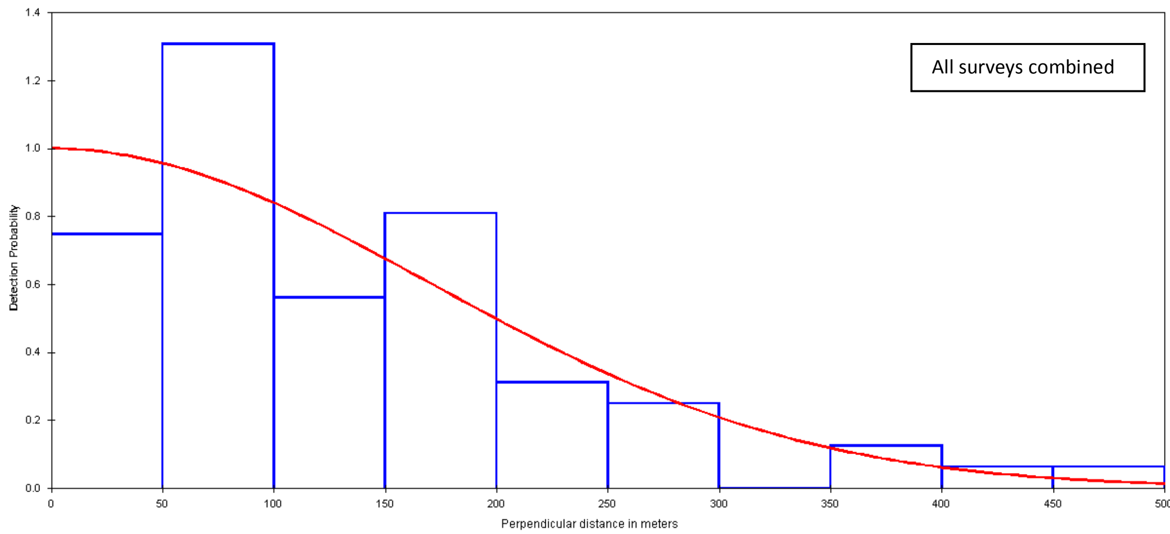


Figure 5. Detection function plot for all surveys of harbour porpoises in the Blasket Islands SAC combined

Table 4. Estimated density, abundance (N) and group sizes of harbour porpoise recorded during each survey in the Blasket Islands SAC in 2014

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Mean group size (95% CI)
1	-	-	-	-	-
2	-	-	-	-	-
3	133 (81-217)	33	0.24	0.59	1.63 (1.23-2.16)
4	232 (145-371)	53	0.23	1.02	1.56 (1.24-1.95)
5	-	-	-	-	-
6	499 (232-1072)	188	0.37	2.20	4.82 (2.72-8.53)
Overall[1]	**146 (41-516)**	**53**	**0.36**	**0.64**	**2.09 (1.63-2.67)**

[1] in sea-state ≤2

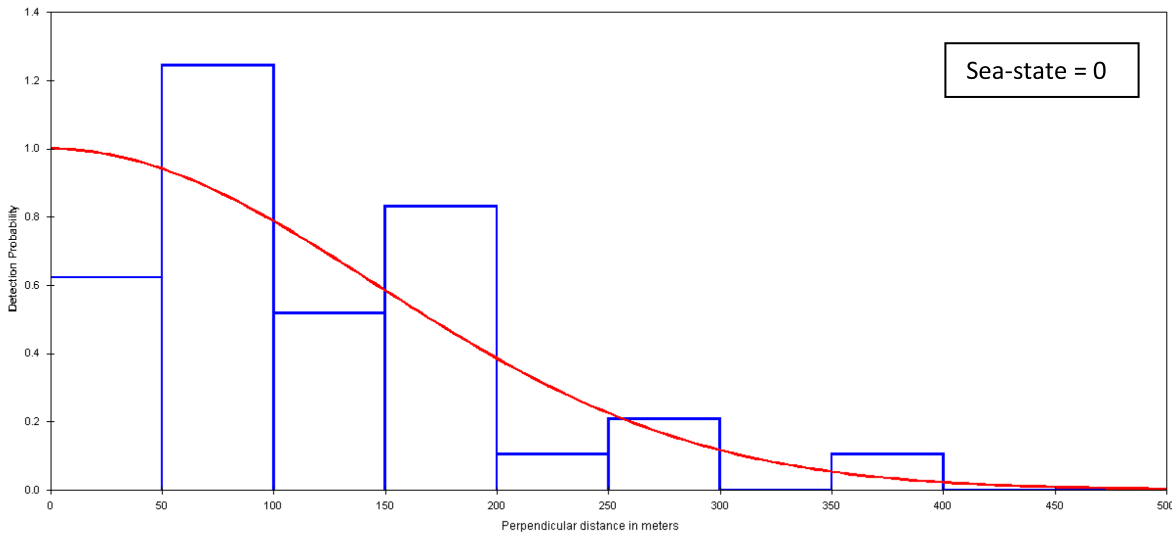
Density and abundance estimates in different sea-states

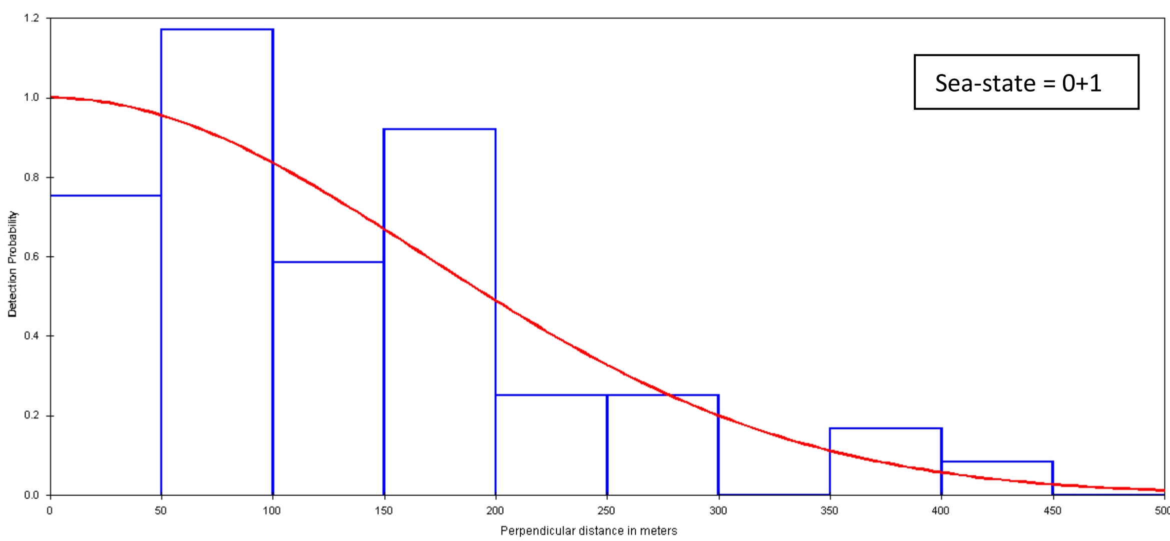
In order to determine whether sea-state had an influence on density estimates, all the data for all surveys were pooled and detection functions calculated for increasing sea-state (i.e. sea-state 0, sea-state 0+1 and sea-state 0+1+2). Total sighting effort (in km) was calculated for each sea-state class and used in the analysis. The model's best fit was generated from data collected in sea-state 0+1+2 (P=0.12) and sea-state 0 (P=0.14). The highest density estimate of porpoises was collected in sea-state 0 (1.20 animals per km^2).

Density estimates decreased considerably in increasing sea-states with 0.61 and 0.64 animals recorded per km^2 in sea-state 0+1 and 0+1+2 (Figure 6a-c). These data suggests that sea-state is an important factor when surveying harbor porpoise in the Blasket Islands SAC with declining sightings rate with increasing sea-state.

Table 5. Density, abundance (N) and group size estimates of harbour porpoise in the Blasket Islands SAC in 2014 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	161.2	0.14	1.89±0.41	1.20	0.20	0.17	273 (196-380)
0+1	367.8	0.38	1.82±0.29	0.61	0.33	0.54	138 (1-1707)
0+1+2	560.8	0.12	2.08±0.26	0.64	0.24	0.36	146 (41-516)





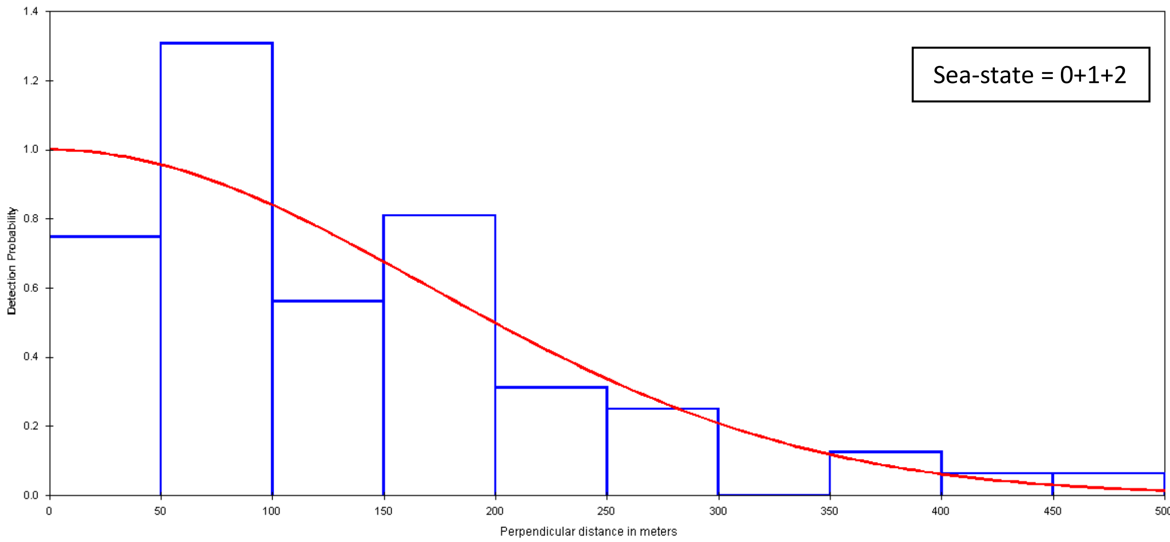


Figure 6a-c. Detection function plots for harbour porpoise surveys in the Blasket Islands SAC according to different sea-state classes

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. 7-16% of all animals seen and was c. 6% overall using the combined dataset. Three calves were recorded in total all on the one survey on 24 June and was c.2% overall using the combined dataset.

Table 6. The numbers and proportion of adult, juveniles and calves recorded during surveys in the Blasket Islands SAC in 2014

Survey	Number of Sightings	Number of Individuals	Adults	Juveniles	Calves	% young	% calves
1	8	10	10	0	0	0.0	0.0
2	6	6	6	0	0	0.0	0.0
3	18	28	25	0	3	10.7	10.7
4	18	27	27	0	0	0.0	0.0
5	3	6	5	1	0	16.7	0.0
6	14	57	53	4	0	7.0	0.0
Overall	**67**	**134**	**126**	**5**	**3**	**6.0**	**2.2**

Acoustic detections

A total of six PAM surveys were completed within the Blasket Islands SAC survey in parallel with the visual survey effort (Fig. 7a-f). Of 37 acoustic detections logged, 76% were of harbour porpoise (28 detections) and 7% (2 detections) of these had simultaneous visual sightings (Table 7; Figure 7a-f). Common dolphins were detected during 3 survey days (Aug and Sept), with a total of 9 acoustic events, where only four had corresponding visual verification at the time of detection.

Table 7. Summary of acoustic detections of small cetaceans recorded in the Blasket Islands SAC survey 2014

Species	Clicks	Whistles	Total no. of detections	Detection duration min-max (secs)	Mean encounter duration (secs)	Detections/km
Harbour porpoise	Y	N	28	10-630	135.9	0.05
Dolphin spp.	Y	Y	9	120-700	364.4	0.02

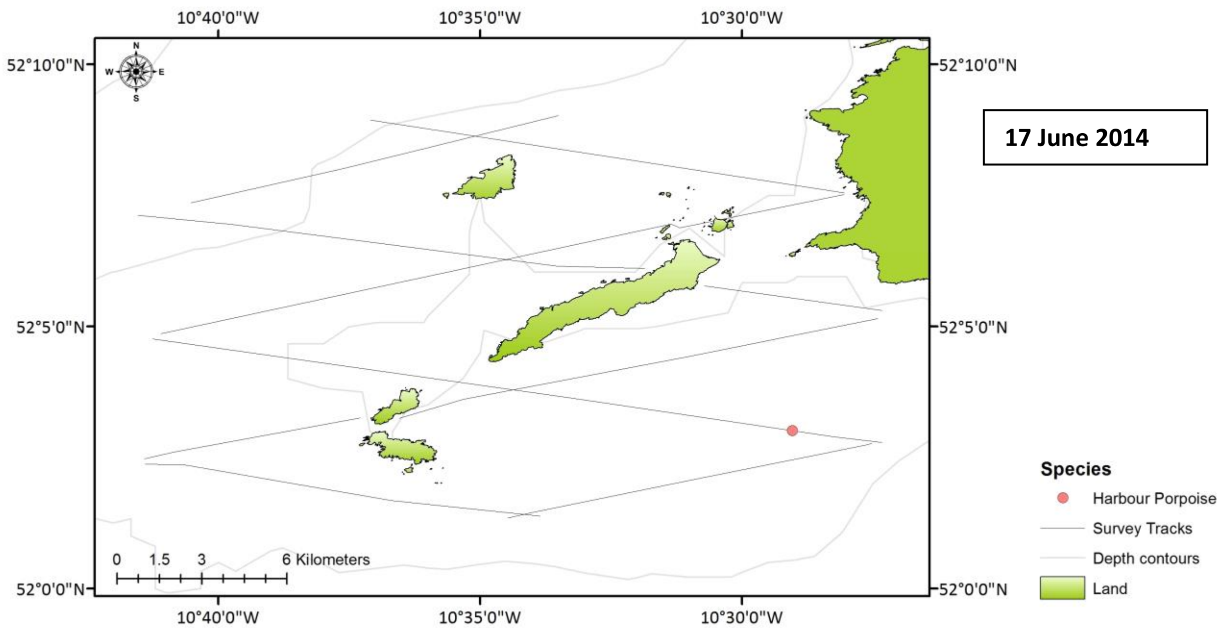


Figure 7a. Track-lines and distribution of acoustic detections on 17 June, 2014

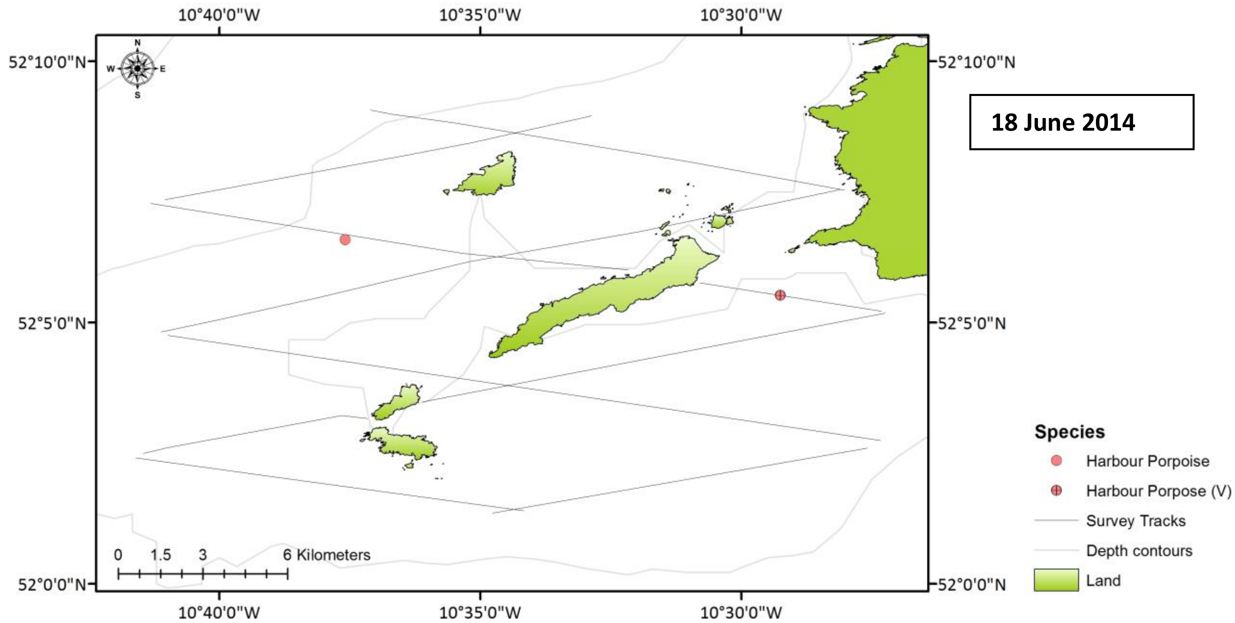


Figure 7b. Track-lines and distribution of acoustic detections on 18 June, 2014

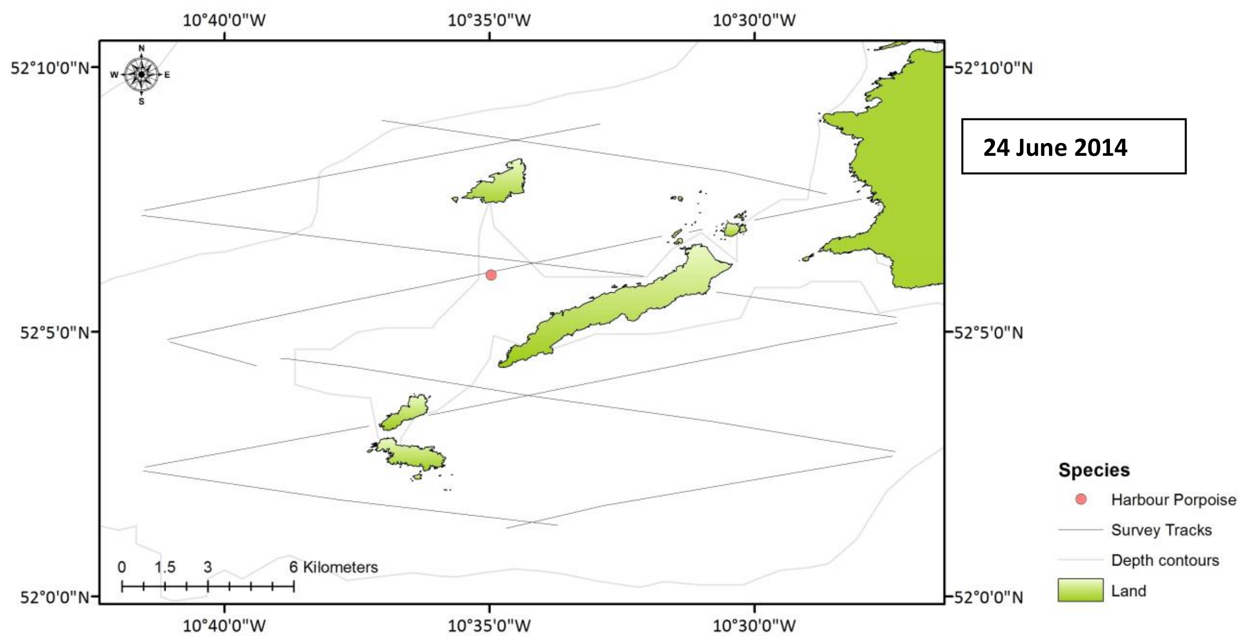


Figure 7c. Track-lines and distribution of acoustic detection on 24 June, 2014

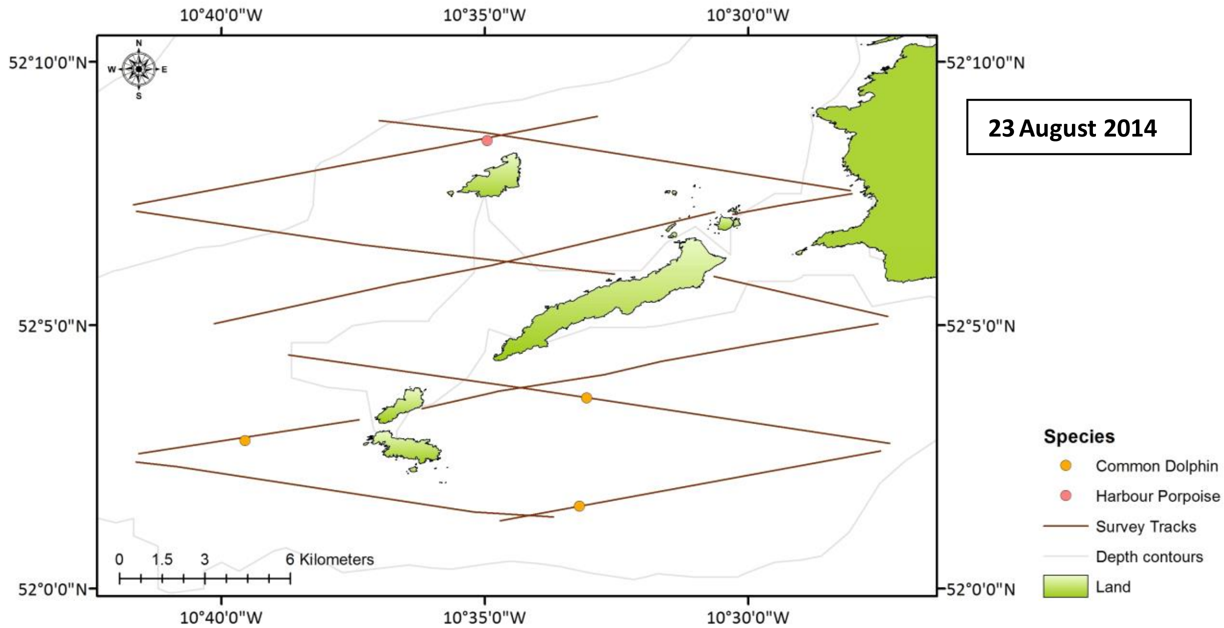


Figure 7d. Track-lines and distribution of acoustic detections on 24 August, 2014

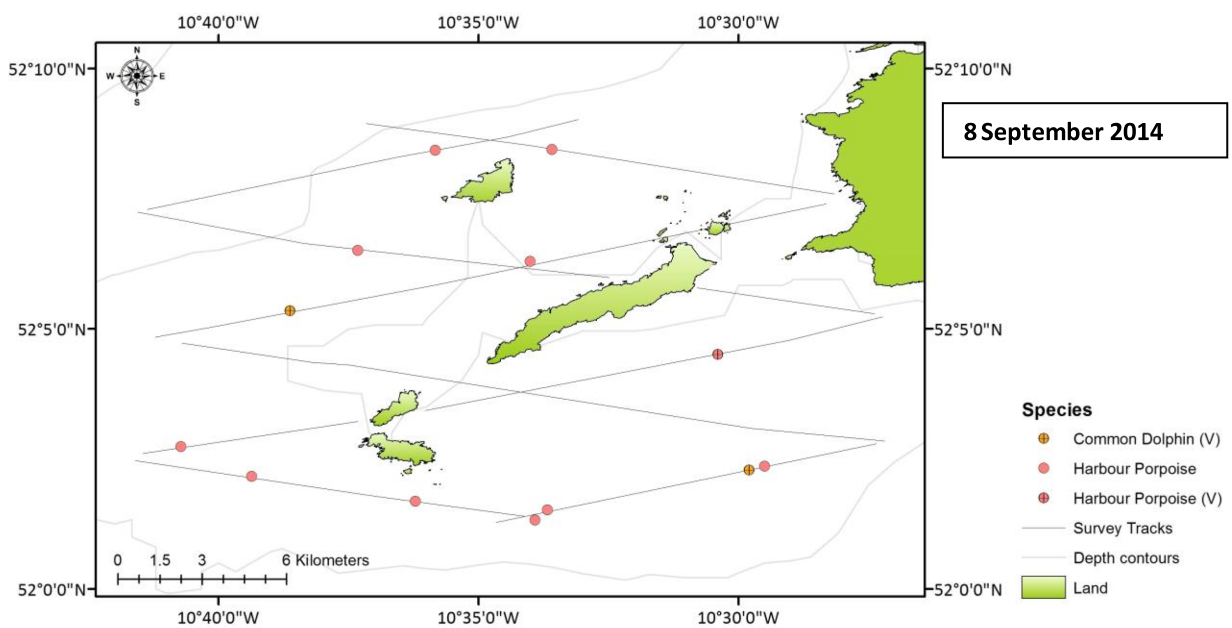


Figure 7e. Track-lines and distribution of acoustic detections on 8 September, 2014

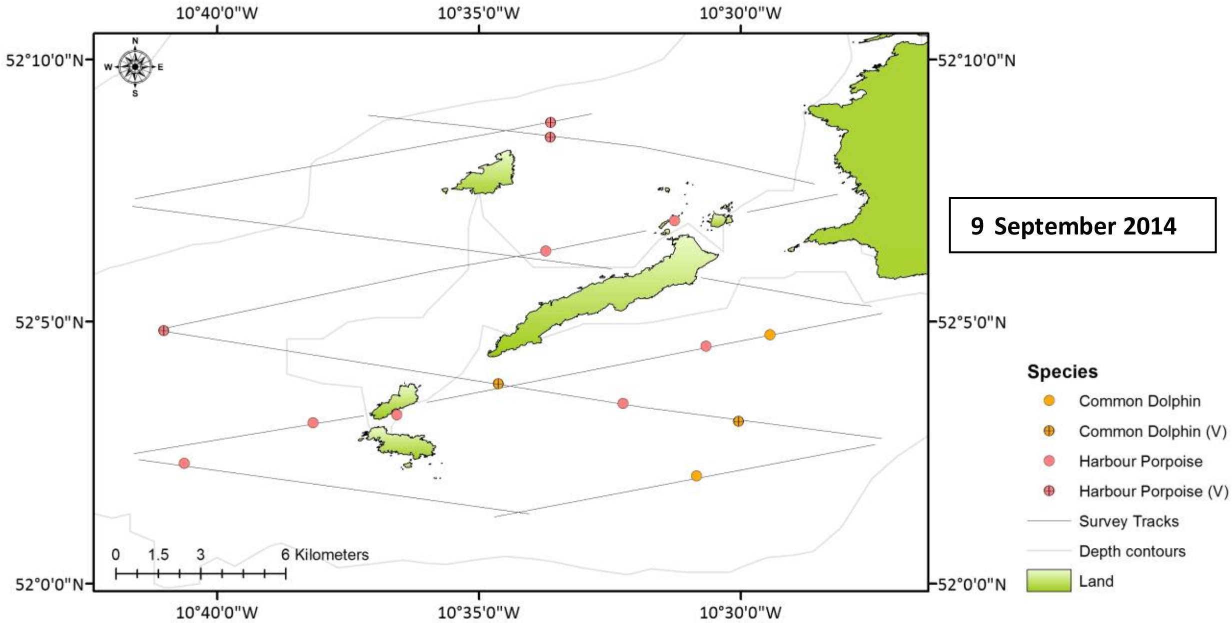


Figure 7f. Track-lines and distribution of acoustic detections on 9 September, 2014

<u>Additional sightings</u>

Other species recorded over the duration of the survey period included minke whale and common dolphins (Table 8). A number of unidentified cetaceans were also noted. Minke whale sightings were the second most abundant behind harbor porpoise, totaling 42 over the survey period. On one survey alone, a total of 15 sightings were recorded of 19 individuals. There were also 4 other cetacean sightings where species could not be verified and were therefore recorded at unidentified cetacean species.

Table 8. Summary of sighting of all other cetacean species during the Blasket Islands SAC survey 2014

Date	*Species*	*No. of sightings*	*Numbers*
17/06/2014	Minke whale	12	12
18/06/2014	Minke whale	5	5
24/06/2014	Minke whale	15	19
23/08/2014	Minke whale	7	7
23/08/2014	Common dolphin	10	107
23/08/2014	Unidentified cetacean	1	1
08/09/2014	Minke whale	2	2
08/09/2014	Common dolphin	2	4
08/09/2014	Unidentified cetacean	2	2
09/09/2014	Minke whale	1	1
09/09/2014	Common dolphin	5	79
09/09/2014	Unidentified cetacean	1	1
	TOTAL	**63**	**240**

A sufficient number of sightings of minke whales were made on two survey days in June to allow an estimate of density using DISTANCE. On 17 June where 11 sightings of single individuals were made the detection function was a reasonable fit (P=0.67) resulting in a density estimate of 0.31 minke whales per km^2. This equated to an abundance of 70 individuals (95% CI of 32-151) with a CV of 0.36. A second estimate on 24 June gave a density of 0.14 minke whales per km^2 following 17 sightings of single individuals (P=0.024) and a 95% confidence interval of 24-41 (CV=0.12). See Appendix II for full details including the detection functions. Most minke whale sightings were to the south of Great Blasket (Appendix I) compared to the northern half of the SAC, so densities here would be much greater compared to the SAC as a whole.

Discussion

Statistical interpretation 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).

The ability to visually detect harbour porpoise at sea is extremely dependent on sea-state. Therefore in order to derive accurate density and abundance estimates, surveys must be carried out in suitable weather conditions. During the present study, surveys were targeted towards days where low wind and little swell were predicted, i.e. sea-state 2 or less. Palka (1996) found that the sighting rates of harbour porpoise decreased by 20% from Beaufort 0 to 1 and by 75% from Beaufort 2-3. We have shown the differences in abundance estimates with sea-state can vary as much as 50% between sea-state 0-1 and sea-state 2. Harbour porpoise surveys should only be carried out in sea-state 0 or 1 to ensure all animals are detected and g(0)=1. However, this is rarely possible given the dynamic nature of sea conditions experienced off the Blasket Islands SAC. We were fortunate during 2014 to be able to carry out as many surveys as we did in relatively good sea-state, but the team found it difficult to fit in the six days surveying over the month month period. Constant weather watching and communication with the skipper on site is what facilitated the successful accomplishment of the six days.

Harbour Porpoise Surveys in the Blasket Islands

This is the third dedicated harbour porpoise survey to be carried out in the Blasket Islands SAC since 2007 making it the most thoroughly surveyed site for harbour porpoise in Ireland. The present harbour porpoise surveys were carried out in favourable conditions with 95% in sea-state <3 and 62% in sea-state 0-1. Sighting rates varied greatly between the six survey days ranging from only 3 sightings of a total of six individuals to 18 sightings of 28 individuals. The highest number of individual porpoises seen in one day was 57 on 9 September. Clearly harbour porpoises in the Blasket Islands SAC are highly mobile and move outside the boundaries of the SAC. This variability at the site between surveys was also noted by Berrow *et al.* (2009) who reported between 4 and 16 sightings and 8 and 36 individual porpoises recorded on six different survey days in 2007 and 5 and 19 sightings and 7 and 37 individuals in 2008 (Berrow *et al.* 2008). The total track lines surveyed each day during the present survey were greater c. 100km compared to 2007 and 2008 when between 60-80 km were surveyed per day. So although the 2014 results showed a greater number of overall sightings, the difference between survey days was still apparent.

The use of distance sampling and modelling to derive density and abundance estimates for harbour porpoises using a single platform has been discussed by Berrow *et al.* (2009; 2014). The assumptions that are made are sometimes violated in this methodology but they have been consistent between years. The track lines were evenly spaced during the present survey and surveyed consistently during each survey which was not the case in 2007 and 2008 but one assumption in distance sampling is 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. Given that track-lines provide good coverage of the SAC and a large number of sightings were included in the model this should not account for the differences in density estimates.

Another assumption is that objects on the track-line are always detected and are detected prior to any movement in response to the observer. Clearly there has been evasive movement away from the survey vessel prior to detection during the present survey but this is consistent with previous years. There was a great difference in the overall density estimate from 2014 compared to other years. Densities in 2007 and 2008 were very consistent at 1.33 and 1.65 animals per km^2. We report less than one-half these estimates at 0.64 animals per km^2 (Table 9).

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 required to be carried out in sea-state 2 or less but when the data were stratified by sea-state there was a large decrease in estimated densities in sea-states >0 compared to survey effort in sea-state 0. It is likely that the estimate in sea-state 0 is the most accurate as fewer porpoises would have been undetected. In most surveys, the total effort in this low sea-state is often too small to used to derive robust density estimates and thus effort from higher sea-states (≥1) are included. In the present survey we achieved good survey effort in sea-state 0 and thus the number of sightings (35) were high enough to put into the model and thus the detection function was a good fit (P=0.14); thus we can use this as the most accurate density estimate. At 1.20 animals per km^2 it is still a lower than reported in 2007 and 2008 which included data from sea-states up to 2 and even 3, thus the low density recorded during 2014 is considered to reflect lower densities of harbour porpoises occurred in the Blasket Islands SAC during 2014 compared to previous surveys, rather than being an artefact of different survey design.

Table 9. Density, abundance and group size estimates for harbour porpoise in the Blasket Islands SAC

Year	Mean group size	% young	Density (per km^2)	Abundance ± SE (95% CI)	CV	Reference
2007	2.32	2	1.33	303±76 (186-494)	0.25	Berrow *et al.* (2009)
2008	1.76	18	1.65	372±105 (216-647)	0.28	Berrow *et al.* (2014)
2014	2.09	6	0.64	146±53 (41-516)	0.36	This survey

Large group sizes of 10 and 15 individuals recorded on the last survey on 9 September had a strong influence on the overall density estimate by increasing mean group size but also contributed to the high CV (0.37) and large confidence intervals. Density estimates though low did increase throughout the survey period which was also noted by Berrow *et al.* (2009) who reported densities of over 3.3 porpoises per km^2 during two surveys in September and October 2007. O'Brien *et al.* (2013) using static acoustic monitoring devices showed a strong seasonal component in harbour porpoise detections from the Blasket Islands with peaks during the summer and winter months, suggesting this is a real phenomenon.

Comparing results from the present study with previous abundance estimates generated for the Blasket Islands SAC in 2007 and 2008, shows that estimates have reduced considerably (Table 10). In 2007 and 2008, values were more similar, whilst there is a drop of almost 50% for values obtained in 2014. It must be noted that the survey design was revised for the 2014 session, where a predefined track was devised at the beginning of the survey and repeated on all 6 surveys between June and September. Previous to this, during the 2007 and 2008 surveys, a different set of random track lines were covered during each of the 6 surveys. This same predefined design was adopted in Roaringwater Bay in 2013, but when results from this survey are compared with the random track-line sampling from 2008, there are little differences in abundance and density estimates. The survey carried out from Rockabill to Dalkey Island SAC in 2013, was similar in 2008 but split into two sections, however results between the two years are similar. This suggests that the reductions in the Blaskets SAC estimates for 2014 are unlikely due to survey design but actually reflect a true decrease in abundance.

The total size of Irelands three harbour porpoise SACs, the Blasket Islands is bigger in size than Roaringwater Bay but smaller than the east coast SAC. The values for the % of young recorded here over the years are similar to the other two sites. The most obvious differences from Table 10 are the dramatic decreases in density and abundance estimates at the Blaskets site in 2014, such a dramatic decrease has not been recorded at any other site. However the CV of the 2014 pooled density estimate (0.36) was the highest such coefficient of variation generated from any porpoise SAC monitoring undertaken to date (Table 10), reflecting significant variability in the porpoise data recorded between individual survey days (Figs. 4a-c, Table 6) in spite of a standardised design and survey protocol, and an experienced survey team. In addition only two previous abundance/density estimates exist from the other SACs (i.e., Roaringwater Bay and Islands, Rockbill to Dalkey Island). Therefore appropriate caution must be taken around such 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 to be recorded and to establish whether their estimates are consistent, increase or decrease over time.

Table 10. Abundance estimates of harbour porpoises within SACs across Ireland.

Location	Year	Area	Mean group size	%	Density	Abundance ± SE	CV	Reference
		(km^2)		young	(per km^2)	(95% CI)		
Rockabill to Dalkey Islands	2013	271	1.47	5	1.44	391±25 (344-445)	0.09	Berrow and O'Brien (2013)
North County Dublin	2008	104	1.41	8	2.03	211±47 (137-327)	0.23	Berrow *et al.* (2008)
Dublin Bay	2008	116	1.19	6	1.19	138±33 (86-221)	0.24	Berrow *et al.* (2008)
Roaringwater Bay and Islands	2013	128	1.56	13	1.18	151±18 (119-192)	0.12	Berrow and O'Brien (2013)
Roaringwater Bay and Islands	2008	128	2.21	7	1.24	159±42 (95-689)	0.27	Berrow *et al.* (2008)
Blasket Islands SAC	2007	227	2.32	2	1.33	303±76 (186-494)	0.25	Berrow *et al.* (2009)
Blasket Islands SAC	2008	227	1.76	18	1.65	372±105 (216-647)	0.28	Berrow *et al.* (2008)
Blasket Islands SAC	**2014**	**227**	**2.09**	**6**	**0.64**	**146±53 (41-516)**	**0.36**	**This survey**

Proportion of young to adult harbour porpoise

The proportion of young porpoises (both to juveniles and calves and just calves) within the Blasket Islands SAC varied between years but the figure of 6% from the present survey is consistent with sites surveyed in 2008 where young accounted for 6-8% of individuals in Dublin Bay and 7% in Roaringwater Bay and Islands SAC (Berrow *et al.* 2008a; 2008b).

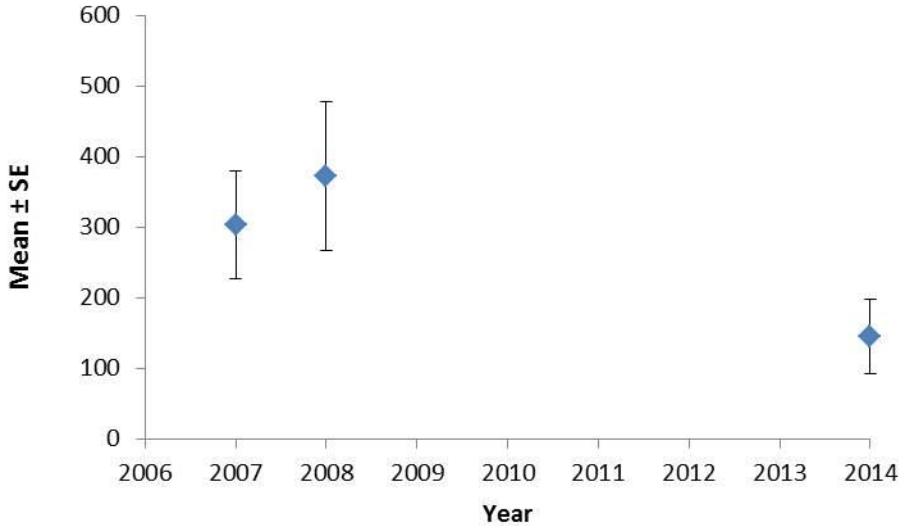


Figure 8. Harbour porpoise mean abundance estimates from 2007 to 2014 in the Blaskets Islands SAC

Acoustic Monitoring

Detections from the passive acoustic monitoring added value to the 2014 dataset, especially during the two surveys in September. This could be attributed to the evasive reaction detected by the porpoises in the visual dataset. It is likely the animals move out of the track of the oncoming vessel but remain in the area and hence we detected them on the hydrophone which was towed 200m behind the vessel. However the detections rates per km are very low 0.05 for harbour porpoise and 0.02 for common dolphin. As the number of detections between surveys were not consistent, it is difficult to establish a way to derive meaningful information from the PAM dataset. It could be used to show missed sightings on the track-line and additionally to verify an evasive movement which could lead to false negatives in the visual dataset, but this was not the case across all surveys as we had no detections in the presence of many visual sightings. Of the 28 harbour porpoise detections, only 18% had corresponding visual sightings, while of the 9 common dolphin detections 44.4% had simultaneous visual sightings. We would expect the opposite scenario as dolphin whistles have a longer detection range than harbour porpoise clicks and therefore it would be more likely to have porpoise detections corresponding to visual sightings.

A more useful method of monitoring at the site over the survey duration would be the use of Static Acoustic Monitoring (SAM). This would contribute more to our understanding of site usage over the entire period as data could be gathered 24/7. Large SAM datasets already exist for the Blasket Islands (O'Brien *et al*. 2013) so it would be more beneficial and cost effective to employ this method in the future.

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 all of June, through to end of September with the possibility of extending into October in order to increase the number of days available to survey during favourable conditions (sea-state ≤2).

2. Density estimates obtained in 2014 were significantly different to those obtained in 2007 and 2008, but the distance and layout of track-lines have changed dramatically since then. It is recommended to keep one or other format and consistently use that method for future surveys.

3. These surveys should be repeated for a number of years to provide a measure of variability between years and to explore trends. The replacement of PAM with SAM would provide robust data on spatial and temporal patterns which could inform survey design for density estimates. Present results compared with previous show that it will take a number of surveys or years to establish reference values for density and abundance from which to monitor population status at the site.

4. Due to the small area of the SAC relative to the range of highly mobile harbour porpoise, 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 overlying to seasonal changes. A power analysis on the current datasets should be carried out to explore how long it would take to measure changes in population given the within year variability.

5. Given the variability in density estimates from distance sampling, consideration should be given to developing acoustic indices from which to monitor population status. It is likely that acoustic datasets when put into appropriate models are likely to be able to identify changes at higher resolution than visual surveys.

Acknowledgements

We would like to thank Mick Sheeran once again for his commitment and good humour to get these harbour porpoise surveys completed in the best possible conditions. This survey was funded by the Department of Arts, Heritage and the Gaeltacht and we thank Dr Oliver O'Cadhla and Dr Ferdia Marnell for their support throughout.

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Appendix 1: Additional species recorded during the 2014 Blasket Island Surveys

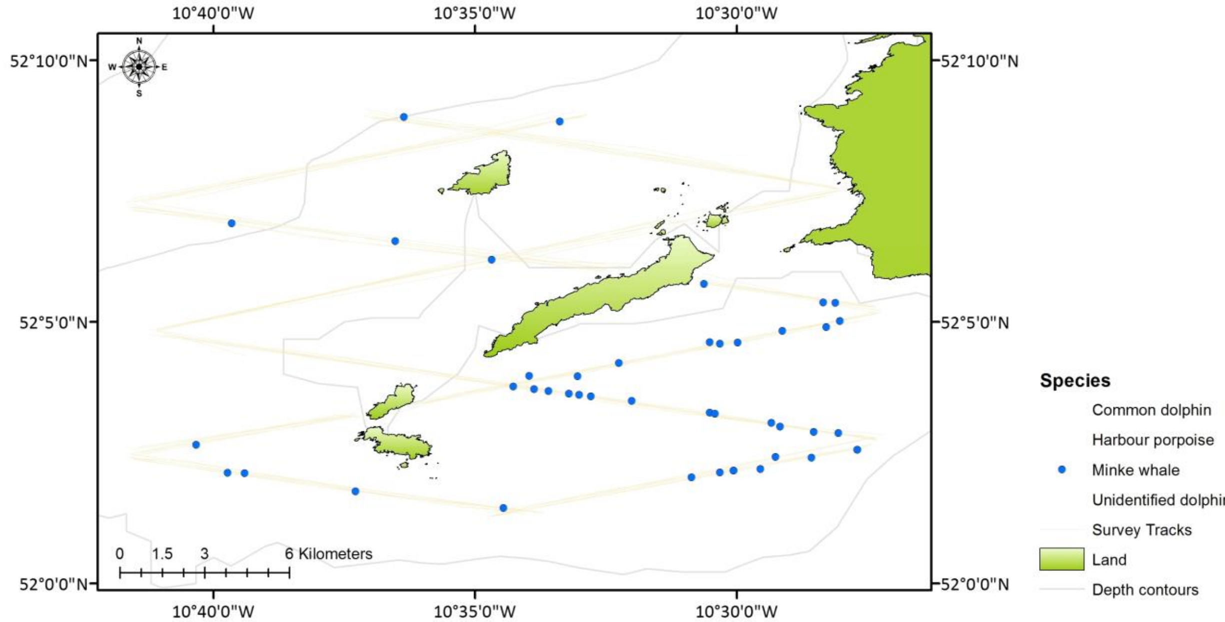

Figure 8. Minke whale sightings recorded during all surveys

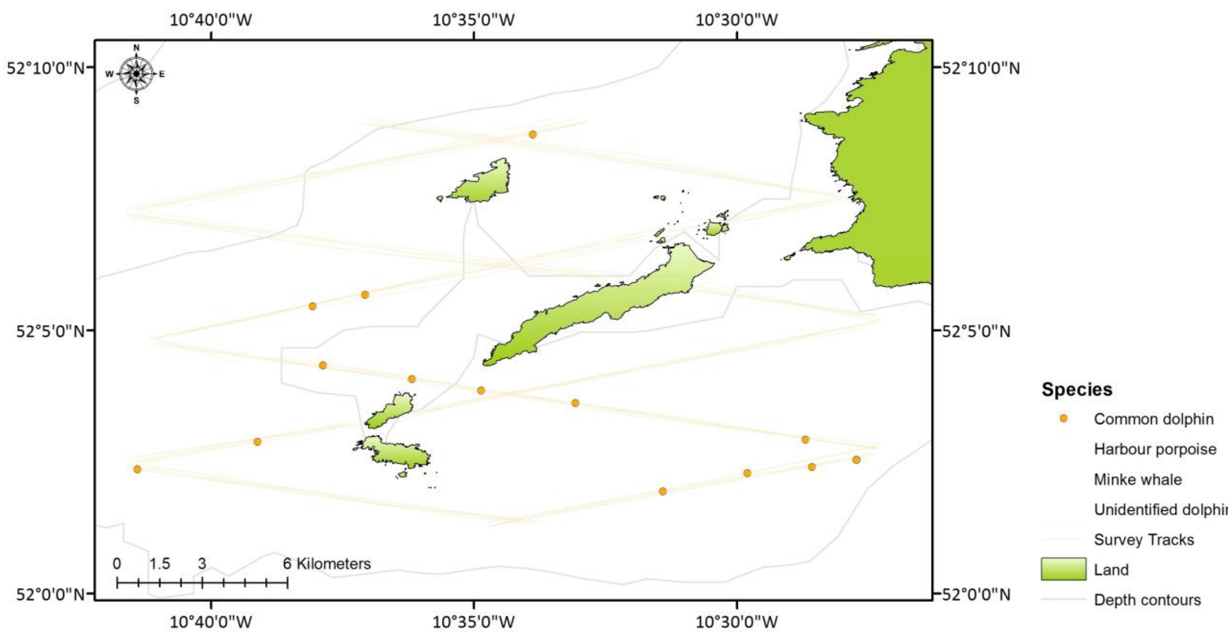

Figure 9. Common dolphin sightings recorded during all surveys

Appendix II: Distance analysis of Minke whale sightings recorded during the 2014 Blasket Island Surveys

Density and abundance estimates of minke whale in the Blasket Islands SAC

Sample Day	Chi^2 P value	Effective Strip Width (m)	Density (per km^2)	SE	CV	N (95% CI)
17 June	0.267	642	0.31	0.11	0.36	70 (32-151)
24 June	0.024	1409	0.14	0.01	0.12	32 (24-41)