HARBOUR PORPOISE SURVEYS IN BLASKET ISLANDS SAC, 2022

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Contents

Executive Summary

A visual survey of harbour porpoises (*Phocoena phocoena*) was carried out in the Blasket Islands SAC in order to derive local density and abundance estimates. Single platform line-transect surveys were carried out according to a standardised design across six days between July and August 2022. Distance sampling was used to produce a detection function based on the observed distribution of harbour porpoise sightings for all surveys combined.

The survey effort in the Blasket Islands SAC ranged from 100-111 km per survey and was 627 km overall. Sea-state was ≤2 for all of five surveys and 82.4% of survey 2. Sea-state 1 dominated for four surveys each.

The number of porpoise sightings per survey ranged from 1 to 4 and from 2 to 5 individuals per survey with a total of 12 sightings of 19 individual porpoises overall. Sightings were spread out throughout the SAC with higher numbers south of Great Blasket and Blasket Sound and to the south of the survey area.

The overall density estimate was 0.08±0.03 porpoises per km^2 with 95% Confidence Interval of 0.03 to 0.18. The coefficient of variation at 0.41 is high suggesting this estimate is not robust and should be treated with caution. Mean group size varied between 1.25 and 3.00 porpoises per survey. The proportion of young porpoises (juveniles and calves combined) recorded on survey days ranged from 6.3% to 9.5% and was 5.5% overall. This density estimate equates to an abundance of just 18 individuals with a 95% Confidence Interval of between 8 and 41.

The density estimate recorded during the current survey was dramatically lower than previous estimates from the Blasket Islands SAC in 2007, 2008, 2014 and 2018 but follows a downward trend since 2008 where density peaked at 1.65 porpoises per km^2. The density estimate in 2022 represent a 71% decline on that reported in 2018 and a 88% decline on that reported in 2014. Mean group size has remained consistent, with 1.63 reported in 2022 compared with 1.28 to 2.32 over the previous four surveys.

Surveys during 2022 were carried out in favourable sea conditions and we are confident that the low sighting rates and subsequent density estimate reported here reflects this low abundance within the Blasket Islands SAC. Whether this reflects a real decrease in population size or more likely a change in the local distribution of porpoises, with more porpoises now occurring outside the boundaries of the SAC, is not clear. Small changes in local distribution, driven by the distribution of their preferred prey can have profound effects on density estimates within a relatively small marine protected area like the Blasket Islands SAC compared to individual's home range.

We recommend these surveys are continued using the same methodology but on a more frequent (annual) basis to provide a more robust data time series within the site. Given the very low sighting rate per survey, consideration should also be given to establishing fixed acoustic monitoring stations to derive acoustic indices from which to monitor population status. A n historic acoustic monitoring datset is available and could be used as a baseline to explore not only whether detections have also declined but fine scale habitat use of the area by porpoises. The most likely driver is the availability of preferred prey which may fluctuate locally over short periods. We recommend a study of the diet of harbour porpoises in the broader area be considered including seasonal components.

Acknowledgements

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1 Introduction

The harbour porpoise (*Phocoena phocoena*) is the most widespread and abundant cetacean species in Irish waters (Rogan *et al.*, 2018). It has been recorded off all Irish coasts, including over the continental shelf but is thought to be most abundant off the southwest and east coasts (Wall *et al.*, 2013; Rogan *et al.*, 2018). It is also consistently one of the most frequently recorded species stranded on the Irish coast (O'Connell & Berrow, 2019; 2020).

There have been a number of dedicated surveys which have estimated absolute abundances of harbour porpoises in Irish waters. In July 1994, an abundance estimate of 36,280 harbour porpoises was calculated for the Celtic Sea as part of an international project called SCANS (Small Cetacean Abundance in the North Sea) (Hammond *et al.,* 2002). This survey was repeated in July 2005 (SCANS-II) when it covered all waters overlying the continental shelf, including the Irish Sea (Hammond *et al.*, 2013). Ship-based double platform line-transect surveys were carried out in the Celtic Sea and in offshore Ireland, while aircraft were used for coastal Ireland and in the Irish Sea. Harbour porpoise abundance estimates were generated for three areas; the Celtic Sea (80,613, CV=0.50), Irish Sea (15,230, CV=0.35) and Atlantic coastal Ireland (10,716, CV=0.37). The offshore Ireland survey area included Scotland and an estimate of 10,002 porpoises (CV=1.24) was generated for both areas combined. Hammond *et al.* (2013) reported a doubling of harbour porpoise density in the Celtic Sea between the SCANS and SCANS II survey years. Rogan *et al.* (2018) recorded a total of 296 harbour porpoise sightings during aerial surveys in 2015 and 2016. Across the total survey area, abundance across both years was higher in the summer than in the winter, with consistently highest summer densities/abundance recorded in the Celtic and Irish Seas. Densities along the south coast in summer 2016 were 0.29 porpoises per km^2 (CV=0.63) and 0.060 porpoises per km^2 (CV=0.73) during winter 2016-17. The predicted distribution of harbour porpoises for both summers highlights the importance of the south west part of the Celtic Sea (over the North Celtic Sea Basin), which had high numbers of sightings and was predicted as an area of high abundance. Recently Nielsen et al. (2021) reported harbour porpoise densities of 0.070 porpoises per km^2 in the Celtic Sea, 0.044 in the North Sea and 0.006 in the English Channel using data from platforms of opportunity.

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).

EU Member States are required to designate Special Areas of Conservation (SACs) for species listed under Annex II of the EU Habitats Directive, one of which is the harbour porpoise. The Blasket Islands SAC and Rockabill to Dalkey Island SAC were designated as candidate SACs for the species in 2000. Designation of the Rockabill to Dalkey site as an SAC, with harbour porpoise as a qualifying interest, followed on from a series of harbour porpoise surveys at eight sites throughout Ireland, including Dublin Bay and North County Dublin, during 2008 (Berrow *et al*., 2008; 2014). Six single platform surveys were carried out at each site between July and October with density estimates calculated for each survey day and for all surveys combined (i.e., pooled estimates). These showed that density estimates were highest for the Blasket Islands SAC, North County Dublin and Dublin Bay.

In 2013, the National Parks and Wildlife Service (NPWS) commissioned a survey of the newly designated Rockabill to Dalkey Island SAC (Berrow & O'Brien, 2013). Density estimates were calculated for five of the six survey days and ranged from 1.13 harbour porpoise per km^2 to 2.61 harbour porpoise per km^2. The overall density was 1.44 which derived an abundance estimate of 391 harbour porpoise within the SAC (Berrow & O'Brien, 2013). A second survey of the Rockabill to Dalkey Island SAC was carried out in 2016 (O'Brien & Berrow, 2016). Density estimates between each survey were very consistent, ranging from 1.37 porpoises per km^2 to a maximum of 1.87 porpoises per km^2, with an overall density of 1.55 ± 0.17 porpoises per km^2 with a very low CV of 0.10. Harbour porpoise abundance ranged from 374 individuals to 511 individuals with an overall estimate of 424±46 with 95% CI of 335-536. Single platform line-transect surveys using distance sampling and acoustic monitoring were also carried out in summer at a further five regional sites (Northwest, West, Southwest, North Irish Sea, South Irish Sea) around Ireland between 2010 and 2012 (Ryan *et al.*, 2010; Berrow *et al.*, 2011; 2012). These sites were generally situated between 6-12 nm offshore and the surveys recorded all cetacean species encountered. Harbour porpoises were recorded at all sites but densities were highest in the Irish Sea with 1.58±0.22 porpoises per km^2 recorded and with an associated CV of 0.14 (Berrow *et al.*, 2011).

Density estimates in 2016 were remarkably consistent to surveys carried out in 2013, with 1.44 harbour porpoise per km^2 recorded compared to 1.55 porpoise per km^2 from the 2013 survey. Sea conditions were good on both surveys with 61% of survey effort in 2013 ≤1 and 87% in 2016, although only four surveys were carried out during 2016. During both studies mean group size was similar which suggests that porpoise densities between the two periods were consistent.

In order to contribute to the Department Housing, Local Government and Heritage (DHLGH) site management and surveillance, visual monitoring of harbour porpoises was carried out in the Blasket Islands SAC during the summer of 2022. This was the fifth dedicated line transect survey of harbour porpoises within this SAC, which will enable ongoing trends in summer density estimates to be explored. The objectives of the survey in 2022 were to:

i) to derive updated summer density and population estimates for Harbour porpoises within the SAC using robust sampling methods for small cetacean density/population estimation.

ii) to estimate associated Coefficients of Variation and 95% Confidence Intervals.

iii) to 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, will also be gathered and delivered within the contract.

2 Methods

2.1 Survey site and Platform

The survey site and line-transect survey design is shown in Figure 1. The area of the Blasket Islands SAC is 227 km^2. Survey track lines were provided by the DHLGH to provide equal coverage probability within the SAC but repeatable over time. Standardized visual survey design for the site, measuring c110km in total transect length was provided by DHLGH. To allow for the greatest coverage of the SAC new survey lines (comprising of start, end and turning points) have been provided each survey year, thus there has been no repetition of survey lines across survey years.

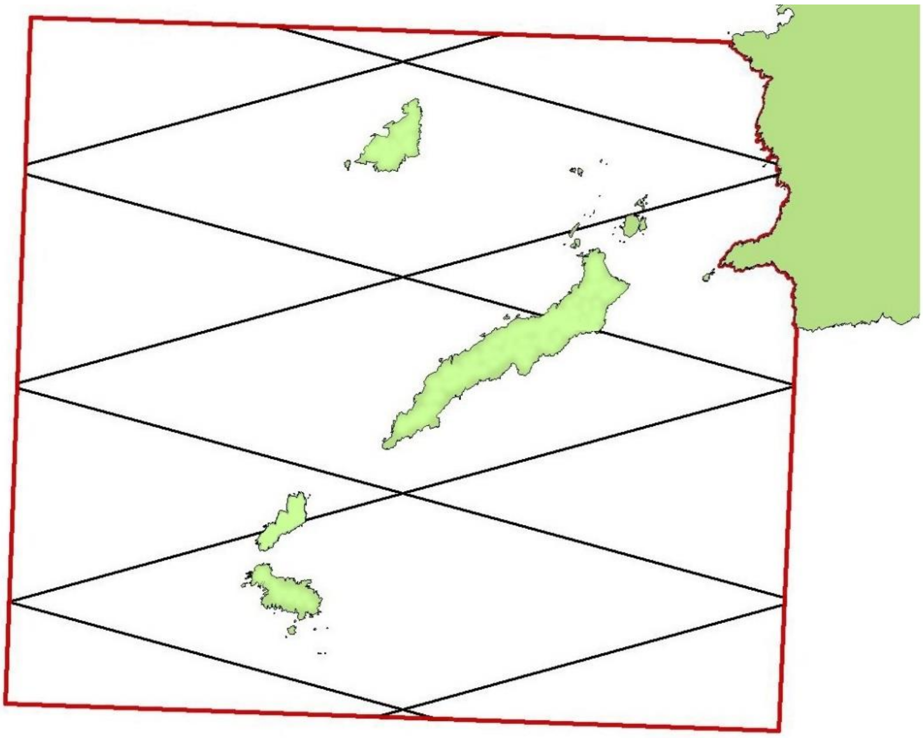


Figure 1 Blasket Islands SAC showing DHLGH track lines selected for coverage in 2022.

MV An Blascaod Mór, skippered by Vincent Browne of Blasket Islands Marine Tours was used for all surveys carried out. The observation platform provided a height of 3.5m above the waterline (Fig 2). MV An Blascaod Mór was used as the survey platform on the previous two harbour porpoise surveys of the Blasket Islands SAC carried out by the IWDG (O'Brien and Berrow 2014; 2018.

Figure 2 MV An Blascaod Mór with flying bridge suitable for line-transect surveys.

2.2 Survey methodology

Conventional single platform line-transect surveys were carried out within the boundaries of the SAC 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 DHLGH in which surveys were to be carried out included Beaufort Force/Sea state 2 or less and good light conditions with a visibility of 6km or more.

The survey vessel travelled at a speed of 16-20 km hr^{-1} (9-10 knots), while on survey effort, which was 2-3 times the average speed of the target species (harbour porpoise) as recommended by Dawson *et al.* (2008). Two primary observers were positioned on the flying bridge, which provided an eye-height above sea-level of between 4-5m depending on the height of each individual observer. Primary observers watched with the naked eye from dead ahead to 90^{o} to port or starboard depending on which side of the vessel they were stationed. All sightings were recorded but sightings more than 200-500m (truncation distance depends on each detection function, see Fig 4) from the track-line were not used in the distance sampling model to improve fit. Calves/juveniles were defined as porpoises ≤ half the length of the accompanying animal (adult) and in very close proximity to it. Small animals seen alone were also classified as juveniles. Sightings off-effort while transiting between track-lines or to the study site were recorded but not included in further data analysis.

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

2.3 Density and abundance estimation

Distance sampling was used to derive a density estimate and to calculate a corresponding abundance estimate. The software programme DISTANCE (Version 7.4, University of St Andrews, Scotland) was used for calculating the detection function, which is the probability of detecting an object a certain distance from the track-line. The detection function was used to calculate the density of animals on the track-line of the vessel. During this survey we assumed that all animals on the track-line were observed, i.e., that g(0) = 1, given the strict operational and environmental conditions under which surveys took place. The DISTANCE software allows the user to select a number of models in order to identify the most appropriate for the data. It also allows truncation of sighting outliers when estimating variance in group size and testing for evasive movement prior to detection.

To calculate density, "survey" was used as the sample regime with sightings used as sampling observations. Estimates of abundance and density obtained via the DISTANCE modelling process were calculated and presented all survey data combined as there were too few sightings per survey to use survey day as a sampling period. An overall pooled abundance/density estimate was derived from all track-lines surveyed combined across all survey days. Buckland *et al.* (2001) recommend a minimum of 40-60 samples are required to provide a robust estimate. We collected a total of 12 samples overall during the six surveys so even with all data combined we are sort of this minimum and outputs should be treated with caution. In conducting this pooled analysis, we assumed that there were no significant changes in distribution within the site between sample days or any immigration into or emigration out of the site. All but one sighting was recorded in seastate 1 so they was no value in deriving density estimates in increasing seastate (e.g. sea-state 0, sea-state 0+1 and sea-state 0+1+2).

The data were fitted to a number of models available in the DISTANCE software. The Half-Normal model with cosine adjustments was found to provide the best fit according to the Akaike Information Criterion delivered by the model. The recorded sighting data were grouped into equal distance bands (the width of which was modified during each model run to get the best fit) up to 300m from the track-line. The DISTANCE model determines the influence of cluster size on variability by using a size-bias regression method with the log(n) of cluster size plotted against the corresponding estimated detection function g(x). A Chi-squared test associated with the estimation of each detection function was provided by the DISTANCE model. If found to be statistically significant it indicated if the detection function was a good fit and that whether the corresponding estimates were robust.

The proportion of the variability accounted for by the encounter rates, detection probability and group size (cluster size) were presented with each detection function. Variability associated with the encounter rate reflects the number of sightings on each track-line. The detection probability reflects how far the sightings were from the track-line and cluster size reflects the range of estimated group sizes recorded on each survey.

2.4 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, survey track-lines and coordinates were obtained from DHLGH. Data concerning transects, effort, sightings, abundance and density were stored in a single MS Access database, which was queried and processed via GIS to produce sighting distribution maps.

3 Results

Six survey days were completed in the Blasket Island SAC during the present study. No surveys were carried out in June due to poor weather conditions. Three surveys were completed in July, two in August and one in September 2022. Favourable conditions, defined as low or no swell, with good light and visibility ≥6km, were recorded during all six surveys (Table 1). No precipitation was recorded.

Table 1 Overall environmental conditions during surveys of the Blasket Islands SAC during 2022.

Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
10 July	1	20	1	E	0/8	None
17 July	1	20	2	E	4/8	None
21 July	1	20	2	SW	8/8	None
7 August	1	20	4	E	2/8	None
10 August	1	5	2	E	0/8	None
17 September	1	20	2	E	4/8	None

Table 2 Sea-state and on-effort sighting data for harbour porpoises recorded in the Blasket Islands SAC during 2022.

Sample Day	Date	Total effort (km) in sea-state ≤2	Sea-state (% of total survey time)			Number of sightings	Total no. of animals
			0	1	2		
1	10 July	100	16.1	75.9	7.6	2	3
2	17 July	82.4	0.1	43.1	39.1	2	3
3	21 July	100	5.8	69.0	25.5	1	3
4	7 August	100	14.4	72.3	12.5	1	2
5	10 August	100	3.4	88.6	8.1	4	5
6	17 September	100	6.4	55.6	38.8	2	3
Total						**12**	**19**

Environmental conditions were favourable during all six surveys. Sea-state can be influenced by wind and tide and can change throughout the survey. Sea-state was ≤2 for the whole of five surveys (Table 2) and 82.4% of survey 2. Sea-state 1 dominated for each of four surveys (surveys 1, 3, 4 and 5) with around 40% of effort carried out in seastate 2 during surveys 2 and 6 .

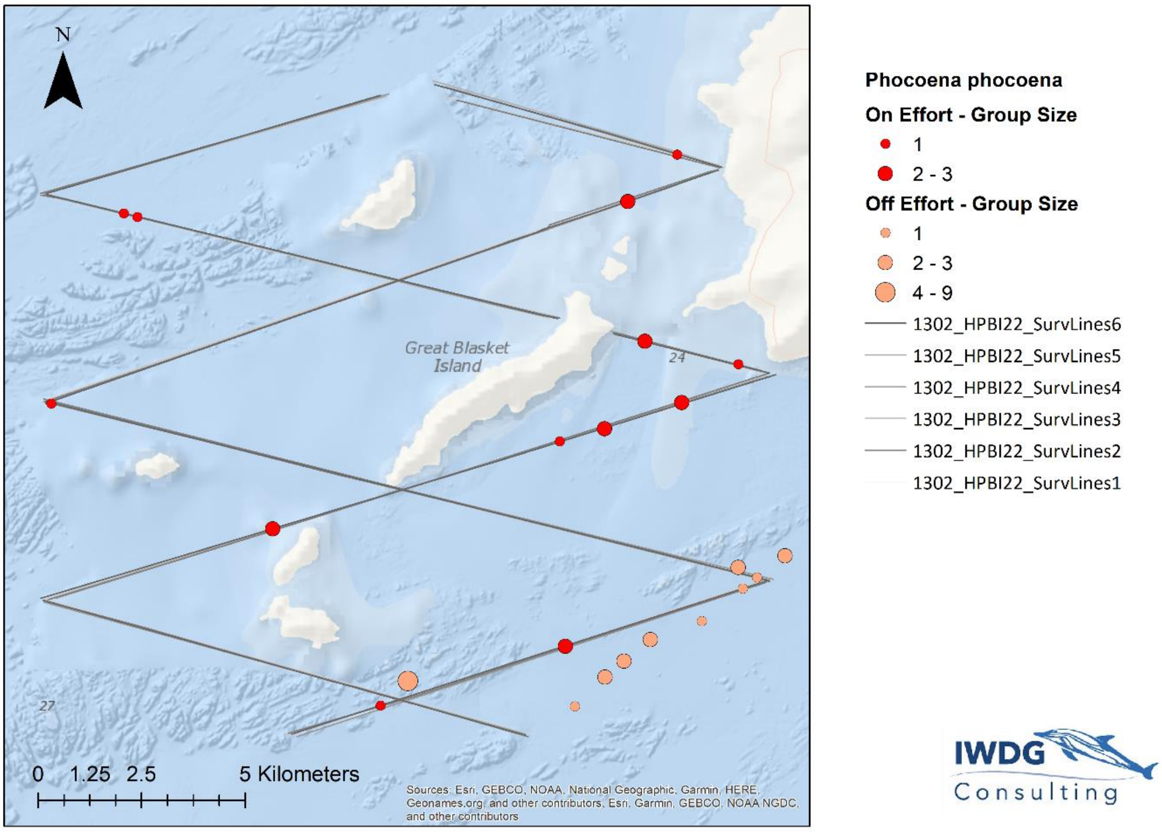


Figure 3 Track-lines and distribution of harbour porpoise sightings in the Blasket Islands SAC from July to September 2022.

The total survey effort in the Blasket Islands SAC per survey day was very consistent ranging from 100-111km per survey, the differences were due to tidal restrictions around the islands on some days. A total of 627 km of trackline was surveyed during this survey.

The number of sightings on effort per survey ranged from only 1 to 4 with a total of 12 overall (Table 2). The highest numbers of sightings were recorded on survey 5 (10 August) with just 4 sightings of a total of 5 individuals, and the lowest number on surveys 3 and 4 (21 July and 7 August), with just one sighting of 3 and 2 individuals (Table 2).

Track-lines surveyed and all harbour porpoise sightings within the Blasket Islands SAC during each survey day are shown in Figure 3 (see Appendix I for individual surveys). Most surveys were (surveys surveyed from south to north with one (Surveys 2) surveyed from north to south to take advantage of calm seas. Sightings were spread out throughout the SAC with higher numbers south of Great Blasket and Blasket Sound and to the south of the survey area.

3.1 Density and abundance estimation

Density estimates for harbour porpoises within the SAC were calculated only for all days combined (Table 3) as there were too few sightings to derive density estimates per survey day. It should be noted that even when combining data there were only 12 sightings and the results of the analysis should be treated with caution (Table 3). The detection function is shown graphically in Figure 4. Data were pooled into six bins and truncated at 300m. Using the Chi-squared test for goodness of fit to the DISTANCE model, the data was not a good fit (P=0.45; Table 3).

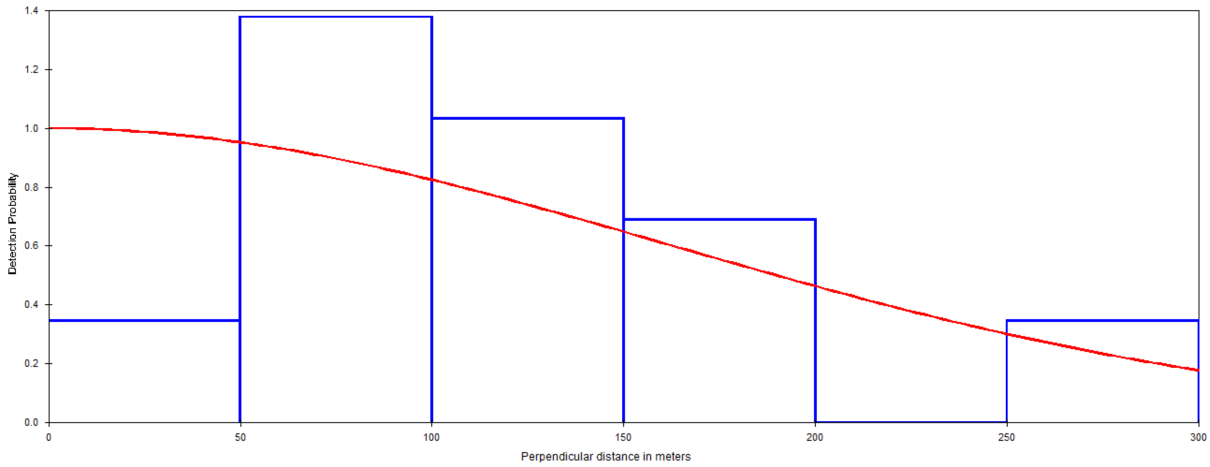


Figure 4 Detection function plots for all surveys of harbour porpoises in the Blasket Islands SAC, 2022 combined (n=6). (Note: detection probability is on the y-axis and perpendicular distance from the track-line on the x-axis).

Evasive reaction of porpoises from the survey vessel, which is typical of harbour porpoise which can react to vessels from considerable distance, was evident with more sightings in bin 2 (50-100m) than predicted. Evasive reactions can lead to an underestimate of animal density, as animals are already moving away from the track-line when first detected, but the effect of this in the current survey was likely to be very small as the influence of sightings on the overall density estimate decreases with increasing distance from the track-line (Buckland *et al.* 2001).

Table 3 Model data used in the harbour porpoise abundance and density estimation for all surveys combined of the Blasket Islands SAC in 2022.

Sample Day	Chi^2 P value	Effective Strip Width (m)	Mean Cluster size ± SE	Variability (D)		
				Detection	Encounter	Cluster
Overall	0.45	189	1.71±0.27	43.1	42.4	14.5

Mean group (cluster) size was 1.71±0.27 (1.58 and 1.42; Table 4), which was towards the end of the survey period. The proportion of variability in the data accounted for by the detection probability was as expected highest for all surveys. Variability associated with cluster size (Table 3) was greatest for surveys 5 and 6 which coincided with the greatest mean group size. This reflects the number of groups with 3 individuals recorded during surveys 5 (3 groups) and survey 6 (5 groups) while no groups this big were recorded during the first four surveys. Overall, the sources of variability were highest for detection rate and lowest for cluster size which is to be expected as there was relatively low variability in the number of sightings per survey (range 12-29; Table 2).

Table 4 Estimated density, abundance (N) and group sizes of harbour porpoise recorded during surveys of the Blasket Islands SAC in 2022.

Sample Day	Density (95% CI) per km^2	SE	CV	Abundance (95% CI)	Mean group size (95% CI)
Overall	**0.08 (0.03-0.18)**	**0.03**	**0.41**	**18 (8-41)**	**1.63 (1.24-2.16)**

Density and abundance estimates for harbour porpoise in the *Blasket Islands* SAC during 2021 are presented in Table 4. Despite differences in the number of sightings per survey and mean group size the density estimates did not vary that much ranging from 0.50 to 0.98 harbour porpoises per km^2, with one-half between 0.66 and 0.80 (Table 4). The highest density (0.98) was recorded on survey 4 (21 July). The lowest density estimate was on survey 1 (0.50) with only 12 harbour porpoise sighting and the lowest mean group size (1.00±0.0) (Table 4).

The overall density estimate was 0.83±0.14 with a 95% Confidence Intervals of 0.59 to 1.17 (Table 4). This estimate had a low CV of 0.17 and produced an abundance estimate of 227±39 porpoises with 95% Confidence Intervals of 161 -321 porpoises (Table 4).

3.2 Proportion of juveniles and calves

The proportion of juvenile porpoises and calves to all porpoises (including adults) was calculated for each survey (Table 6). Only one juvenile and one calf were seen on two separate surveys (21st July and 17th September respectively).

Table 6 The numbers and proportions of adult harbour porpoises, juveniles and calves recorded during surveys of the Rockabill to Dalkey Island SAC, 2021.

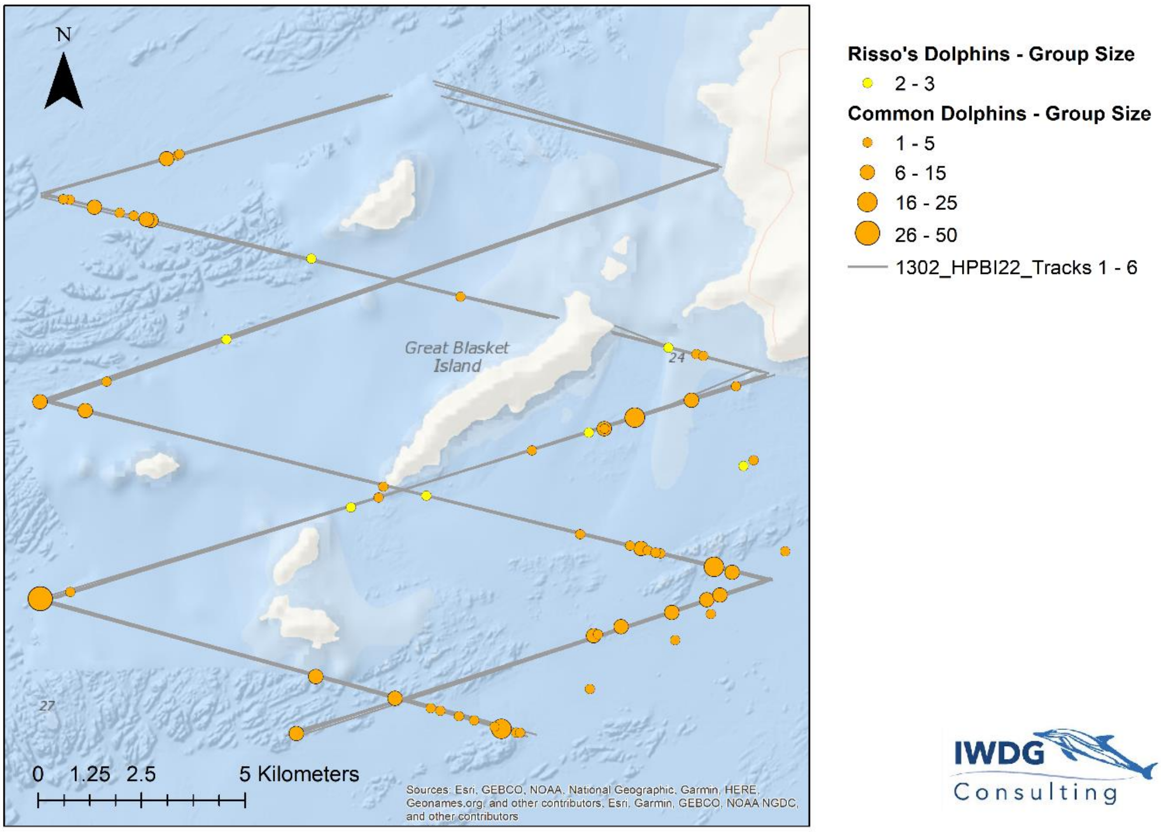
Survey	Number of sightings	Number of Individuals	Adults	Juveniles	Calves	% juveniles	% calves
Overall	**12**	**19**	**17**	**1**	**1**	**5.6**	**5.6**

3.4 Additional marine mammal and megafauna sightings

Outside of Harbour porpoises, there were three other cetacean species and one seal species recorded on effort. Short-beaked common dolphin (*Delphinus delphis*) were the most frequently recorded other marine mammal species and was recorded on all six surveys and in high numbers (2-162) (Table 8) and throughout the survey area (Figure 6). Grey seals (*Halichoerus grypus*) were also recorded on every survey, throughout the survey area, usually on their own. Small groups of Risso's dolphin (*Grampus griseus*) were recorded on 4 surveys and single minke whales (*Balaenoptera acutorostrata*) on four surveys (Table 8), mainly to the southwest of the study area (Figure 8b). Single sightings of humpback whale (*Megaptera novaengliae*) and a large baleen whale (probably fin whale *Balaenoptera physalus*) were also recorded off effort while transiting to a from the survey lines.

Table 8 Other marine mammal species recorded during surveys in Blasket Islands SAC, 2022.

Survey	Date	Number of sightings (total number of individuals)	Species		
		Common dolphin	Risso's dolphin	Minke whale	Grey seal
1	10 July	15 (162)	3 (7)	10	8
2	17 July	4 (31)	2 (4)	0	5
3	21 July	9 (67)	0	1	6 (7)
4	7 August	10 (51)	1 (2)	1	15
5	10 August	13 (80)	0	2	7
6	1 September	1 (2)	1 (3)	0	9
Overall		**52 (393)**		**14 (14)**	**50 (51)**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Great Blasket Island
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Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors
Risso's Dolphins - Group Size
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Common Dolphins - Group Size
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16 - 25
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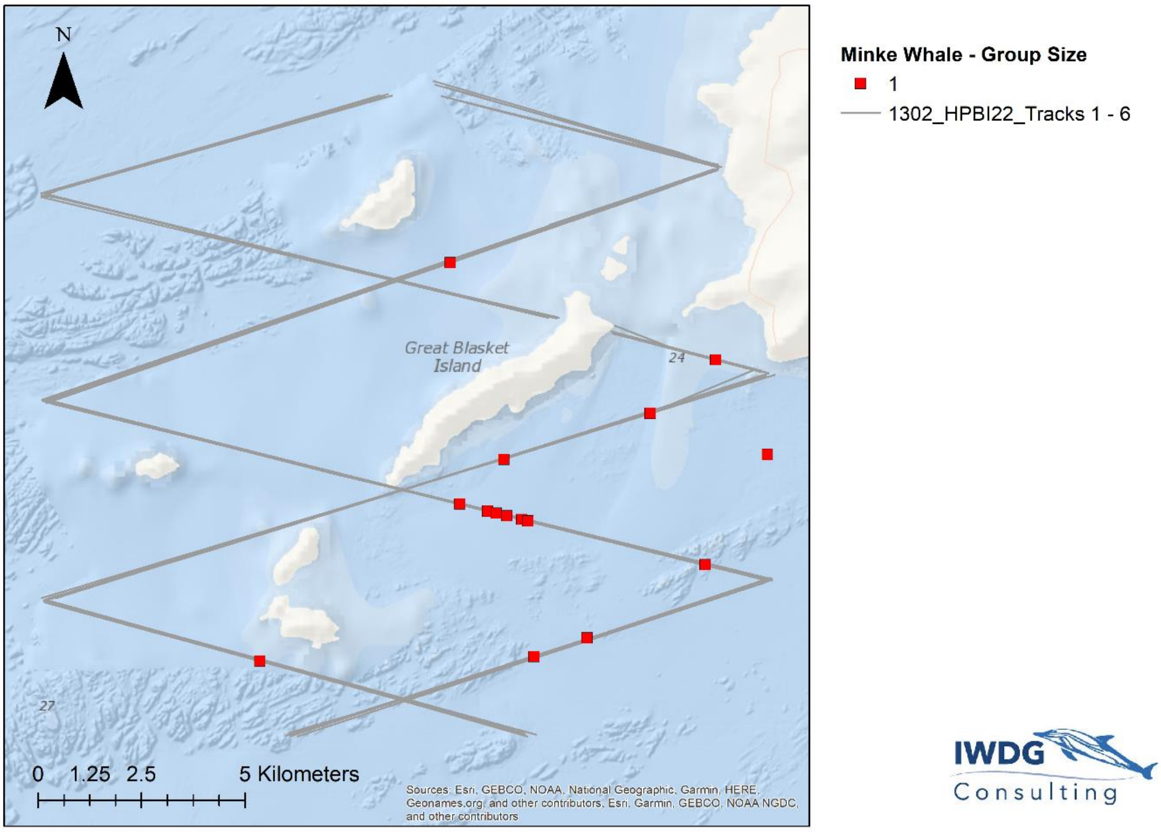
1302_HPBI22_Tracks 1 - 6

a)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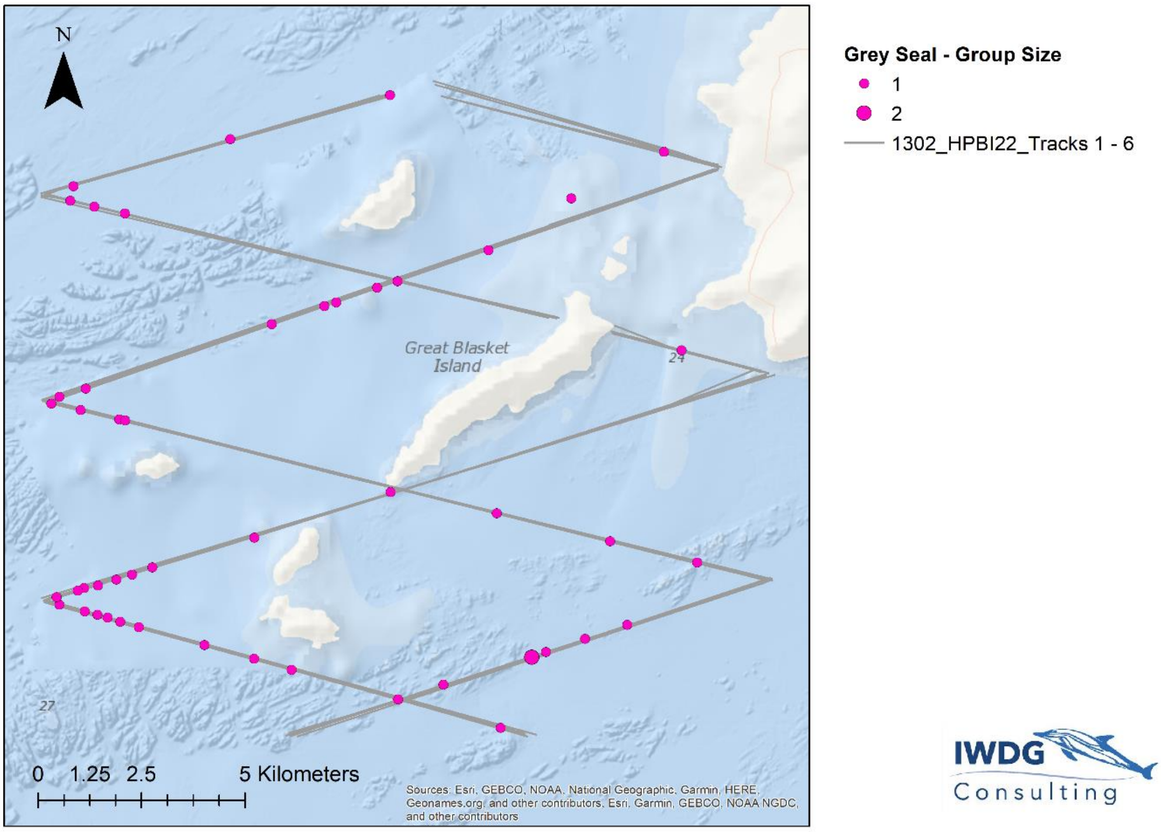

c)

Figure 6a-c Distribution of marine mammals other than harbour porpoises recorded during surveys of the Blasket Island SACs during 2021. A) dolphins, b) whales and c) grey seal

The limited species diversity of marine mammals is consistent with previous surveys although the species recorded was different. During the survey in 2013 a single minke whale was reported and during 2016 only seals, with a total of 12 grey and common seal sightings and no cetaceans.

4 Discussion

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

To minimise the effect of animal movement on the detection rate and detection function it is recommended that the speed of the observation platform is at least twice the speed of the object, as performed in this study. If this is the case, then movement of the object causes few problems in line-transect sampling (Buckland *et al.,* 2001). Typically for broad-scale surveys of harbour porpoise g(0)= 0.30-0.40 (Hammond *et al.,* 2002), or even as low as 0.21 (Hammond *et al.,* 2013). Thus, less than half of the animals on the track-line may only be detected. If this was the case during the present survey then we could perhaps double the density estimate to obtain a truer density estimate. Without a double-platform line-transect methodology it is not possible to accurately determine the number of porpoise detections on the track-line that were missed. The detection function derived in the current survey does provide some evidence of evasive movement relative to the survey boat, which will tend to lower the density estimates. However, this source of downward bias was consistent with previous surveys and cannot account for the low density estimate.

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 five surveys were carried out in sea-state 2 or less (as per contractual obligations), with only 17.6% of survey 2 carried out in seastate 3. Thus high sea states cannot explain the low sighting rates.

4.1 Harbour porpoise density estimates in the Blasket Islands SAC

This was the fifth dedicated survey of harbour porpoises in the Blasket Islands Special Area of Conservation (SAC) since it was designated in 2000. Initial survey design in 2007 was more randomised and included a towed hydrophone survey (PAM). In 2008 only three surveys were carried out using a fixed route but did not cover all areas equally. Similar single platform line transect surveys to that carried out in 2022 were also carried out in 2014 (including PAM) and 2018 and provide a time-series trends in density and the status of this qualifying interest. The current survey was carried out favourable sea conditions throughout all six surveys and the sighting rate of harbour porpoises was consistently low across all surveys suggesting porpoise abundance was very low.

Abundance estimates were carried out in the Blasket Islands SAC during the summer of 2007 and 2008 as part of a wide ranging survey to identify sites with elevated harbour porpoise densities (Berrow *et al.* 2014). This was repeated in 2014 and 2018 using similar track-lines but reversed, with different start and end points but with the same total transect length (O'Brien & Berrow, 2014; 2018). The results of these surveys are presented in Table 9.

Table 9 Density, abundance and group size estimates for harbour porpoise within Blasket Islands SAC from 2007 to 2022.

Year	Density ± SE (per km^2)	Mean group size	Abundance ± SE	CV	Reference
2022	0.08	1.71	18±7.4 (8-41)	0.41	This study
2018	0.28	1.28	60±14 (39-93)	0.22	O'Brien and Berrow (2018)
2014	0.64	2.09	146±53 (41-516)	0.36	O'Brien and Berrow (2014)
2008	1.65	1.76	372±105 (216-647)	0.09	Berrow *et al.* (2008)
2007	1.33	2.32	303±76 (186-494)	0.25	Berrow *et al.* (2007)

Proportion of juveniles and calves

Only one juvenile and one calf were seen during the six surveys. However, due to the low number of sightings during the surveys, conclusions on population demographics cannot be made.

4.3 Trends in harbour porpoise density estimates in Blasket Islands SAC

Although line-transect survey designs were notably different in 2008, the model outputs are worth comparing with more recent surveys (Table 9). Density estimates in 2013 and 2016 were similar to that reported in 2008 especially for North County Dublin, suggesting there had been little change in porpoise densities over this eight year period. The density estimate in 2021 (0.83 harbour porpoise per km^2) is around 44% of that reported in 2013 and 2016. The number of sightings per survey were similar in 2013 and 2016 but down by around 17% on the mean of the previous surveys. The total number of individuals recorded was also down by 26% on those recorded in 2016 but very similar to the total number of individuals recorded in 2013 however the total survey effort was also lower in 2013 by around 30%. Mean group size (1.31) was 20% less than that recorded in 2016 (1.62, Table 9).

The data here were collected during favourable sea conditions, on excellent platforms and with experienced surveyors and we are satisfied the density estimate is accurate. Thus there does seem to have been a real decrease in the density of harbour porpoises recorded in the Rockabill to Dalkey Island SAC during 2021, compared to the two previous surveys in 2013 and 2016. This is of concern and the drivers of the local distribution and abundance of harbour porpoises in this SAC needs to be explored.

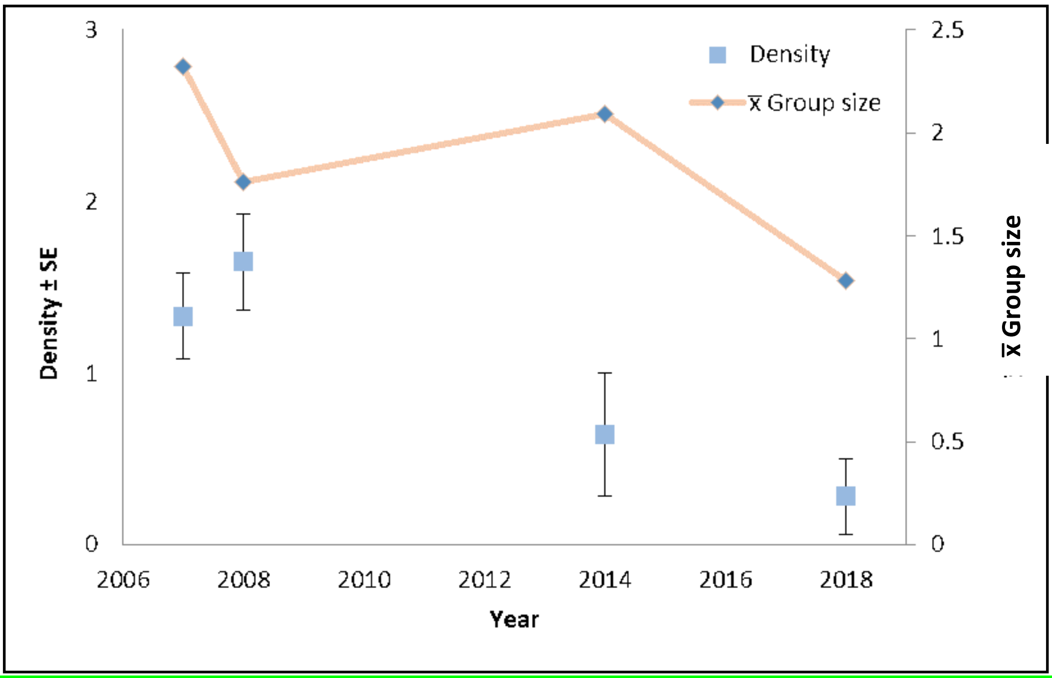

Figure 9 Harbour porpoise density estimates (animals per km^2 ±SE) and mean group size recorded during line transect surveys from 2007 to 2022, in the Blasket Islands SAC.

This decrease in harbour porpoise density in the Blasket Islands SAC should be put into a wider context. The most recent harbour porpoise surveys, using the same methodology, in the other two SACs with harbour porpoise as qualifying interests, namely Roaringwater Bay and Islands SAC in Co Cork and Rockabill to Dalkey Islands SAC in Co Dublin also reported significant declines in harbour porpoise densities. O'Brien & Berrow (2020) reported a 70% decline in porpoise densities in the Roaringwater Bay and Islands SAC between 2016 and 2020 while Berrow et al. (2021) reported a 46% decline in harbour porpoise densities between 2016 and 2021 in the Rockabill to Dalkey Islands SAC. This suggests that the drivers of the decline in harbour porpoise densities is widespread in Irish coastal waters.

This does not necessarily imply a decline in overall population size but perhaps changes in distribution and habitat use at a local scale. The distribution and abundance of top predators such as harbour porpoises is strongly influenced by the availability and distribution of their preferred prey. The diet of porpoise in Ireland is not well known, but it is thought to be a mixture of pelagic and benthic fish including sandeels and gobies as well as crustaceans (Rogan, 2008). One possible reason for a decline in density within the Blasket Islands SAC is a change in the distribution of their preferred prey outside of the SAC boundaries, resulting in lower densities of porpoises within the site. A better understanding of the ecology of harbour porpoise in this region, including their diet and foraging ecology, is required in order to interpret this apparent decline in abundance between survey years.

We recommend a review of harbour porpoise diet is carried out from existing samples collected from stranded harbour porpoises since 1992. This should include samples stored at University College , Cork (see Rogan 2008; Levesque et al. 2022). Following this review and gap analysis, priority should be given to the collection of stranded harbour porpoises in good to moderate body condition for post-mortem examination to remove stomach contents. Consideration could also be given to encouraging fishers to land any bycaught harbour porpoise from the Blasket Islands SAC and adjacent waters as these would provide the best samples for exploring porpoise diet in the area.

Survey technique: sensitive to changes
Why?

4.4 Recommendations

1. These surveys should be continued and given the continued decrease reported here repeated to determine if this is an outlier, or part of a trend.

2. Consideration should be given to establishing fixed acoustic monitoring stations to derive acoustic indices from which to monitor population status. It is possible that acoustic datasets when put into appropriate models could identify long-term changes at a higher resolution than boat-based visual surveys and offer year-round coverage as well as exploring fine-scale habitat use.

3. Surveys should be carried out in adjacent waters to the north and south of the SAC to determine whether the decline in sightings are due to population decline or changes in their distribution.

4. It is unclear what is driving this long-term decline in the density of harbour porpoises within the Blasket Islands SAC. The most likely driver is the distribution of preferred prey which may fluctuate locally over short periods. We recommend a study of the diet of harbour porpoises in the region be considered including seasonal components.

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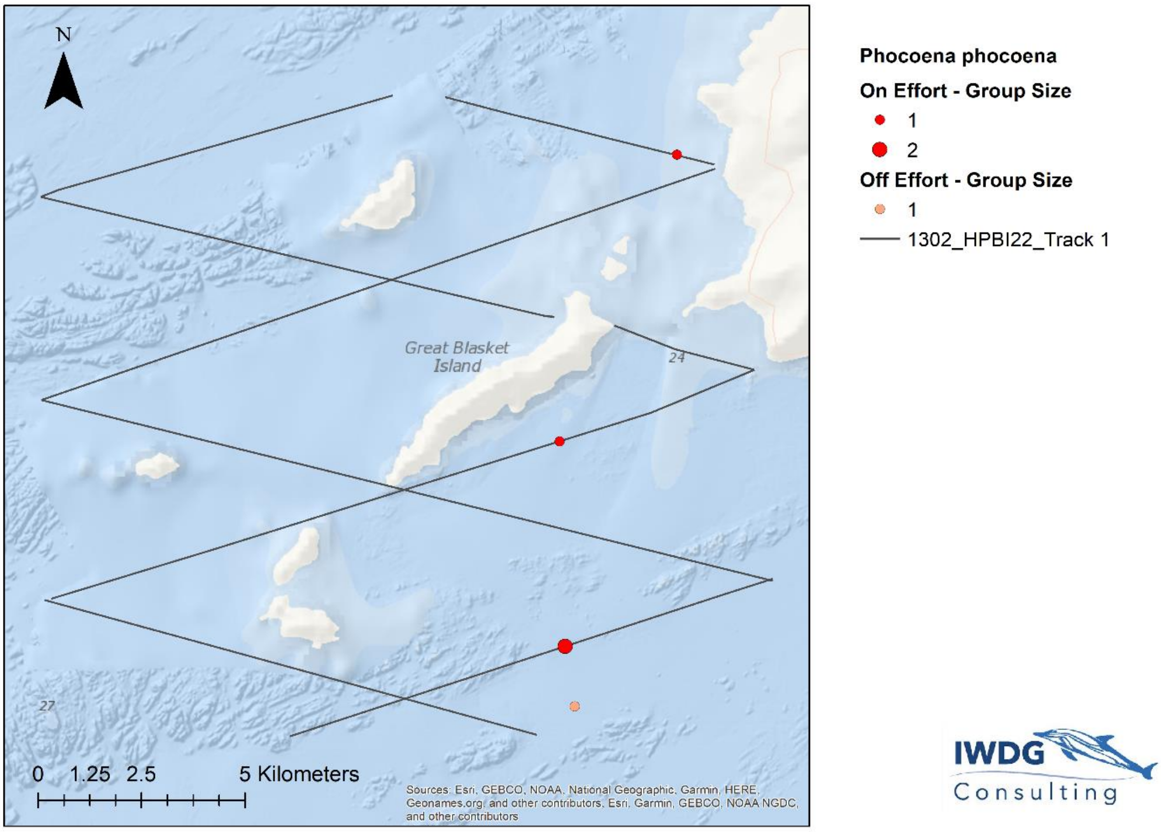
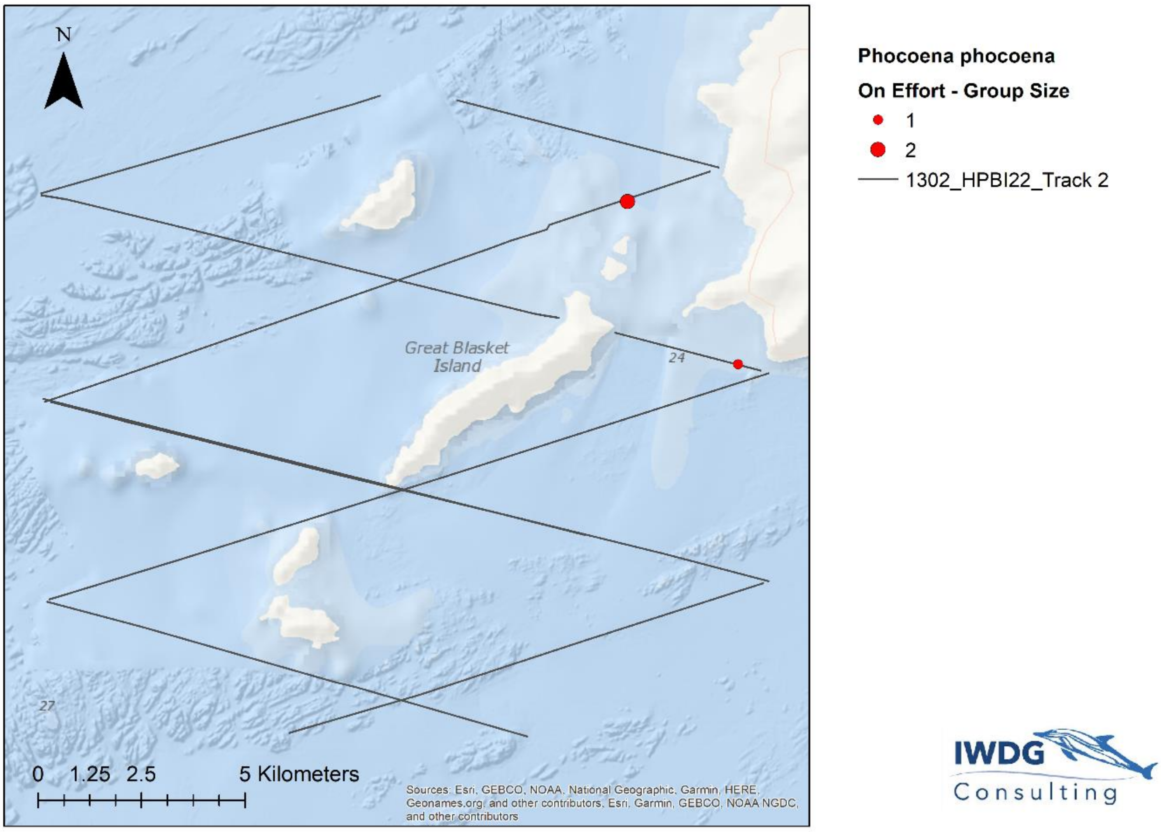
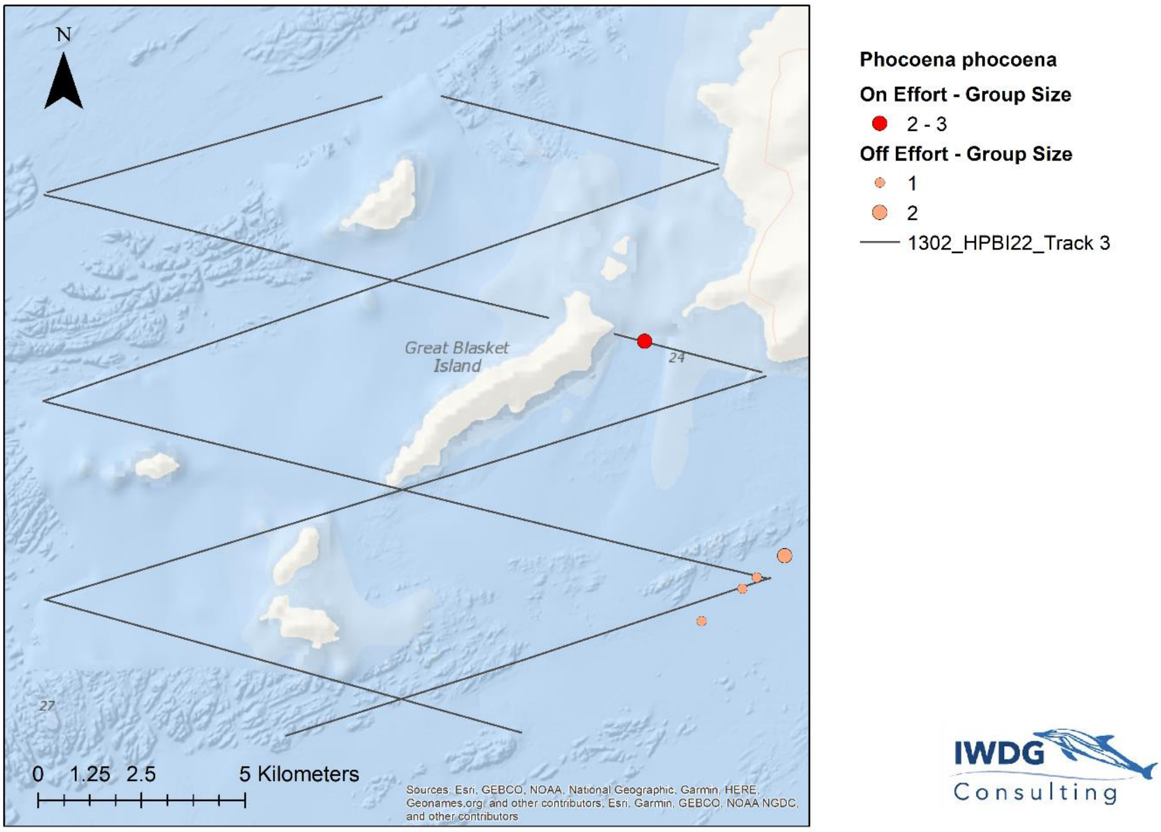
Appendix 1:



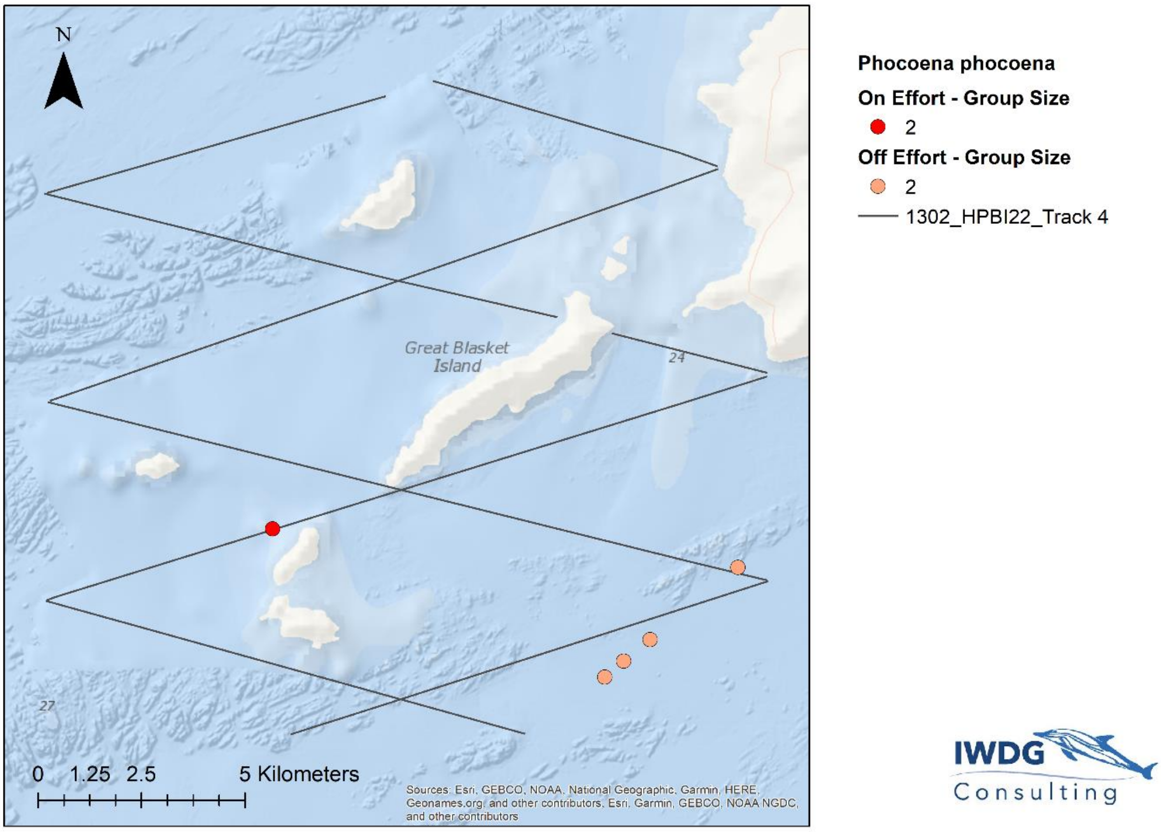
Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 10 July 2022



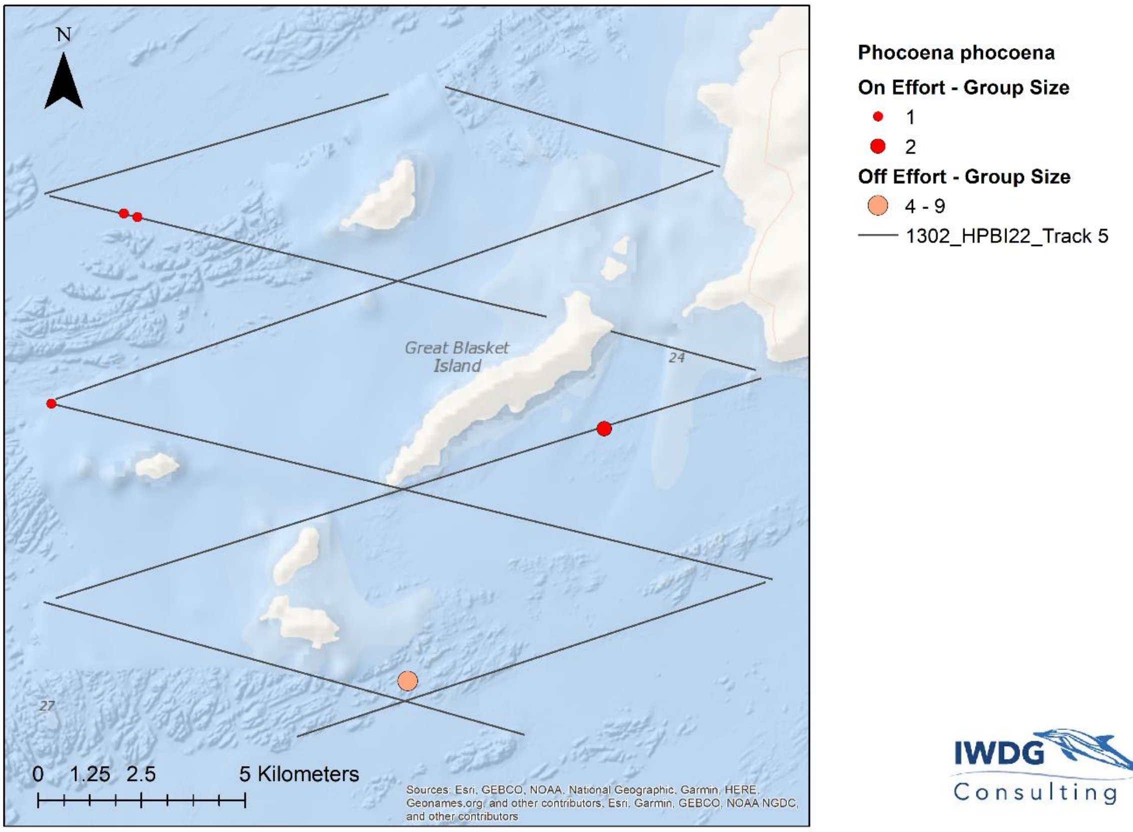
Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 17 July 2022



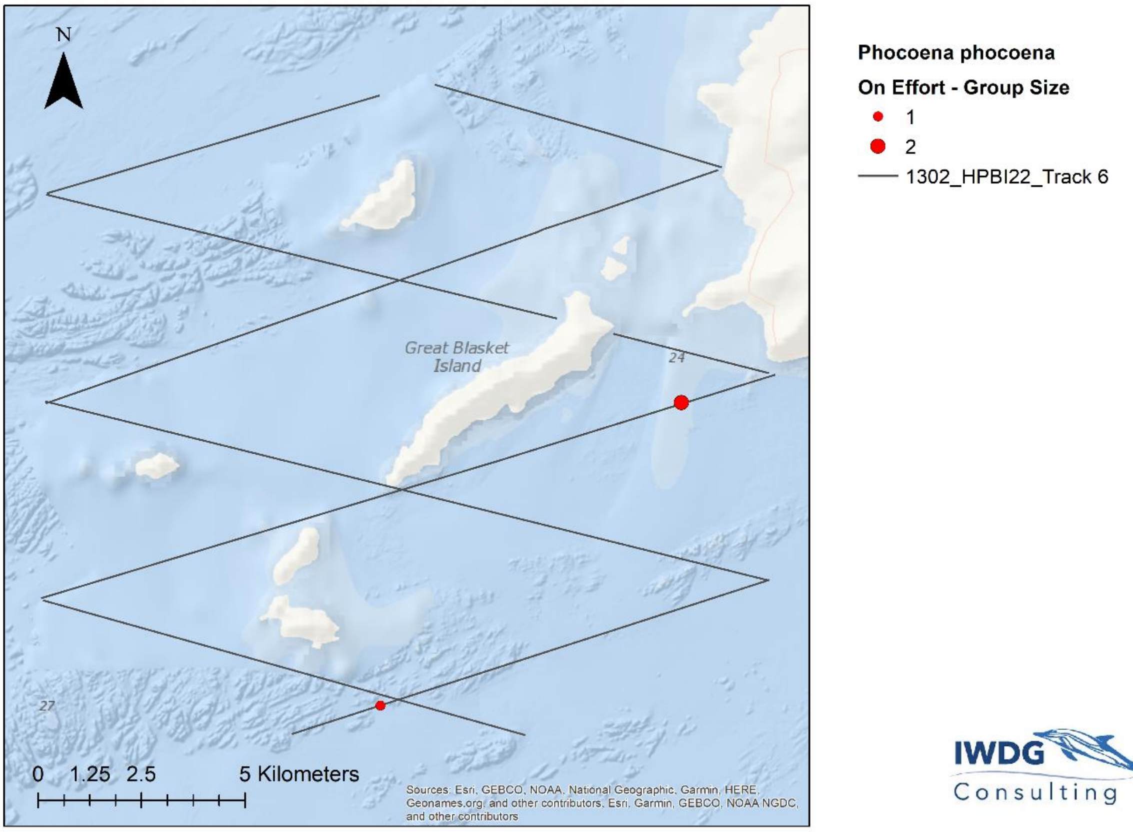
Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 21 July 2022



Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 7 August 2022



Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 10 August 2022



Trackline and harbour porpoise sightings during survey of Blasket Islands SAC on 1 September 2022