

Harbour porpoise surveys in the Basket Islands SAC, 2018



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Executive Summary

A set of visual surveys for harbour porpoise (*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 on six days between June and September 2018. Distance sampling was used to produce a detection function based on the observed distribution of harbour porpoise sightings. Abundance estimates were calculated in different sea-states from 0 to 4. The estimate in sea-state ≤ 2 was used as the best density and abundance estimate.

Surveys were carried out in favourable weather on five of the six surveys and for 94% of total survey effort. However, on the last survey on 24 September, sea-state 3 persisted for 33% of the survey effort (32.3 km) and sea-state 4 for 1.8km, resulting in only 65% of this survey carried out within the terms of the contract (sea-state ≤ 2). This was due to the wind picking up earlier than forecast, resulting in higher sea-states than predicted over the six surveys. A total of 550 km of track-line effort was surveyed throughout the SAC in sea-state ≤ 2 . Harbour porpoise sightings per survey were very low in number and ranged from 1 to 7 per survey and from only 2 to 9 individuals, with a total of 26 sightings of 34 individual porpoises overall. Harbour porpoise density estimates ranged from 0.21 animals per km² to 0.28 per km² depending on the sea-state, with comparatively low coefficients of variation of 0.22 to 0.33. Mean group size was also low and quite consistent at 1.28-1.40. No juveniles or calves were reported, making all sightings of adults. The best estimate (sea-state ≤ 2) was 0.28 harbour porpoises per km² which gave an abundance estimate of 60 ± 13 (95% Confidence Intervals [CI] = 39-93) with a CV of 0.22. Other species recorded included minke whale (24 sightings, 35% of total non-harbour porpoise sightings), common dolphin (40 sightings, 59% of total of non-harbour porpoise sightings) and Rissos dolphin (4 sightings 6% of total of non-harbour porpoise sightings). A density estimate for minke whales on 13 July was calculated at 0.38 minke whales per km², (CV=0.29) which equated to an abundance of 86 individuals (95% CI of 46-159).

Sighting rate and group size recorded during the survey of the Blasket Islands SAC in 2018 were very low compared to previous surveys of this site. In 2014 using similar tracklines, 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. The density estimate in 2014 at 0.64 harbour porpoise per km² was over twice that recorded in 2018 (0.28 /km²), but less than half of those estimates from 2007 (1.33/km²) and 2008 (1.65/km²). This is of concern as surveys in 2018 were carried out in excellent sea-state, with 83% of effort over the six surveys in sea-state ≤ 1 and along very similar track-lines.

We are confident that the density and abundance estimates presented here reflect a very low occurrence of harbour porpoise within the Blasket Islands SAC during the survey period (June to September 2018). We can only suggest that there was a shift in the distribution of harbour porpoise this summer, probably associated with the distribution of their prey. The site is small in relation to the likely daily movements of these highly mobile marine mammals and even a small change in prey distribution could result in most prey occurring outside the boundaries of the SAC, resulting in low densities of harbour porpoise within the SAC. A better understanding of the ecology of harbour porpoise, including diet and foraging ecology, is required in order to interpret this decline in abundance.



Excellent survey conditions in June 2018.



Excellent survey conditions in July 2018.

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 and in the Irish Sea (Wall *et al.* 2013; Berrow *et al.* 2014). The harbour porpoise is also consistently one of the most frequently recorded species stranded around the Irish coast (McGovern *et al.* 2016). The species is listed on Annex II of the EU Habitats Directive and thus Special Areas of Conservation (SACs) have been required in order to protect a representative range of habitats for this species within Member States and across the European Union. These sites designated as SACs must be surveyed regularly to ensure the 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, 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 in July 1994. A repeat of this survey in July 2005 (SCANS-II) targeted all Irish continental shelf 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 had 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). In 2016, during the third SCANS survey, Hammond *et al.* (2017) showed that the apparent shift in distribution recorded in the North Sea between 1994 and 2005 was maintained in 2016, with highest densities found in the southwestern North Sea, and to the north and east of Denmark.

Previous abundance estimation surveys for harbour porpoise have been carried out in the Blasket Islands SAC in 2007, 2008 and 2014 under contract to the National Parks and Wildlife Service (NPWS) (Berrow *et al.* 2007; 2008; O'Brien and Berrow 2014). Six single platform surveys were carried out at each site between July and October in 2007 and 2014 and 3 surveys in 2008 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 km², with the most robust estimate using all the data from each track-line combined and giving an estimate of 1.33 porpoises per km². This resulted in an abundance of 303±76 (95% CI: 186-494; CV=0.25). In 2008 the overall density estimate at the site was 1.65 porpoises per km, equating to an abundance of 372±105 (95% CI: 216-647; CV=0.28). In 2014 the pooled density estimate was 0.64 porpoises per km² producing an abundance estimate of 146±53 (95% CI: 41-516; CV = 0.36). During previous surveys at the site a strong seasonal increase in density was recorded from July through to September (Berrow *et al.* 2007; 2008; O'Brien and Berrow 2014).

The Blasket Islands SAC was designated with harbour porpoise as a qualifying interest in 2000. In order to contribute towards the Department of Culture, Heritage and the Gaeltacht's (DCHG) monitoring obligations, a set of visual harbour porpoise surveys were carried out during summer of 2018. The objectives of this survey contract were to:

- a) To derive updated summer density and population estimates for Harbour porpoises within the SAC using robust sampling methods for small cetacean density/population estimation.
- b) To estimate associated Coefficients of Variation and 95% Confidence Intervals.
- c) 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, was also be gathered and delivered within the contract.

Methods

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 km². Track-lines were provided by the DCHG and were chosen to provide equal coverage probability within the SAC. They were similar to those surveyed in 2014 but consisted of a newly randomised pattern of transect lines for the current year.

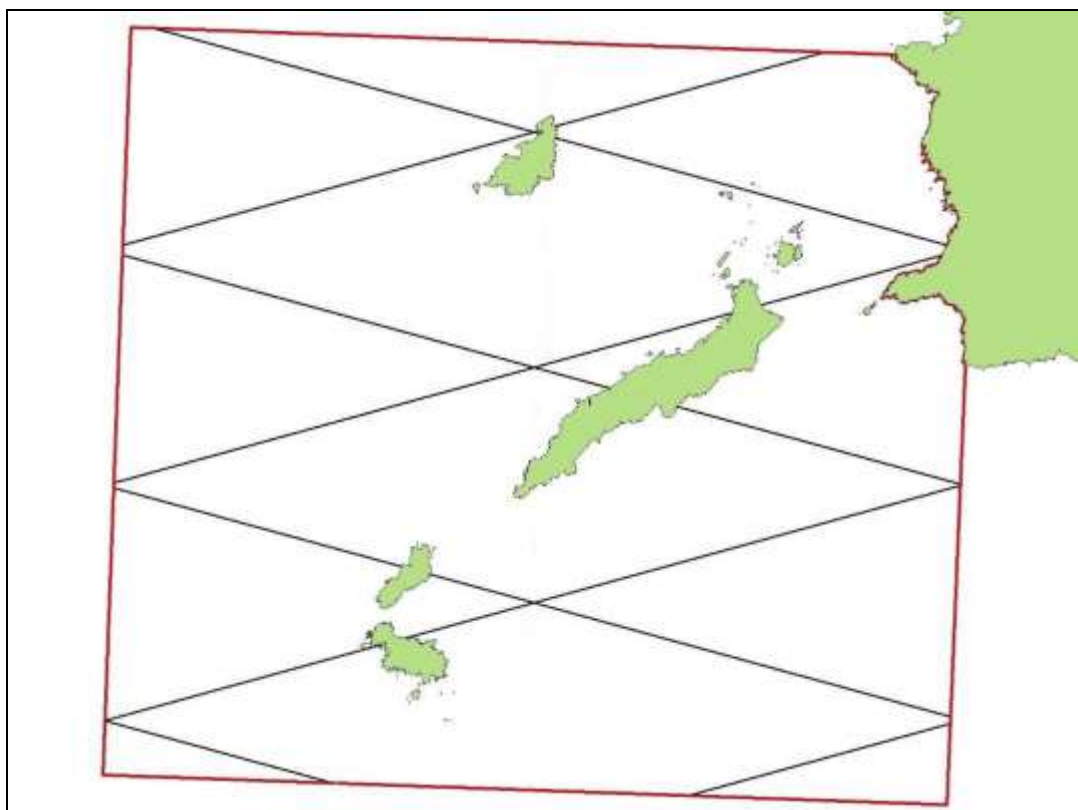


Figure 1. The Blasket Islands SAC, Co. Kerry with its marine limits defined by the solid red line. A randomly-positioned and standardised design by NPWS for line transect surveys in 2018 is shown by the black zigzag lines.



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

Survey platform

The same vessel was used on each survey, the MV An Blascaod Mór, skippered by Mick Sheeran and Vincent Browne of Blasket Islands Marine Tours. The observation platform provided 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 DCHG in which surveys were to be carried out included: Beaufort Force/Sea state 2 or less and good light conditions with visibility of 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 were also recorded but not included in the analysis of abundance and density.

During each transect the position of the survey vessel was tracked continuously through a GPS receiver connected to a laptop computer, while survey effort data 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 important for distance sampling. Measuring sticks (Heinemann 1981) were used 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 the Blasket Islands SAC. The software programme DISTANCE (Version 6, University of St Andrews, Scotland) was used for calculating the detection function, which is the probability of detecting an object on the vessel's 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 one 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 are summarised in the table below (Table 2). To calculate density we used "sea-state" as the sample regime with sightings as the sampling observations. Estimates of abundance and density obtained via the DISTANCE modelling process were presented for all survey effort in sea-state 0 and sea-states 0+1, etc. as there were too few sightings per survey to use "day" as the sample regime. This was necessary in order to obtain sufficient sightings to estimate density/abundance using the DISTANCE software model. Buckland *et al.* (2001) recommended the minimum number of observations required for robust estimates to be around 40–60 records. In conducting this analysis using pooled data we assumed that each sample survey was representative of the

natural occurrence of porpoises within the study area and there were no significant changes in porpoise distribution within the site between survey days nor any significant 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 0-50m, 50-100m up to 300m (6 groups). 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 calculated 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 DCHG. 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.

Results

Six surveys were carried out in the Blasket Islands SAC between June and September 2018 (Table 1). Environmental conditions were favourable on all six surveys. Despite some fog on surveys 1 and 2, visibility was still >1km and at least 6km for the vast majority of survey effort (Table 1).

Table 1: Overall environmental conditions during the surveys of Blasket Islands SAC in the summer-autumn of 2018.

Date	Swell (m)	Visibility (km)	Wind strength (knots)	Wind direction	Cloud cover	Precipitation
5 June	0-1	1-5	4	NW	8/8	Fog
6 June	0-1	5-10	4	SE	8/8	Fog
25 June	0-1	16-20	4	E	4/8	None
5 July	1	16-20	3	-	7/8	None
13 July	0-1	16-20	3-4	-	4/8	None
24 September	1	11-15	3-5	SE	2/8	None

A total of 550 km of track line was sampled in sea-state ≤ 2 over 6 days from June to September (Table 2). Sea conditions were excellent for five of the six surveys (Table 2) with sea-state 0 predominating for two surveys (surveys 2 and 3) and sea-state ≤ 1 for five of the 6 surveys. Only during the last survey (survey 6) were conditions poor with sea-state ≥ 2 for 33% of the survey effort.

The number of harbour porpoise sightings per survey in 2018 was very low and ranged from just 1 to a maximum of 7 on one survey. Even on surveys where the sea-state was ≤ 1 porpoise sightings were few in number with only 3 to 7 per survey. There were 26 sightings in total while the observer team was on effort. Recorded group size was small too, resulting in only 34 individuals recorded during the whole survey (Table 2). Furthermore, there were no juveniles or calves recorded on any survey, an usual occurrence for this time of year.

Table 2. Sea-state and on-effort sightings data for harbour porpoises recorded within the Basket Islands SAC in the summer-autumn of 2018.

Sample Day	Date	Total effort (km) in sea-state ≤ 2	Sea-state (% of total survey time)				Number of sightings	Total no. of animals
			0	1	2	3		
1	5 June	98.0	38	52	9	0	6	7
2	6 June	99.4	63	37	0	0	5	7
3	25 June	98.2	52	48	0	0	3	4
4	5 July	98.2	29	67	4	0	7	9
5	13 July	93.2	6	85	8	0	4	5
6	24 Sept	63.7	0	16	49	33	1	2
Total		550					26	34

The distribution of harbour porpoise sightings on each survey is shown in Figures 3a-f. Harbour porpoises were observed throughout the SAC with no obvious clusters in distribution. The surveys always progressed 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.

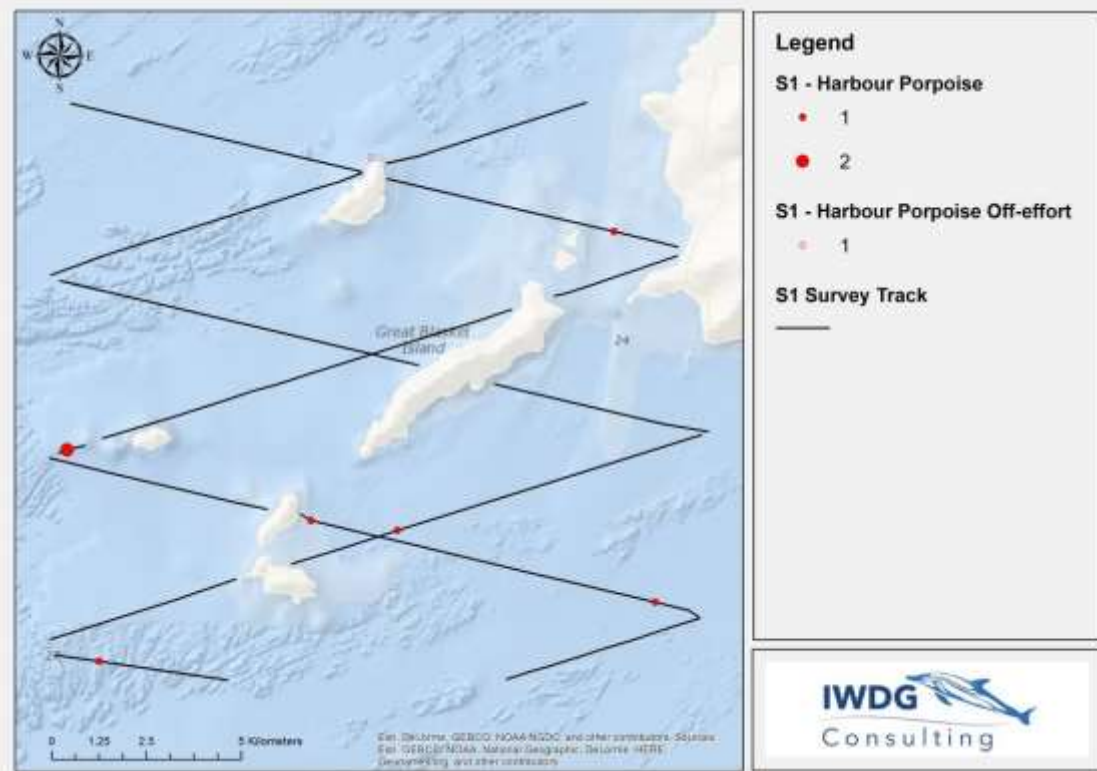


Figure 3a. Vessel track-lines and the distribution of harbour porpoise sightings on 5 June, 2018. Numbers of porpoises are shown by the red circles.

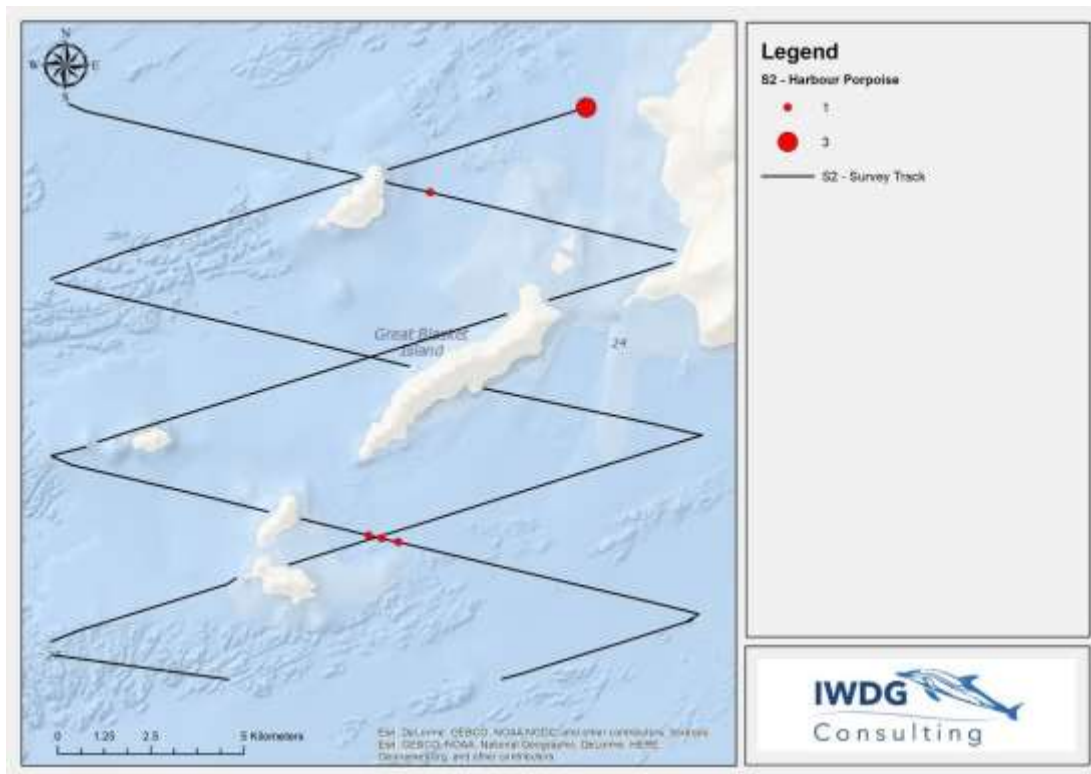


Figure 3b. Vessel track-lines and distribution of harbour porpoise sightings on 6 June, 2018. Numbers of porpoises are shown by the red circles.

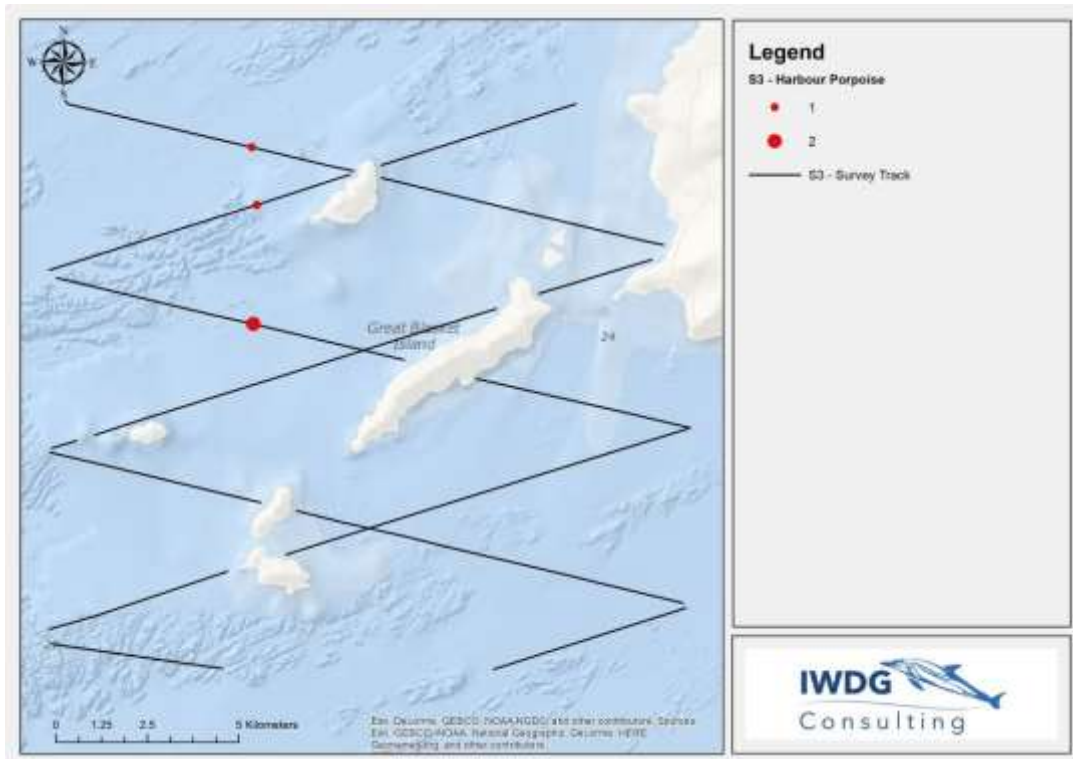


Figure 3c. Vessel track-lines and distribution of harbour porpoise sightings on 25 June, 2018. Numbers of porpoises are shown by the red circles.

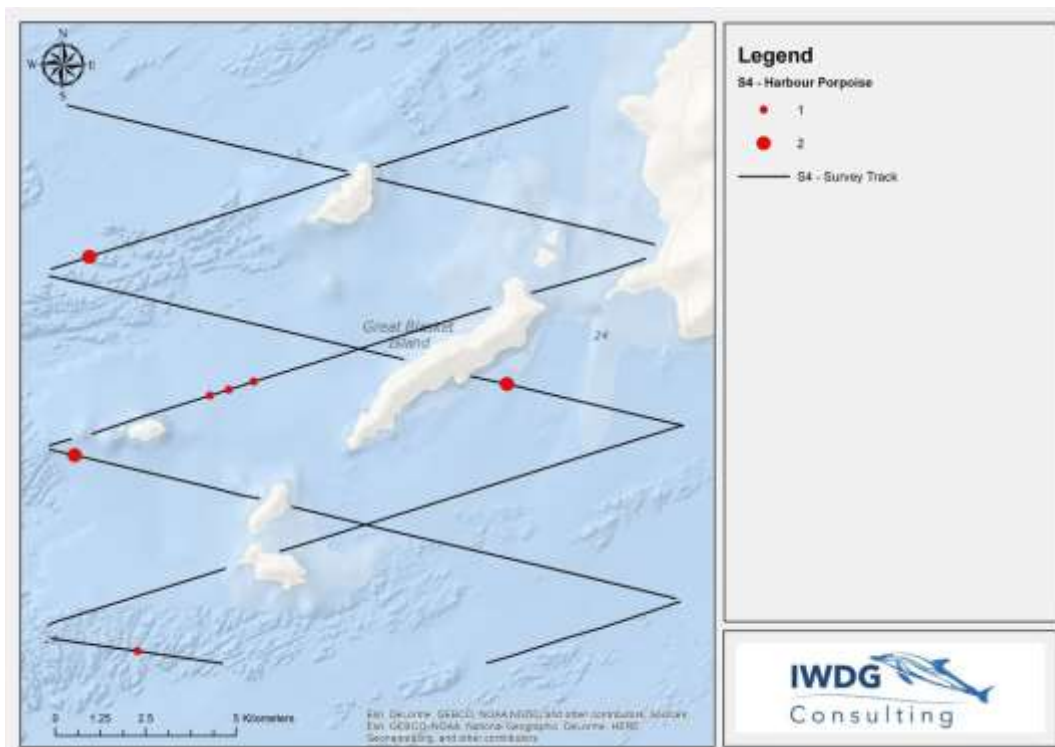


Figure 3d. Vessel track-lines and distribution of harbour porpoise sightings on 5 July 2018. Numbers of porpoises are shown by the red circles.

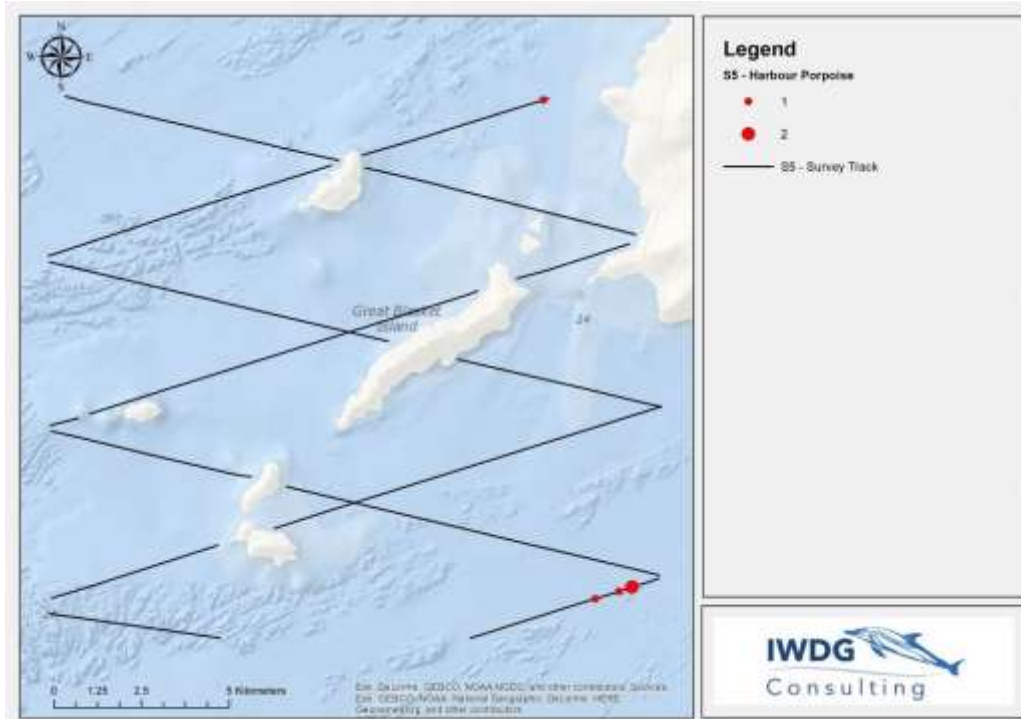


Figure 3e. Vessel track-lines and distribution of harbour porpoise sightings on 13 July 2018. Numbers of porpoises are shown by the red circles.

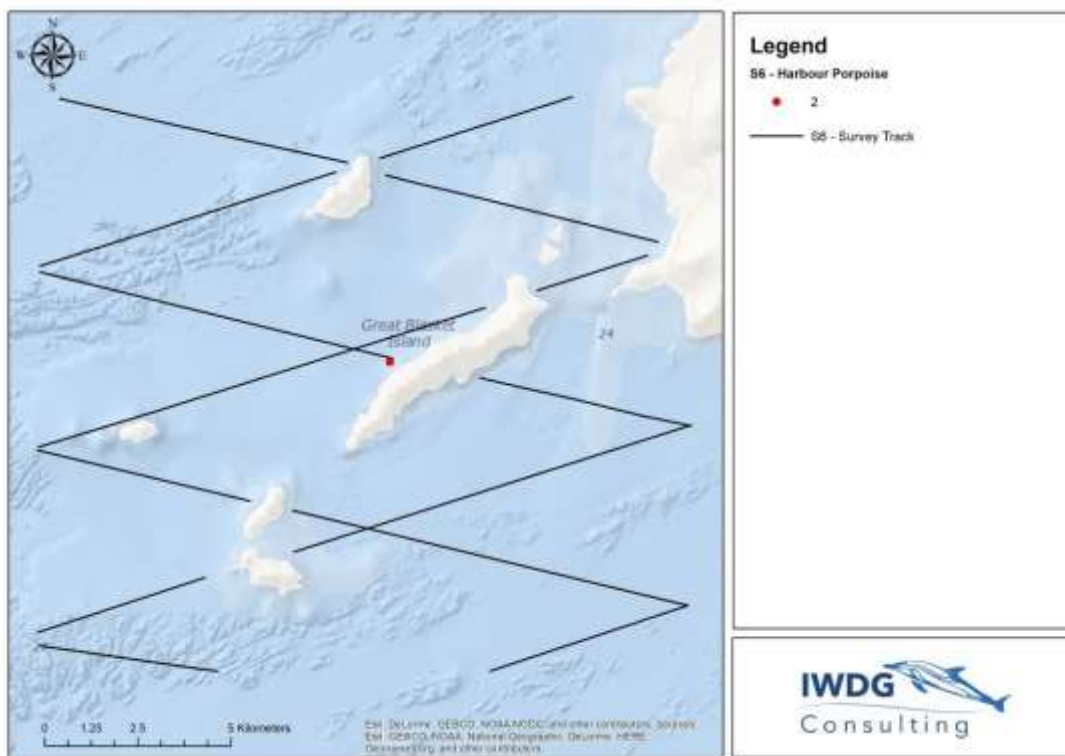


Figure 3f. Vessel track-lines and distribution of harbour porpoise sightings on 24 September 2018. Numbers of porpoises are shown by the red circles.

Density and abundance estimation

Density estimates for harbour porpoises within the SAC were calculated from sighting data obtained combined across all survey days. It was not possible to present density estimates for each survey day as the number of sightings, even in favourable sea conditions ranged from only 3-7 (Table 2). Thus all data were pooled and presented in categories of increasing sea-state (i.e. sea-state 0, sea-states 0+1 and sea-states 0+1+2). The sightings dataset for each analysis was truncated at 300 m from the track-line for each survey day.

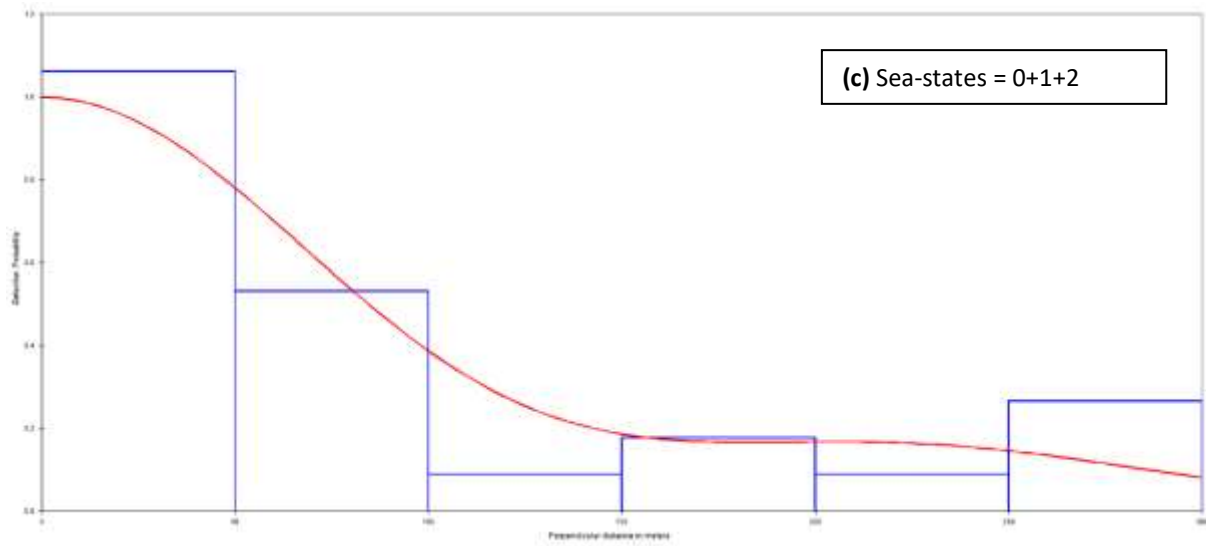
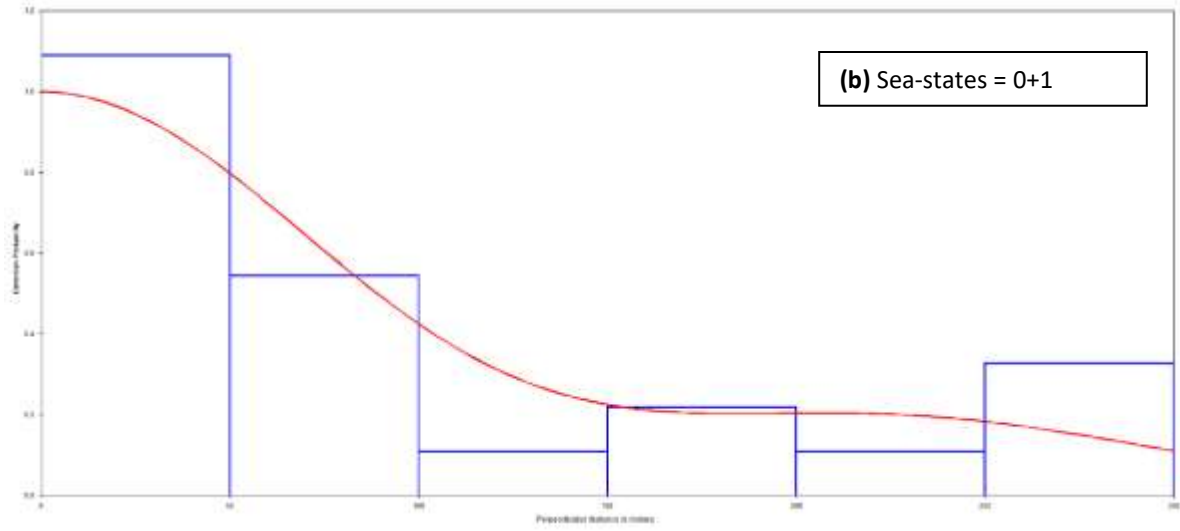
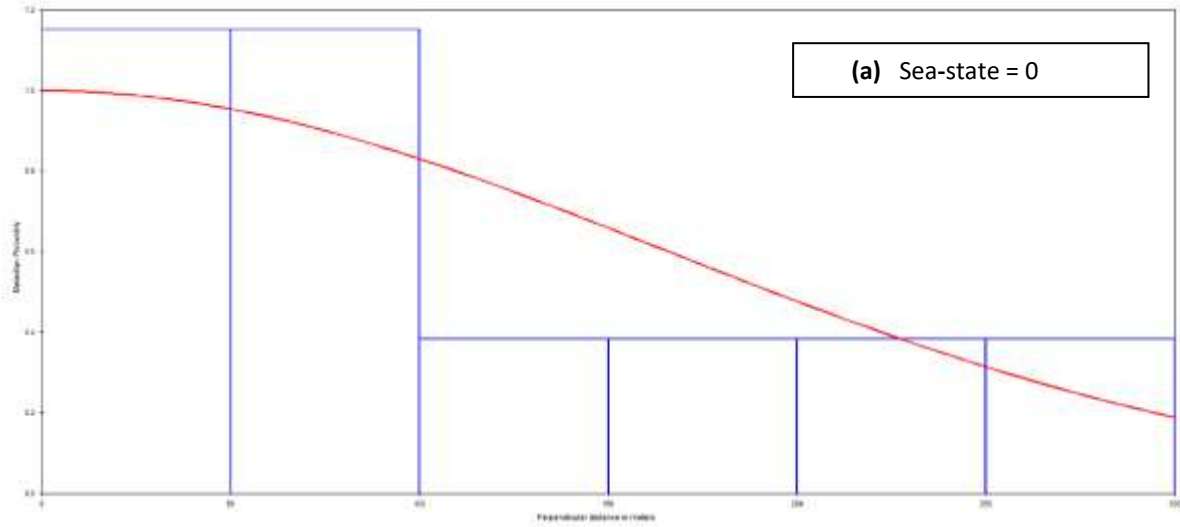
A summary of the data outputs from the DISTANCE model is shown in Table 3 and the detection functions are shown graphically in Figures 4a-e. Chi-squared values delivered by the model were not generally favourable but improved slightly with more data up to and including all survey effort and sightings to sea-state $s \leq 2$ (Table 3). This suggests that the detection functions were not a good fit and the resulting estimates are to be treated with caution.

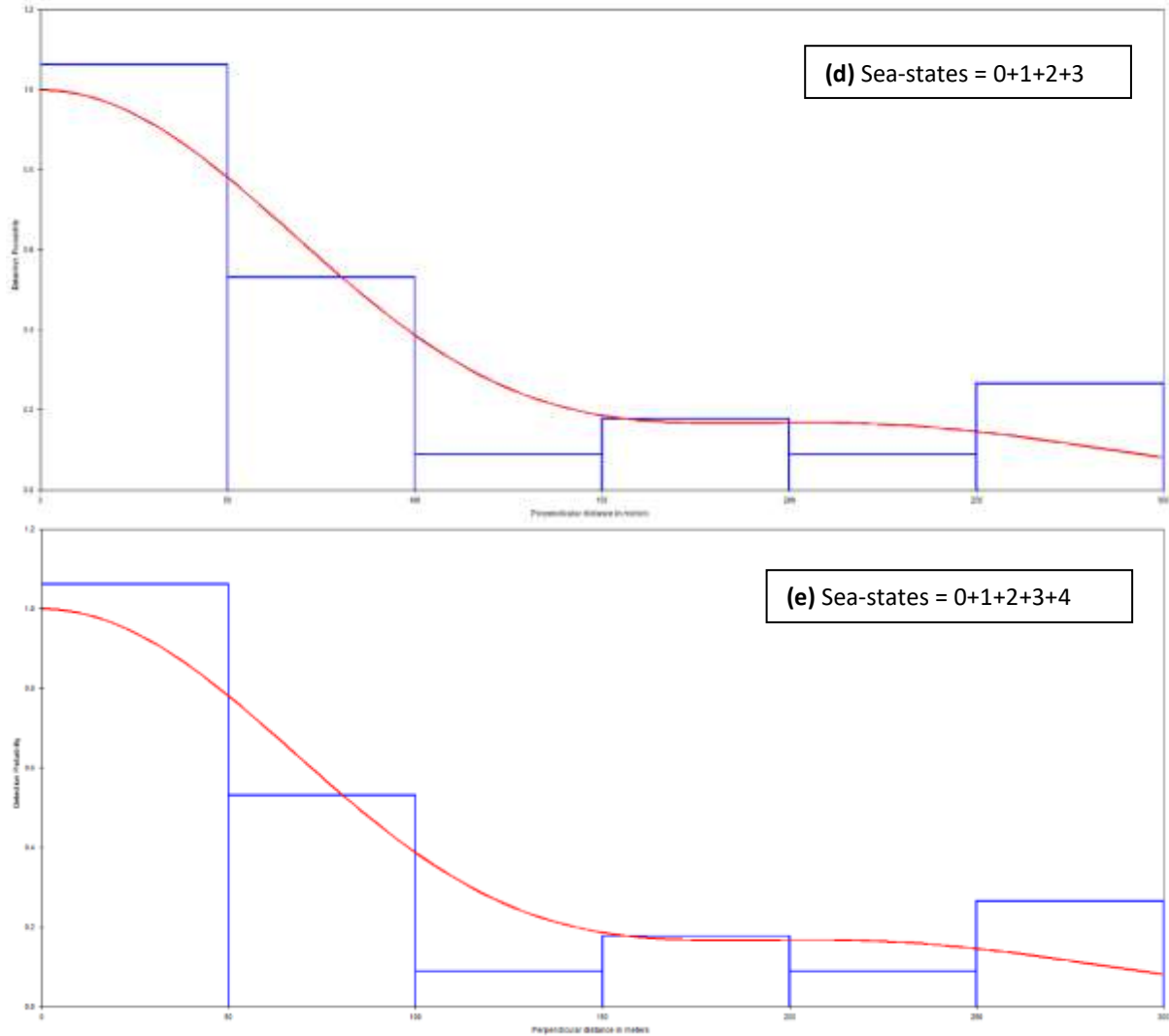
The effective strip half-width ranged from 110-192 m. Most variability was attributed to the detection probability rather than cluster size since group size generally consisted of single animals with some group sizes of two and one with 3 individuals recorded on one occasion (Table 3).

Table 3. Model data used in the harbour porpoise abundance and density estimation process for each survey of the Basket Islands SAC in June-September 2018.

Note: A half-normal model with cosine series adjustments was used and sighting data were truncated at 300 m.

Sea-state	Chi ² P value	Effective Strip Half-Width (m)	Mean Cluster Size \pm SE	Variability (D)		
				Detection	Encounter	Cluster
0	0.69	192	1.40 \pm .022	76.8	-	23.2
0+1	0.43	119	1.27 \pm 0.11	89.5	-	10.5
0+1+2	0.39	110	1.28 \pm 0.06	88.4	-	11.6
0+1+2+3	0.39	110	1.28 \pm 0.06	88.4	-	11.6
0+1+2+3+4	0.39	110	1.28 \pm 0.06	88.4	-	11.6





Figures 4a-e. Detection function plots for harbour porpoise surveys in the Basket Islands SAC according to different sea-state classes.

Harbour porpoise density and abundance estimates in the Basket Islands SAC, measured with increasing sea-state, are shown in Table 4. Density estimates ranged from 0.21 animals per km² (sea-state 0) to 0.28 per km² in sea-state ≤ 2 . The coefficients of variation around the estimates ranged from 0.22 to 0.33. Given that the density estimate was greatest at sea-states ≤ 2 , and the small amount of additional effort in sea-states ≥ 2 made little difference to the density estimate, we recommend that the data collected in sea-state ≤ 2 be used as the best density and abundance estimate for the site in 2018 (Table 4).

Table 4. Estimated density, abundance (N) and group sizes of harbour porpoise recorded during each survey in the Basket Islands SAC in 2018. The best estimates for 2018 are highlighted in bold font.

Sea-state	Sightings	Effort (km)	Density \pm SE (per km ²)	Mean group size \pm SE (95% CI)	N (95% CI)	SE	CV
0	10	185.8	0.21 \pm 0.07	1.40 \pm 0.22 (1.00-1.99)	49 (25-97)	15.9	0.33
0+1	23	481.1	0.26 \pm 0.06	1.27 \pm 0.06 (1.05-1.54)	58 (35-96)	14.4	0.25
0+1+2	26	549.7	0.28\pm0.06	1.28\pm0.11 (1.07-1.52)	60 (39-93)	13.0	0.22
0+1+2+3	26	582.0	0.27 \pm 0.06	1.28 \pm 0.11 (1.07-1.52)	60 (39-93)	13.0	0.22
0+1+2+3+4	26	583.5	0.27 \pm 0.06	1.28 \pm 0.11 (1.07-1.52)	60 (39-93)	13.0	0.22

Proportion of young porpoises to adults

No juveniles or calves were recorded over the duration of all surveys, with all individuals' sighted considered to be adults.

Additional sightings

Other species recorded during the summer-autumn survey period included common dolphin, minke whale and Risso's dolphin (Table 5; see Appendix for maps). Common dolphin sightings declined from June to September but the total numbers observed were most consistent and suggested that group size increased a little in September. Minke whales were particularly abundant in the study area in July.

Table 5. Additional data concerning sightings of non-target cetacean species during harbour porpoise surveys of the Basket Islands SAC in the summer-autumn of 2018.

Survey	Date	Common dolphin		Minke whale		Risso's dolphin	
		Sightings	Individuals	Sightings	Individuals	Sightings	Individuals
1	5 June	12	74	1	1	1	1
2	6 June	12	83	2	2	1	3
3	25 June	1	6	2	2	0	0
4	5 July	8	22	5	5	0	0
5	13 July	4	12	14	14	1	3
6	24 Sept	3	41	0	0	1	1
Total		40	238	24	24	4	8

A sufficient number of sightings of minke whales were made on 13 July to allow an estimate of density using the DISTANCE software. The detection function was a good fit ($P=0.15$; Figure 5) resulting in a density estimate of 0.38 minke whales per km². This equated to an abundance of 86 individuals (95% CI: 46-159; CV=0.29) which is the highest figure recorded in the SAC to date (Table 6; Figure 5). The estimate was similar to another estimate produced during a similar survey of the Basket Islands SAC on 17 June 2014 (Table 6).

Table 6. Density and abundance estimates for minke whales in the Basket Islands SAC in the summer-autumn of 2018 (13 July) and summer 2014.

Sample Day	Chi ² P value	Effective Strip Half-Width (m)	Density (per km ²)	SE	CV	N (95% CI)	Reference
17 June 2014	0.267	642	0.31	0.11	0.36	70 (32-151)	O'Brien and Berrow (2014)
24 June 2014	0.024	1409	0.14	0.011	0.12	32 (24-41)	O'Brien and Berrow (2014)
13 July 2018	0.153	184	0.38	0.11	0.29	86 (46-159)	This survey

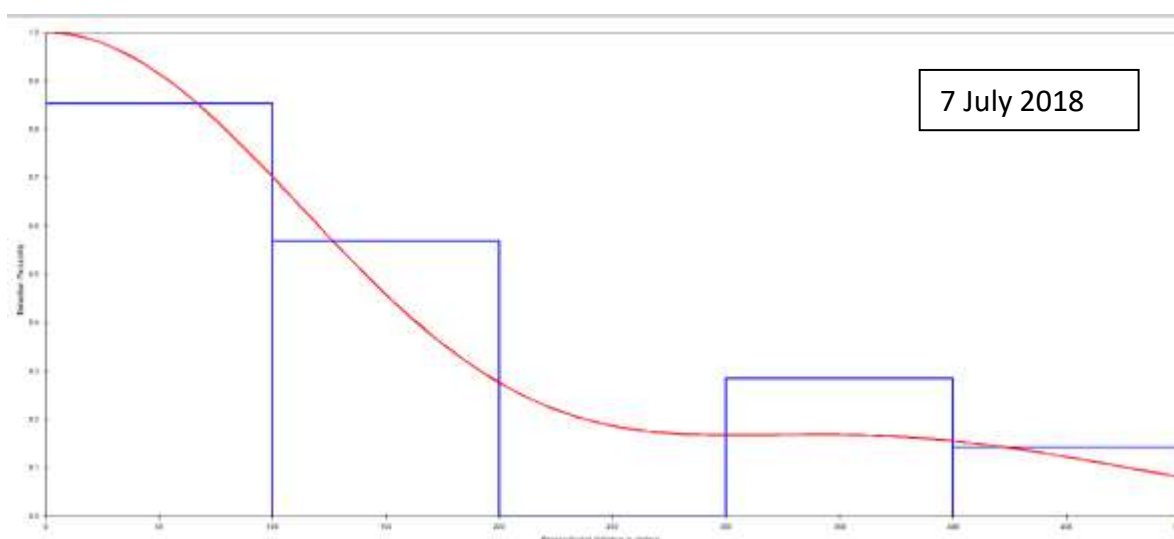


Figure 5. Detection function for minke whales observed during harbour porpoise survey of the Basket Islands SAC on 13 July 2018.

Discussion

This is the fourth dedicated harbour porpoise survey assessment carried out in the Basket Islands SAC. Surveys now span an 11 year period and this is the most surveyed SAC site for harbour porpoises in Ireland. As per previous monitoring practice, distance sampling was used to derive density and abundance estimates and to compare to previous surveys of this site to explore possible trends.

The 2018 surveys were carried out in favourable conditions with 95% taking place in sea-states <3 and 82% in sea-states 0-1. Sighting rates were extremely low nonetheless and mean group size was also the lowest recorded during all dedicated surveys of this SAC so far. This resulted in a large difference in the overall density estimate calculated during 2018 compared to previous years. Densities in 2007 and 2008 were quite consistent at 1.33 and 1.65 animals per km². The estimate from 2014 was less than one-half of these estimates at 0.64 animals per km² and this year (2018) over half that again at 0.28 animals per km² (Table 7).

Table 7. Density, abundance and group size estimates for harbour porpoises in the Blasket Islands SAC between 2007 and 2018.

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 <i>et al.</i> (2009)
2008	1.76	18	1.65	372±105 (216-647)	0.28	Berrow <i>et al.</i> (2014)
2014	2.09	6	0.64	146±53 (41-516)	0.36	O’Brien and Berrow (2014)
2018	1.28	0	0.28	60±14 (39-93)	0.22	This survey

The use of distance sampling and modelling to derive density and abundance estimates for harbour porpoise in Ireland using a single observation platform has been discussed by Berrow *et al.* (2009; 2014). Statistical interpretation using distance sampling rests on 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 target objects are uniformly distributed with respect to track-line in any given direction. These assumptions are sometimes violated but in this case the survey methodology has been relatively consistent between years, particularly the last two survey years. The track lines surveyed during the present study were similar to those surveyed in 2014 and were again randomly positioned within the SAC, though this was not the case in 2007 and 2008. The 2018 track-lines again provided good coverage of the whole SAC and a large number of sightings were obtained in previous surveys, so this feature should not account for the differences in density estimates. Furthermore the CV generated around the density estimates in 2018 was the lowest recorded so far, indicating a robust survey methodology and consistency in sighting rates and group sizes.

The ability to visually detect harbour porpoises 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 focused on 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 porpoises decreased by 20% from Beaufort 0 to 1 and by 75% from Beaufort 2-3. In the present survey most (85%) of survey effort was carried out in sea-states ≤1 so conditions were very favourable for detecting the species.

Recorded group size was very low throughout this survey season and this will have a strong influence on the overall density estimates. Even if sighting rates were low the density estimate would not be so low if group size was higher but a combination of low sighting rates and smaller group sizes contributed to the low overall density estimates in 2018. The lack of juveniles or calves was also significant and may also explain the lower group sizes seen in the field. The absence of sightings of porpoise calves suggests that there may have been a poor breeding year in the area for example or that adults with calves in summer-autumn 2018 occurred elsewhere outside the SAC boundaries.

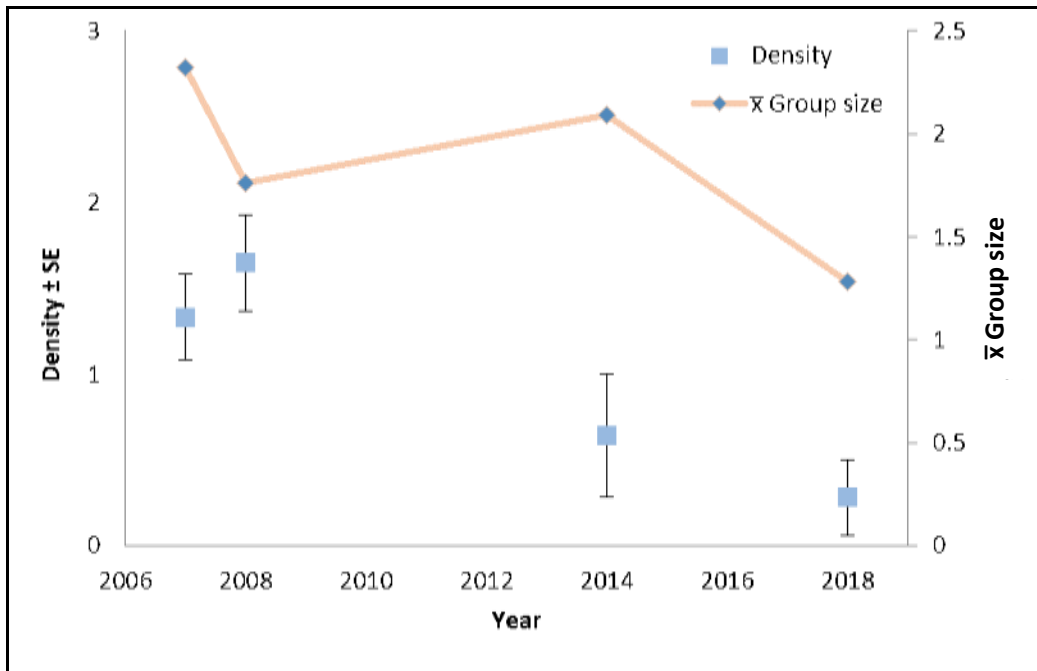


Figure 6. Harbour porpoise pooled density estimates (animals per km² ±SE) and mean group sizes recorded during line transect surveys in the summer-autumn period, 2007 to 2014, in the Basket Islands SAC.

Broadly comparing results from the present study with density estimates for the Basket Islands SAC in 2007, 2008 and 2014 shows that porpoise estimates may have declined considerably since 2007/08 (Table 7; Figure 6) as well as group size. In 2007 and 2008 values were more similar, whilst there was a drop of almost 50% for estimates obtained in 2014 and a further 56% decline between 2014 and 2018. Consistency in survey design, survey platform, observers and track-lines coupled with the favourable sea conditions that most survey effort was carried out in suggest that this is a real decrease in density observed between 2014 and 2018. However, the effective comparison of surveys carried out in 2007-2008 (Berrow et al., 2007; Berrow et al., 2008; Berrow et al., 2009) with more recent surveys is difficult, since in 2007-2008 the transect designs and routes differed considerably, and track-line positions were not randomised with respect to the spatial extent of the SAC or the survey year for example. Such factors may have introduced an element of bias in the survey design and its results. Further replicate surveys of the kind undertaken in the SAC in 2014 and 2018 will enable further exploration of this potential issue in the future. We can only suggest that there was a major change in the distribution of harbour porpoises in the site in this summer compared to previously. This was possibly associated with the distribution of their prey. The site is small in relation to the potential daily movement of highly mobile cetaceans such as harbour porpoises, and even a small change in prey distribution could result in most prey occurring outside the boundaries of the SAC, resulting in low densities of porpoises within the site. A better understanding of the ecology of harbour porpoise in the region, including diet and foraging ecology, is required in order to interpret this apparent decline in abundance between survey years. Furthermore, studies of the natural variation in porpoise occurrence in the wider region are recommended.

Recommendations

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

1. These surveys should be replicated for a number of years to provide a measure of variability between years and to explore possible trends in occurrence, density, etc. If SAC monitoring surveys are to be carried out once every three years it will take a long time before short-term and long-term trends can be identified and potential conservation actions considered and/or taken. We recommend annual surveys to explore whether this apparent short-term trend is real or if significant inter-annual fluctuations occur.
2. 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 between-year variability recorded in studies of the site so far.
3. 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 possible that acoustic datasets when put into appropriate models could identify changes at a higher resolution than boat-based visual surveys.
4. Due to the small area of the SAC relative to the potential range of highly mobile harbour porpoises, large variations in densities within the SAC would be expected unless there were critical factors driving a preference for habitats within the site. These short-term variations are likely to be driven by local prey availability in addition to underlying seasonal changes, which are poorly understood at present. A better understanding of the ecology of harbour porpoise in the Blasket Islands SAC is required, including information on diet and reproductive rates.
5. Since 2007 a considerable body of data on harbour porpoise distribution and abundance in this SAC has been collected. We recommend that these data are explored more fully, including using habitat modelling to explore fine-scale use of the SAC by harbour porpoise in order to inform management and conservation.

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Appendix 1: Additional marine mammal species recorded during the 2018 Basket Islands SAC Surveys.

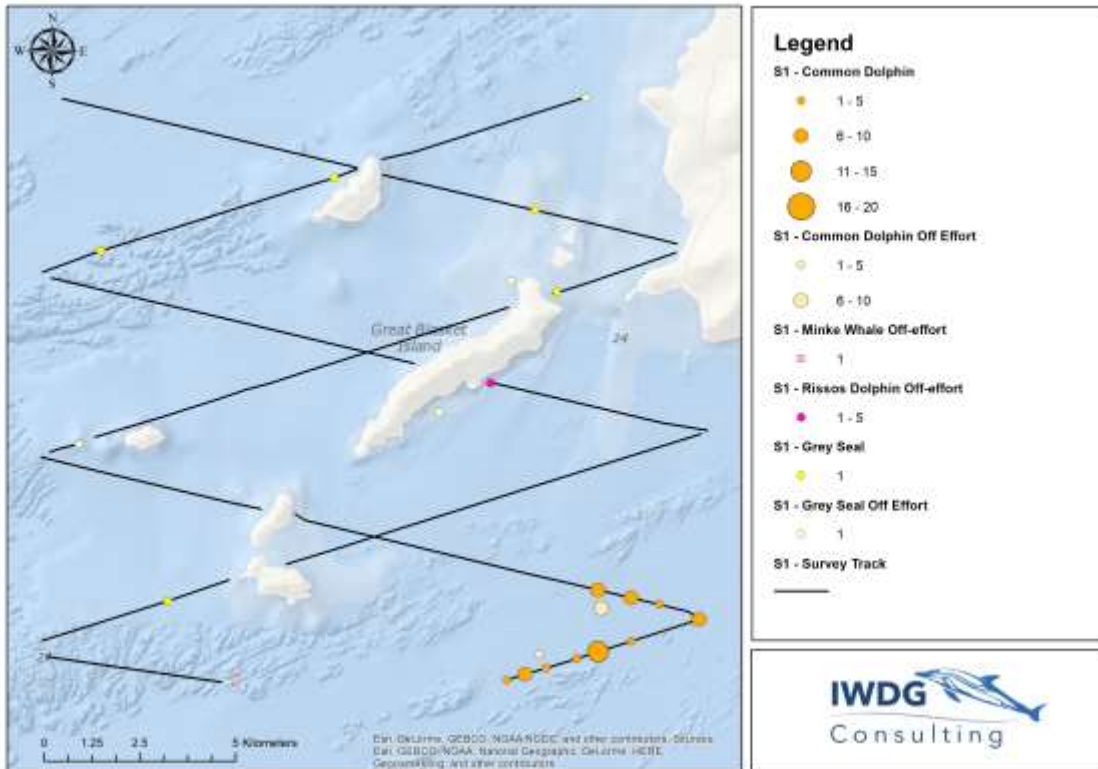


Figure 7. Vessel track-lines, estimated group sizes and distribution of other species sighted on 5 June, 2018

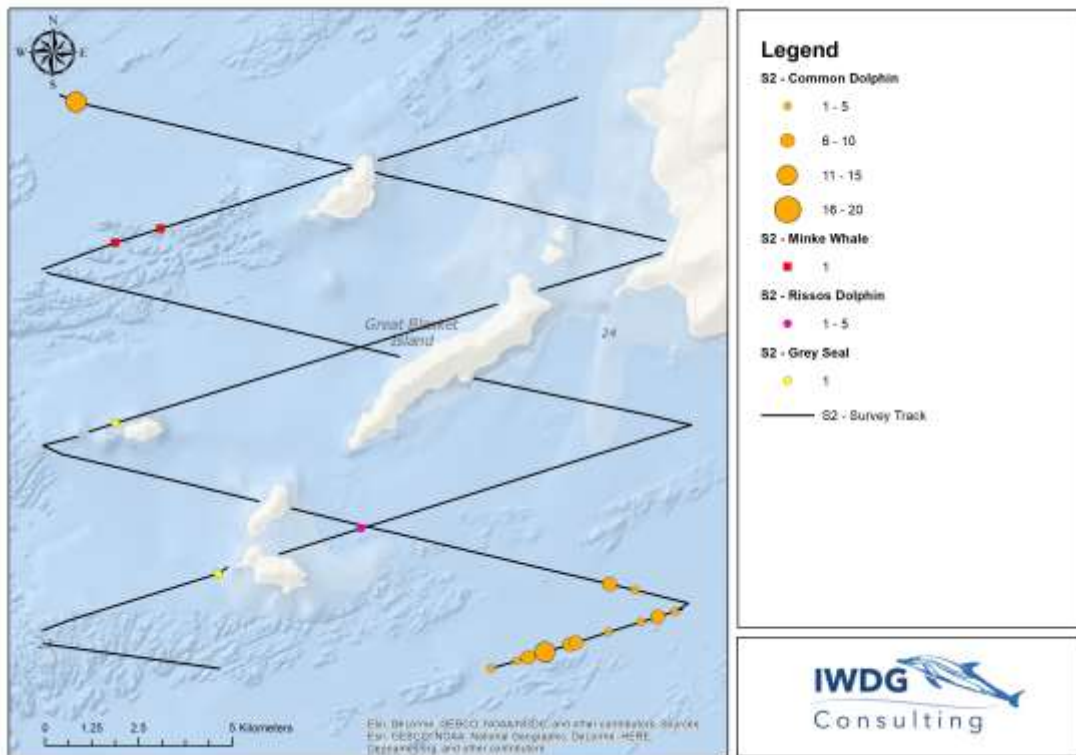


Figure 8. Vessel track-lines, estimated group sizes and distribution of other species sighted on 6 June, 2018

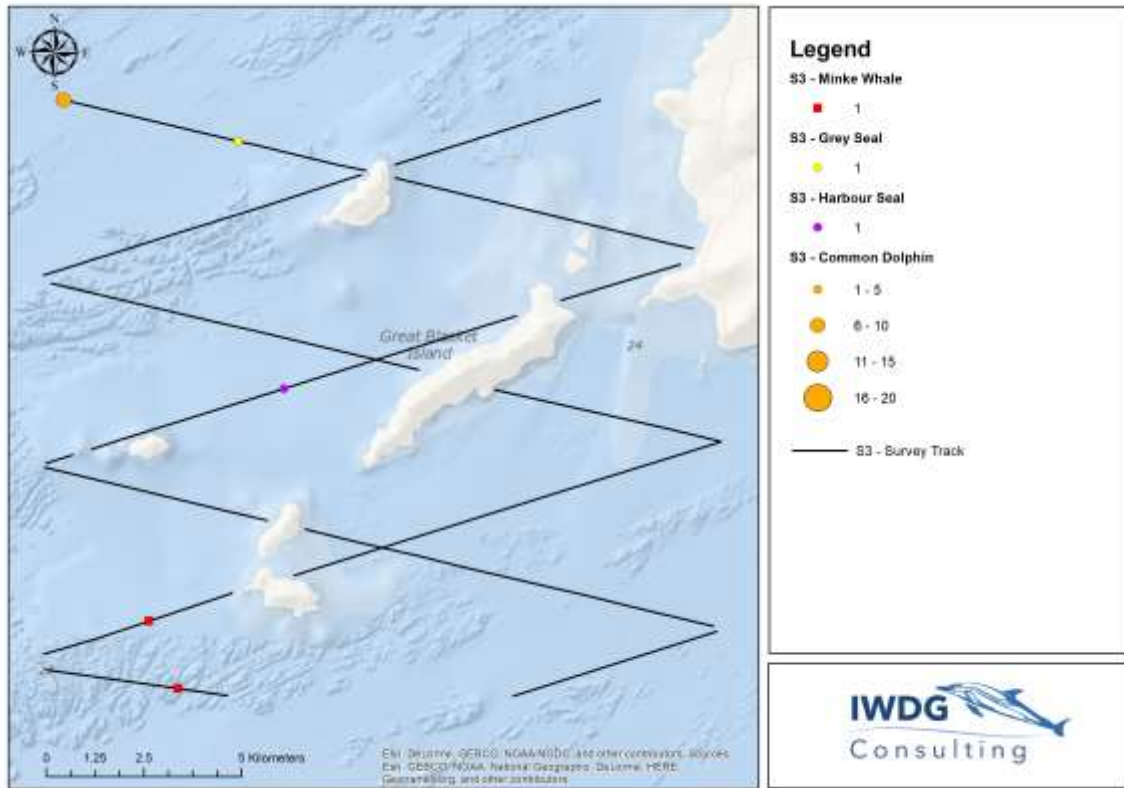


Figure 9. Vessel track-lines, estimated group sizes and distribution of other species sighted on 25 June 2018

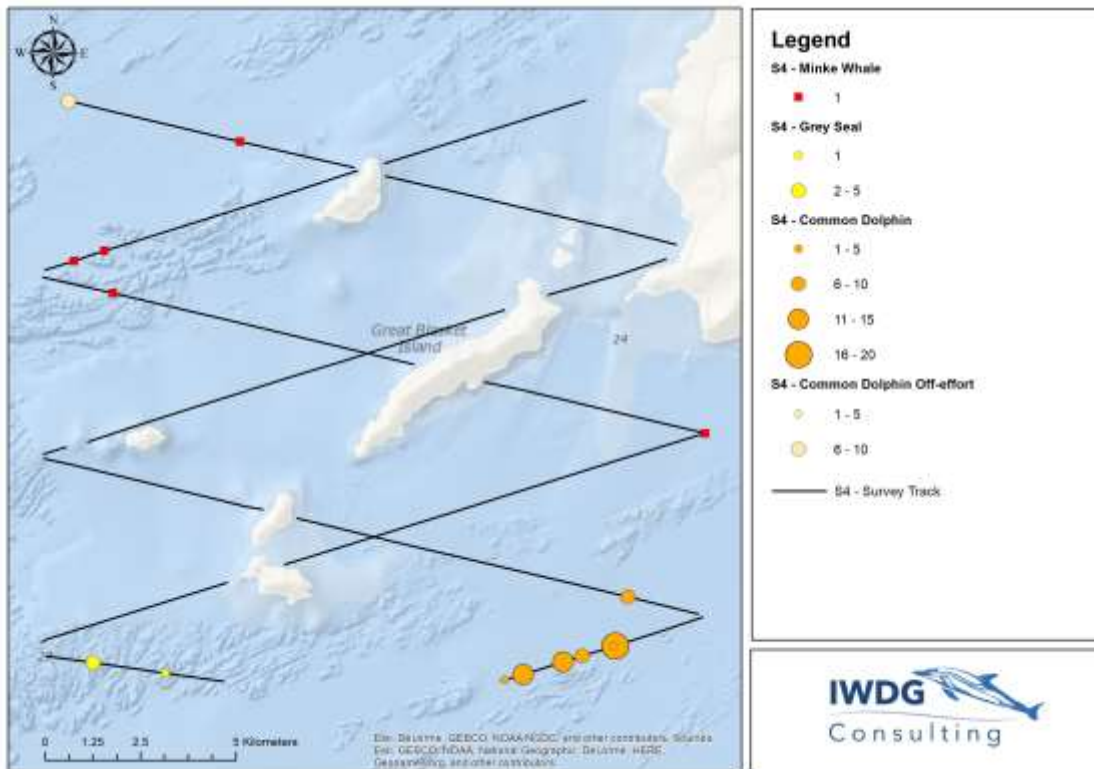


Figure 10. Vessel track-lines, estimated group sizes and distribution of other species sighted on 5 July 2018

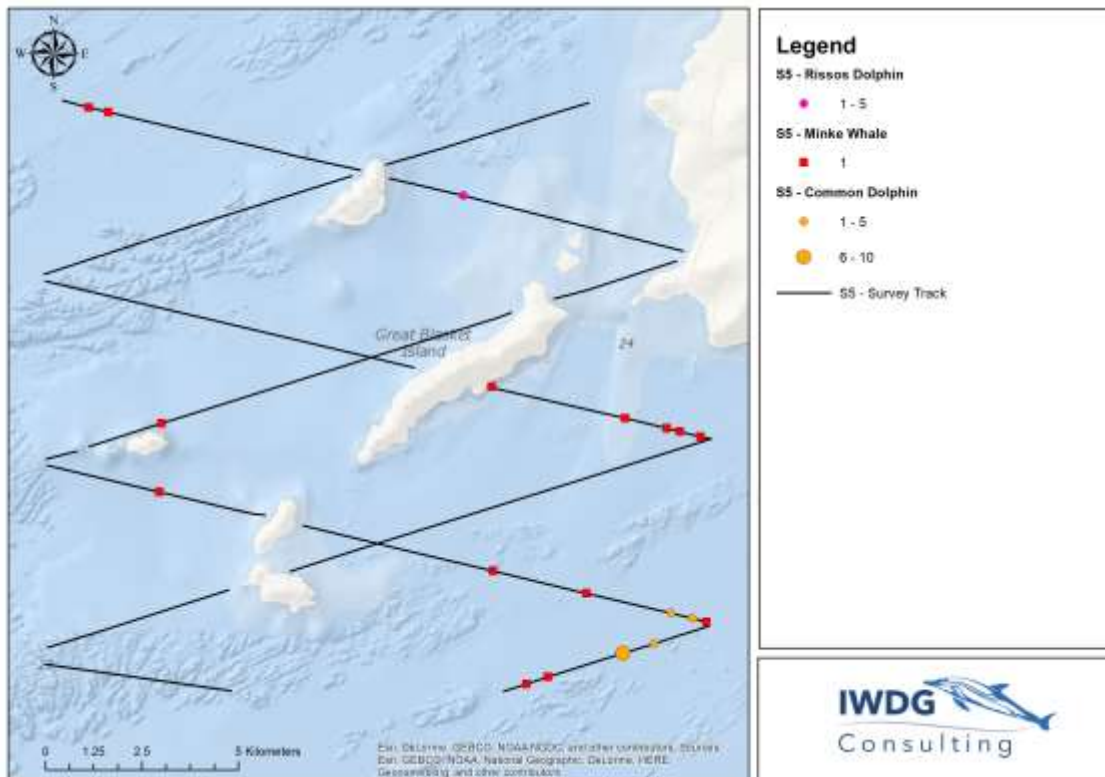


Figure 11. Vessel track-lines, estimated group sizes and distribution of other species sighted on 13 July 2018

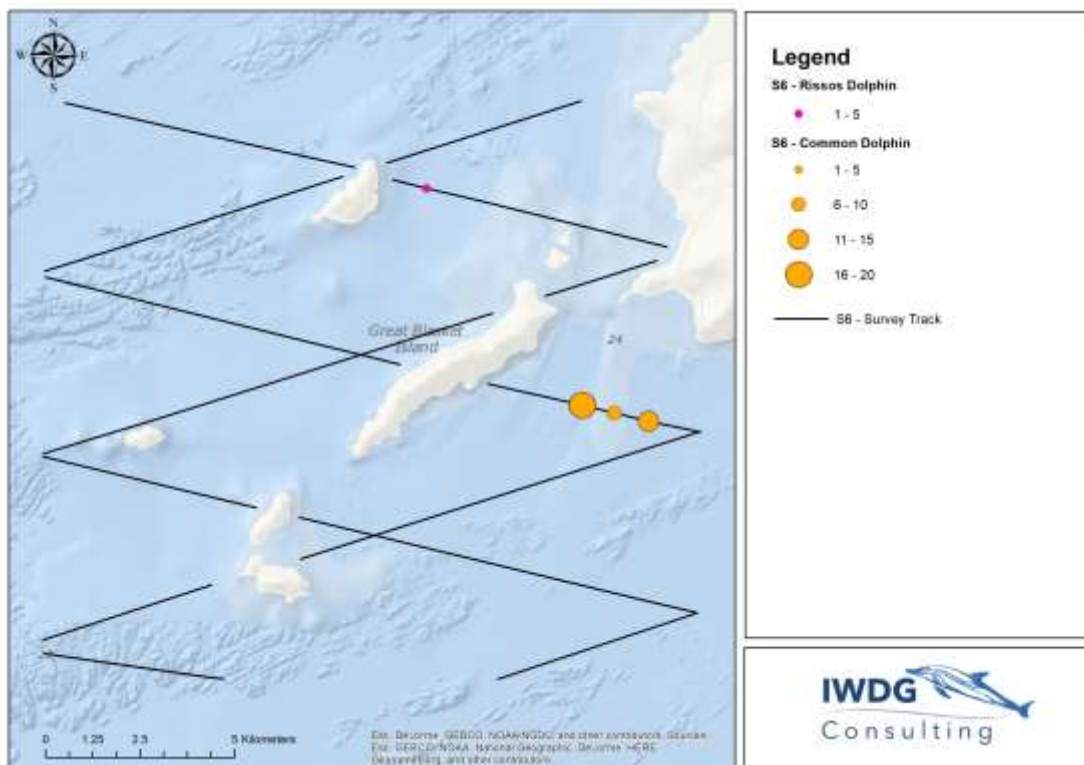


Figure 12. Vessel track-lines, estimated group sizes and distribution of other species sighted on 25 September 2018