Inshore boat-based surveys for cetaceans: Irish Sea

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Cover image: Minke whale riding the stern wave in the Irish Sea during the inshore survey © DAHG

Inshore boat-based surveys for cetaceans

Summary

Concurrent visual and acoustic surveys for cetaceans were carried out in two survey blocks in the Irish Sea to investigate species distribution, relative abundance and absolute abundance where possible.

Single platform line-transect surveys were carried out in the northern Irish Sea in July and in the southern Irish Sea in August 2011. During the two surveys, we carried out 348km of survey effort along 23 track-lines of which 100% of the northern Irish Sea survey and 79% of the southern Irish Sea survey were in sea-state ≤3. We recorded a total of 71 cetacean sightings comprising 111 individuals of two species. In addition there were five seal sightings of two species and a single sighting of a basking shark. Harbour porpoise was by far the most abundant species followed by minke whale. Grey seal was the most frequent seal species with only a single sighting of a common seal.

A total of 57 sightings of cetaceans were made in Block A in the northern Irish Sea; 51 harbour porpoise sightings and six sightings of individual minke whales. In addition single grey seals were sighted on two occasions. In Block B in the southern Irish Sea 14 cetacean sightings were recorded, all harbour porpoise sightings and sightings of a single common seal and two sightings of single grey seals. This provided sighting rates of harbour porpoise of 0.29 sightings per km or 5.24 sightings per hour in Block A and 0.10 harbour porpoise per km or 1.91 sightings per hour in Block B. Relative abundance was estimated at 0.50 harbour porpoise per km or 9.15 per hour in Block A and 0.16 harbour porpoise per km or 3.00 individuals per hour in Block B.

In Block A the adult to sub-adult ratio was 5.8:1 or 14.7% sub-adults (juveniles and calves) and the adult to calf ratio was 9.7:1 or 10.3%. In Block B the adult to sub-adult ratio was 3.4:1 or 23% and the adult to calf ratio was 17:1 or 6%.

Passive Acoustic Monitoring was carried out during each survey and a total of 16 acoustic encounters were logged at an overall rate of 0.05 acoustic encounters per km. All detections were of harbour porpoise. The number of acoustic encounters recorded per survey was consistent, but was low, especially in block A, when compared to the total number of sightings. Of the 16 detections logged, a total of 12 (75%) were only logged acoustically with no concurrent visual record. Thus acoustic monitoring does suggest not all harbour porpoise present in the survey area were recorded visually but it also suggests that no dolphin sightings within the acoustic monitoring range of the vessel were over-looked.

Sufficient sightings for a robust estimate were only available for harbour porpoise in Block A. A density estimate of 1.585 ± 0.219 harbour porpoise per km^2 was recorded with a CV of 0.14. This CV was increased to 0.32 if the track line was used as the sample but with no change to the overall density estimate. Densities in the northern Irish Sea were high compared to similar surveys carried out along the western seaboard of Ireland in 2010 using the same methodology.

Despite differences in overall sea conditions the data suggests harbour porpoise densities are lower in the southern Irish Sea compared to areas further north and the area adjacent to North County Dublin and Dublin Bay may provide particularly good habitats for harbour porpoise.

Introduction

Waters within the Irish Exclusive Economic Zone (EEZ) are known to be some of the most important in Europe for cetaceans (Berrow, 2001). While there has been a steady increase in cetacean research in Ireland, dedicated surveys to estimate the abundance of cetaceans in a defined area are limited to date and are presently insufficient to detect population trends (O'Brien *et al.* 2009).

Since 1994 there has been a concerted effort to map the distribution and relative abundance of all cetacean species occurring within the Irish EEZ largely using platforms of opportunity. These surveys including initiatives such as European Seabirds at Sea (ESAS) research, ISCOPE and PReCAST have attempted to include seasonal coverage, especially of offshore waters (Pollock *et al*. 1997; Ó Cadhla *et al*. 2004; Wall *et al*. 2006; 2011; Berrow *et al.* 2006; 2010).

The first dedicated double-platform cetacean survey in Ireland was SCANS-I (Small Cetacean Abundance in the North Sea) carried out during summer of 1994, but it only covered the Celtic Shelf region of the Irish EEZ (Hammond *et al.* 2002). During 2000, the SIAR survey covered both inshore and offshore waters of the western seaboard using a double-platform visual survey technique from which the abundance of common and white-sided dolphins was estimated (Ó Cadhla *et al.* 2004). In summer 2005, a second SCANS survey (SCANS-II, 2008) was carried out which this time included all Irish continental shelf waters and the Irish Sea. Abundance estimates for a variety of species including harbour porpoise, common, bottlenose and white-beaked dolphin and minke whale were derived (SCANS-II, 2008). In 2007, a survey of species in European Atlantic waters beyond the continental shelf (CODA) was carried out offshore and provided abundance estimates for common, striped and bottlenose dolphins and long-finned pilot, sperm, minke, fin whales and beaked whales (Hammond *et al*. 2010).

Small scale dedicated surveys were carried out at eight survey locations since 2007 in coastal waters and bays using a single-platform line transect technique to estimate the abundance of harbour porpoises (Berrow *et al*., 2008a; 2008b; 2009; Ryan *et al.* 2010). Land-based surveys through ISCOPE attempted to record and monitor cetaceans inshore (Berrow *et al*. 2010). However, there are still many gaps in coverage (see Wall, 2010).

The Irish Whale and Dolphin Group (IWDG) and the Galway-Mayo Institute of Technology (GMIT) were contracted to carry out concurrent visual and passive acoustic surveys of two survey blocks in the Irish Sea during 2011, as part of the monitoring of cetacean species in Irish continental shelf waters.

<u>Objectives</u>

The objectives of the present survey were, within each survey block, to determine:

(a) occurrence of cetaceans and other marine species of interest;
(b) species relative abundance (no. of sightings/individuals per unit effort);
(c) cetacean species abundance, where possible (i.e. population/density estimation).

Methods

Survey blocks

The two inshore survey blocks in the Irish Sea are shown in Figure 1. Each block was 336 nm^2 (1152 km^2) in surface area with a perimeter of 48nm by 7nm and was located approximately between 6nm and 12nm from shore off the east coast of Ireland.

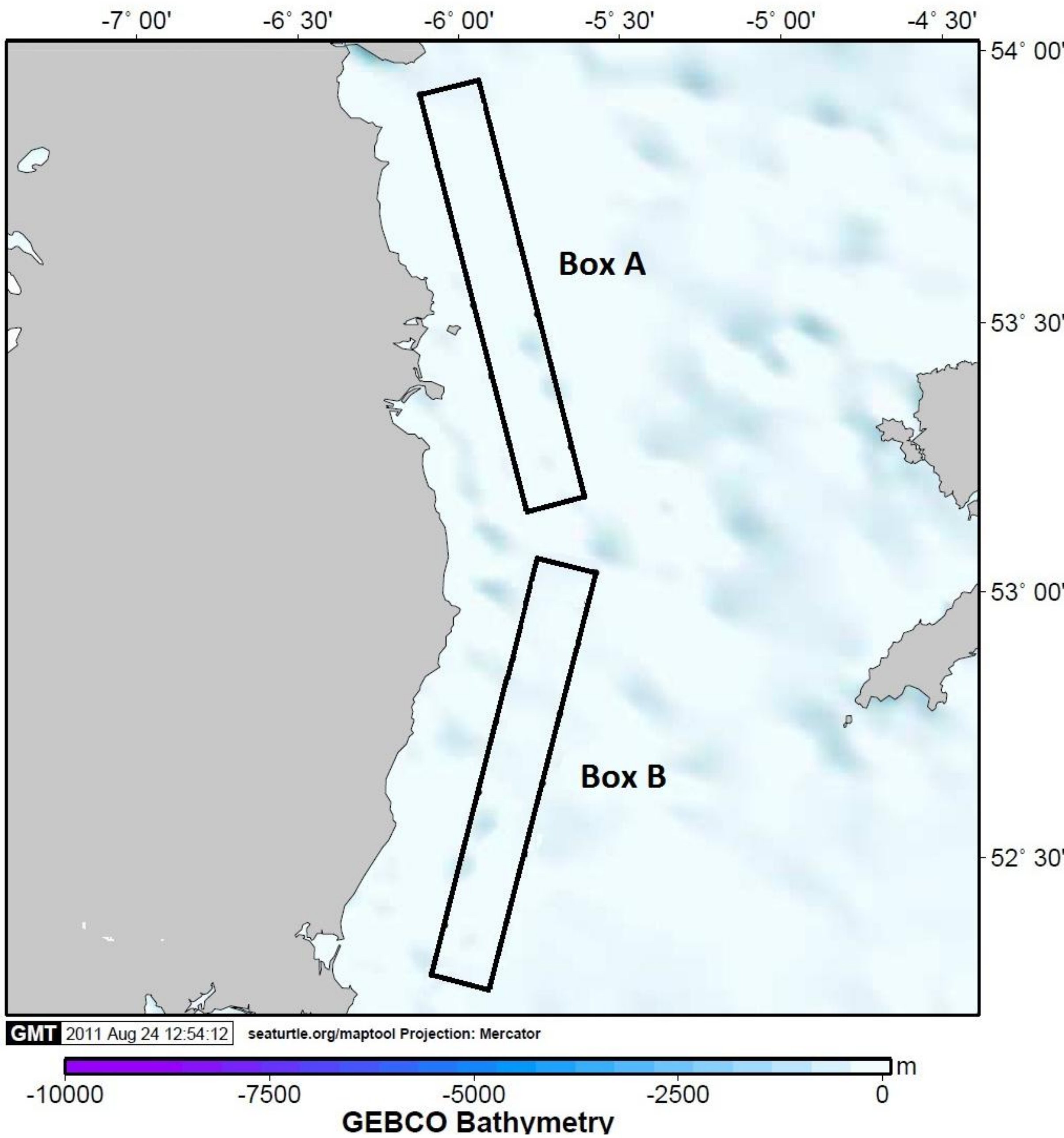

Figure 1. Map of Ireland showing the locations of survey blocks surveyed for cetaceans in 2011.

Survey platform

One vessel was chartered to cover both survey blocks during the survey period. *MV Rocinante* is an ex pilot boat capable of cruising speeds of 10kts. It has a viewing area on top of the wheelhouse which gives a platform height of 4m above sea level which provides an excellent survey position (Fig. 2).

Figure 2. *MV Rocinante* with survey platform on the flying bridge

Survey methodology

Conventional single platform line-transect surveys were carried out along pre-determined track lines supplied by the NPWS. These were similar in survey design to NPWS-contracted survey blocks off western Ireland in 2010 (see Ryan *et al*., 2010)

During survey effort, the vessel travelled at a speed of 12-16 km hr^{-1} (8-10 knots), which was 2-3 times the average speed of the species most likely to be encountered (e.g. harbour porpoise) as recommended by Dawson *et al.* (2008). Two primary observers were positioned at any one time, on the flying bridge and a rotation of 30 minutes on port, 30 minutes on starboard and 30 minutes rest was observed. Only observers with experience in cetacean visual surveys and species identification in Irish waters were used as primary observers. Primary observers watched with naked eye from dead ahead to 90^o to port or starboard depending on which side of the vessel they were stationed. Opticron 10x50 marine binoculars with reticle eyepieces were used to confirm species identification and assist in distance estimation. In addition, sightings of seals and any other marine megafauna (e.g., basking shark) were also recorded.

During each transect the position of the survey vessel was tracked continuously through a GPS receiver fed directly into a laptop while survey effort, including environmental conditions (sea-state, wind strength and direction, glare etc.) were recorded directly onto LOGGER software (©IFAW) every 15 minutes. When a sighting was made the position of the vessel was recorded immediately in LOGGER and the angle of the sighting from the track of the vessel and the radial distance of the sighting from the vessel recorded. The angle was recorded to the nearest degree via an angle board attached to the vessel immediately in front of each observer. These data were communicated to the recorder in the wheelhouse via two-way radio. Accurate distance estimation is essential for distance sampling. Distance sticks were made for observers using the Heinemann Equation (Heinemann, 1981) which were used to aid distance estimation.

Sightings rate and relative abundance

Sightings rate was calculated as the number of sightings per km traveled or hour of survey effort, while relative abundance was calculated as the number of animals recorded per km of transect or per hour of coverage. Both measures were restricted to observations made in sea state ≤3.

Absolute abundance estimation

The statistical package DISTANCE (Version 5, Release 2.0, 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 estimated detection function is used to calculate the density of animals within a prescribed area passed through by the vessel. In this survey we assumed that all animals occurring on the track-line were observed i.e. that the detection function g(0) = 1. 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 for truncation of outliers when estimating variance in group size.

All sightings are listed in the survey block summary tables. We used the survey day as the sample with sightings used as observations. To be consistent with, and enable comparisons with Ryan *et al.* (2010), we also used the track-line as the sample with sightings used as observations. Estimates of abundance were calculated for harbour porpoise as appropriate within each survey block. Buckland *et al.* (2001) recommend a minimum of around 40-60 sightings are required for a robust estimate using the DISTANCE model.

Various models were fitted to the data. It was found that a Half-Normal model with Hermite Polynomial series adjustments best fitted the data according to Akaike's Information Criterion (AIC) which provides an objective, quantitative method of model selection. Density estimates using models selected by the software were calculated together with estimates from data grouped into equal distance intervals of 20m up to 300m. This follows the recommendation of Buckland *et al*. (2001) who suggested that grouping of data can be used to improve robustness in the density estimator in cases of heaping or movement prior to detection (often the case with harbour porpoise) by smoothing the distance data. Buckland *et al*. (2001) also recommended at least 5% of the data at the extreme end of the observations should be truncated as they contribute little to the overall density estimation and truncation facilitates fitting of the model. We truncated at 300m which removed just one sighting from the survey of block A. The influence of cluster size (i.e. Group size) is analysed by DISTANCE using size-bias regression method with log(n) of cluster size plotted against estimated g(x).

A Chi-squared test is associated with the calculation of each detection function. If significant then this indicated that the detection function was a good fit and the estimate generated was robust. The proportion of the variability accounted for by the rate of sighting encounters, detection probability and group size is presented with each detection function. Variability associated with the encounter rate reflects the number of sightings on each track-line, which varied from zero to up to ten sightings during the present survey. The detection probability reflects how far the sightings were from the track-line; the further sightings were from the track-line the less likely they were detected, and group size the range in group sizes recorded at each survey block.

Maps were created using Irish Grid (TM65_Irish Grid) with ArcView 3.2 and using SeaTurtle.org Maptool© while design coordinates for the survey areas were obtained from NPWS. Data related to transects, effort, location of visual and acoustic detections, abundance and density estimates were stored in a single MS Access database, which was queried from within the GIS to produce maps.

Passive Acoustic Monitoring

Passive Acoustic Monitoring (PAM) was carried out using a towed hydrophone at a distance approximately 200m astern of the survey vessel and at a depth of c.2 to 5m beneath the sea surface.The towed hydrophone array consisted of a 200m-long cable running from a fluid-filled tube containing two high frequency hydrophone elements (HP-03) situated 25cm apart at the end of the cable. The hydrophone connected to a MAGREC HP-27 buffer-box which was connected to a National Instrument DAQ-6255 USB soundcard run through a laptop computer. The track-line of the acoustic survey effort was recorded using an external GPS receiver, which provides NMEA data to PAMGUARD software (version 1.6.01 Beta).

A dedicated acoustic observer continuously monitored the incoming audio stream both visually (audio-spectrogram) and aurally using PAMGUARD. Acoustic detections of cetacean vocalisations (both clicks and whistles) were noted, described and their time and GPS locations recorded. Raw recordings were saved continuously as .WAV files and backed-up daily on an external hard-drive.

An acoustic encounter was considered a separate encounter, when a silent period of 10 minutes was recorded between acoustic detections. This followed the method used by Aguilar de Soto *et al.* (2004) and was consistent with similar surveys in 2010 (Ryan *et al.* 2010). Harbour porpoise echolocation clicks are characterized as being narrow-band, high frequency between 110 and 150kHz, with an average click duration of 2µs and a mean source level of 150dB. In comparison, dolphin clicks are characterized as being broadband ranging in frequency from 200Hz and 150kHz, therefore making identification to species level often impossible, due to overlaps in their frequency range. Further analysis of acoustic data was carried out in the lab. Species assignment was based on the criteria presented in Appendix I.

Results

Both survey blocks were surveyed in favourable conditions (i.e. sea-state ≤3) (Table 1) as per requirements outlined in the contract. All surveys were carried out during conditions where visibility was 15-20km or greater, with no precipitation and where swell height was occasionally light (≤1m).

Table 1. Date, effort, sea-state and number of cetacean sightings in the Irish Sea survey blocks

Survey block	Date	Distance Surveyed (km)	Proportion of effort in sea-state ≤3	Number of sightings	Total No. of Animals
Block A	10 July	178	100%	57	89
Block B	2 August	170	79%	14	22

Sightings data

During the two surveys, we carried out 349km of survey effort along 23 track-lines of which 100% of survey effort in Block A and 79% of survey effort in Block B was in sea-state ≤3. We recorded a total of 71 cetacean sightings comprising 111 individuals of two species. In addition, there were five seal sightings of two species and a single sighting of a basking shark. Harbour porpoise was by far the most abundant species followed by minke whale. Grey seal was the most frequent seal species with only a single sighting of a common seal. Harbour porpoise was by far the most abundant species followed by minke whale and grey seal. There was a single sighting of a common seal in Block B. A summary of effort and the number of cetacean sightings is presented in Table 1.

Species List

A total of two cetacean and two seal species were recorded during the survey period (Table 2). Harbour porpoise was recorded in both survey blocks while minke whale was only recorded in Block A. Grey seal was recorded in both survey blocks and common seal only in Block B. There were additional sightings of two individual basking sharks recorded in Block A.

Table 2: Species present in each survey block (in order of frequency of occurrence)

Survey block	Species	Sightings	Individuals	Mean Group Size (± SD)
Block A	Harbour porpoise	51	83	1.69±1.31
	Minke whale	6	6	1
	Grey seal	2	2	1
Block B	Harbour porpoise	14	22	1.57±0.85
	Grey seal	2	2	1
	Common seal	1	1	1

<u>Acoustic Detections</u>

Acoustic detections of cetaceans were recorded in each block (Table 3). Clicks were recorded in both blocks during the surveys but only of harbour porpoise. Encounter duration was short with a mean of 59 seconds in Block A and eight seconds in Block B.

Table 3: Summary of acoustic detections at each survey block

Survey block	Date	Clicks	Whistles	Acoustic events	Total detections	Range of Duration min-max (secs)	Mean encounter duration (secs)
Block A	10/07/11	Y	N	15	8	5-310	59.2
Block B	02/08/11	Y	N	11	9	2-34	8.2

Density and abundance estimates

Sufficient sightings for a robust density estimate were calculated for harbour porpoise in the northern Irish Sea (Block A) (Table 4). During the survey of the southern Irish Sea (Block B) the total number of harbour porpoise sightings was fourteen, below the minimum required to generate robust estimates. Two analytical methods were used to determine density. Both methods provided similar density estimates (1.585 and 1.541 harbour porpoise per km^2) but the method which used the track-line as the sample gave a much higher CV and therefore higher standard error and wider 95% confidence intervals (Table 4).

Table 4. Density and abundance estimates of harbour porpoise in the northern Irish Sea (Block A) on 10 July 2011.

Sample	Density ± SE (km^{-2})	Abundance ± SE	CV	95% CI
Day as sample	1.585 ± 0.219	1826 ± 252	0.14	1389 - 2400
Track line as sample	1.541 ± 0.493	1776 ± 569	0.32	917 - 3440

Site Analysis

Northern Irish Sea (Block A)

A survey of the Block A in the northern Irish Sea was carried out on 10 July 2011 with sea conditions of Beaufort sea-state ≤3 for the entire survey and sea-state ≤ 1 for 77.9% of survey effort (Figure 3). A total of 57 sightings of cetacean were made; 51 harbour porpoise sightings and six sightings of minke whale. In addition single grey seals were sighted on two occasions.

Species Diversity

Species diversity was low given the high number of sightings, with only two species of cetacean (harbour porpoise and minke whale) recorded and one seal species (grey seal). Single basking sharks were recorded on two occasions (one off effort east of Clogherhead while transiting to the start of the survey of Block A).

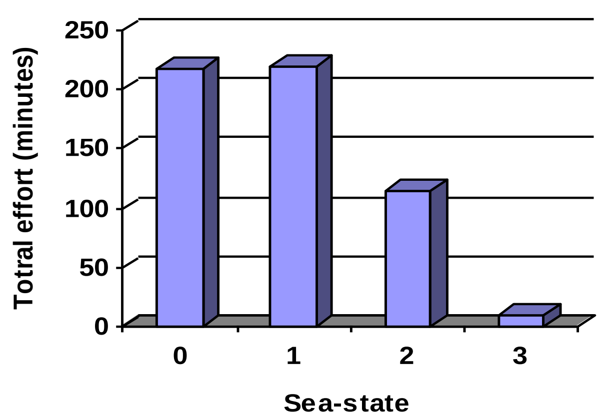

Figure 3. Sea state conditions for the survey of the Northern Irish Sea (Block A)

Relative abundance

Harbour porpoise were by far the most abundant species in Block A with a sightings rate of 0.33 sightings per km or 5.41 sightings per hour of survey effort. Relative abundance of harbour porpoise was estimated at 0.55 porpoise per km or 8.99 porpoise per hour of survey (Table 5). This was an order of magnitude greater than the relative abundance of minke whale or grey seal (Table 5).

Table 5. Relative abundance of cetaceans and seals recorded in Block A.

	No. of sightings	No. of individuals	Sightings per km	Numbers per km	Sightings per hr	Numbers per hr
Harbour porpoise	51	89	0.29	0.50	5.24	9.15
Minke whale	6	6	0.03	0.03	0.64	0.64
Grey seal	2	2	0.01	0.01	0.21	0.21

The distribution of sightings along the track lines are shown in Figure 4. Most sightings of harbour porpoise were east of Rockabill and Lambay Island off north County Dublin and towards the southern end of the survey area east of Greystones, Co. Wicklow (Fig 4a). There were six sightings of individual minke whales with most sightings east of Rockabill and Lambay Island off north County Dublin (Fig. 4b).

Of the total of 83 individual harbour porpoise recorded 58 were considered adults, four juveniles and six calves. Thus the adult to sub-adult ratio was 5.8:1 or 14.7% of the population was considered sub-adults. The adult to calf ratio was 9.7:1 or 10.3%.

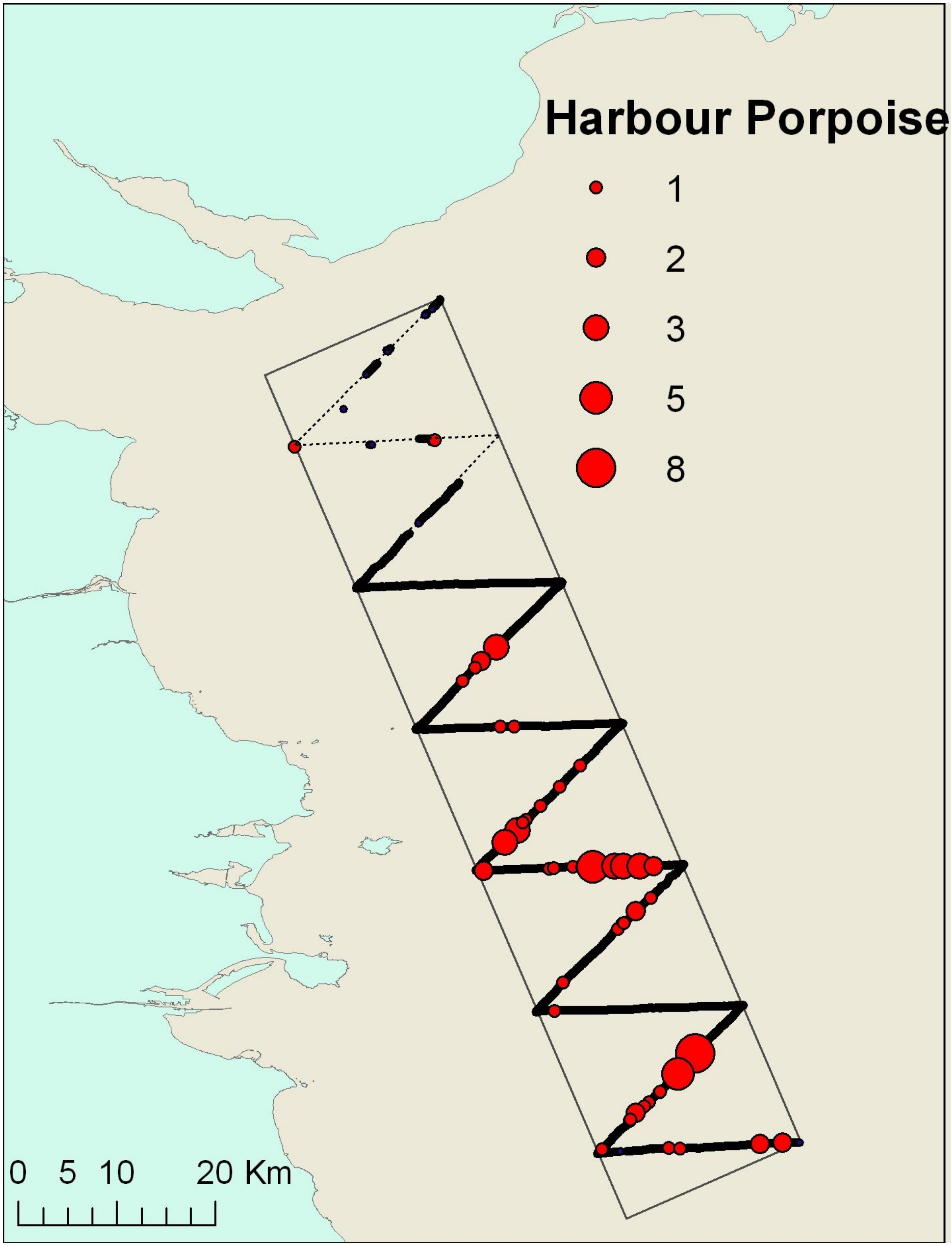

Figure 4a. Sighting records of harbour porpoise in Block A.

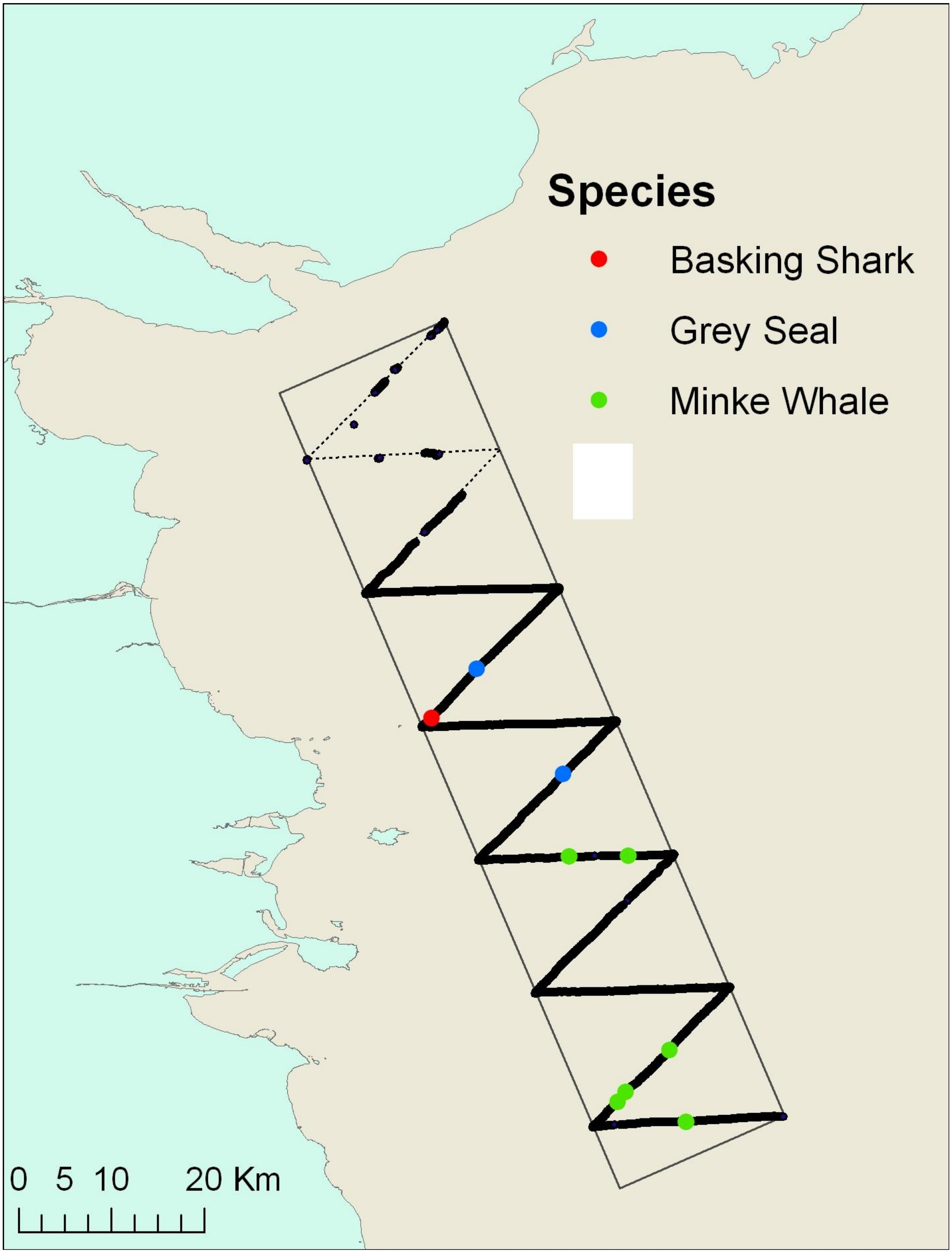

Figure 4b. Sighting records of other species (minke whale, grey seal and basking shark) in Block A.

Acoustic detections

During the survey of Block A, detections comprised only of harbour porpoise. A total of 15 acoustic events was recorded. When using the 10-minute sampling rule to separate encounters, there were a total of eight acoustic encounters (Fig. 5). Of the eight acoustic encounters, four did not have corresponding visual detections.

Figure 5. Acoustic survey effort (grey line) and harbour porpoise detections. Additional outer circles indicate simultaneous visual and acoustic detections. (Gap in track line was a result of GPS failure and not break in survey effort. No acoustic detections recorded during this period)

Absolute abundance

When using the day as the sample a half-normal with Cosine adjustments gave the lowest AIC (254.8) using DISTANCE. Data were truncated at 300m with the loss of one sighting. Mean (±SE) cluster size was 1.67 ± 0.18 and the effective search half-width was 151m or 302m effective search width. Although most variability occurred in the detection probability (65%), variability associated with cluster size was quite large accounting for 35%, which reflects the range of group sizes recorded from 1 to a maximum of 8 individuals. There was some evidence of avoidance action by porpoises as demonstrated by the peak in the 20-40 and 40-60m distance categories (Fig. 6).

The detection function is shown in Fig. 5. A chi-squared test showed it to be an excellent fit with (X^2 = 3.83, df = 10, P=0.99). This gave a density estimate (±SE) of 1.585 ± 0.219 harbour porpoises km^{-2} with a CV of 0.14. The abundance estimate was 1826 ± 252 with a 95% Confidence Interval of 1389 – 2400 porpoises.

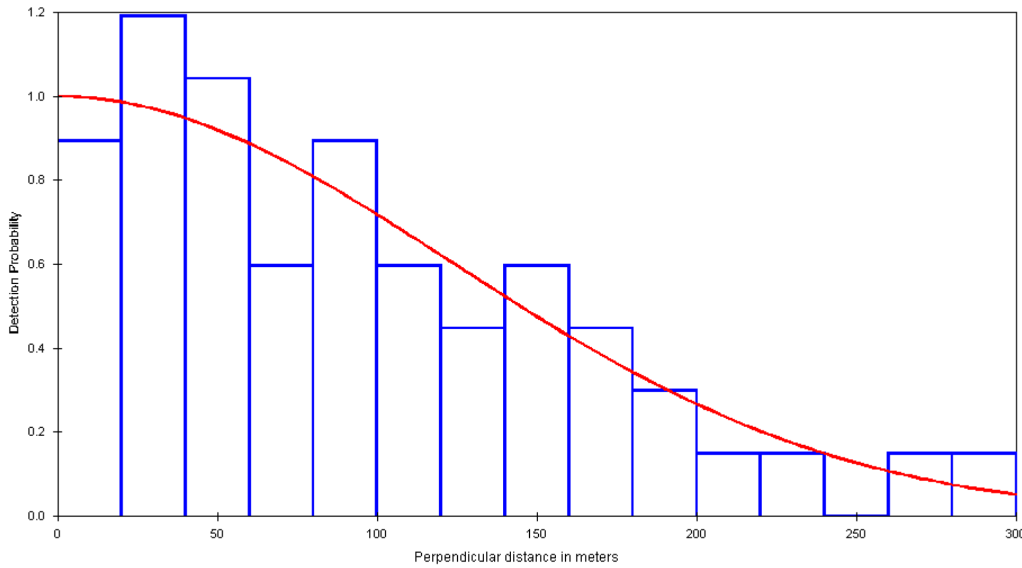

Figure 6a. Detection function for harbour porpoise sightings in Block A using the day as the sample

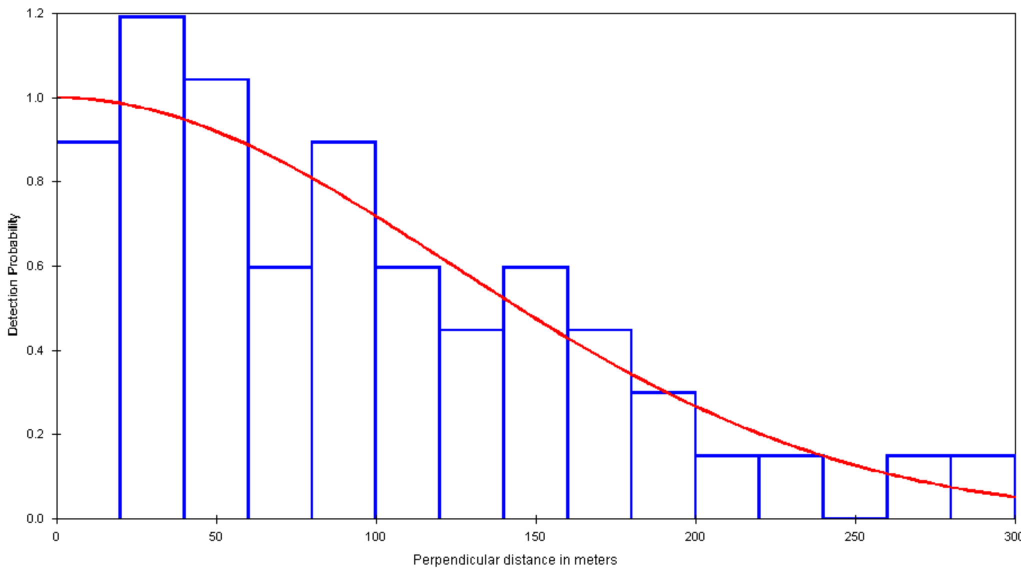

Figure 6b. Detection function for harbour porpoise sightings in Block A using track-line as the sample

When using the track-line as the sample there was no difference in the overall density estimate though a big increase in the coefficient of variation from 0.14 to 0.32 and the standard error of the density estimate. The detection function was still an excellent fit (X^2 = 3.83, df = 10, P=0.99). Encounter rate attributed to 81.4% of the variability with detection probability (12.1%) and cluster size (6.6%) accounting for the remaining 19%. This gave a density estimate (±SE) of 1.541 ± 0.493 harbour porpoises km^{-2} with a CV of 0.32. The abundance estimate was 1776 ± 569 with a 95% Confidence Interval of 917 – 3440 porpoises.

Southern Irish Sea (Block B)

A survey of the southern Irish Sea (Block B) was carried out on 2 August 2011. Sea-state ≤3 was recorded during 79.2% of effort and sea-state ≤2 for just over one-half (53%) of the survey (Fig. 7). The survey was terminated about one-quarter way through the final transect as the sea-state had increased to sea-state 5. This was due to a change in the tide resulting in poor sea-state as the wind direction was in the opposite direction and thus against the tide.

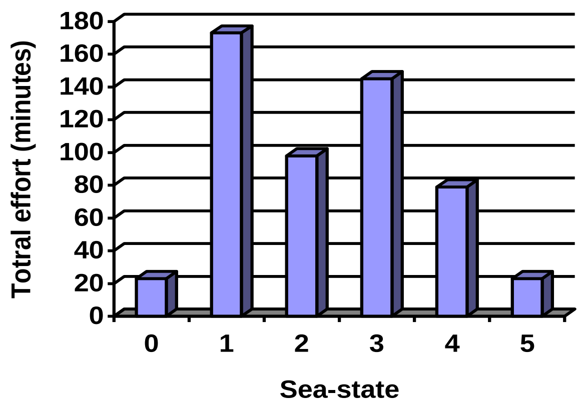

Figure 7. Sea state conditions for the survey of the Southern Irish Sea (Block B) on 2 August

<u>Species Diversity</u>

Species diversity was very low, with only one species of cetacean (i.e. harbour porpoise) present although two species of seal (grey and common seal) were also recorded.

Table 6. Relative abundance of cetaceans and seals in Block B

	Sightings	Individuals	Sightings km^{-1}	Numbers km^{-1}	Sightings hr^{-1}	Numbers hr^{-1}
Harbour Porpoise	14	22	0.101	0.159	1.91	3.00
Grey seal	2	2	0.014	0.014	0.27	0.27
Common Seal	1	1	0.007	0.007	0.14	0.14

Relative abundance

Sea-state was ≥3 for 115 minutes or 38km. These data were omitted when calculating sighting rates and relative abundance. Harbour porpoise was the most abundant species in Block B with a sightings rate of 0.101 sightings per km or 1.91 sightings per hour of survey effort. Relative abundance of harbour porpoise was estimated at 0.159 porpoise per km or 3.0 porpoises per hour of survey (Table 6). This was an order of magnitude greater than the relative abundance of grey and common seal in the same block (Table 6).

The distribution of sightings along the track lines are shown in Figure 8. All sightings of harbour porpoise were clustered towards the centre of the survey block.

a.

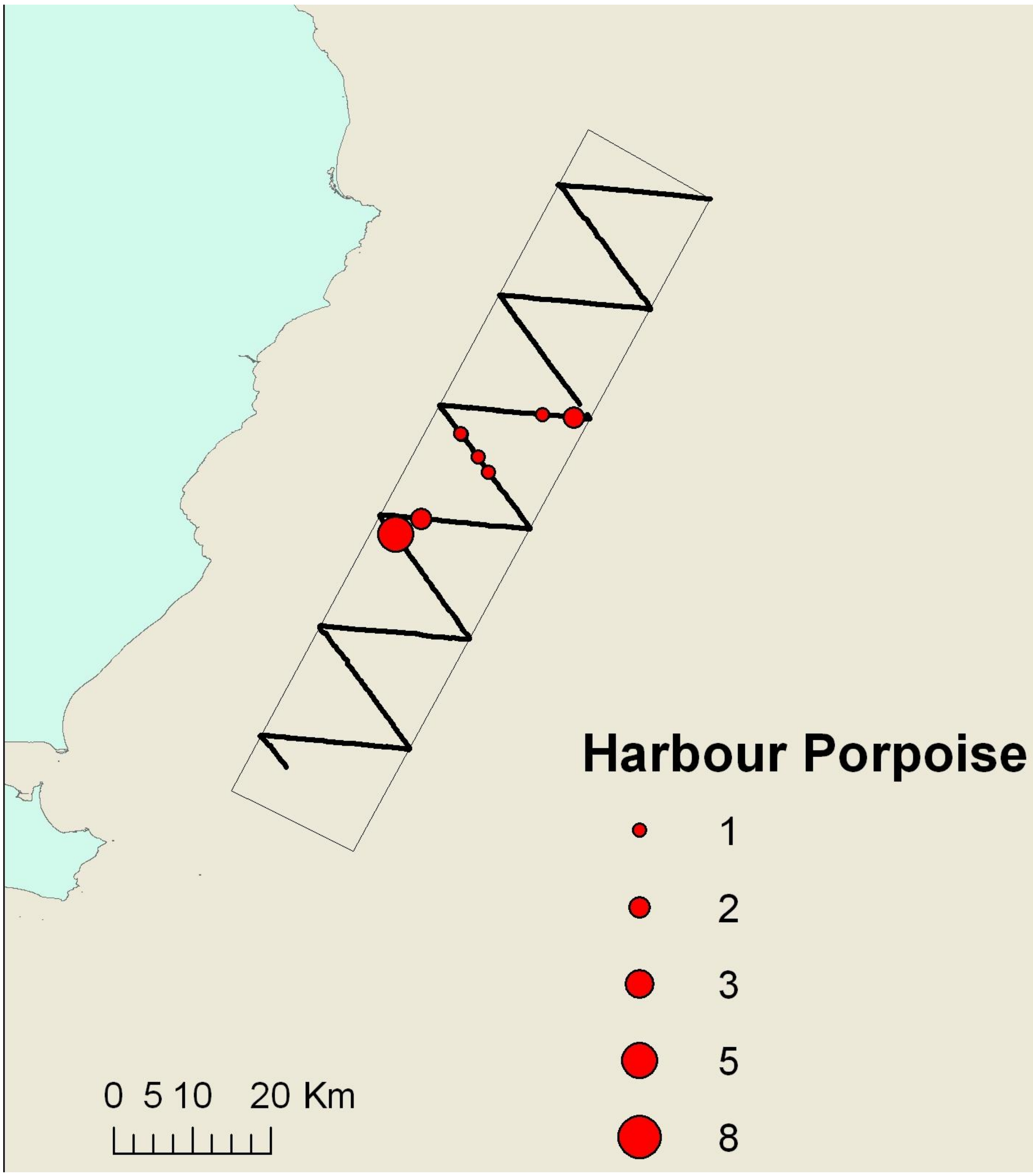

Figure 8a. Relative abundance of harbour porpoise in the southern Irish Sea (Block B) on the 2 August

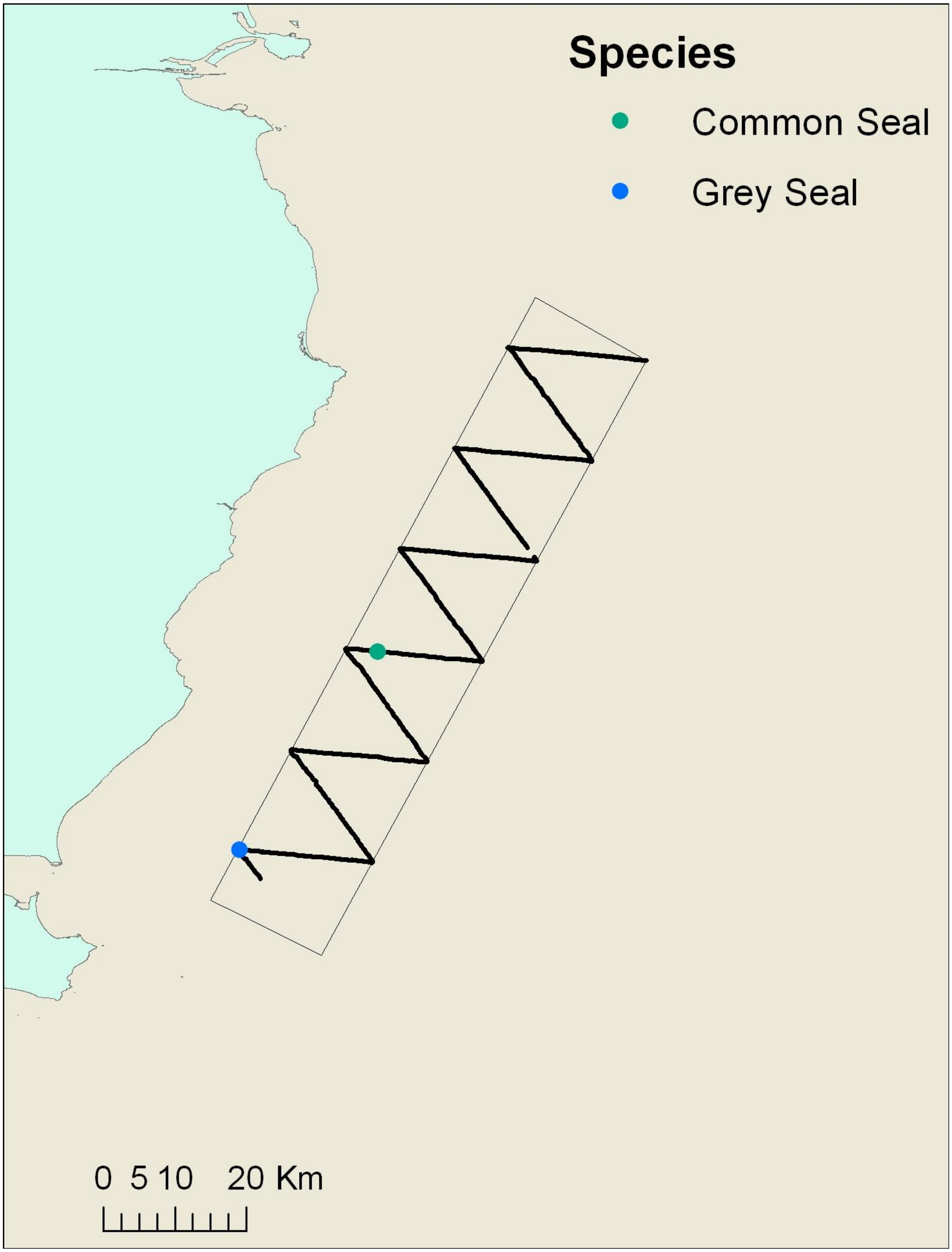

Figure 8b. Relative abundance of grey and common seals in the southern Irish Sea (Block B) on the 2 August

Of the total of 22 individual harbour porpoise recorded 17 were considered adults and four juveniles with one calf. Thus the adult to sub-adult ratio was 3.4:1 or 23% of the population was considered sub-adults. The adult to calf ratio was 17:1 or 6%.

Acoustic detections

There were a total of 11 acoustic events recorded in Block B. When using the 10-minute sampling rule to separate encounters, this equated to 9 acoustic encounters, comprising exclusively of harbour porpoise detections (Fig. 9). Five acoustic detections were recorded without a corresponding visual record.

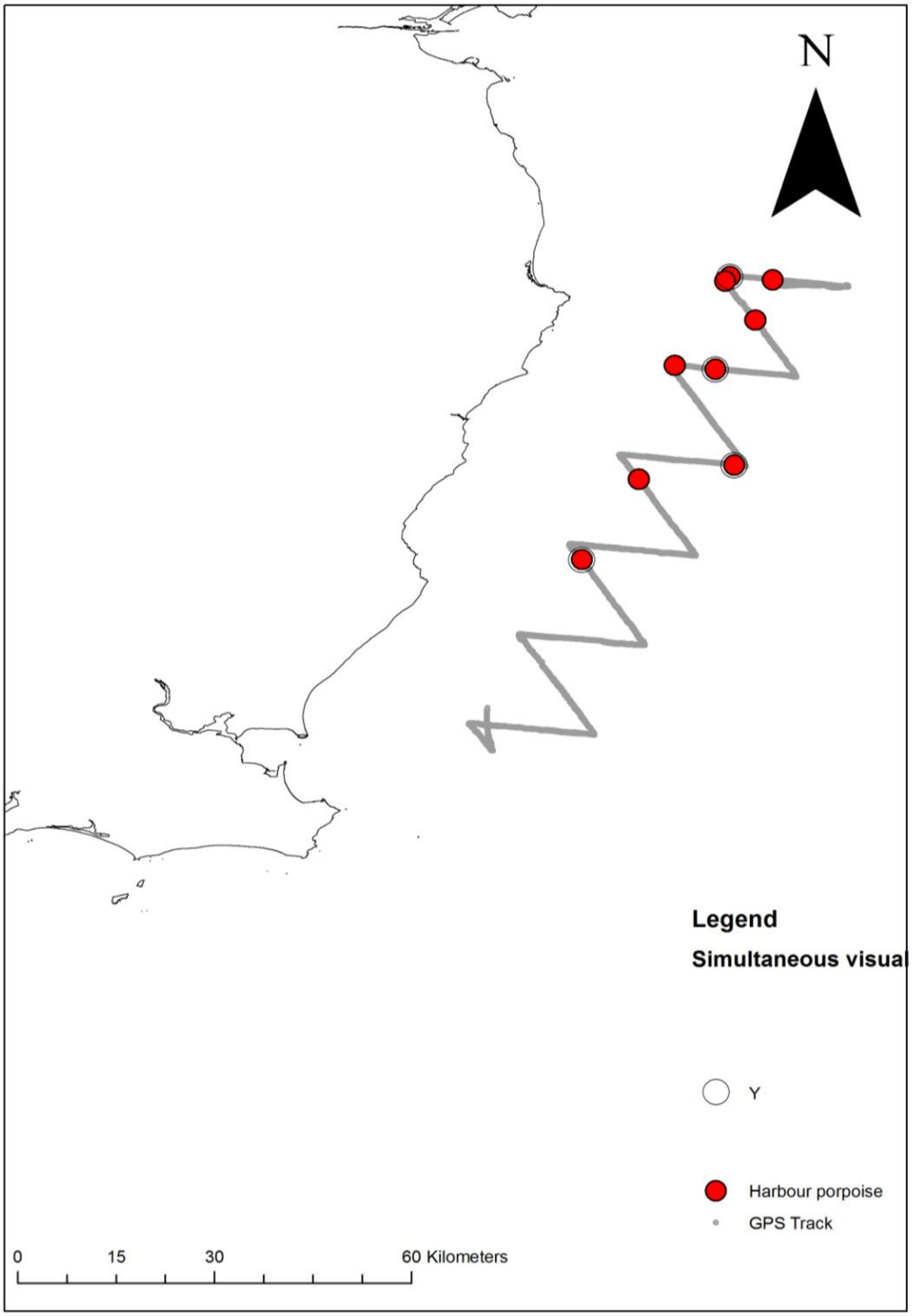

Figure 9. Acoustic survey effort (grey line) and acoustic detections of harbour porpoise on 2 August in Block B.

Discussion

This survey was the second such effort targeting regional inshore waters off the Irish coast. Results from the present survey provided a good return for effort; including estimation of sighting rates and relative abundances for two cetacean species and absolute abundance estimates for harbour porpoise.

Visual and Acoustic Detections

Results from the visual surveys showed there was some consistency in species encountered at both sites, with harbour porpoise by far the most frequently recorded species. There was however a large difference in the sighting rate and relative abundance between the two blocks. The abundance of harbour porpoises in the southern Irish Sea appears to be much lower compared to the northern Irish Sea. A second survey was carried out by the IWDG in the southern Irish Sea on 11 July 2011 (see Appendix) which provided consistent results to that carried out in the same area on 2 August.

Sighting rates of harbour porpoise, and thus local densities, were notably higher adjacent to Rockabill and Lambay Islands in the northern Irish Sea and in the southern part of Block A. This was consistent with Berrow *et al.* (2008) who recorded high densities during smaller scale harbour porpoise surveys in the same area. This suggests that this could be a good habitat for harbour porpoises.

The data from passive acoustic monitoring (PAM) is limited when compared to visual data. During both surveys a total of 65 harbour porpoise sightings were recorded, while only 17 acoustic detections were logged. Of these only 10 sightings were simultaneously logged acoustically. Therefore, it is clear that relying on PAM data to assess or estimate harbour porpoise activity in an area in the absence of visual methods is not acceptable. PAM provides no information on density and results would lead to an area being overlooked when assessing importance, which would have serious implication where assessment relying on this method alone. Harbour porpoise clicks have a narrow bandwidth centered around 130 kHz, with little energy below 100 kHz (Verboom and Kastelein 1997) and therefore these clicks rapidly attenuate due to their high frequency nature. Harbour porpoise are known to avoid vessels and it is likely many porpoise were moving away from the vessel and thus there echolocation clicks would be traveling in the wrong direction to be detected by the towed hydrophone. The hydrophone was towed 200m astern of the survey vessel and with an estimated detection distance of around 200m, at the limit of its detection range. During the present survey there were 12 acoustic detections with simultaneous visual detections and 12 acoustic detections with no corresponding visual detections. This demonstrates the usefulness of simultaneous PAM with visual surveying but it should not be relied upon alone as it may not truly reflect the species present in an area and will add no value to density estimates.

However the lack of dolphin (whistle) detections suggests they are either not present or uncommon in the survey blocks during the summer. One common dolphin sighting was made in July 2011 during a similar survey of this area (Appendix I) which coincided with a number of whistle detections. These whistles were detected when the dolphins were estimated to be at least 2km from the vessel. This suggests that if dolphins were present elsewhere we would have detected them acoustically if not visually. The lack of dolphin acoustic detections suggests the visual data were accurate and dolphin sightings in the survey blocks were infrequent.

While there is merit to carrying out both visual and acoustic surveying for cetaceans, the results here demonstrate that when two techniques are used simultaneously a more robust record of species presence and abundance is achieved.

Sighting rate and Relative Abundance

Information on relative abundance and density estimates are useful for comparing cetacean occurrence within and between survey blocks. Broad-scale sighting surveys designed to estimate the abundance of harbour porpoise in Ireland are limited (O'Brien *et al.* 2009). Reid *et al.* (2003) showed harbour porpoise to be widespread and abundant in the Irish Sea and off southwest Ireland as far north as Galway Bay but largely absent from the northwest coast. Pollock *et al*. (1997) reported sighting rates of 0.01-0.09 harbour porpoise per hour off the east coast of Ireland during seabird surveys on platforms of opportunity. Sighting rates for harbour porpoise within the Irish Sea were elevated in the northern half of the Irish Sea with rates of 2.5-10 counts per hour (Baines and Evans, 2009). This elevated abundance may be associated with a seasonal front known to occur regularly in this area.

Results from the present survey can be directly compared with results from Ryan *et al*. (2010) who used the same survey methodology and surveyed the same sized blocks using a standardised survey design provided by NPWS. Relative abundance and sighting rates are presented in Table 7. Sighting rates of harbour porpoise in the Northern Irish Sea were higher up to three times higher than any other site surveyed and an order of magnitude higher than that recorded from sites along the western seaboard. Relative abundance was also higher in the northern Irish Sea. The sighting rate in the southern Irish Sea on 2 August was very similar to that recorded by the IWDG on 11 July 2011.

The proportion of calves in block A and block B was consistent at around 6% which was very similar to that reported in 2008 in the same area (6-8%) and that reported elsewhere in Ireland (Berrow *et al.* 2008a).

Table 7. Sighting rates and relative abundances of harbour porpoises recorded in Irish inshore waters during comparable surveys in the summer of 2010 and 2011.

		Sightings km^{-1}	Numbers km^{-1}	Sightings hr^{-1}	Numbers hr^{-1}	Reference
Northern Irish Sea	July 2011	0.29	0.50	5.24	9.15	This study
Southern Irish Sea	August 2011	0.10	0.16	1.91	3.00	This study
	July 2011	0.09	0.09	1.41	1.51	IWDG *unpub. data*
Northwest	August 2010	0.02	0.02	0.23	0.23	Ryan *et al.* (2010)
	July 2011	0.01	0.01	0.20	0.20	Berrow *et al.* (2011)
West	October 2010	0	0	0	0	Ryan *et al.* (2010)
Southwest	September 2010	0.06	0.03	0.56	1.11	Ryan *et al.* (2010)

Density Estimates

Statistical inference using distance sampling rests on the validity of several assumptions (Buckland *et al.,* 2001). These include 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 (g(0)=1) and are detected at their initial location prior to any movement in response to the observer. Finally, if objects on or near to the track-line are missed the density estimate will be biased low.

From the concurrently acoustic and visual data collected during the present survey there were and 12 acoustic detections with no corresponding visual detections. Some harbour porpoise were therefore missed by observers even in good sea conditions, showing that g(0) did not equal 1. Typically for surveys of harbour porpoise g(0)= 0.4 or 0.5, i.e. only one-half of the animals on the track-line are detected (Hammond *et al.* 2002). This is likely to be much less for common dolphins where g(0) is closer to 1. (Hammond *et al.* 2010) However harbour porpoise often show movement away the vessel and thus density and abundance is under-estimated if this movement occurs prior to detection (Hammond *et al*. 2002). There was no evidence of this during the survey in block A. Without a double-platform methodology it is not possible to accurately determine the numbers missed on the track-line. However these sources of variability were constant between survey blocks allowing comparisons between these blocks and were consistent with previous studies in Ireland and thus direct comparisons are possible

The density estimates from the present survey and similar surveys carried out in 2008 by Berrow *et al.* (2008a; 2008b; 2009) are shown in Table 8. The survey methodologies differed however track-lines were placed systematically through the survey areas, which were smaller and more coastal than surveyed in 2010 and 2011. Nevertheless, broad-scale comparisons are relevant as the data analysis was very similar.

The density estimate in the northern Irish Sea in the present survey (1.58) was similar to that recorded in the two candidate SACs off the southwest coast (Blasket Islands; 1.33-1.65 porpoise per km^2 and Roaringwater Bay; 1.24 porpoise per km^2) in 2007 and 2008. The highest density of harbour porpoises at any site surveyed to date in Ireland was from north County Dublin, where Berrow *et al.* (2008a) obtained estimates ranging from 0.54 to 6.93 porpoise per km^2 during each survey with a mean of 2.03 porpoise per km^2. Most of the sightings in the present survey were off north County Dublin and east of Dublin Bay which supports the findings of these previous studies and confirms that waters off County Dublin are important for harbour porpoises.

A density estimate of 0.34 (CV=0.35) harbour porpoise per km^2 was reported for the Irish Sea during July 2005 which was greater than that reported (0.28 harbour porpoise per km^2) during the same survey for coastal areas outside the Irish Sea supporting the finding that densities in the Irish Sea generally are elevated.

Table 8. Density estimates for harbour porpoises in Irish coastal and inshore waters.

Site	Month and Year	Density (km^{-2})	CV	Reference
Northern Irish Sea	July, 2011	1.58	0.14	This survey
North County Dublin	July-September, 2008	2.03	0.23	Berrow *et al.* (2008a)
Dublin Bay	July-September, 2008	1.19	0.24	Berrow *et al.* (2008a)
Blasket Islands cSAC	July-September, 2007	1.65	0.28	Berrow *et al.* (2009)
	July-September, 2008	1.33	0.25	Berrow *et al.* (2008b)
Roaringwater Bay cSAC	July-September, 2008	1.24	0.27	Berrow *et al.* (2008a)

The results from the present survey have further shown that with a good survey methodology and favourable weather conditions a high sighting rate of harbour porpoises, can be achieved. This not only enable species occurrence data to be collected from an area but also quantitative data such as sighting rates, relative abundance and even density and absolute abundance estimates. The latter are the most useful when comparing within and between sites and the estimate calculated for the northern Irish Sea was considered robust with a low CV (0.14). Although a double-platform would be able to correct for those sightings not detected on the track line and to enable direct comparison with broad-scale surveys (e.g. SCANS, SIAR, CODA), the increased costs associated with a larger vessel and additional personnel may be restrictive. Providing the methodology is consistent single platform surveys can be used to compare sites and, over time, may be able to assess trends.

This survey has shown there are similarities in species occurrence between the northern and southern Irish Sea but there are large differences in abundance. Greatest densities of harbour porpoise occurred during summer 2011 in the northern sector especially off north County Dublin and east of Dublin Bay.

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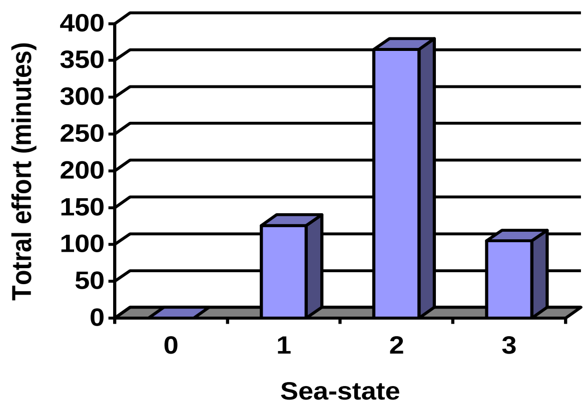
Appendix I: Results of a survey of the southern Irish Sea carried out by the IWDG on 11 July 2011

A survey of the southern Irish Sea was carried out on 11 July 2011. Sea-state of ≤3 was recorded on 100% of survey effort but 61.2% of effort was in sea-state 2, which can still be difficult to observe harbour porpoise.



Sea state conditions for the survey of the Southern Irish Sea on 11 July 2011

Species diversity was low with only three species of cetacean (harbour porpoise, minke whale and common dolphin) recorded and two species of seal (grey and common seal). Harbour porpoise were the most abundant species in Block B with a sighting rate of 0.087sightings per km or 1.41 sightings per hour of survey effort. Relative abundance of harbor porpoise was estimated at 0.090 orpoise per km or 1.51 porpoise per hour of survey. This was an order of magnitude greater than the relative abundance of common dolphin, minke whale or grey and common seal in the same area

Relative abundance of cetaceans and seals on 11 July 2011

	Sightings	Individuals	Sightings km^{-1}	Numbers km^{-1}	Sightings hr^{-1}	Numbers hr^{-1}
Harbour Porpoise	14	15	0.087	0.090	1.41	1.51
Common dolphin	1	20	0.006	0.120	0.10	2.01
Minke Whale	1	1	0.006	0.006	0.10	0.10
Grey seal	1	1	0.006	0.006	0.10	0.10

Most sightings of harbor porpoise were towards the south of the survey block but occurred throughout the survey area on 11 July while there were single sightings of minke whale and common dolphin.

There were a total of 11 acoustic events recorded in on 11 July. When using the 10-minute sampling rule to separate encounters, this equated to seven acoustic encounters, comprising of four harbour porpoise encounters, one unidentified dolphin species and one common dolphins encounters. Three of the seven acoustic events did not have corresponding visual detections on day one.

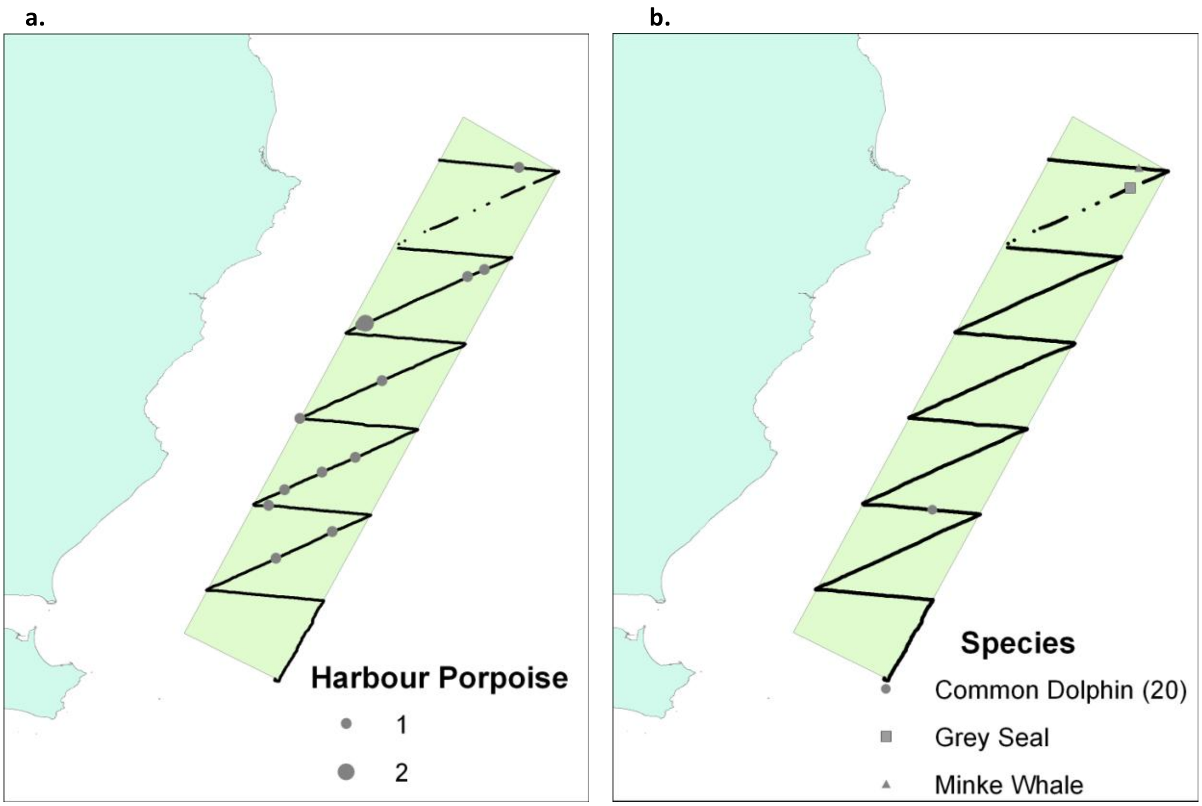
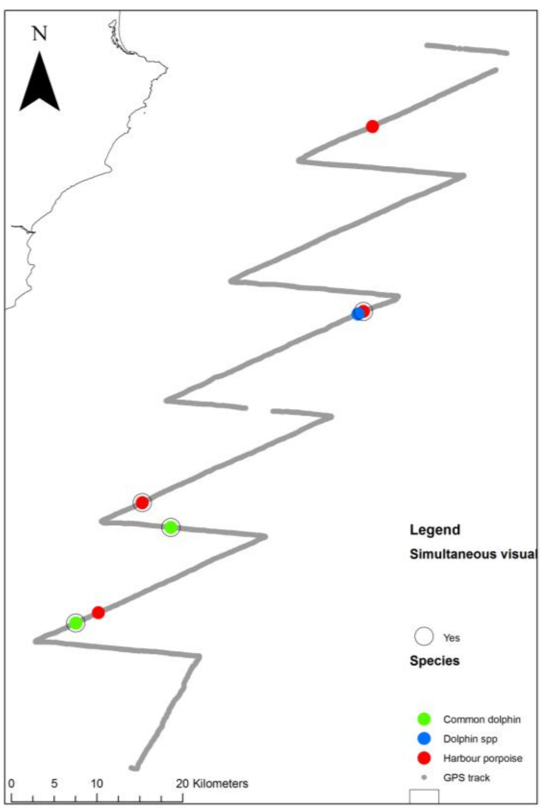


Figure 8. Relative abundance of a. harbour porpoise and b. other species in the southern Irish Sea on 11 July



Acoustic survey effort (grey line) and acoustic detections of harbour porpoise, common dolphin and unidentified dolphin species on 11 July

Appendix I

Criteria used for species assignment of acoustic detections

Vernacular	Signal Type	Frequency Range (kHz)	Frequency at Maximum Energy (kHz)	Source Level (dB re 1 µPa)	References
Harbour porpoise	Clicks	2 - 140	110 - 150	100 - 205	Busnel and Dziedzic (1966), Whitlow *et al.* (1999)
Common dolphin	Whistles	2- 23.51	0.5 - 18	-	Busnel and Dziedzic (1966), Caldwell and Caldwell (1968), Ansmann *et al*. (2007)
	Clicks	0.2 - 150	30 - 67	-	Busnel and Dziedzic (1966)