Inshore boat-based surveys for cetaceans

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Cover image: Killer whale photographed during the inshore survey off the southwest coast © DEHLG

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Summary

Concurrent visual and acoustic surveys for cetaceans were carried out within three survey blocks along the western seaboard of Ireland (Northwest – Block A, west – Block B and southwest – Block C) to investigate species distribution, relative abundance and absolute abundance where possible.

Single platform line-transect surveys were carried out in each survey block between July and October 2010. Distance sampling was used to estimate the density and abundance of common dolphins (*Delphinus delphis*), within two survey blocks. A towed hydrophone was used to survey acoustically along the track-line.

During the three surveys, 450 km of survey effort along 33 track-lines was carried out, of which around two-thirds was performed in sea-state ≤3. A total of 92 sightings comprising 528 individuals of at least six species were recorded. With 63 sightings of 458 individuals, common dolphins were by far the most abundant cetacean species recorded. There was a total of seven sightings of 12 harbour porpoise (*Phocoena phocoena*) recorded, 10 sightings of 12 grey seals (*Halichoerus grypus*), two sightings of single minke whales (*Balaenoptera acutorostrata*), one sighting of eight bottlenose dolphins (*Tursiops truncatus*) and one sighting of two killer whales (*Orcinus orca*). Six sightings with a total of 67 dolphins were not identified to species level.

A total of 31 acoustic detections were recorded. An acoustic encounter was considered a separate encounter, when a silent period of 10 minutes was recorded between acoustic detections. Most were whistles with only one detection reliant on clicks alone. Eleven acoustic detections did not have corresponding visual observations but results broadly reflected the visual survey.

Species diversity was greatest in the southwest block and abundance in the western block. Harbour porpoise were recorded with relatively higher frequency and abundance in the southwest and grey seals in the northwest survey blocks. Relative abundance of common dolphins were similar in southwest and western blocks but lower in the northwest.

Density and abundance estimates were derived for common dolphins in the west survey area (4.56 individuals km^{-2}) equivalent to an abundance of 5254 ± 2311 (CV = 0.44) and in the southwest survey area (2.44 individuals km^{-2}), equivalent to an abundance of 2812 ± 1254 (CV = 0.45). These density estimates were almost an order of magnitude higher than those from previous more extensive dedicated cetacean surveys.

This survey has shown there are differences in species diversity and abundance across regions in inshore waters. Sites can be readily surveyed using small vessels and narrow weather windows providing an opportunity to survey these sites and derive abundance estimates and acoustic detections suitable for monitoring.

Introduction

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

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) 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).

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*., 2004; Berrow *et al.* 2006; 2010). Small scale dedicated surveys were carried out at eight survey blocks in 2007 and 2008 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). Land-based surveys through ISCOPE attempt to record and monitor cetaceans' inshore (Berrow *et al*. 2010). However there are still many gaps in coverage (see Wall 2010).

EU member states are required to designate Special Areas of Conservation (SAC) for species listed under Annex II of the EU Habitats Directive. The Lower Shannon River is a candidate Special Area of Conservation (cSAC) for bottlenose dolphins and the Blasket Islands and Roaringwater Bay have been designated as cSACs for harbour porpoise. Coastal waters off the western and southern coasts of Ireland are considered to be important habitats for bottlenose dolphins (Reid *et al*., 2003), however for many species more survey effort is required to identify areas or seasons with elevated densities.

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 three survey blocks during 2010, 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:

(a) cetacean species abundance, where possible (i.e. population/density estimation);
(b) species relative abundance (no. of sightings/individuals per unit effort);

Methods

<u>Survey blocks</u>

The inshore survey blocks are shown in Figure 1. Each block was 336 nm^2 (1089 km^2) in surface area with a perimeter of 48nm by 7nm and was located approximately between 6nm and 12nm from shore off the western seaboard.

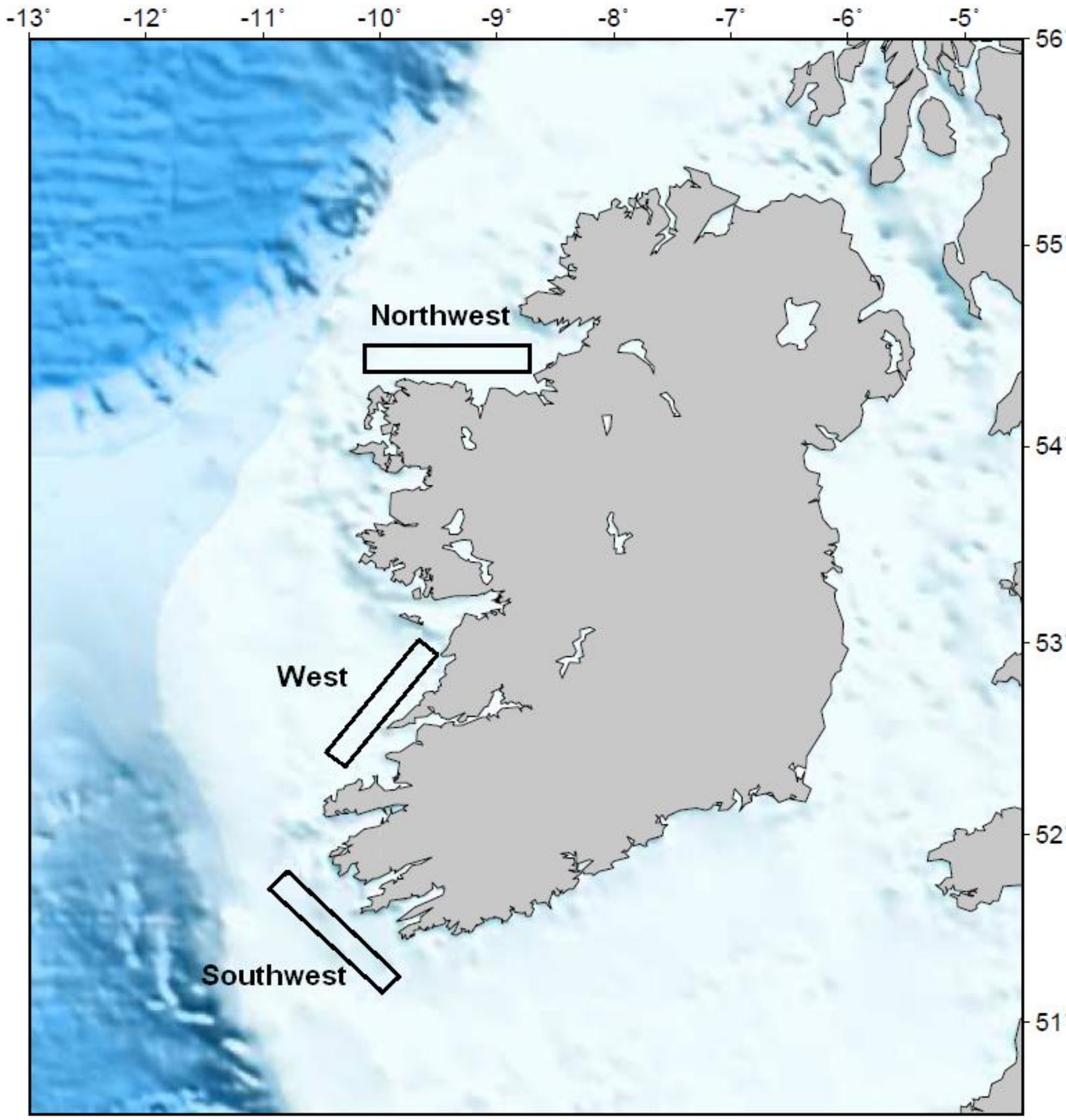


Figure 1. Map of Ireland showing the locations of survey blocks surveyed for cetaceans during 2010.

Survey platforms

Two different vessels were chartered during the survey period (Table 1). The *MV Blascaod Mór* was used to carry out surveys of both the southwestern and western blocks, while the *MV Smoothhound* was used to survey the northwestern block.

Table 1. List of vessels chartered during inshore boat-based surveys in 2010.

Vessel	Port	Type	Length (m)	Platform height (m)
MV Blascaod Mór	Ceann Trá, Co Kerry	Lochin 40	10	3.1
MV Smoothhound	Killybegs, Co Donegal	Vigilante	11	3.0

Survey methodology

Conventional single platform line-transect surveys were carried out along pre-determined track lines supplied by the NPWS. Transect lines were plotted across potential depth and distance-to-coast gradients and to approach equal coverage probability using systematic line spacing that may result in better precision than randomized line spacing (Dawson *et al.*, 2008).

During survey effort, vessels 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., common dolphin, minke whale, bottlenose dolphin, 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 around 3m for both platforms used (Table 1). 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 90º 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 (basking shark, sunfish) 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 and the angle of the sighting from the track of the vessel and the radial distance of the sighting from the vessel recorded. These data were communicated to the recorder in the wheelhouse via two-way radio. The angle was recorded to the nearest degree via an angle board attached to the vessel immediately in front of each observer. Accurate distance estimation is essential for distance sampling. Distance sticks were made for observers using the Heinemann Equation which were used to aid distance estimation.

Relative abundance

Relative abundance was calculated as the number of animals per km of transect or per hour of coverage in sea state ≤3. These are presented in tabular form and graphically by overlaying a 5 x 3 km^2 grid over each survey block and allocating survey effort within each square. Relative abundance was calculated as the number of sightings and individuals divided by the total effort as expressed per km^2 or by $hour^{-1}$.

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 and testing for evasive movement prior to detection.

All sightings are listed in the survey block summary tables. We used the track-line as the sample with sightings used as observations. This provides a lower standard deviation without affecting the density estimate (Berrow *et al.* 2009). Thus the number of samples in each block were the number of track-lines surveyed rather than treating the survey day as one sample. Estimates of abundance were calculated for each species within each survey block, provided there were sufficient sightings to generate an estimate. A minimum of around 40-60 sightings are recommended for a robust estimate using the DISTANCE model (Buckland *et al.,* 2001).

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 0-100m, 100-200m up to 900-1000m for some survey blocks. This follows the recommendation of Buckland *et al*. (2001) who suggests 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 for common dolphin) by smoothing the distance data. Buckland *et al*. (2001) also recommends 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. The influence of Cluster size (i.e. Group size) is analysed by DISTANCE using size-bias regression method with log(n) of cluster size 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 encounter of sightings, 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 containing two high frequency hydrophone elements (HP-03) situated 25cm apart in a fluid filled tube 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 (version 1.6.01 Beta) software. 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. All PAM surveys were carried out by Alessandro Pierini.

Further analysis of acoustic data was carried out in the lab. Species assignment was based on the criteria presented in Appendix I.

Photo-identification

The use of photo-identification for estimating the abundance of coastal populations of cetaceans is becoming more widespread (Evans and Hammond, 2004). This approach can provide accurate estimates with a measure of precision. Some species such as bottlenose dolphins lend themselves to this technique as they often have unique and permanent marks that can be easily photographed.

At least two high quality digital cameras were carried on each survey. Canon EOS D20 bodies with Canon US80-200mm f2.8 lense with 2x converter and a Canon 80-300mm lense were used. If an opportunity for photo-identification presented itself, the vessel broke from the survey track to follow the target animals but returned to the same place in the track-line once the survey resumed.

Results

All three survey blocks were surveyed. Two blocks (west – Block B and southwest – Block C) were covered in very favourable conditions while conditions in the northwest survey block (A) were marginal and at times unworkable. All surveys were carried out during conditions where visibility was 15-20km or greater, with no precipitation and where swell height was ≤2m.

Sightings data

Table 2. Date, effort, sea-state and number of sightings at all survey blocks

Survey block	Date	No. of track lines completed	Total distance in sea-state ≤3 (km)	Number of sightings	Total No. of Animals
Northwest	30 Aug	8	98.75	11	13
Northwest	31 Aug	2	34.08	0	0
Southwest	25 Sept	11	156.46	42	225
West	12 Oct	12	159.83	39	290
		33	**449.12**	**92**	**528**

During the three surveys, we carried out 450km of survey effort along 33 track-lines of which two-thirds was in sea-state ≤3. We recorded a total of 92 sightings comprising 539 individuals of at least six species. Common dolphin was by far the most abundant species followed by harbour porpoise and grey seal. There were single sightings of bottlenose dolphin, killer and minke whale. A summary of effort and the number of sightings is presented in Table 2. Most sightings were made in the southwestern survey block (42 sightings) with greatest numbers of animals recorded in the western survey block. No sightings were recorded on 31 August in the northwest which was attributed to high sea-states.

Species List

A total of five cetacean species were recorded during the survey period (Table 3). Harbour porpoise and common dolphin were recorded in two survey blocks while bottlenose dolphin, minke whale and killer whale were also recorded in one survey block. Unidentified dolphins were recorded in all three survey blocks. These were all thought to be common dolphins but were too distant to identify to species level. Sightings of grey seal were also recorded in the northwest and southwest survey blocks. No basking sharks or sunfish, or other large marine megafauna, were recorded in any survey block.

Table 3: Species present in each survey block (in order of frequency of occurrence)

Survey block	Species	Sightings	Individuals	Mean Group Size (± SE)
Northwest	Grey seal	8	10	1.25 ± 0.16
	Harbour porpoise	2	2	1
	Unidentified Dolphin	1	1	
Southwest	Common Dolphin	30	207	7.13 ± 1.39
	Harbour Porpoise	5	10	1.22 ± 0.55
	Minke Whale	2	2	1
	Killer Whale	1	2	
	Unidentified Cetacean	1	1	
	Unidentified Dolphin	1	1	
	Grey seal	2	2	1
West	Common Dolphin	36	279	7.75 ± 1.08
	Bottlenose Dolphin	1	8	
	Unidentified Dolphin	2	3	1.5 ± 0.5

Acoustic Detections

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 the protocol established under PReCAST (Pierini, 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.

Where concurrent visual and acoustic observations were made of dolphins, species identification was more precise. A summary of acoustic detections is presented in Table 4.

Table 4: Summary of acoustic detections at each survey block

Survey block	Date	Clicks	Whistles	Total detections	Range of Duration min-max (sec)	Mean encounter duration
Northwest	30 August	1	3	4	120-1140	285
	31 August	0	0	0	0	0
Southwest	25 Sept	0	17	14	30-5407	386
West	12 Oct	1	13	17	191-1984	117

<u>Abundance estimates</u>

Density estimates were calculated where sufficient sightings for a given species were recorded. There were only sufficient data to estimate abundance of common dolphins (and common and unidentified dolphins combined) in the west and southwest survey blocks.

Site Analysis

Northwest – Block A

A survey of the northwestern survey block was carried out on 30 and 31 August 2010 with sea conditions of Beaufort sea-state 4 for 65% of survey effort (Figure 2). Sea-state 3 or less was only recorded for 33% of survey effort. Eight out of the 12 track-lines were completed on the first day in an easterly direction and an attempt to complete the remainder in a westerly direction was aborted due to deterioration in the weather giving a sea-state of 5. All the while, the sea state inshore, inside Donegal Bay, was between 0 and 2.

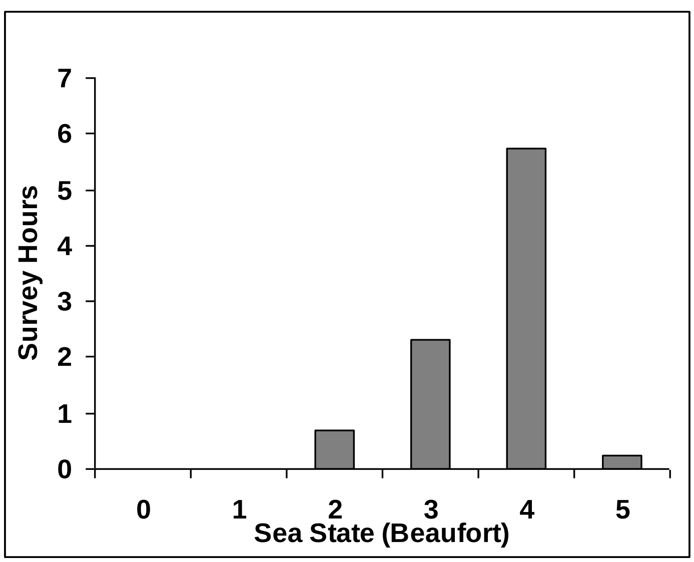


Figure 2. Sea state conditions for the survey of the northwest survey block.

Relative abundance

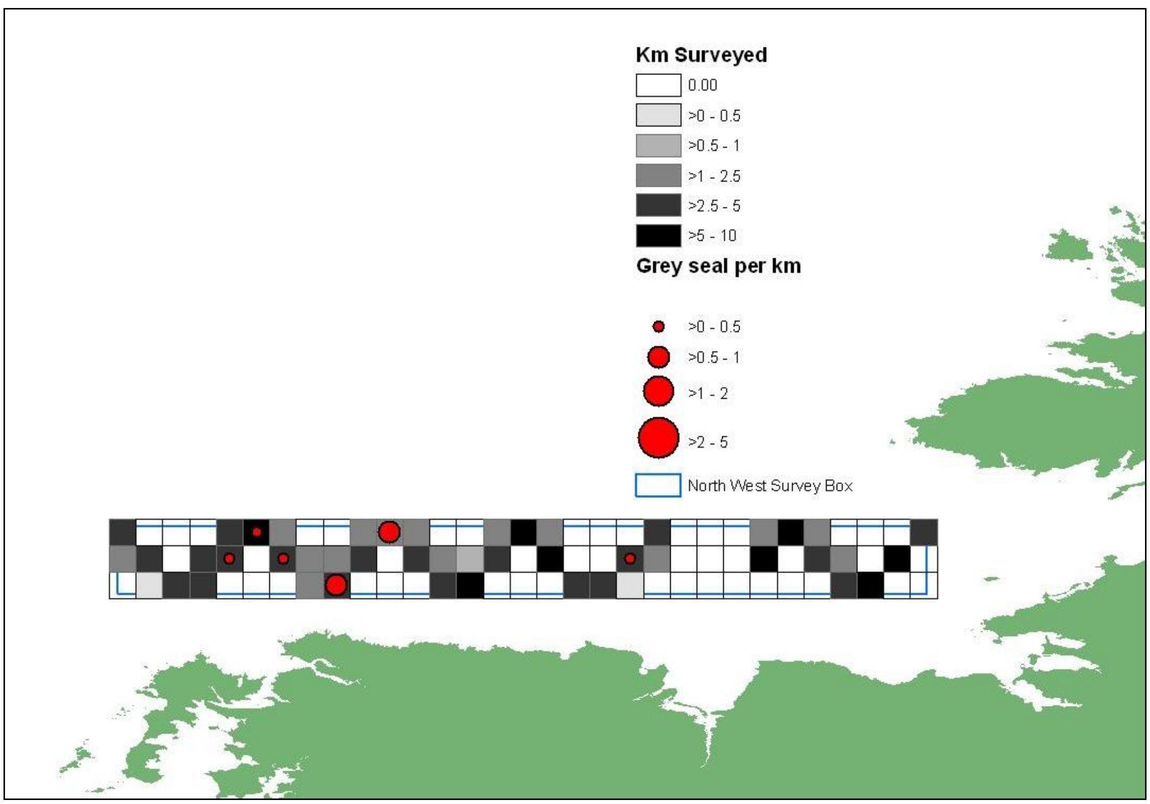
Cetacean relative abundance and diversity were lowest in the northwest, compared with the other two sites, where the most abundant and frequently sighted marine mammal was the grey seal (Table 4). The only cetacean species identified was harbour porpoise with two sightings of individual animals. One sighting of unidentified dolphins were probably common dolphin. The distribution of sightings along the track lines are shown in Figure 3. Most sightings were top the western edge of the survey block (Fig 3).

Table 4. Relative abundance of cetaceans and seals in the northwest survey block.

	No. of sightings	No. of individuals	Sightings per km	Numbers per km	Sightings hour $^{-1}$	Numbers hr^{-1}
Grey Seal	8	9	0.06	0.08	0.92	1.03
Harbour Porpoise	2	2	0.02	0.02	0.23	0.23
Unidentified dolphin sp.	1	1	0.01	0.01	0.11	0.11

Acoustic detections

There was a total of 10 acoustic events recorded on day 1 and none on day 2. When using the 10-minute sampling rule to separate encounters, there were a total of four acoustic encounters comprising three unidentified dolphins and one harbour porpoise (Fig. 4). Three acoustic events (all dolphin sp.) did not have corresponding visual detections.



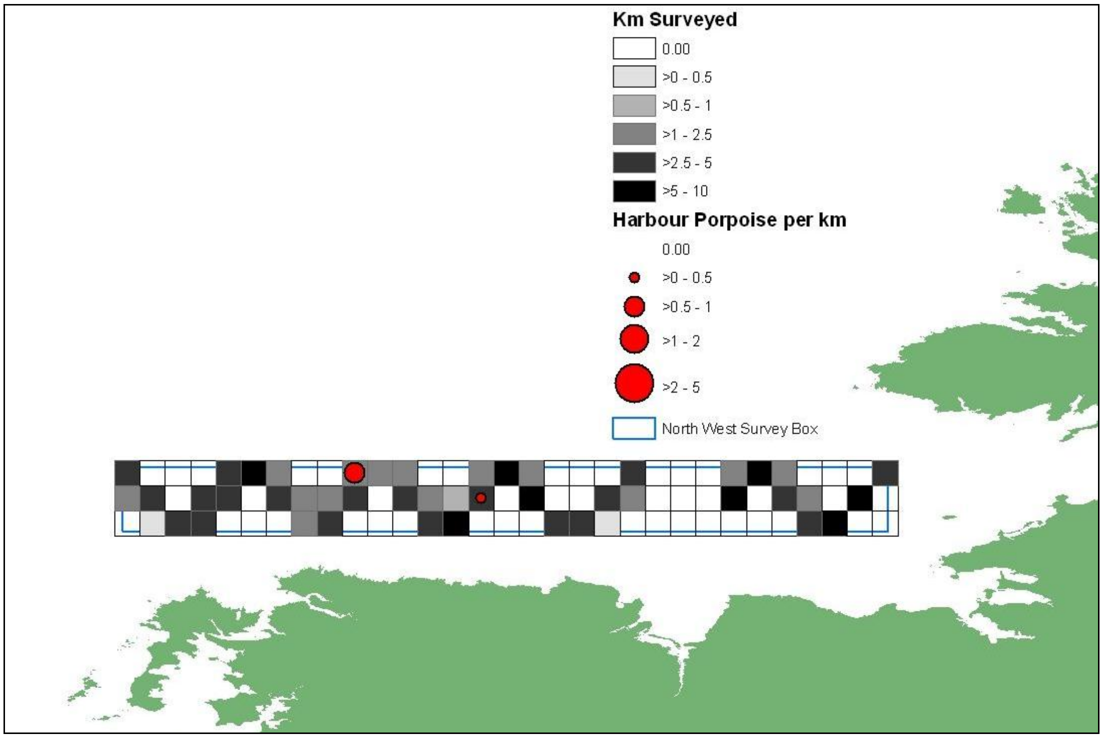


Figure 3. Relative abundance of grey seal and harbour porpoise in the northwest survey block

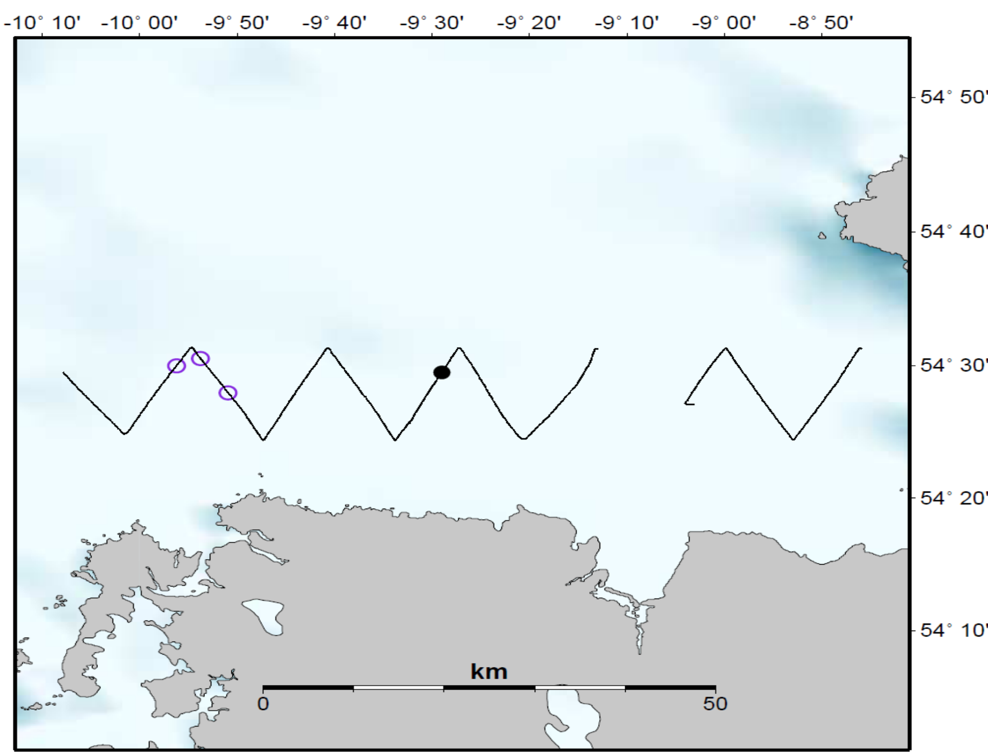


Figure 4. Acoustic survey effort (black line) and acoustic detections. Closed circles indicate simultaneous visual and acoustic detections. Open circles indicate acoustic detections only. Black = Harbour Porpoise, Purple = Unidentified Dolphin

Southwest – Block C

A survey of the southwest survey block was carried out on 25 September 2010. Sea-state of 1 to 2 was recorded for 90% of survey effort and ≤3 for the entire survey (Figure 3). A total of 11 out of the 12 track-lines were completed before it became too dark to record and the survey terminated. The track-lines were completed in a southerly direction.

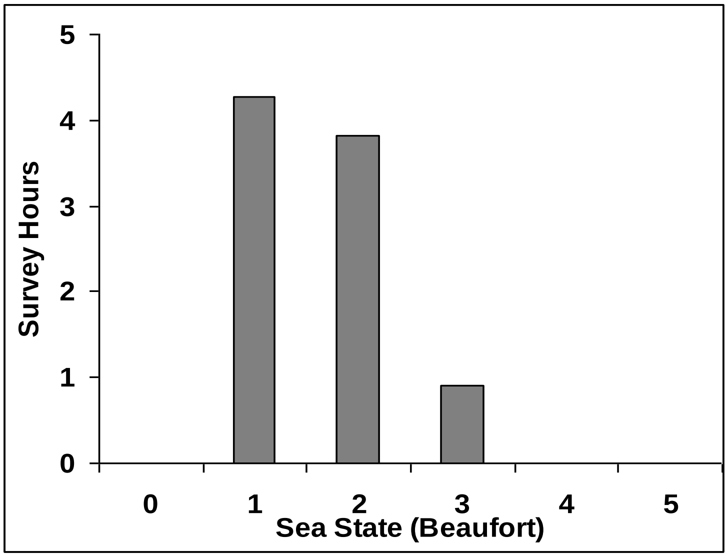


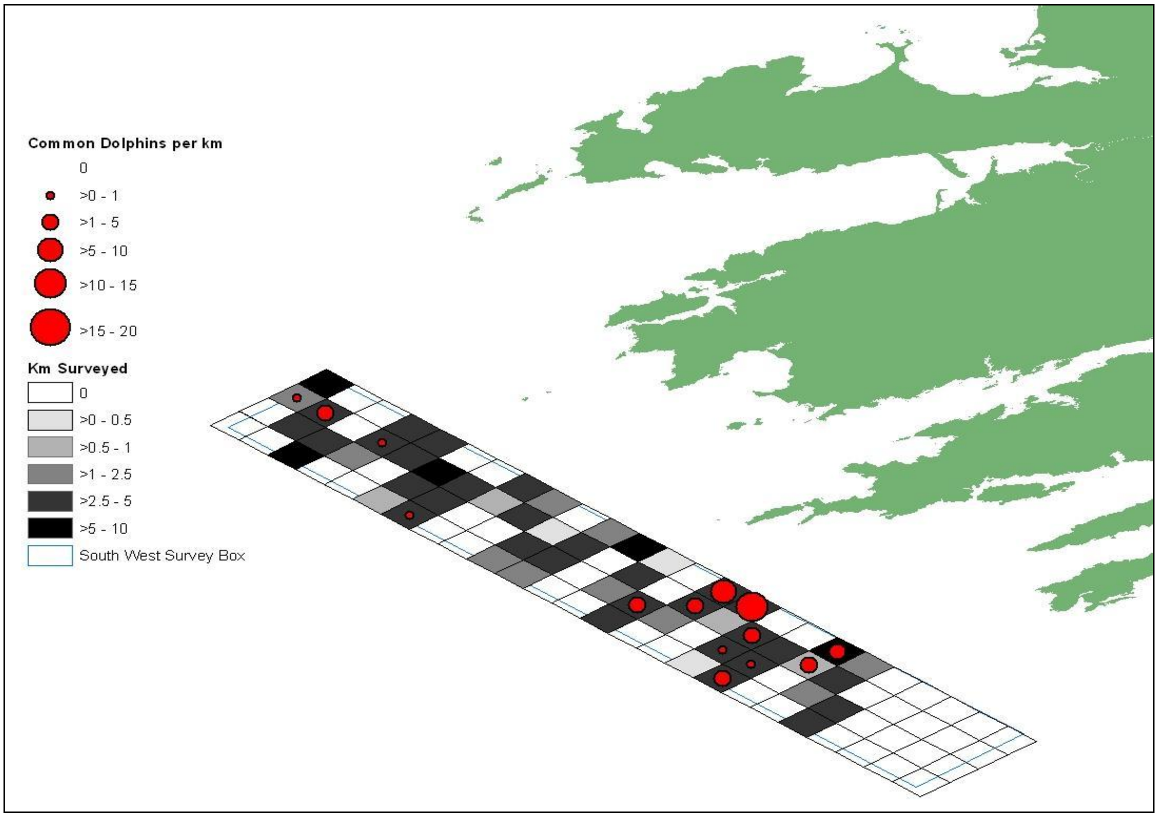
Figure 5. Sea state conditions for the survey of the southwestern survey block.

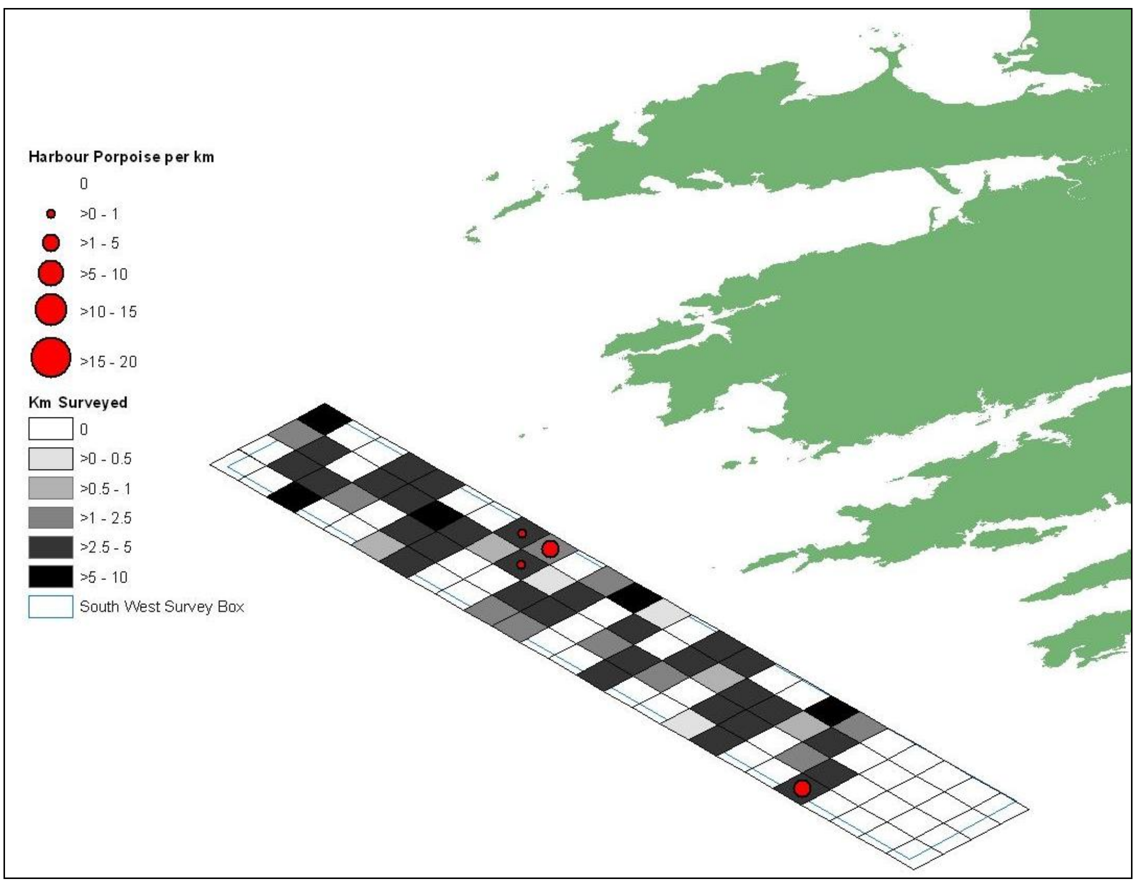
<u>Relative abundance</u>

The highest diversity of marine mammal species was observed in the southwest survey block, with four cetacean species and one seal species identified to species level (Table 5). Relative abundance of common dolphin was greatest at this site (n=30 sightings) followed by harbour porpoise (n=5 sightings).

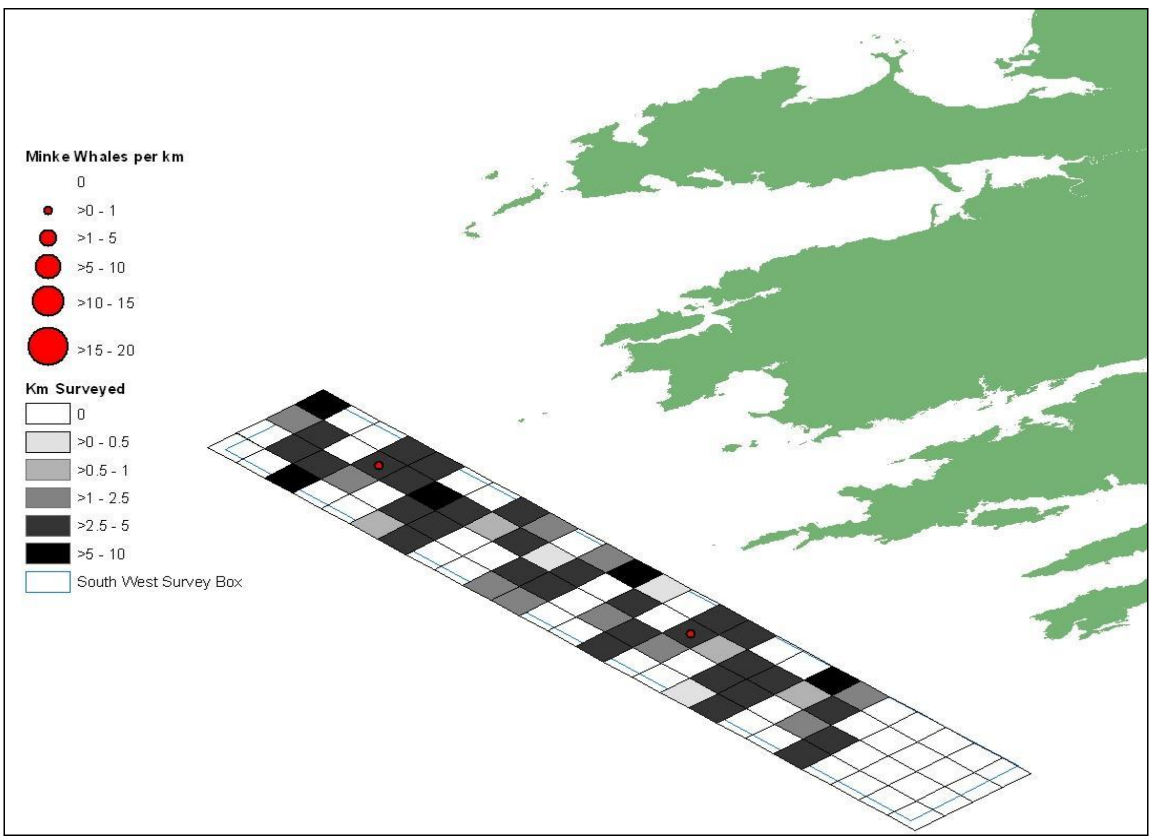
Table 5. Relative abundance of cetaceans and seals in the southwest survey block

	Sightings	Individuals	Sightings km^{-1}	Numbers km^{-1}	Sightings $hour^{-1}$	Numbers hr^{-1}
Common Dolphin	30	207	1.39	0.19	3.00	23.00
Harbour Porpoise	5	10	0.06	0.03	0.56	1.11
Minke Whale	2	2	0.01	0.01	0.22	0.22
Killer Whale	1	2	0.01	0.01	0.11	0.22
Grey Seal	2	2	0.01	0.01	0.22	0.22
Unidentified cetacean	1	1	0.01	0.01	0.11	0.11
Unidentified dolphin sp.	1	1	0.01	0.01	0.11	0.11


Common Dolphins per km
0
>0 - 1
>1 - 5
>5 - 10
>10 - 15
>15 - 20
Km Surveyed
0
>0 - 0.5
>0.5 - 1
>1 - 2.5
>2.5 - 5
>5 - 10
South West Survey Box


Harbour Porpoise per km
0
>0 - 1
>1 - 5
>5 - 10
>10 - 15
>15 - 20
Km Surveyed
0
>0 - 0.5
>0.5 - 1
>1 - 2.5
>2.5 - 5
>5 - 10
South West Survey Box


Killer Whales per km
0
>0 - 1
>1 - 5
>5 - 10
>10 - 15
>15 - 20
Km Surveyed
0
>0 - 0.5
>0.5 - 1
>1 - 2.5
>2.5 - 5
>5 - 10
South West Survey Box


Minke Whales per km
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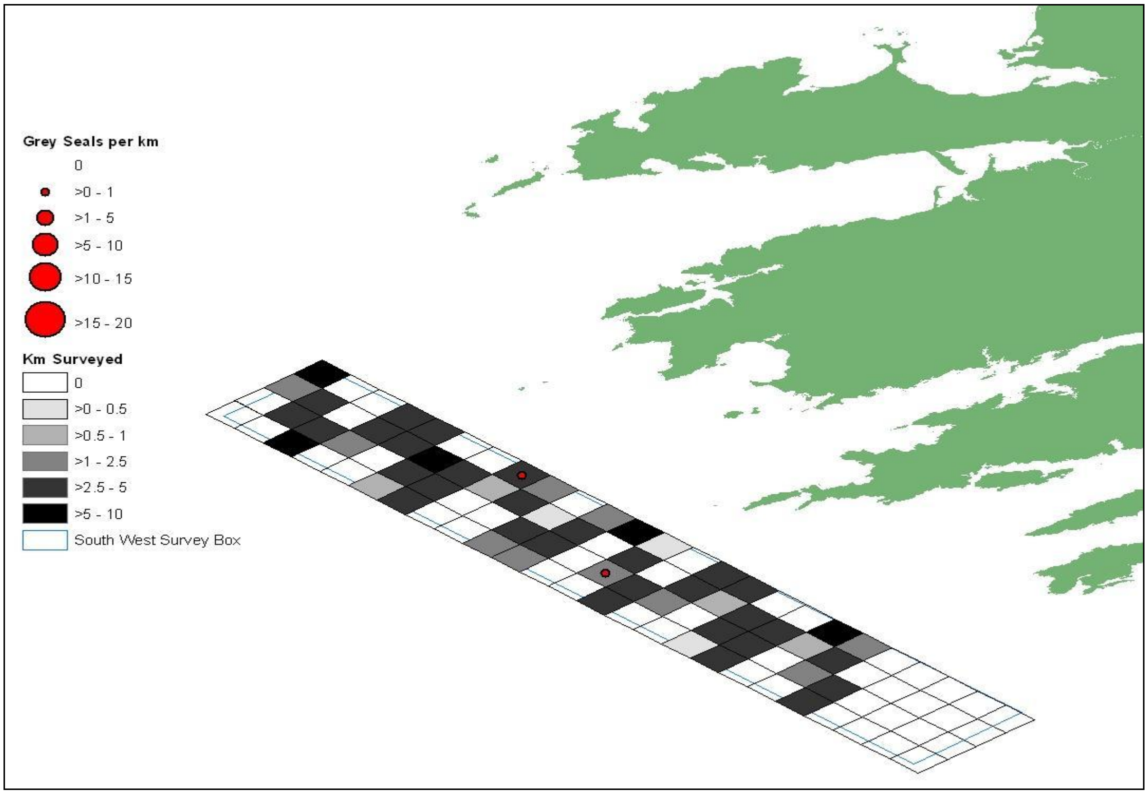
>0 - 1
>1 - 5
>5 - 10
>10 - 15
>15 - 20
Km Surveyed
0
>0 - 0.5
>0.5 - 1
>1 - 2.5
>2.5 - 5
>5 - 10
South West Survey Box



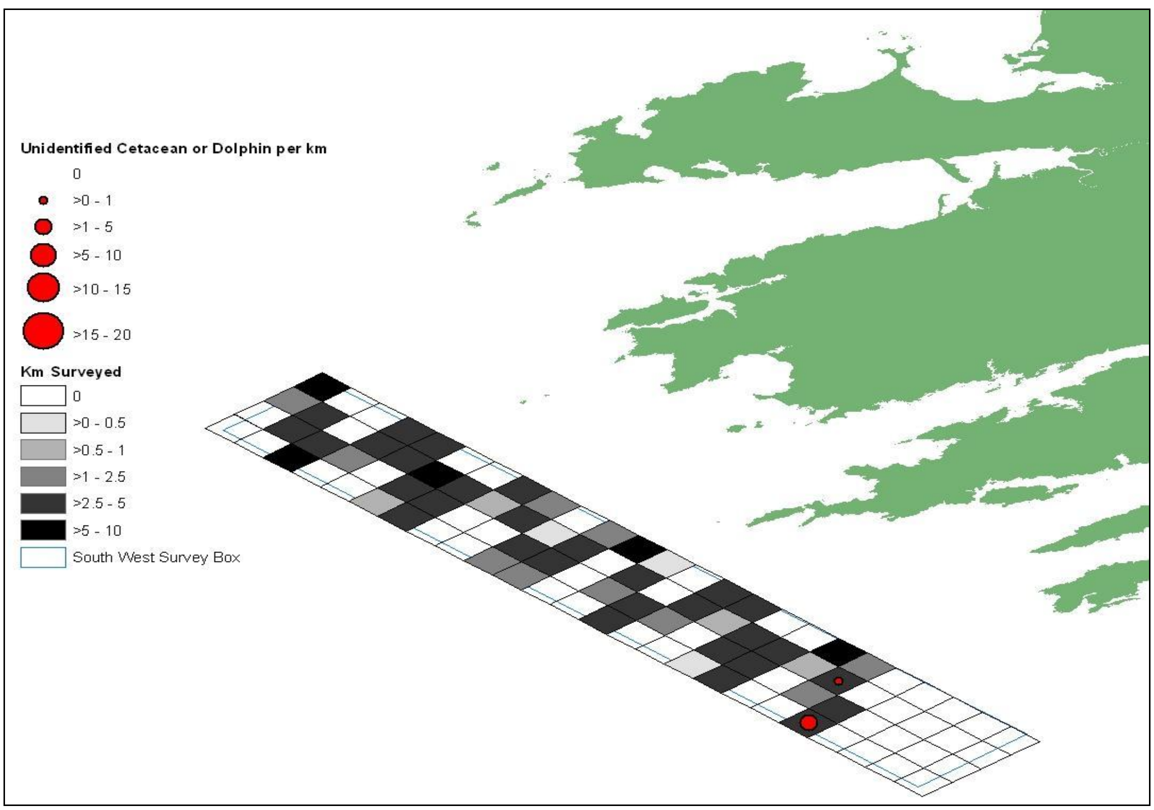


Figure 6. Relative abundance of common dolphin, harbour porpoise, killer and minke whale and unidentified dolphins in the southwest

Acoustic detections

A total of 76 acoustic events were recorded which corresponds to 14 acoustic encounters using the 10-minute separation rule to differentiate between events. These encounters comprised eight common dolphin, one harbour porpoise, one killer whale and four unidentified dolphin species. Five acoustic events did not have corresponding visual detections

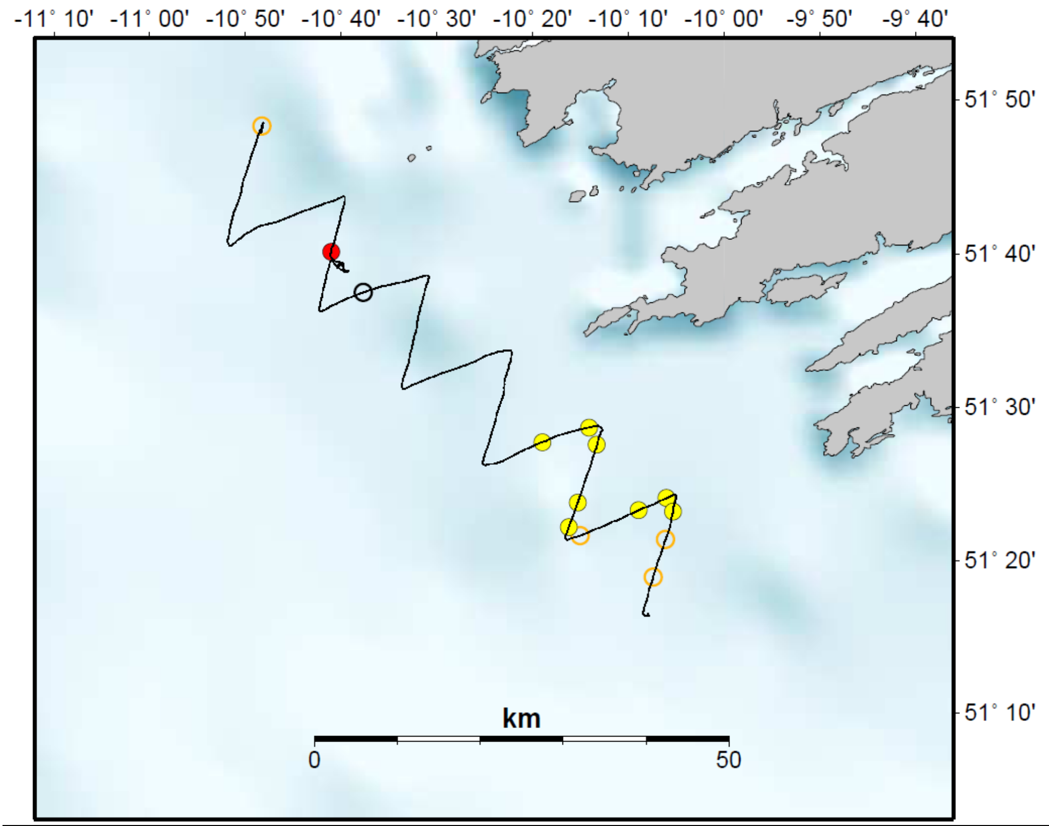


Figure 7. Acoustic survey effort (black line) and acoustic detections. Closed circles indicate simultaneous visual and acoustic detections. Open circles indicate acoustic only detections. Yellow = Common Dolphin, Red = Killer Whale, Black = Harbour Porpoise.

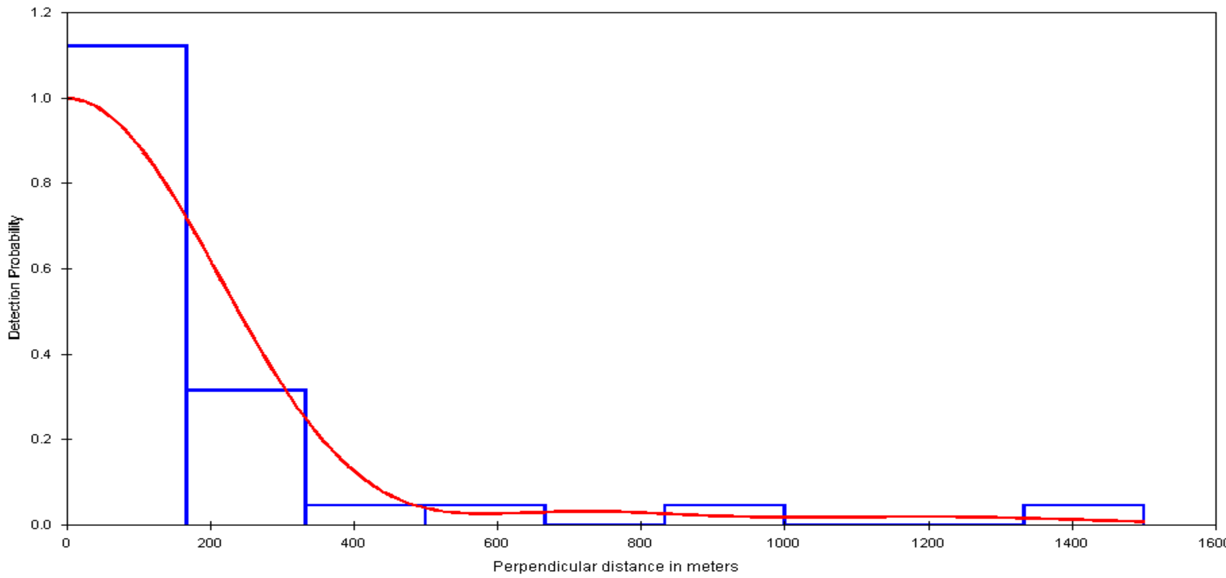
Absolute abundance

Common dolphin

A half-normal with Cosine adjustments gave the lowest AIC using DISTANCE. The dataset comprised 11 samples (track-lines) with 30 observations. Mean cluster size was 7.00 ± 1.35 and Effective Search Half-Width of 195m. Most variability occurred in the encounter rate (63.0%) with cluster size accounting for 24.7% and detection probability approximately 12.3%. Thus variability associated with cluster size was greater than for common dolphins in the west coast survey block (17.2%) reflecting the greater range in group size recorded.

The detection function is shown in Fig 8. A chi-squared test showed it to only be a reasonable fit with (X^2 = 7.36, df = 5, P=0.19). This gave a density estimate of 3.018 ± 1.382 dolphins km^{-2} with a CV of 0.46. The abundance estimate was 3477 ± 1592 with a 95% Confidence Interval of 1412 – 8561 dolphins.

A.



B.

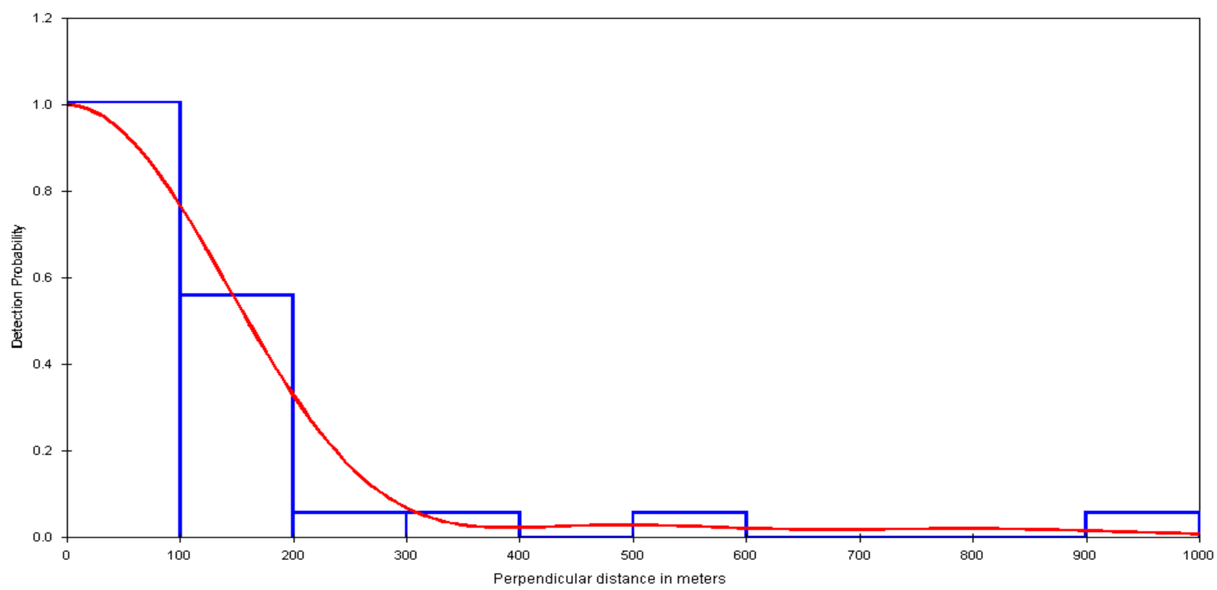


Fig 8. Detection function for common dolphin sightings in the west survey block.
A) unsorted and b) data sorted into 100m intervals

When data was grouped into 100m intervals a half-normal model gave the lowest AIC. The fit was slightly worse (X^2 = 5.87, df = 4, P=0.21) than ungrouped data but the CV was similar (0.45). However this decreased the density estimate by 23% to 2.44 ± 1.086 resulting in a decreased abundance estimate to 2812 ± 1254 with 95% Confidence Intervals of 1161 – 6808 (Table 6).

Table 6. Density and abundance estimates of common dolphins at the southwest survey block

	Density ± SE (km^{-2})	Abundance ± SE	CV	95% CI
Non-truncated	3.018±1.382	3477±1592	0.46	1412-8561
100m intervals	2.441±1.088	2812±1254	0.45	1161-6808

West – Block B

A survey of the western survey block was carried out on 12 October 2010 with sea conditions of between 1 to 3 for 92% of survey effort (Figure 9). Sea-state was ≥3 for only 8% of survey effort. All 12 track-lines were completed from a southerly direction.

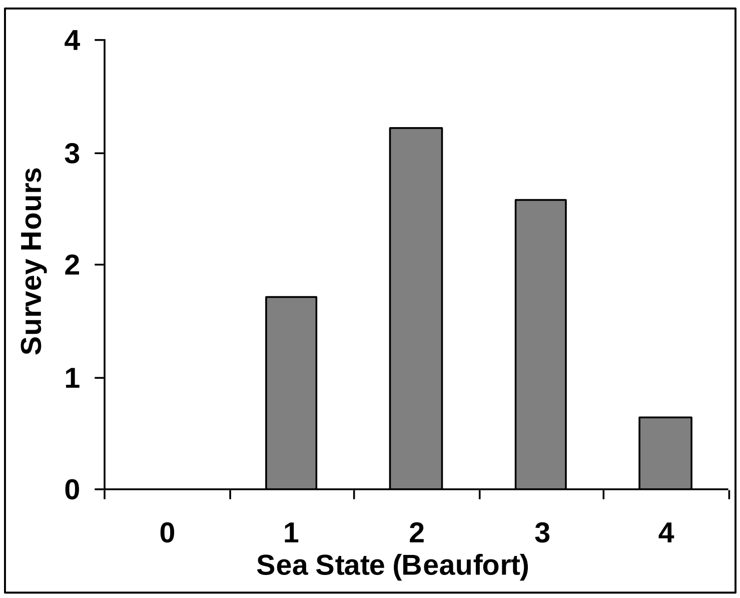


Figure 9. Sea state conditions for the survey of the western survey block.

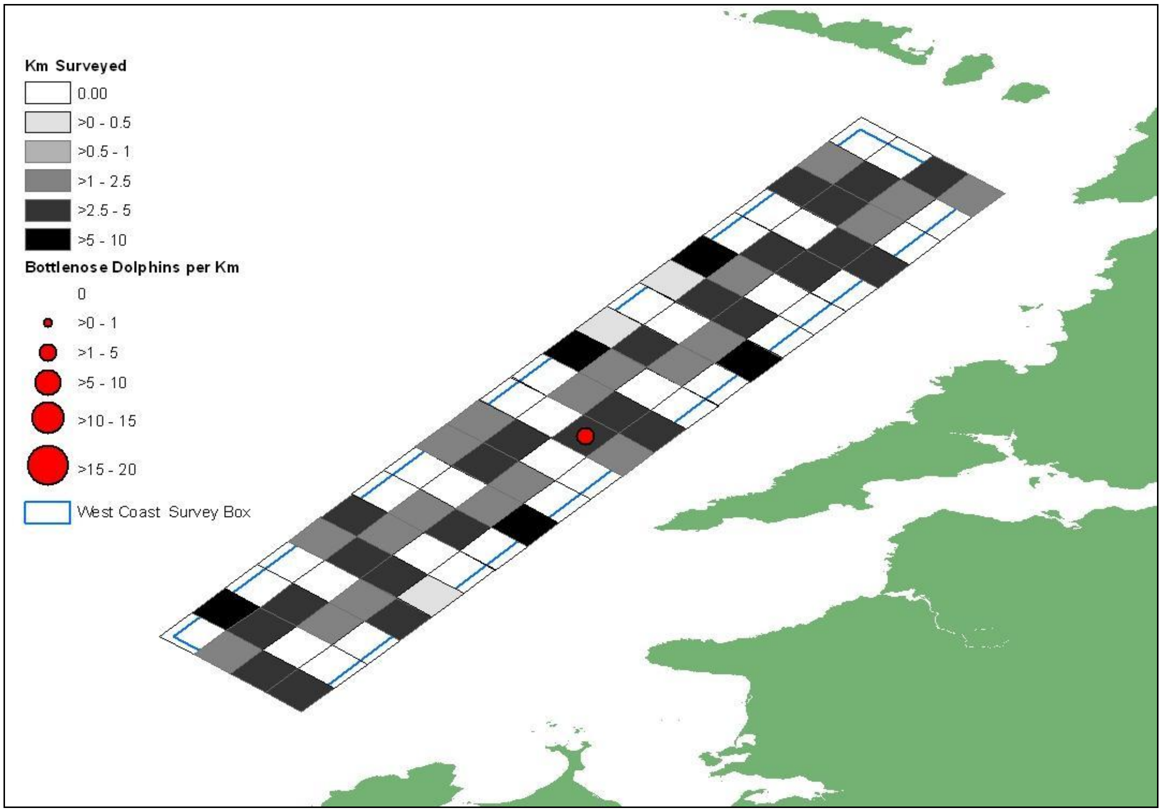
Relative abundance

The highest relative abundance of cetaceans in all three survey blocks occurred in the western survey block, however the number of species encountered was low compared to the southwest. Sightings were dominated by common dolphins, with bottlenose dolphins observed once. Both unidentified dolphin sightings were recorded as probable common dolphin. The common dolphin had the highest relative abundance in the west site compared to the other two sites surveyed.

The distribution of common dolphins was clumped towards the northern and southern ends of the survey area. Interestingly the single bottlenose dolphin sighting was in the centre of the survey area (Fig. 10).

Table 7. Relative abundance of cetaceans in the west survey block.

	Sightings	Individuals	Sightings km^{-1}	Numbers km^{-1}	Sightings $hour^{-1}$	Numbers hr^{-1}
Common Dolphin	36	241	0.23	1.52	4.09	30.81
Bottlenose Dolphin	1	8	0.01	0.05	0.13	1.02
Unidentified dolphin sp.	2	3	0.01	0.02	0.25	0.38



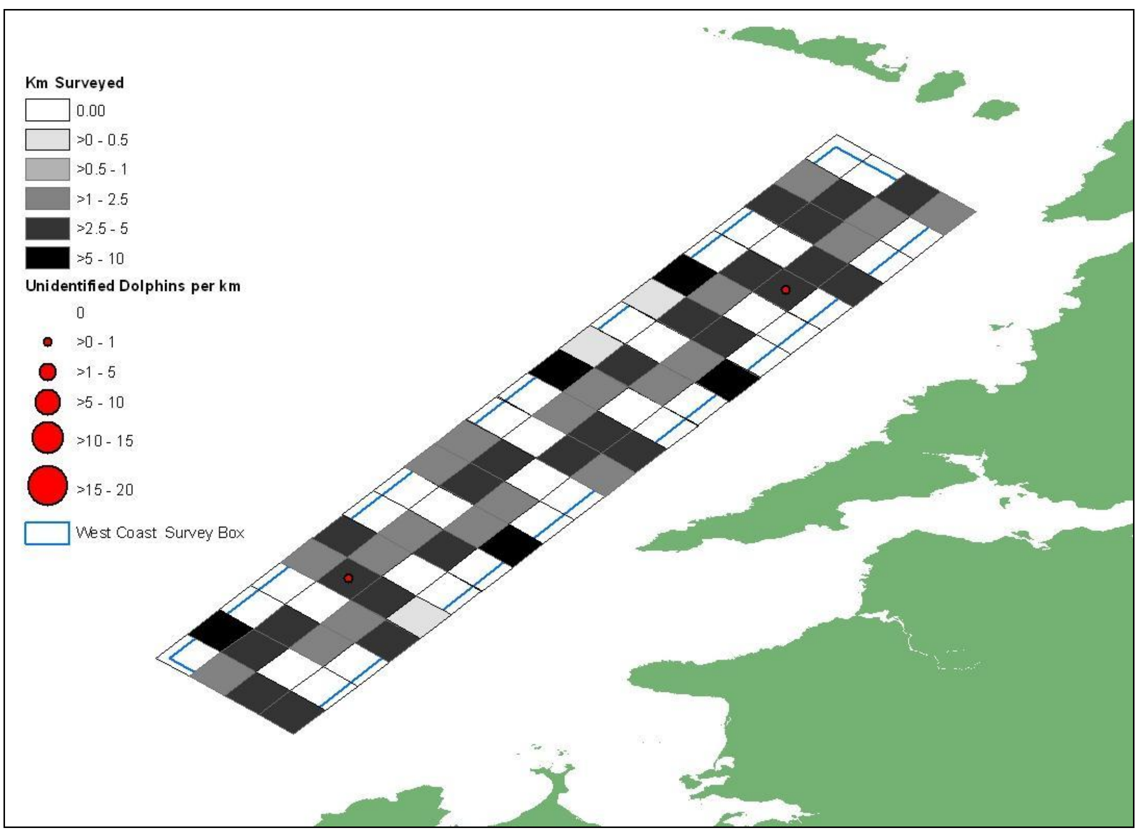


Figure 10. Relative abundance of common, bottlenose and unidentified dolphins in the west survey block

Acoustic detections

A total of 79 acoustic events were logged which corresponds to 17 acoustic encounters when applying the 10-minute silent interval to differentiate between encounters. These comprised 13 common dolphin and three unidentified dolphin encounters. Three acoustic events did not have corresponding visual detections

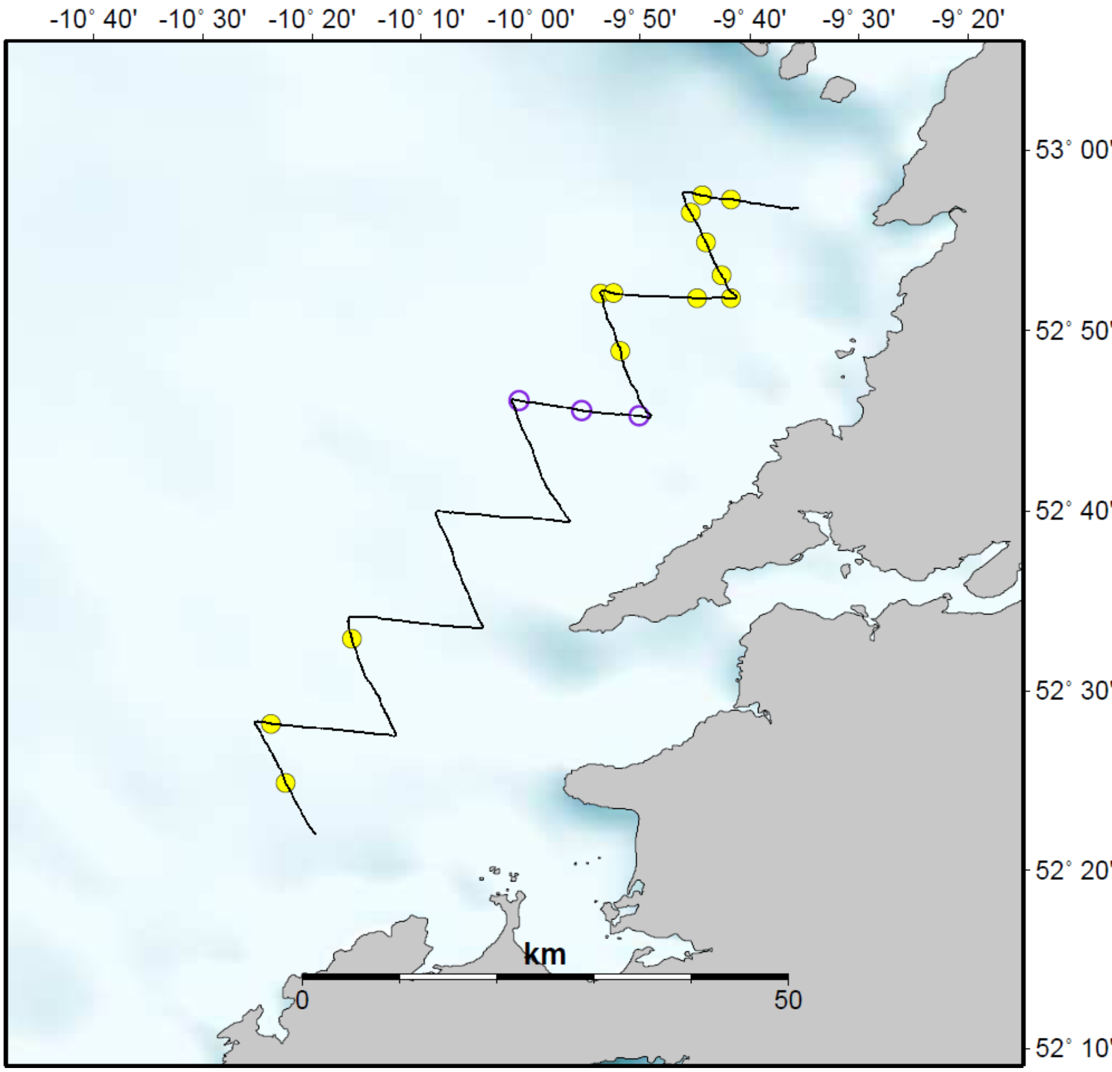


Figure 11. Acoustic survey effort (black line) and acoustic detections. Closed circles indicate simultaneous visual and acoustic detections. Open circles indicate acoustic only detections. Yellow = Common Dolphin, Purple = Unidentified

Absolute abundance

Common dolphin

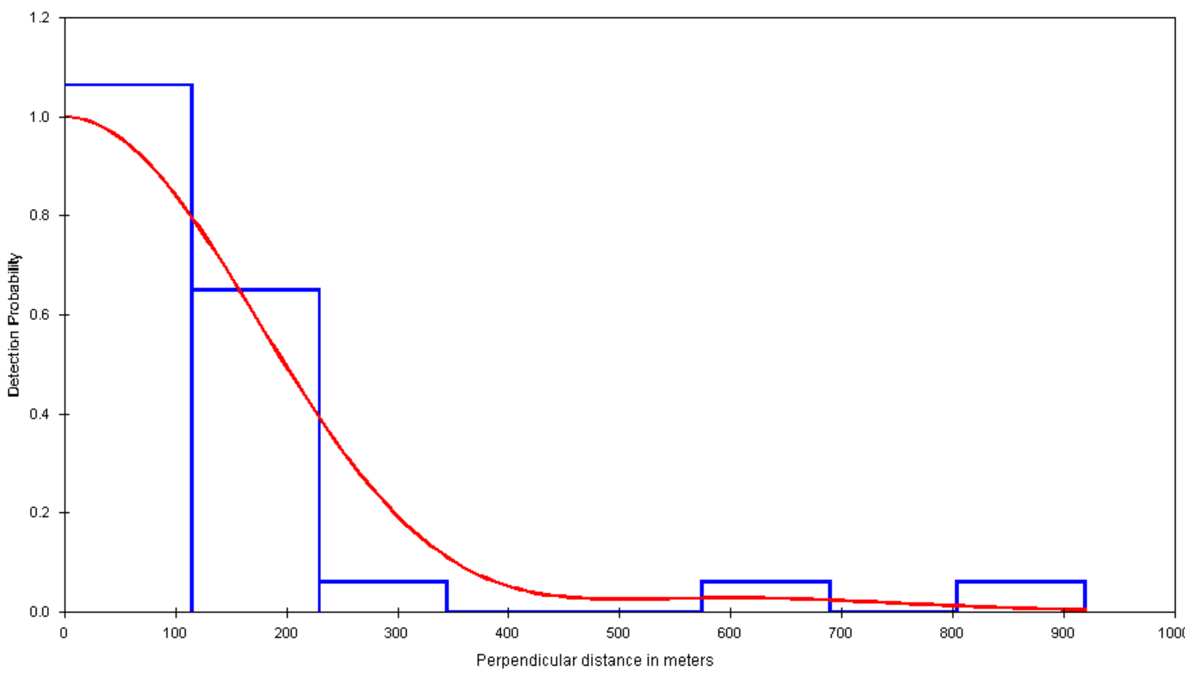
A half-normal model with Cosine adjustments gave the lowest AIC using DISTANCE. The dataset comprised 12 samples (track-lines) with 36 observations. Mean cluster size was 7.53 ± 1.11 and an Effective Search Half-Width of 178m. Most variability occurred in the encounter rate (70.5%) with cluster size accounting for 17.2% and detection probability approximately 12.4%. This was to be expected given the variation in the number of sightings per track-line.

The detection function is shown in Fig 11. A chi-squared test (X^2 = 11.56, df = 5, P<0.05) showed it to be a good fit. This gave a density estimate of 3.83 ± 1.73 dolphins km^{-2} with a CV of 0.45. The abundance estimate was 4416 ± 1996 with a 95% Confidence Interval of 1804-10811 dolphins. When data was grouped into 100m intervals a half-normal model gave the lowest AIC. The detection function was not such a good fit compared to un-grouped data (Chi-squared test X^2 = 7.38, df = 5, P=0.19) although the CV was similar (0.44). This resulted in the density estimate increasing to 4.56 ± 2.01 dolphins km^{-2} giving an abundance estimate of 5254 ± 2311 with 95% Confidence Intervals of 2181 – 12658 (Table 8).

Table 8. Density and abundance estimates of common dolphin and common + unidentified dolphin in the west survey block

Species		Density ± SE (km^{-2})	Abundance ± SE	CV	95% CI
Common dolphin	Non-truncated	3.833±1.732	4416±1996	0.45	1804-10811
	100m intervals	4.561±2.007	5254±2311	0.44	2181-12658
Common + Unidentified dolphin combined	Non-truncated	3.330±1.461	3852±1689	0.44	1621-9157
	100m intervals	3.825±1.558	4407±1829	0.42	1923-10101

A.



B.

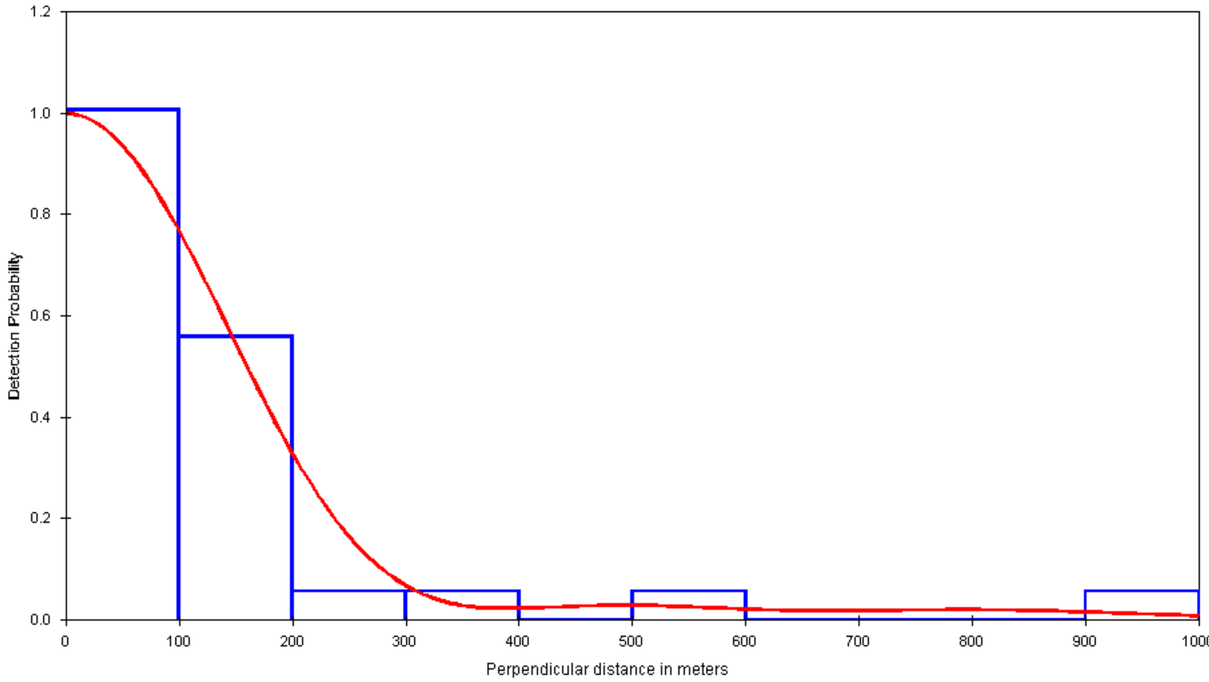


Fig 12. Detection function for common dolphin sightings in the west survey block. A) unsorted and b) data sorted into 100m intervals

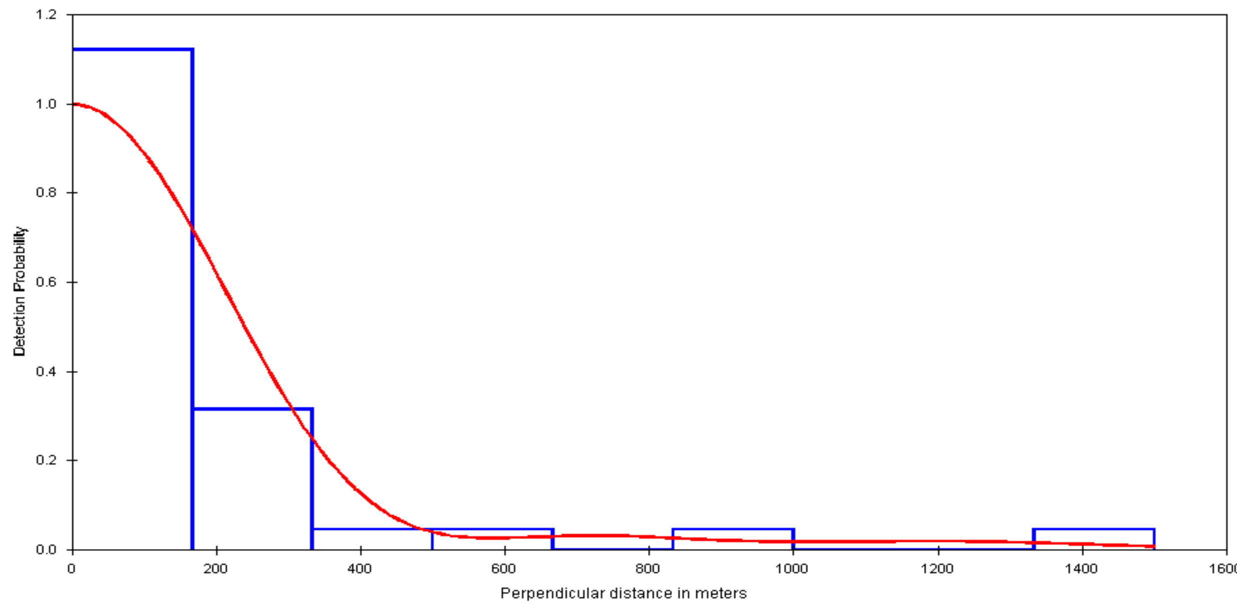
Common and Unidentified dolphin

There were three dolphin sightings which could not be identified to species level but were most likely also common dolphins. If we include these data into the model then the number of samples (track-lines) remains at 12 but the number of observations increased to 35. Most variability occurred in the encounter rate (66.5%) with cluster size accounting for 20.8% and detection probability approximately 12.6%.

Mean cluster size was 7.86 ± 1.13 and Effective Search Width 269m. The detection function is shown in Fig 12 and was a reasonable fit (X^2 = 8.05, df = 4, P<0.10). This gave a density estimate of 3.330 ± 1.461 dolphins km^{-2} with a CV of 0.44.

The abundance estimate increased on that for common dolphin alone by 13% to 3852 ± 1689 with a 95% Confidence Interval of 1621 – 9157 dolphins (Table 8). If we group the data into 100m intervals the detection function (Fig 12b) is a better fit (Chi-squared test (X^2 = 18.16, df = 7, P<0.05). The CV reduced (0.42) and the density estimate increased to 3.825 ± 1.558. This increased the abundance estimate to 4407 ± 1829 with 95% Confidence Intervals of 1923 – 10101 (Table 8).

A.



B.

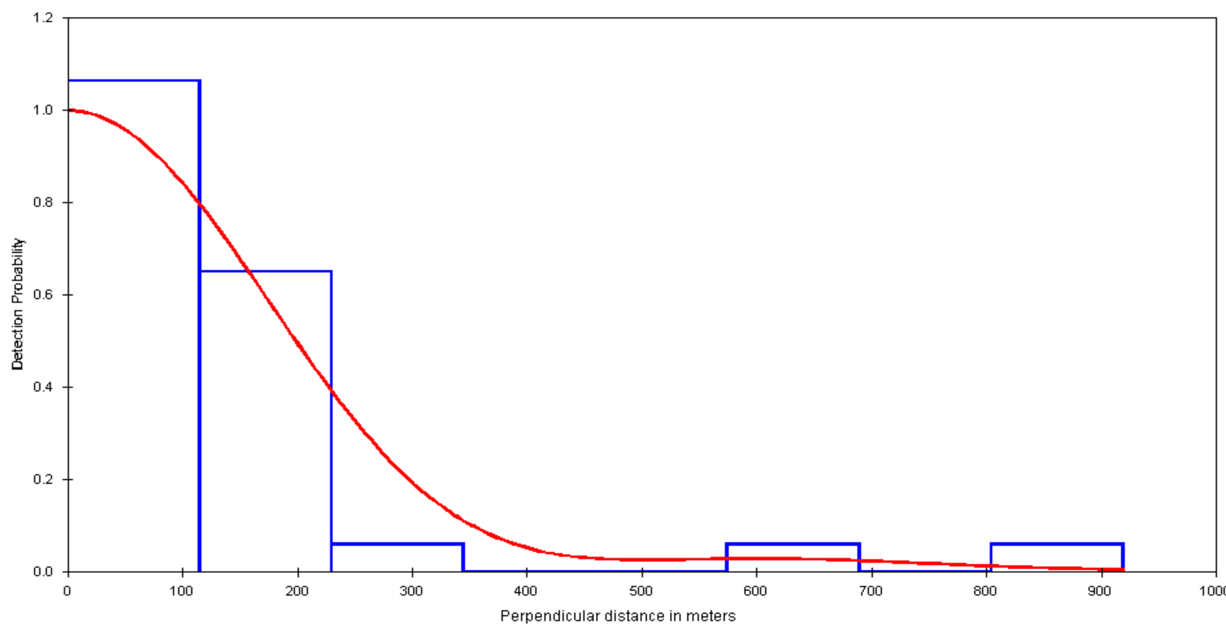


Fig 13. Detection function for common and unidentified dolphin sightings combined in the west survey block. A) unsorted and b) data sorted into 100m intervals

Photo-identification

Images suitable for photo-identification were obtained of two killer whales in the southwestern survey block. The sighting was made 14.5km southwest of Sceilig Mhichíl. Neither whale had previously been photo-identified by Project NAKID (North Atlantic Killer Whale ID Project) (Andrew Foote, University of

Aberdeen/Copenhagen, pers. comm.) and are thus newly recognised individuals. Voucher images of dorsal fins, eye-patches and saddle patches will be submitted to this catalogue (copyright remains with DEHLG).

Figure 14. Images of killer whales taken in the southwest survey block and submitted to the North Atlantic Killer Whale ID Project. (Images taken by Conor Ryan © DEHLG)

Discussion

This was the first attempt to carry out this type of survey, at this scale, in Ireland and it's multi-disciplined approach provided a good return for survey effort; including estimation of relative and absolute abundances for certain species, acoustic detections and also photo-identified individual cetaceans. However due to unfavourable weather conditions for much of July-September, which was the contracted survey period, the deadline for fieldwork was lengthened by two weeks until 15 October 2010. This extension enabled us to complete survey work in the west and southwest survey blocks resulting in survey effort in all three survey blocks.

Ideally additional survey effort is required in the northwest block for full coverage but this was not possible during the survey period. While some of the survey in the northwest block was carried out in unfavourable sea-state, the numerous and distant visual detections of grey seals (which are difficult to detect in high seas) suggests that this area was indeed lacking in cetaceans and that the visual survey results were representative. As motor engine noise is the primary source of noise during towed hydrophone surveys of this kind, there was no discernable difference in background noise between all three surveys due to sea state suggesting this was not a contributing factor in differences in acoustic detections.

<u>Visual Detections</u>

Results from the visual surveys showed there was some variation between the three survey blocks in terms of both species diversity and abundance. The northwestern survey block had the lowest number of records of cetaceans but the highest number of records of seals. The relatively high number of visual detections of seals suggests that it is unlikely we missed many sightings of cetaceans within 300m of the vessel due to sea conditions.

The western survey block had the highest overall abundance, which was dominated by common dolphins but low species diversity (two species). The distribution of common dolphins was almost continuous, except in a region to the northwest of Loop Head, Co Clare where a group of bottlenose dolphins was observed. This apparent partitioning of common dolphins and bottlenose dolphins is interesting, given that violent interactions between these species have been recorded in Ireland (Berrow *et al.* 2010, Murphy *et al.* 2005).

The southwestern survey block exhibited the highest diversity of species and a high abundance of common dolphins.

Further surveys of this kind may derive sufficient data to investigate the drivers of cetacean occurrence and abundances in relation to distance to shore, headlands and benthic topography. The randomization of track-lines in the survey design would improve such analysis (Zuur *et al.* 2007). This was not possible to perform in 2010 for operational and logistical reasons. Sightings of harbour porpoise at all three survey blocks were much lower than at other inshore survey blocks where similar survey methodologies were applied in 2008 (Berrow *et al.* 2008a; 2008b) which may reflect higher densities closer inshore, off headlands and in bays.

Acoustic Detections

In three survey blocks, acoustic detections, with no corresponding visual sightings, were made and vice versa, with sightings but no acoustic detections. Where visual sightings were made in the absence of acoustic detections, this may primarily be due to the observed animals not vocalizing, or may be beyond the detection distance of the hydrophone array. Where acoustic detections were recorded in the absence of visual sightings, this may be attributed to observer ability/variability, or simply the animals may have just been beyond visual range. In the northwest survey block, three acoustic detections (whistle events) were made of an unidentified dolphin species, while no simultaneous sightings were made. However, a distant feeding frenzy of gannets was noted at this time which could have had dolphins associating with it but due to observer elevation and the persistence of a slight sea swell, they were not detected visually.

Common dolphin whistles range in frequency between 3.56kHz to 23.51kHz (Ansmann *et al*. 2007), and Richardson *et al.* (1995) estimated that the maximum detection range for many delphinid species is on the order of 1km. Recent work in the Shannon Estuary carried out by Hansen (2010) suggested that bottlenose dolphin whistles could be detected at a maximum range of around 1200m from a statically moored hydrophone array. Therefore, it is difficult to determine the detection distance of individual species using towed arrays. Acoustic detections are further impacted upon due to background noise, which can mask detections and fill the spectrogram with noise making it difficult and sometimes impossible for the software or indeed an observer to identify detections. This effect was experienced at varying degrees depending on the vessel used, but was controlled and minimized where possible through the use of a by-pass filter and by towing the hydrophone at a distance of 200m behind the vessel.

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. A maximum detection distance of between 200-300m was estimated by Tougaard *et al.* (2006) for harbour porpoises using static acoustic monitors (T-PODs), However, during the southwest survey an acoustic detection of harbour porpoise was made but without a corresponding visual sighting. This event demonstrates the usefulness of simultaneous PAM with visual surveying, as this vocalizing animal must have occurred within 200-300m of the vessel but was missed by visual observers, even in good sea conditions. This suggests that g(0) does not equal 1. However we did not have sufficient sightings of harbour porpoise to derive abundance estimates thus this implication of missed detections is not relevant. High quality recordings of killer whale clicks, whistles and 'moans' were recorded during a survey of the southwest survey block.

The primary constraint experienced using PAM over the duration of surveys, was that common dolphins had a tendency to react to the vessel and hydrophone, and consequently follow it for prolonged periods. This proved problematic for the acoustic observer when trying to differentiate between new encounters, and new individuals approaching the vessel. In this case the 10 minute silent period was not appropriate to differentiate between new encounters, and hence impacted upon the total number of acoustic encounters reported per survey.

Visual versus Acoustic Detections

While there is merit to 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. Furthermore, work on species assignment according to known acoustic repertoires in Irish waters is an ongoing process.

Relative Abundance

Information on relative abundance is useful for comparing within and between survey blocks and can be broadly compared to data from larger scale surveys such as Wall *et al.* (2006). However, it is important to note that the number of observers, observer height and area covered differ between these surveys. During single platform surveys carried out on platforms of opportunity between May and September 2004, Wall *et al.* (2006) covered an area that encompassed both the west and southwest survey blocks from this survey. They also found high abundances of common dolphins in these regions; however the relative abundance was much lower at 12.1 individual cetaceans hr^{-1} (for three species combined) compared to the average of 26.9 individuals hr^{-1} across both survey blocks from the present survey. This discrepancy may be due to a seasonal effect, given the present survey was carried out in autumn and not summer. Wall *et al.* (2006) observed no harbour porpoise or killer whales however recorded occurrence of minke whale was similar, with just two sightings.

O'Cadhla *et al.* (2004) reported that common dolphin is the most abundant species on the Atlantic margin. The results presented here confirm this observation for inshore waters of the Atlantic margin for autumn 2010. The mean group sizes for common dolphin here (7.75 ± 1.08 and 7.13 ± 1.39 for blocks B and C respectively) were larger than the 6.5 ± 37.4 reported by O'Cadhla *et al.* (2004). The number of sightings per km of common dolphin from the present study (0.23 and 1.39 for blocks B and C respectively) were also higher than that reported for shelf waters <500m (<0.01). Broad-scale seabird and cetacean surveys also demonstrated a southwesterly distribution of common dolphins in Irish inshore waters with highest relative abundance of the southwest and northwest coasts (Pollock *et al.* 1997; Reid *et al.* 2003).

Abundance 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.

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. This is likely to be much less for common dolphins where g(0) is close to 1. However common dolphins often show movement towards the vessel and thus density and abundance is over-estimated Hammond *et al*. 2002). There was some evidence of this in the current survey as demonstrated by the U-shaped normal distribution of the ungrouped data of the detection function does demonstrate a rapid decrease in sightings with distance. 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 survey blocks.

There were only sufficient sightings to estimate density of common dolphin and only in two survey blocks (west and southwest). Density estimates for common dolphins in the west (3.83 individuals km$^{-2,}$ CV=0.45) and southwest survey blocks (3.02 individuals km^{-2}, CV = 0.46) were very similar but almost two orders of magnitude greater that those from SIAR survey (0.039 individuals km^{-2}, CV = 0.39) and one order of magnitude greater than that from SCANS-II (0.40 individuals km^{-2}, CV=0.78). However both SIAR and SCANS-II were double-platform surveys and were on a much broader scale so only gross comparisons should be made. Also the number of sightings in the present survey (30 in the southwest and 36 in the west) were at the lower end of the number required for robust density estimates using distance sampling so these estimates should also be treated with caution. However, the waters between 6 and 12nm from shore along the western and south-western sea-board may support some of the highest densities of common dolphins recorded in Irish waters to date.

A double-platform survey could be considered to test the assumption that g(0)=1 and enable direct comparison with broad-scale surveys carried out in Ireland (SCANS, SIAR, CODA). However this will increase costs as a larger vessel and additional personnel and analysis is required.

This survey has shown there are differences in species diversity and abundance across regions in inshore waters. Sites can be readily surveyed using small vessels and narrow weather windows providing an opportunity to survey these sites and derive abundance estimates and acoustic detections suitable for monitoring.

Acknowledgements

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Appendix I

Criteria used for species assignment of acoustic detections

Binomial	Vernacular	Signal Type	Frequency Range (kHz)	Frequency at Max. Energy (kHz)	Source Level (dB re 1 µPa)	References
Phocoena phocoena	Harbour porpoise	Clicks	2 - 140	110 - 150	100 - 205	Busnel and Dziedzic 1966, Whitlow *et al.* 1999,.
Delphinus delphis	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,
Tursiops truncatus	Bottlenose dolphin	Whistles	0.8-24	3.5-14.5b	125-173	Lilly and Miller 1961, Tyack 1985, Schultz and Corkeron 1994, Ding *et al.* 1995
		Click	0.2-150	110-130	218-228	Diercks *et al.* 1971, , Au *et al.* 1984, Au 1993
Orcinus orca	Killer whale	Whistles	1.5-18	6-12	-	Ford and Fisher 1983, Thomsen *et al*. 2001
		Click	0.1-35	12-25	180	Schevill and Watkins 1966, *Diercks et al.* 1971, Diercks 1972
Cetacea	Unid Cetacean	Clicks	0.2 - 150	-	-	
Delphinidae	Unid Dolphin	Whistles	0.8 - 24	-	-	