Harbour Porpoise Survey 2008

Simon Berrow[1], Ronan Hickey[1], Joanne O'Brien[2], Ian O'Connor[2] and David McGrath[2]

[1] Irish Whale and Dolphin Group, Merchants Quay, Kilrush, County Clare
[2] Marine Biodiversity Research Group, Galway-Mayo Institute of Technology, Dublin Road, Galway

Report to the National Parks and Wildlife Service

October 2008

Harbour Porpoise
Survey 2008

Survey team:

Simon Berrow	**(Primary, LOGGER, T-PODs)**
John Brophy	**(LOGGER)**
Eileen Diskin	**(LOGGER)**
Bojana Ferlan	**(Primary and LOGGER)**
Brian Glanville	**(LOGGER)**
Sophie Hansen	**(LOGGER and T-PODs)**
Ronan Hickey	**(Primary and LOGGER)**
Eugene McKeown	**(LOGGER)**
Dana Miller	**(Primary and LOGGER)**
Joanne O'Brien	**(Primary and T-PODs)**
Fiacc O'Brolchain	**(LOGGER)**
Mick O'Connell	**(Primary)**
Tracey O'Shea	**(LOGGER)**
Debbie Pedreschi	**(LOGGER)**
Conor Ryan	**(Primary)**
Dave Wall	**(Primary)**
Faith Wilson	**(Primary)**
Peter Wilson	**(LOGGER)**
Pádraig Whooley	**(Primary)**

Citation: Berrow, S.D., Hickey, R., O'Brien, J. O'Connor, I. and McGrath, D. (2008) Habour Porpoise Survey 2008. Report to the National Parks and Wildlife Service. Irish Whale and Dolphin Group. pp.33.

Cover image: Harbour porpoises © Simon Berrow/NPWS

Harbour Porpoise Survey 2008

Summary

A survey of harbour porpoises (*Phocoena phocoena*) was carried out at five sites (North County Dublin, Dublin bay, Cork coast, Roaringwater bay cSAC and Galway bay) to derive density and abundance estimates. Single platform line-transect surveys were carried out on six days at each site between July and September 2008. Distance sampling was used to derive g(0), which is the density of harbour porpoises on the track of the vessel. Abundance estimates were calculated using the track-line as the sample and the sighting as the observation.

During 28 survey days a total of 354 track-lines were surveyed for a total distance of nearly 20,000 km in seastate ≤2. From the 269 sightings of a total of 496 individual harbour porpoise were recorded. There were 13 sightings with a total of 171 common dolphins (*Delphinus delphis*), eight sightings of single minke whales (*Balaenoptera acutoratrata*) and one sighting of 20 bottlenose dolphins (*Tursiops truncatus*). Five sightings with a total of 18 dolphins were not identified to species level.

Overall density estimates from the five sites ranged from 0.53 to 2.03 porpoises per km^2. The highest density was recorded in North County Dublin and the lowest in the Cork coast site. Mean group size varied from 1.41 to 2.67. The largest overall abundance estimate was from Galway bay (402±84.1) which reflected the large area of this site (547km^2). A high density was also recorded in Roaringwater bay cSAC due partly to a high mean group size. Densities in Dublin bay were also high with 1.19 per km^2. Harbour porpoise densities in the Cork coast were the lowest of any site despite high mean group size.

Passive Acoustic Monitoring was carried out at three sites (Dublin bay, Cork coast and Roaringwater bay cSAC) through the deployment of self-contained click detectors called T-PODs. An accumulated total of 214 days were monitored acoustically between 11 July and 8 October 2008. All sites in all months, with the exception of one month (August) at one site (Roaringwater bay) recorded porpoise detections every day. Data were presented as mean Detection Positive Minutes per hour (DPM). By far the highest DPM was from Dublin bay which recorded the highest detection rate recorded in Ireland from any T-POD study to date. T-PODs in Roaringwater bay had slightly higher DPM than from the Cork coast.

Results from a similar survey of the Blasket Islands cSAC in 2007 were used as a reference with which to compare density estimates. Only North County Dublin (2.03) had a higher overall density than the Blasket Islands cSAC (1.33). Density estimates in Roaringwater bay cSAC (1.24), which is also designated for harbour porpoises and Dublin bay (1.19) were both high. Densities in Galway bay were just over one-half of the reference density. In terms of acoustic detections, only Dublin bay (11.8) was greater than the mean DPM from two sites in the Blasket Islands cSAC (1.5) monitored in 2007.

We recommend that North County Dublin and Dublin bay are combined into one site and designated as an SAC for harbour porpoise. Galway bay should also be designated as an SAC for harbour porpoise and further monitoring of the Cork coast is required to see if harbour porpoise densities meet the level consistent with designation as an SAC for harbour porpoise. There is potentially considerable variation in density estimates between months and between years. We recommend twice monthly sampling from April to October to obtain sufficient sightings for a robust density estimate with a low CV. Passive Acoustic Monitoring, should be used to compliment visual surveys and be continued for a number of years to establish robust reference values for long-term monitoring.

Introduction

The harbour porpoise is the most widespread and abundant cetacean species in Irish waters (Rogan and Berrow 1996). It has been recorded off all coasts and over the continental shelf but is thought to be most abundant off the southwest coast (Reid *et al.,* 2003). They are also consistently one of the most frequently recorded species stranded on the Irish coast (Berrow and Rogan, 1997).

There have been a number of dedicated surveys which have estimated absolute abundances of harbour porpoises in Irish waters. In July 1994 an abundance estimate of 36,280 harbour porpoises was calculated for the Celtic Sea as part of an international project called SCANS (Small Cetacean Abundance in the North Sea) (Hammond *et al.* 2002). This survey was repeated in July 2005 (SCANS-II) but encompassed all Irish waters including the Irish Sea (SCANS II, 2008). Ship-based double platform line-transect surveys were carried out in the Celtic Sea and in offshore Ireland while aircraft were used for coastal Ireland and in the Irish Sea. Harbour porpoise abundance estimates were generated for three areas; Celtic Sea (80,613, CV=0.50), Irish Sea (15,230, CV=0.35) and Atlantic coastal Ireland (10,716, CV=0.37). The offshore Ireland survey area included Scotland and an estimate of 10,002, (CV=1.24) was generated for both areas combined. Harbour porpoise density had doubled in the Celtic Sea between SCANS I and SCANS II representing an increase of 11% per annum between 1994 and 2005. In 2007 the National Parks and Wildlife Service commissioned a survey of the Blasket Islands cSAC (Berrow *et al.* 2007). Six days were spent surveying the site between July and October with density estimates ranging from 0.71 to 3.39 porpoises per km^2. This gave abundance estimates ranging from 162±120 to 768±198 depending on the number of sightings per day. The most robust estimate ± SE, using all the data from each track-line combined, was 303±76 (CV=0.25 and 95% Confidence Intervals=186-494).

EU member states are required to designate Special Areas of Conservation (SAC) for species listed under Annex II of the EU Habitats Directive. The Blasket Islands and Roaringwater Bay have already been designated as candidate Special Areas of Conservation (cSAC) for harbour porpoise. The NPWS seek information on a number of other sites to assess their potential for designation as harbor porpoise SACs.

Objectives

The objectives of the present survey were to:

1. calculate the density of harbour porpoise at five sites
2. assess the abundance of harbour porpoise within these sites
3. carry out passive acoustic monitoring at three sites
4. record other species of interest
5. make recommendations as to the suitability of each site as potential SACs

Methods

Survey sites

The survey sites are shown in Figure 1. The two sites in Co Dublin were small (North County Dublin = 104 km^2; Dublin bay = 116 km^2), while the Cork coast at 326 km^2 was the second largest site after Galway bay which was 547 km^2. Roaringwater bay cSAC in Co Cork was also small at 129 km^2. The boundary of Galway bay was extended to the west following consultation with NPWS and formed a line between Golam Head and the west tip of Inishmór.

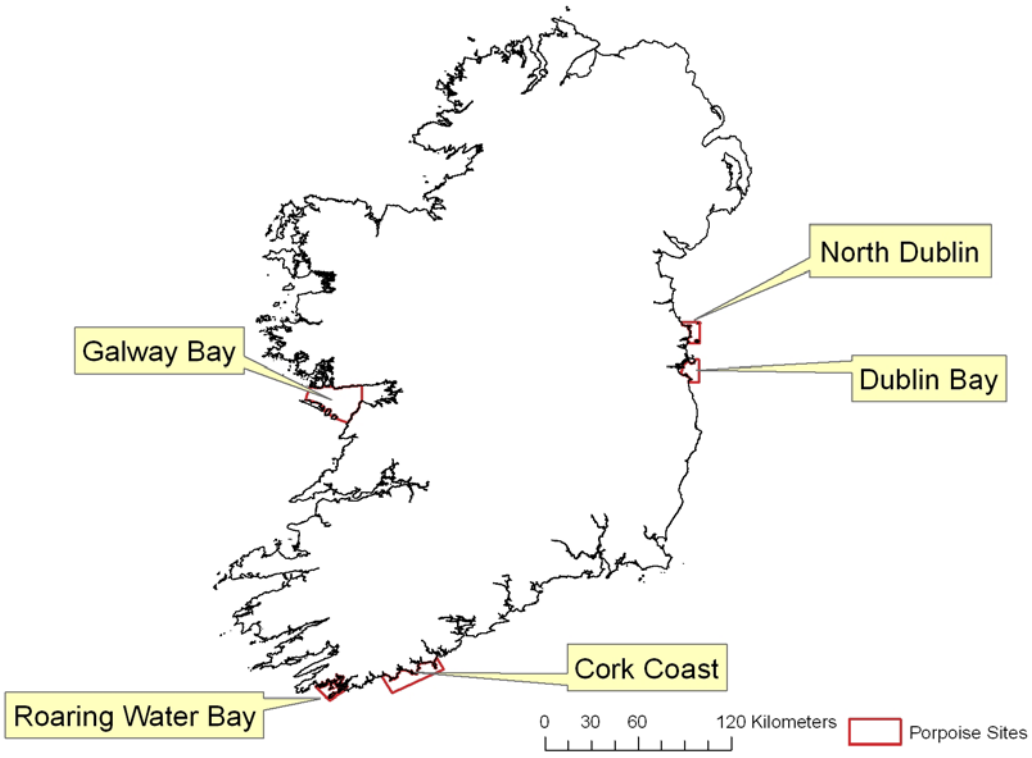

Figure 1. Map of Ireland showing location of sites surveyed for harbour porpoise during 2008

Survey platforms

Eight different vessels were chartered over the duration of the survey period (Table 1). The MV Beluga carried out all surveys in North County Dublin and Dublin bay, while the MV Holly Jo carried out eight of the eleven survey days in the Cork coast and Roaringwater bay sites. In Galway bay the MV Tarrea Queen was used for the first three surveys as the proposed survey vessel, the MV Conamara, was unavailable due to work commitments elsewhere in the country. The remaining three surveys were carried out from the MV Conamara and the MV Whitewater II.

Table 1. List of vessels chartered during the Harbour porpoise survey 2008

Vessel	Port	Type	Length (m)	Platform height (m)
MV Beluga	Dun Laoghaire, Co Dublin	Cruiser	13	3.1
MV Conamara	Rossaveal, Co Galway	Survey vessel	13.5	3.0
MV Holly Jo	Castletownshend, Co Cork	Blyth catamaran	11	3.2
MV Naiomh Ciaran	Cape Clear, Co Cork	Island ferry	18	3.0
MV Tarrea Queen	Galway, Co Galway	Sorca 1500	15	3.1
MV Whitewater II	Barna, Co Galway	Evolution	12	2.5
MV Whispering Star	Kinsale, Co Cork	Aquastar	13	2.3
MV Wave Chieftan	Baltimore, Co Cork	Offshore 125	13	3.0

Survey training

For this tender we proposed to establish a team of surveyors who could take advantage of suitable weather conditions at short notice. This strategy contributed to the successful completion of the survey (combined with the Small Cetacean Site Investigations Survey 2008) as on two occasions, three teams surveyed three different sites simultaneously, while on two occasions two sites were surveyed on the same day. However, this use of multiple observers can increase the variability within a dataset through inter-observer error and variability in observer performance and was therefore a potential concern.

In order to address this issue a training weekend was organized from 6-8 June in Kilrush, Co Clare. All participants were introduced to the theory behind line-transect surveys and how the data will be handled and analysed. A survey of the Shannon estuary aboard two chartered vessels was carried out to gain experience of LOGGER software and how to estimate distance and angle to sightings. Trials on an observer's ability to detect small cetaceans were carried out on bottlenose dolphins from two land-sites sites (Kilcredaun point and Moneypoint) in the Shannon estuary. Two teams of six observers were sent to each site on two occasions. All observers were visually excluded from each other and asked to record the time of any sightings and an estimate of group size, therefore allowing for the assessment of variability between observers in time taken to record first sighting, estimation of distance to the observed animals, number of groups and group size.

To assist in estimating distance, two trials were carried out where observers were asked to estimate distances to a RIB on the estuary. The distance was then verified using a Leica Rangemaster 1200. This range finder reports an accuracy to within ±2m over 800m or ±0.5% over 600m. In the first trial observers were given 10 distances to estimate between 50 and 1000m with no feedback provided between estimations as to the actual distance. The results show very accurate distance estimation up to 200m with a very small under-estimate at short distances (Figure 2a). At greater distances accuracy was less with a tendency to under-estimate the distance. In the second trial, ten more distances were estimated but observers were told the actual distance between each estimate, thus enabling them to improve on their subsequent estimation following this feedback (Figure 2b). Results showed that observers improved their ability to estimate large distances when feedback was provided between estimations, while shorter distance estimates proved to be a little less accurate. The model used for this survey was set to truncate beyond 200m, and therefore sightings beyond this were not used to generate density estimates. There would have been variability between observers, however overall errors were considered minimal. Thus, the team of observers used during the survey proved to be capable of accurately determining distances up to 200m.

Figure 2a. Trial 1

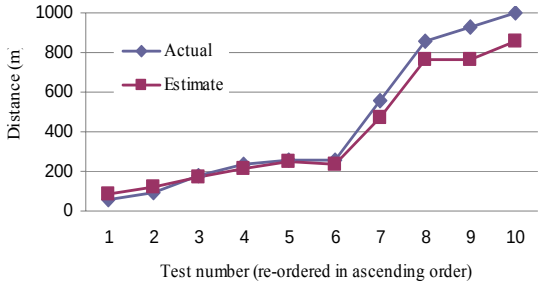

Figure 2b. Trial 2

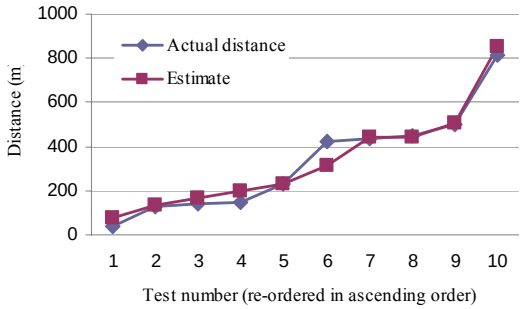

Figure 2. Mean distance estimates during blind trials with a. No feedback and b. With feedback

Another source of variability found during trials in the Shannon estuary was the estimation of group size. For these trials we used bottlenose dolphins as the target species and group sizes ranged from four to 19 individuals. However, harbor porpoise group size tends to be much smaller, typically 1-3 and very occasionally up to 8 individuals. Thus, it was assumed that this was not going to be a significant variable as observers would be able to determine harbour porpoise group size with a high degree of accuracy.

Survey methodology

Conventional single platform line-transect surveys were carried out within or in close proximity to the boundaries of survey sites along pre-determined routes. Transect lines were chosen to cross depth gradients and provide as close to equal coverage probability as possible following the recommendations of Dawson *et al.* (2008) who suggested systematic line spacing resulted in better precision than randomized line spacing. The lines were changed for each survey to try and get full coverage of the cSAC over the study period to ensure no important porpoise concentrations were overlooked. Distance sampling was used to derive a density estimate and to calculate an abundance estimate. During this survey we assumed g(0) was equal to one, i.e. that all the harbour porpoise on the track-line were recorded.

Each survey vessel traveled at a speed of 12-16 km hr^{-1} (7-9 knts), which was 2-3 times the typical average speed of the target animal (harbour porpoise) as recommended by Dawson *et al.* (2008). Traveling too fast could result in fewer sightings as there will be less time for the animals to surface within viewing range. Two primary observers were positioned on the flying bridge, which provided an eye-height above sea-level of between 4-6m depending on the height of the platform (Table 1) and each individual observer. 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. All sightings were recorded but sightings over 200m (300m if sea-state 0 predominated) from the track-line were not used in the distance model as these extreme values give little information and make it difficult to fit the detection function and estimate density. Calves/juveniles were defined as porpoises ≤ half the length of the accompanying animal (adult) and in very close proximity.

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 perpendicular distance of the sighting from the vessel recorded. These data were communicated to the recorder in the wheelhouse via VHF 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. At some sites during each survey an orange buoy 225mm in diameter was towed 200m astern of the observers' position on the survey vessel. This provided a reference point against which to estimate distances.

Abundance estimate

The software programme DISTANCE (Version 5, University of St Andrews, Scotland) was used for calculating the density of harbour porpoises on the track of the vessel (g(0)) and thus deriving abundance estimates. This software allows the user to select a number of models in order to identify the most appropriate for the data. It also allows truncation of outliers when estimating variance in group size and testing for evasive movement prior to detection.

Berrow *et al.* (2007) showed that using the track-line as the sample with sightings used as observations reduced the variance around the mean without changing the density estimate. This was due to the sample size being much greater than if the day was used as the sample. This method of analysis was used throughout.

Under the NPWS contract all sightings in sea-state 2 or less were to be used in the analysis. All sightings in sea-state 3 are listed in the site summary tables but were excluded from the DISTANCE analysis. Estimates of abundance are presented for each survey day providing there were sufficient sightings to generate an estimate. The overall abundance estimate was derived from all track-lines in sea-state 2 or less from all days combined. This was necessary to obtain sufficient sightings (minimum of 40—60) for a robust estimate using the DISTANCE model. We have assumed that there were no major changes in distribution within each site between sample days or any immigration or emigration into or out of the site.

We fitted the data to a number of models. We found that a Half-Normal model with Hermite Polynomial series adjustments best fitted the data according to Akaike's Information Criterion. The recorded data were

grouped into equal distance intervals of 0-20, 20-40 up to 180-200 for most sites which 0-30, 30-60 up to 300m for surveys with good sea-state. Cluster size was analysed using size-bias regression method with log(n) of cluster size against estimated g(x). The variance was estimated empirically.

Maps were created using Irish Grid (TM65_Irish Grid) with ArcView 3.2; while maps of the proposed SACs were obtained from National Parks and Wildlife Service. Data used in the creation of the maps of transects, effort, abundance and density estimates were stored in a single MS Access database, which was queried from within the GIS to produce maps.

Acoustic monitoring

Acoustic monitoring was carried out through the deployment of T-PODs which are manufactured by Chelonia Ltd in the UK. They consist of a self-contained computer and hydrophone and can log the times and duration of click trains which resemble the echo-location clicks produced by porpoises. The T-PODs detect clicks using two band-pass filters. One filter is called the target filter A, while the other filter B is the reference filter. T-PODs were set to log only harbour porpoise clicks, using the generic harbour porpoise settings. This meant that the target filter A was set to 130Khz (peak frequency of harbour porpoises), while the reference B filter was set to 92kHz (as at this frequency there is very little or no energy of the porpoise sonar signal at that frequency) (Table 2). During the analysis the filter CET-ALL was used as this enables the same settings to be used across all conditions and avoids having to manually inspect all doubtful click trains (Ingram *et al.* 2004). Encounters were separated by a period of 10 minutes without detections. Data were analysed using the latest version of the dedicated software, T-POD.exe Version 8.21, which is available free from www.chelonia.co.uk.

Table 2. T-POD settings used for porpoise monitoring during the Harbour Porpoise Survey 2008

Scan	1	2	3	4	5	6
Target A Filter reference kHz	130	130	130	130	130	130
Reference B Filter reference kHz	92	92	92	92	92	92
Click Bandwidth	4	4	4	4	4	4
Noise Adaptation	++	++	++	++	++	++
Scan Limit on N of clicks logged	240	240	240	240	240	240

T-POD Calibration trials

In order to enable the comparison of acoustic data collected by different units, simultaneously recording from different sites, it was necessary to carry out a calibration trial to assess the variability in sensitivity between units. Prior to field trials, all T-POD units were calibrated in a tank by Chelonia LTD. This exercise was carried out in order to determine the correct sensitivity of each unit which should be set at in order to maximize its performance. Field calibrations trials were then carried out over an 18 day period in Galway Bay, from a site two miles east of Spiddal, Co. Galway between 19 and 30 June 2008. Eight T-PODs were deployed in close proximity to each other. All T-PODs were set to the settings in Table 2, and each unit was set to the appropriate sensitivity as derived during controlled testing. Upon recovery, data were extracted as total Detection Positive Minutes (*DPM)* per day.

Results from the calibration trial are showed in Table 3. The T-PODs had remarkably similar results for total *DPM*, showing the sensitivities between T-PODs were very similar. T-POD 651 recorded the most detections and was therefore used as the reference in order to generate a correction factor to allow for varying sensitivities between each of the units. A correction factor (CF) from Leeney (2007) was

calculated using the following equation where X is equal to the mean number of Detection Positive Minutes (DPM) per hour recorded by each unit during calibration trials:

$$CF = \frac{X^{651}}{X^{\text{T-POD Y}}}$$

Table 3. Summary of acoustic data logged during calibration trials in Galway Bay

T-POD No.	T-POD version	Sensitivity setting	Deployment duration	Total DPM	Mean DPM per h^{-1}
324	4	9	8d 18 hrs	163	0.78
451	5	15	8d 18 hrs	163	0.78
505	4	16	8d 18 hrs	201	0.95
641	5	16	8d 18 hrs	179	0.85
645	5	15	8d 18 hrs	145	0.69
651	5	15	8d 18 hrs	221	1.05
652	5	13	8d 18 hrs	189	0.89

Moorings

The mooring system used was a simplified version of that used in 2007, modified after equipment losses reported by Berrow *et al.* (2007). The mooring comprised of a 40 kg (Dublin bay) or 60 kg weight (Roaringwater bay and Cork coast) with two small buoys attached. The smaller buoys were designed to provide minimum resistance to sea swell and wind. The T-POD was attached to the single mooring at a depth of 5m from the bottom, and kept vertical with the addition of a small ecobuoy (see www.ecobuoy.com) at the hydrophone end to increase its buoyancy. The moorings in Co Cork were recovered with the aid of a pot hauler and those in Dublin bay were pulled by hand from the surface. Written on each main mooring buoy was "*IWDG Harbour Porpoise Survey. Phone 086 8545450*".

Deployment positions of T-PODs

A single T-POD was deployed at six locations, two in each of three sites (Dunlin bay, Cork coast and Roaringwater bay). The T-PODs were recovered once during the survey, the data was downloaded onboard the survey vessel, the batteries replaced and the T-POD re-deployed at the same locations. No T-POD was found on 21 August at the Muglins on the south side of Dublin bay. Divers from the UCD Sub-aqua club dived the site on two occasions looking for the lost T-POD or mooring but no sign of either was reported.

All other T-PODs were recovered on 21 and 22 August for downloading and re-deployment before finally being recovered on 25 September (Roaringwater bay), 28 September (Dublin bay), 26 September (Galley head in the Cork coast) and 8 October (Old Head of Kinsale on the Cork coast).

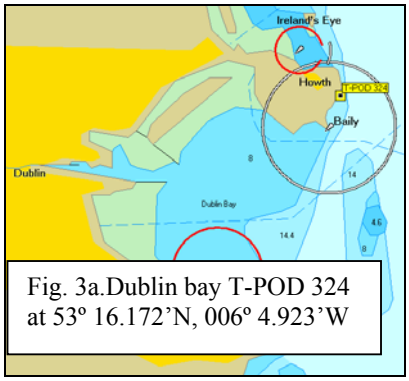

Fig. 3a.Dublin bay T-POD 324 at 53º 16.172'N, 006º 4.923'W

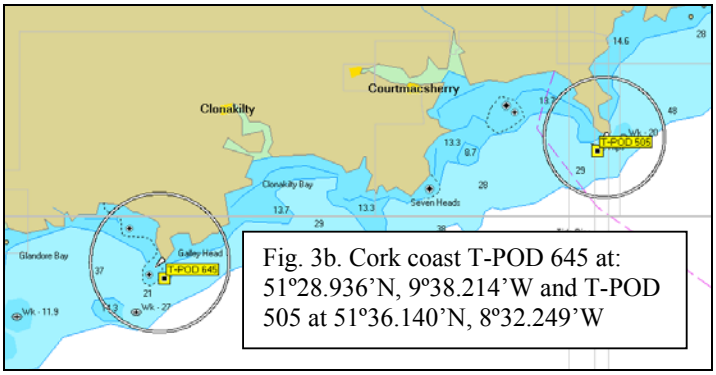

Fig. 3b. Cork coast T-POD 645 at: 51º28.936'N, 9º38.214'W and T-POD 505 at 51º36.140'N, 8º32.249'W

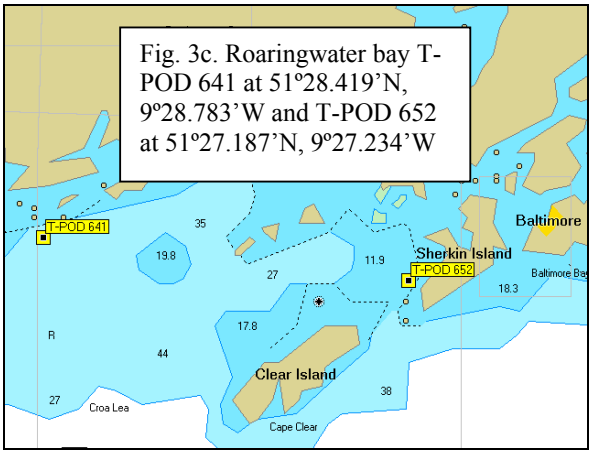

Fig. 3c. Roaringwater bay T-POD 641 at 51º28.419'N, 9º28.783'W and T-POD 652 at 51º27.187'N, 9º27.234'W

Figure 3. Map of locations where T-PODs were deployed

Results

Results are presented under each site with a summary table presented in the Discussion. All sightings recorded in all sea-states during each survey are shown in the summary table but only those sightings made in sea-state 2 or less were used in the DISTANCE analysis. All density estimates have used the track-line as the sample and harbour porpoise sightings as the observation.

North County Dublin

Six surveys were carried out in North County Dublin (Table 4). On 20 July sea-state 2 and 3 was recorded at the beginning of the survey, resulting in no sightings of harbour porpoises in 2.7km of effort in sea-state 2 before the trip was abandoned. On 20 August, although sea-state 3 was recorded on 36% of the survey, sea-state 1 was recorded on 21% of the time which resulted in 9 sightings being recorded. Even in good sea conditions there was considerable variation in the number of sightings on each survey day. On 12 July despite sea-state 0 and 1 occurring for 94% of the survey only 8 sightings of a total of 9 individuals were recorded. On 29 August a total of 48 sightings of a total of 67 individuals were recorded. However only 2 weeks later in excellent sea conditions only 15 sightings of 21 individuals were recorded and two weeks later, again in excellent sea conditions only two sightings of a total of five individuals were recorded (Table 4). This suggests that there was significant immigration into the site on 29 August.

Table 4. Date, effort, sea-state and number of sightings of harbour porpoises within North County Dublin during 2008

Sample	Date	No. of track lines	Total distance in sea-state ≤2 (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	12 July	12	47.20	13.6	73.2	7.3	5.9	8	9
2	20 July	1	2.70	0	0	54.3	45.7	0	0
3	20 August	8	35.01	0	21.6	24.8	36.4	9	9
4	29 August	18	71.70	27.8	60.2	12	0	48	67
5	12 September	17	69.26	38.7	48.1	13.2	0	15	21
6	27 September	13	67.97	12	82.7	5.3	0	2	5
Total		**69**	**293.75**					**82**	**111**

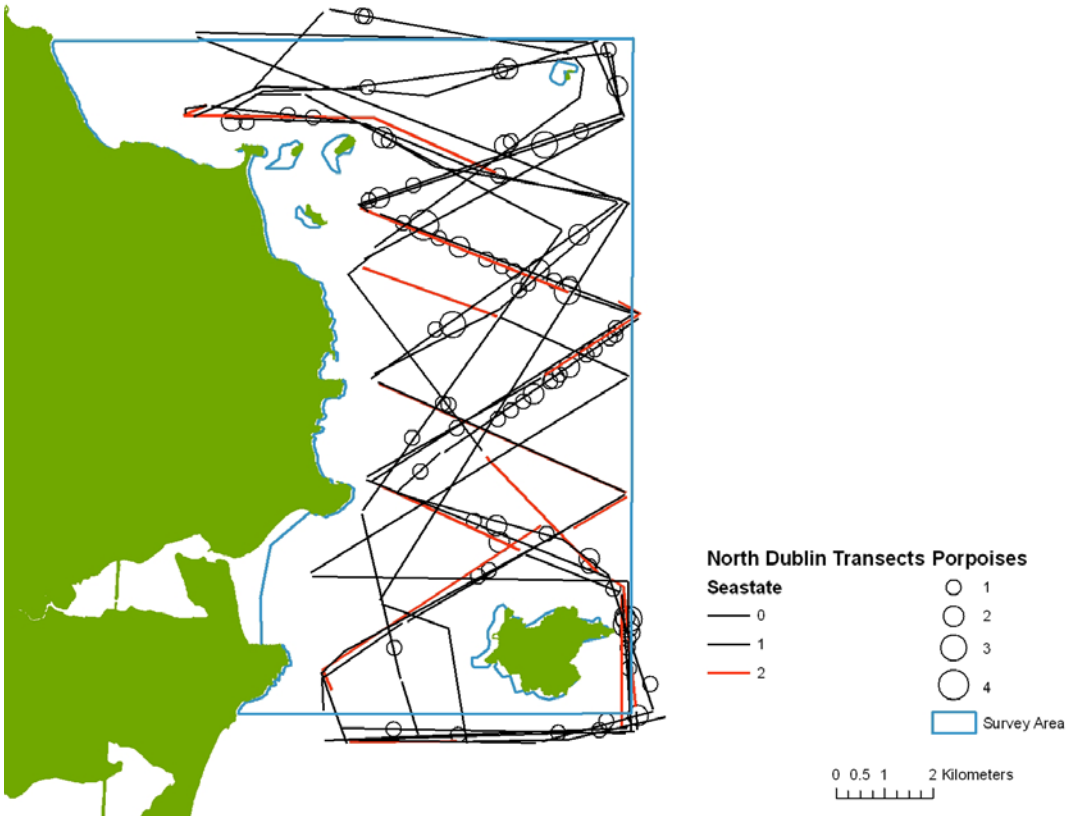

Figure 4. Map showing location of all track lines surveyed and harbour porpoise observed

Track-lines and sightings for North County Dublin are shown in Figure 4. The distribution of effort in sea-state 0 and 1 (black lines) is good with effort in all areas of the study site. If sightings are presented as sighting rate per 2km^2 cell (Figure 5) we can see that harbour porpoise were distributed throughout the study area with the biggest concentration northwest of Lambay island to the south east of the site.

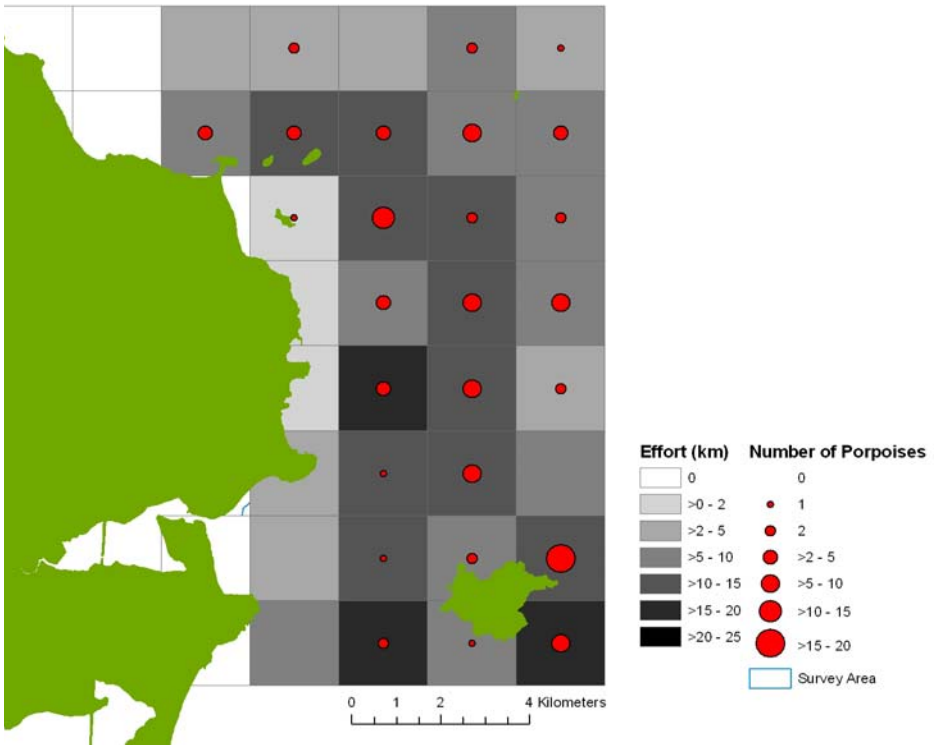

Figure 5. Map of North County Dublin with effort and harbour porpoise sightings shown within a 2km^2 grid

The detection function of harbour porpoise in North County Dublin is shown in Figure 6. There is evidence of evasive movement with a peak in sightings 20-60m from the track-line. The proportion of the variability accounted for by the encounter rate was 80.3%, with 15.3% attributed to detection probability and 4.4% due to group size. This shows that it is the number of sightings on each track-line that shows the greatest variability, which is to be expected as many track-lines will have no sightings while others will have many sightings. This shows the detection function was a good fit and the estimate is robust.

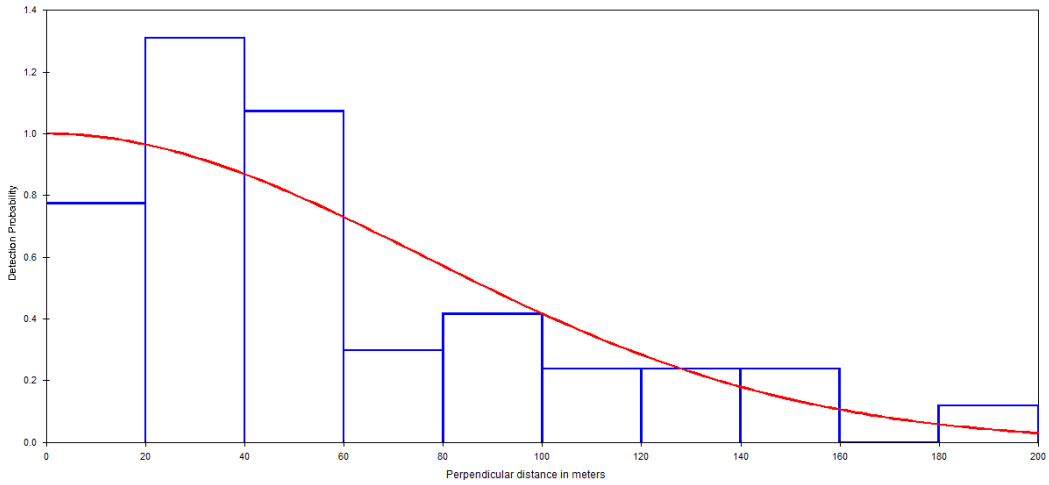

Figure 6. Detection Function for harbor porpoises in North County Dublin (X^2 = 13.7, 8df, p=0.09)

Density estimates for North County Dublin are shown in Table 5. No estimate was possible for the second or sixth survey day as there were too few sightings for the model to run the DISTANCE analyses. The

density estimates ranged from 0.54 per km^2 on 12 July to 6.93 per km^{2}on 29 August. This led to abundance estimates from 57 to 720 individuals. Mean group size was consistent at between 1.14 and 1.41 per sighting. The overall density estimate was 2.03 per km^2 which gave an abundance estimate of 211±47 (95% CI = 137-327) with a small CV (0.22).

Table 5: Mean density and abundance of harbour porpoise per track line per day in North County Dublin

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
1	57 (21-152)	27.0	0.49	0.54	1.14 (1.00-1.55)
2	-	-	-	-	-
3	76 (18-319)	55.0	0.72	0.73	1.33 (1.00-2.51)
4	720 (420-1237)	192.6	0.27	6.93	1.41 (1.24-1.59)
5	111 (55-224)	39.9	0.36	1.06	1.40 (1.09-1.78)
6	-	-	-	-	-
Overall	**211 (137-327)**	**47.1**	**0.22**	**2.03**	**1.41 (1.26-1.56)**

Dublin bay

A total of five survey days were carried out in Dublin bay. It was agreed with NPWS that the sixth day would be re-allocated to the Cork coast as good coverage of Dublin bay had been achieved and an additional survey day in the Cork coast site would be a better use of the vessel charter. On two occasions (13 and 28 July) sea conditions were not ideal for surveying harbour porpoises with sea-state 2 and 3 predominating. Only one sighting was made in sea-state <2 on 13 July but all three sightings on 28 July were in sea-state 2 and have been used to derive an abundance estimate. The best sea-states were recorded on 21 August and 28 September which coincided with the two highest number of sightings and total number of porpoises recorded (Table 6).

Table 6. Date, sea-state and number of sightings of harbour porpoises within Dublin bay during 2008

Sample	Date	No. of track lines	Total distance in sea-state ≤2 (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	13 July	6	14.58	0	31	1	58	2	3
2	28 July	15	83.60	0	0	87.3	12.7	3	4
3	21 August	19	63.12	43.5	41.6	14.7	0	24	27
4	7 September	19	65.53	24.2	12.6	63.2	0	13	14
5	28 September	16	62.55	11.4	84.7	3.9	0	14	21
Total		**75**	**289.38**					**56**	**69**

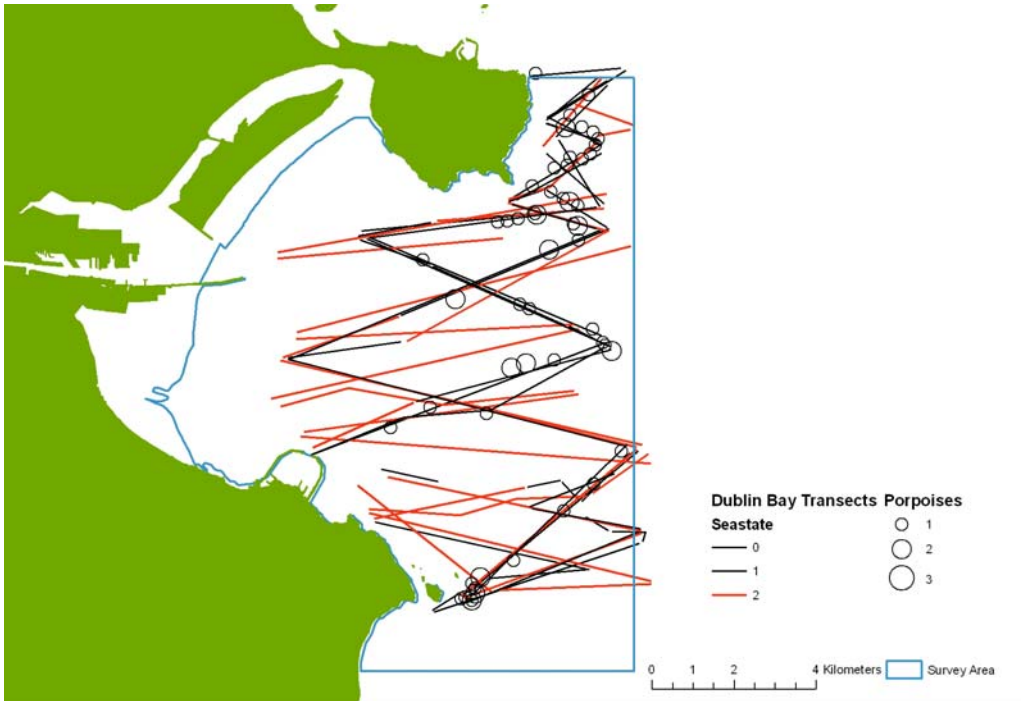

Figure 7. Map showing location of all track lines surveyed and harbour porpoise observed

Track-lines and the position of each sighting for Dublin bay are shown in Figure 7. Effort in sea-state 0 and 1 was distributed throughout the site though generally there was more effort in sea-state 2 (red lines). There were concentrations of harbour porpoises off Howth Head to the north of the site but porpoises were distributed throughout the study site (Figure 8).

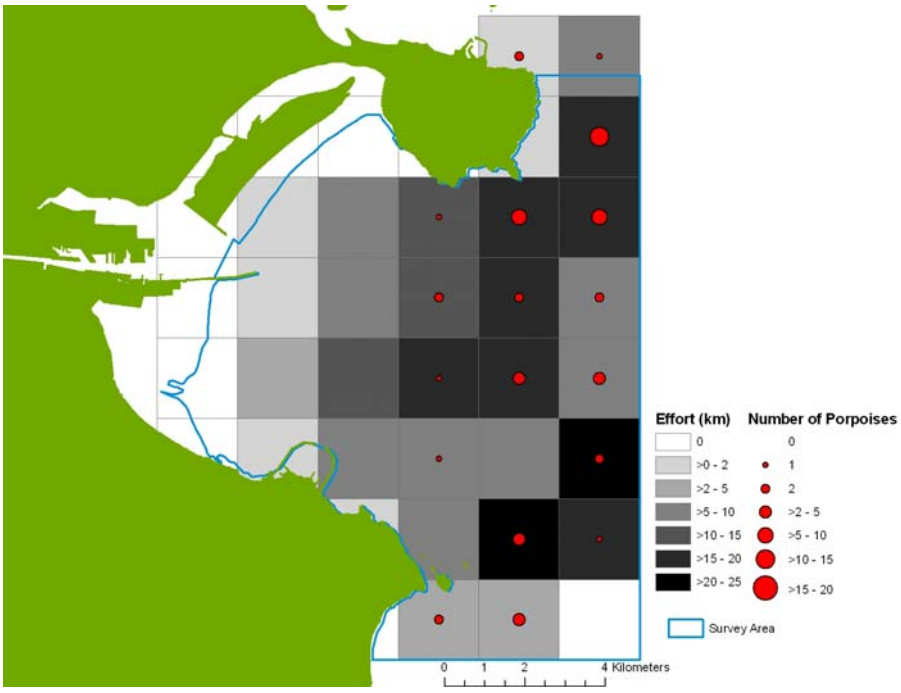

Figure 8. Map of Dublin bay with effort and harbour porpoise sightings shown within a 2km^2 grid

For the DISTANCE analysis data from the first two days (13 and 28 July) were omitted as the sea-state was high and the number of sightings low (two and three on each day). Thus a total of 54 track-lines and 50 sightings were used in the analysis. The detection function is shown in Figure 9 which indicates evasive movement with a peak in sightings 20-60m from the track-line. The proportion of the variability encounter for by the encounter rate was 78%, with 19% attributed to detection probability and only 2.9% due to group size. This shows that it is the number of sightings on each track-line that contributes the greatest variability, which is to be expected as many track-lines will have no sightings while some will have many sightings. This shows the detection function was a good fit and the estimate is robust.

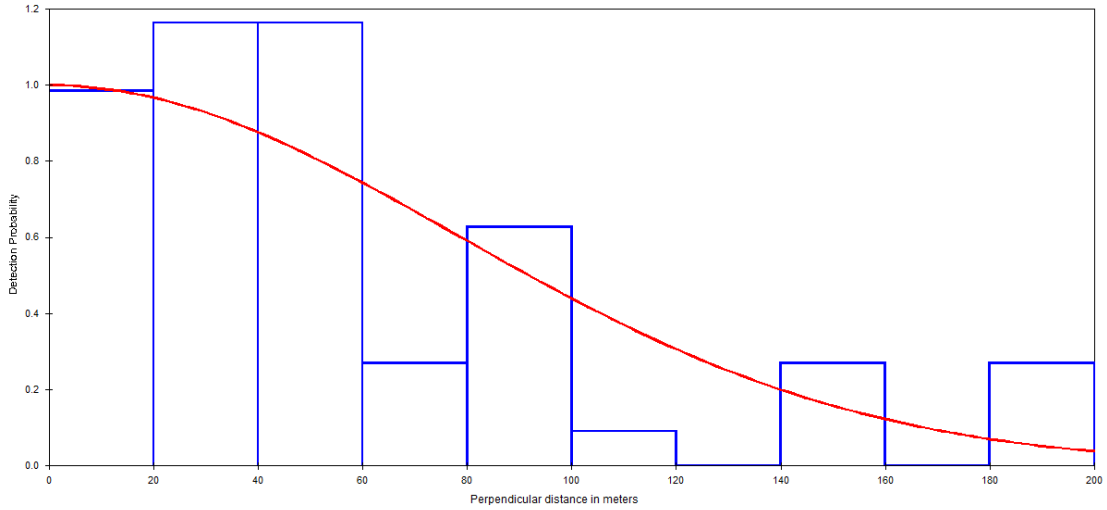

Figure 9. Detection Function for harbor porpoises in Dublin Bay (X^2 = 22.4, 8df, p=0.004)

The density estimates for each sample day are shown in Table 7. There were too few sightings on day 1 (12 July) to derive an estimate. Density estimates ranged from 0.48 to 2.05 per km^2 which gave abundance estimates of between 56 and 238 harbour porpoises. The mean group size was quite consistent ranging from 1.08 to 1.50. The overall density estimate was 1.19 per km^2 which gave an abundance of 138±33 (95% CI 86-221) with a low CV (0.24).

Table 7. Mean density and abundance of harbour porpoise per track line per day in Dublin bay

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
1	-	-	-	-	-
2	56 (13-237)	36.0	0.68	0.48	1.33 (1.00-3.85)
3	238 (110-514)	92.6	0.39	2.05	1.13 (1.00-1.28)
4	174 (75-401)	74.1	0.43	1.49	1.08 (1.00-1.26)
5	175 (87-354)	62.1	0.36	1.51	1.50 (1.23-1.83)
Overall	**138 (86-221)**	**33.2**	**0.24**	**1.19**	**1.22 (1.11-1.34)**

Cork coast

To date five survey days have been completed in the Cork coast site (Table 8). The survey on 14 July was abandoned due to increasing sea-state soon after the start. Only on one day (8 August) was the predominant sea-state 1 or less, however the sighting rate was still low with only 6 sightings of 12 individuals reported. On 15 September sea-state 1 or less accounted for just over one-half of the survey time with sea-state 2 accounting for 47% but there were only eight sightings of a total of 21 individuals. Thus even in favourable sea conditions the number of sightings and total number of animals observed have been low. With only 28 sightings recorded to date there is insufficient data for a robust density estimate using DISTANCE. In order to try and increase the number of sightings available for analysis an additional survey day has been re-allocated from Dublin bay. With permission from NPWS, the fieldwork has been extended into October and possibly November to wait for very favourable conditions and maybe immigration into the site to increase the chances of encountering good numbers of harbour porpoise in order to derive a robust density estimate.

Table 8. Date, sea-state and number of sightings of harbour porpoises within the Cork coast during 2008

Sample	Date	No. of track lines	Total distance in sea-state ≤2 (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	14 July	-	-	0	0	34.4	65.6	1	1
2	8 August	13	105.93	0	78.7	21.3	0	6	12
3	22 August	22	109.58	2.2	35.1	58.8	3.9	8	25
4	15 September	12	125.55	13.8	38.2	48	0	8	21
5	18 September	11	94.91	0	19.4	78.9	1.7	6	14
Total		**58**	**435.97**					**28**	**72**

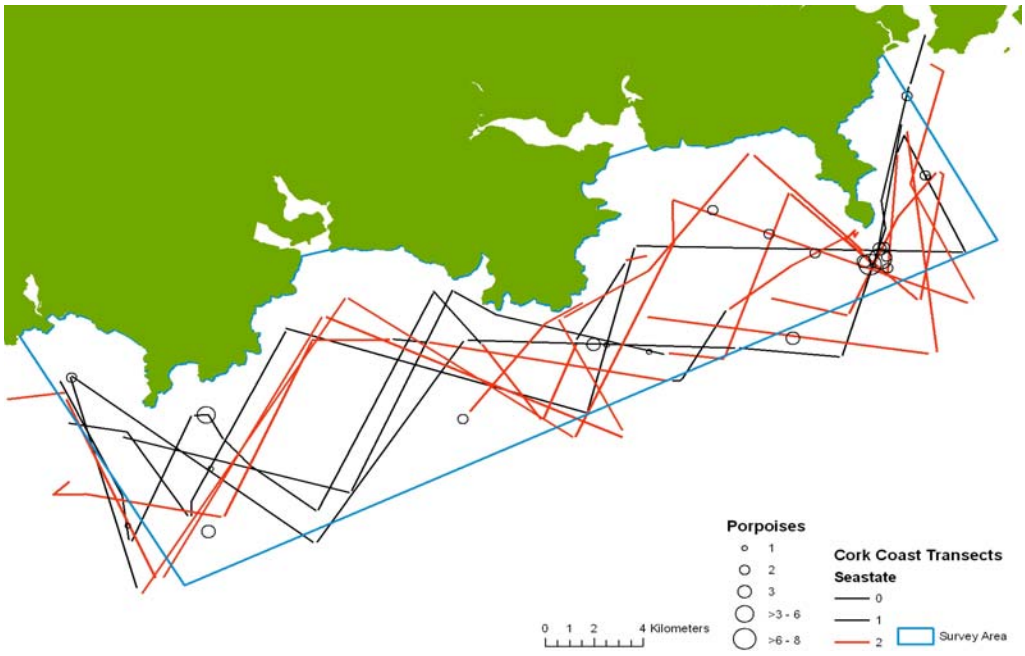

Figure 10. Map showing location of all track lines surveyed and harbour porpoise observed

Track-lines and sightings for the Cork coast are shown in Figure 10. Sea-state ≤1 and sea-state 2 were distributed throughout the site but most sightings were off the Old Head of Kinsale and to a lesser extent Seven Heads and Galley Head (Figure 11).

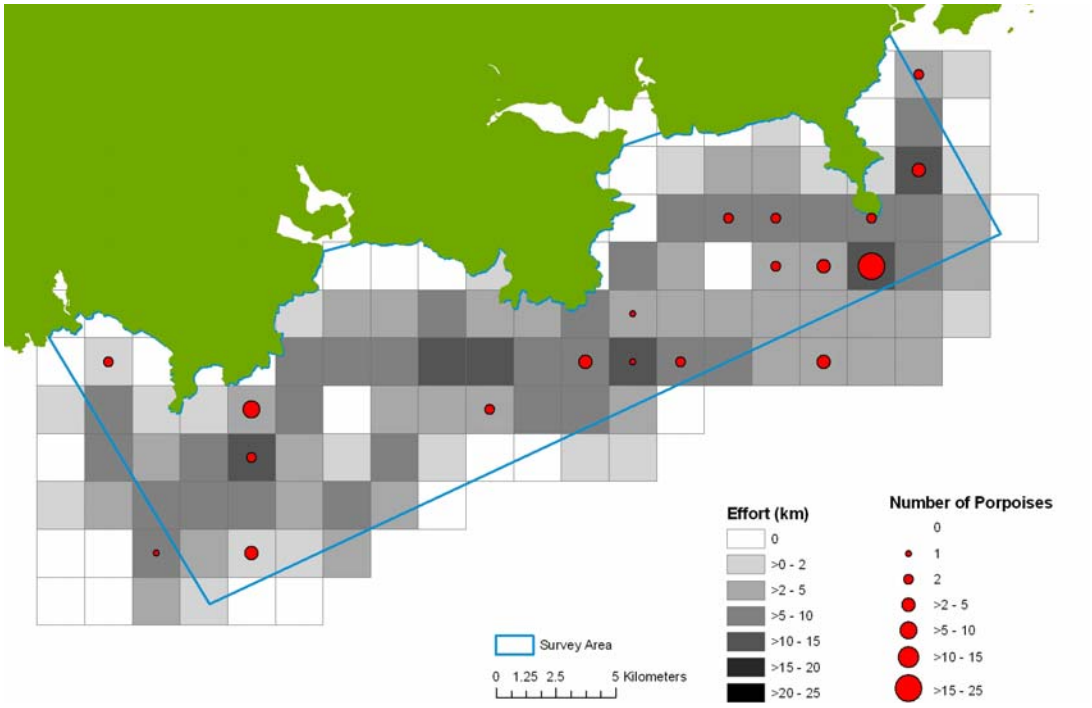

Figure 11. Map of Cork coast with effort and harbour porpoise sightings shown within a 2km^2 grid

The detection function is shown in Figure 12, which is not considered a good fit (P=0.55). There was some evidence of evasive reaction, with a peak on the track-line but also at 60-100m from the track-line. The proportion of the variability accounted for by the encounter rate was 55.0%, with 26.8% attributed to detection probability and 18.2% due to group size. This is somewhat different to other sites where the variation due to encounter rate was higher with lower variation due to group size. However the dataset for this site is small and a few sightings of large groups (up to eight individuals) may have a big influence on the detection function.

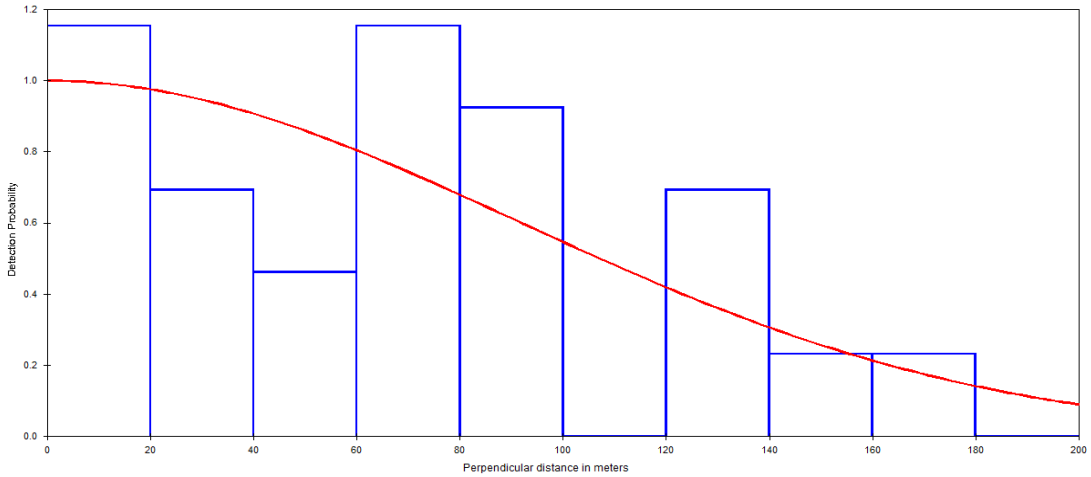

Figure 12. Detection function for harbour porpoise in the Cork coast (X^2 = 6.86, 8df, p=0.55)

Density estimates from the Cork coast are shown in Table 9. Low sighting rates meant no estimate could be made for Day 1 (14 July) and those estimates that are presented have a high CV as the total number of sightings from each survey day were eight or less. Even the overall estimate was calculated using only 24 sightings from 58 track-lines, which is well below the 40-60 minimum recommended for use with DISTANCE software, thus estimates must be treated with caution. The overall density estimate is higher than might have been imagined from the low sighting rate which is due to the high group size estimates, including two observations of eight harbour porpoises and one of six.

Table 9: Mean density and abundance of harbour porpoise per track line per day

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
1	-	-	-	-	-
2	330 (103-1062)	201.0	0.61	1.01	1.83 (1.20-2.81)
3	320 (96-1060)	204.5	0.64	1.98	3.13 (1.59-6.16)
4	82 (20-333)	61.8	0.75	0.25	3.00 (1.27-7.09)
5	86 (19-387)	58.7	0.63	0.26	2.50 (1.73-3.61)
Overall	**173 (92-326)**	**56.6**	**0.33**	**0.53**	**2.67 (1.96-3.64)**

Roaringwater bay cSAC

Roaringwater bay was designated a candidate SAC in 2000. A preliminary study was carried out by Leeney (2007) but no surveys suitable for deriving density estimates were carried out. Six survey days were carried out in Roaringwater bay cSAC during the present study. Good sea conditions were recorded on two days (15 and 17 September) which returned 13 and 23 sightings. The first and last days were abandoned after the start of the track-lines die to deteriorating sea conditions. Overall there were 47 sightings of a total of 110 individuals.

Table 10. Date, sea-state and number of sightings of harbour porpoises within Roaringwater bay cSAC during 2008

Sample	Date	No. of track lines	Total distance in sea-state ≤2 (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	11 July	-	-	0	12.1	24.4	63.5	0	0
2	6 August	14	81.87	4.7	74	21.3	0	4	13
3	21 August	14	78.37	2.1	58.1	19.8	20	5	8
4	15 September	18	52.04	3.9	96.1	0	0	13	28
5	17 September	19	81.19	54.5	45.5	0	0	23	58
6	25 September	5	34.12	0	36.1	52.9	11	2	3
Total		**70**	**330.63**					**47**	**110**

Track-lines and sightings for Roaringwater bay are shown in Figure 13. Track-lines surveyed in sea-state ≤2 were distributed throughout the site with track-lines departing significantly to the west of the site on two occasions. Most sightings were around Gascanane Sound between Sherkin and Clear Islands and off the western tip of Cape Clear (Figure 11).

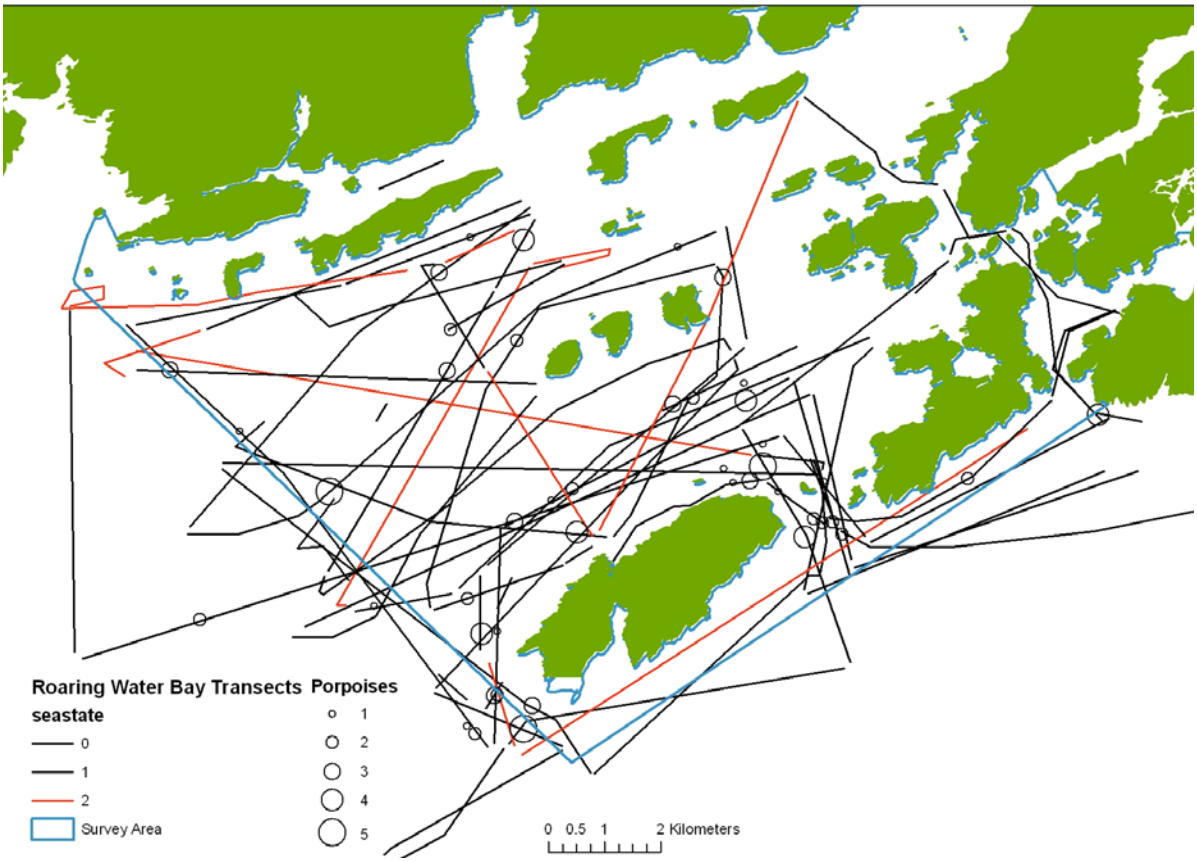

Figure 13. Map showing location of all track lines surveyed and harbour porpoise observed

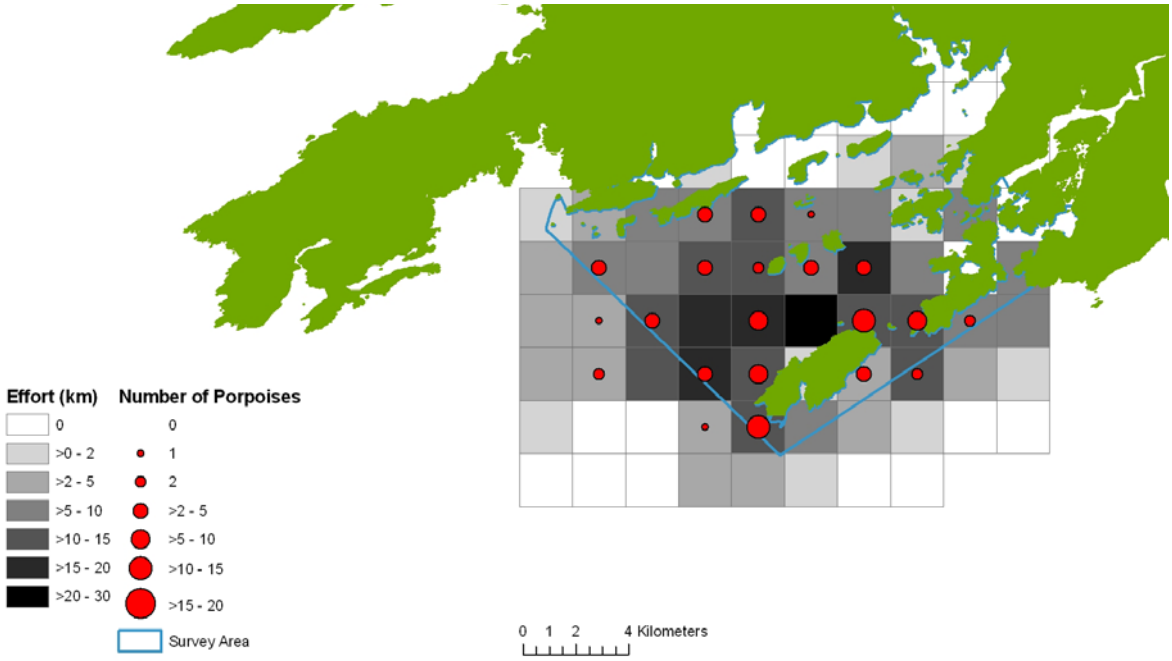

Figure 14. Map of Roaringwater bay cSAC with effort and harbour porpoise sightings shown within a 2km^2 grid

The detection function is shown in Figure 15 which is not considered a good fit (P=0.60). There was some evidence of evasive reaction, with a peak on the track-line but also at 20-40m and 60-100m from the track-line. The proportion of the variability accounted for by the encounter rate was 61.2%, with 25.1% attributed to detection probability and 13.7% due to group size. This was similar to the Cork coast and may be due to the high variability in the number of sighting per survey day.

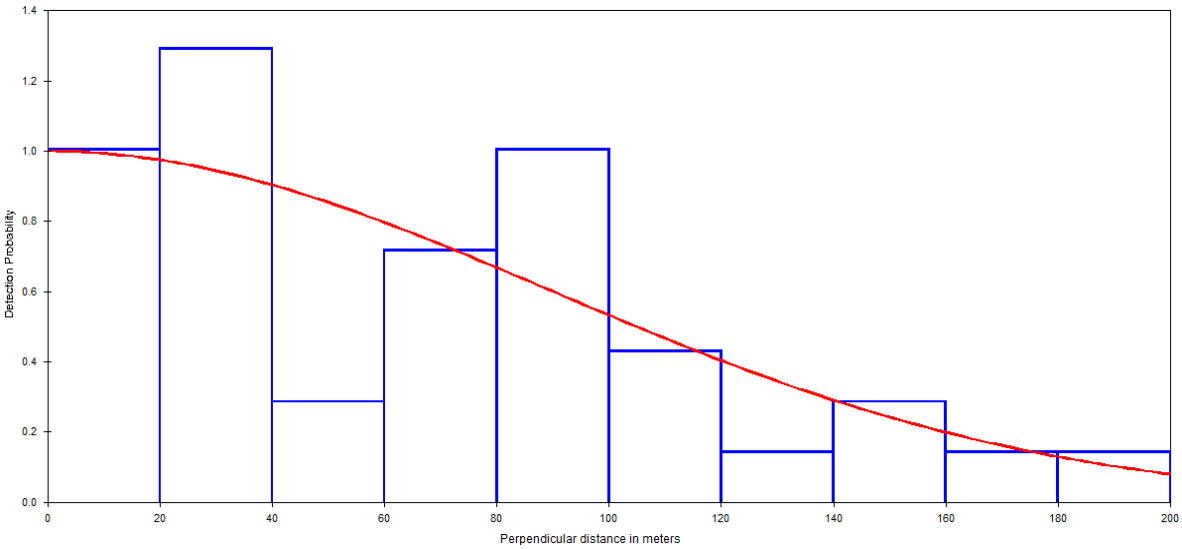

Figure 15. Detection function for harbour porpoise in the Roaringwater bay cSAC (X^2 = 6.43, 8df, p=0.6)

Density estimates from the Cork coast are shown in Table 11. No sightings were recorded on day 1 (11 July) or day 6 (25 September), which were abandoned during the course of the survey due to deteriorating sea conditions. Only four sightings were made on day 2 (6 August) which meant no estimate could be derived. The estimate for day 3 (21 August) has a very high CV (0.98) reflecting only five sightings of a total of eight animals. The density estimate on day 5 was the most robust as there were 23 sightings of a total of 58 individuals, the second highest daily total of any survey day throughout the summer. Mean group size was consistent at around two animals. The overall density estimate was 1.24 with a CV of 0.27. This gave an abundance estimate of 159±42 with 95% Confidence Intervals of 95-689.

Table 11: Mean density and abundance of harbour porpoise per track line per day in Roaringwater bay cSAC

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
1	-	-	-	-	-
2	-	-	-	-	-
3	22 (2-268)	21.5	0.98	0.72	2.00 (1.00-808.61)
4	273 (125-595)	107.91	0.40	2.13	2.00 (1.58-2.54)
5	346 (173-689)	121.8	0.35	2.70	2.21 (1.58-2.96)
6	-	-	-	-	-
Overall	**159 (95-689)**	**42.4**	**0.27**	**1.24**	**2.21 (1.85-2.64)**

Galway bay

Six surveys were carried out in Galway bay (Table 12). A total of 84 track-lines were surveyed covering 627 km in sea-state ≤2. This resulted in 62 sightings of a total of 134 individuals. On 31 August sea-state was predominately 3 and only one harbour porpoise sighting was made and this sample day was excluded from the DISTANCE analysis. On 23 July sea-state was predominately 2 and only five sightings were made. For all other survey days sea-states 0 and 1 accounted for over 50% of the survey time and the number of sightings were nine or more on each day. On 28 July, 18 sightings of a total of 40 individuals were recorded and on 4 September 18 sightings of a total of 35 individuals were recorded, which provide the best density estimates from a single survey day.

Table 12. Date, sea-state and number of sightings of harbour porpoises within Galway bay during 2008

Sample	Date	No. of track lines	Total distance in sea-state ≤2 (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	23 July	12	120.18	3.2	15.9	76.3	4.6	5	8
2	28 July	15	140.63	24.2	62.7	13.1	0	18	40
3	21 August	10	109.33	41.2	43.3	4.4	11.1	11	35
4	31 August	6	21.33	0	0	27.6	72.4	1	1
5	4 September	24	141.45	66.3	28.7	5	0	18	35
6	24 September	15	94.18	4.2	50.7	28.3	16.8	9	15
Total		**82**	**627.10**					**62**	**134**

The track lines surveyed in Galway bay are shown in Figure 16. Effort in sea-state 0 and 1 and sea-state 2 is distributed throughout the survey area. Harbour porpoises were distributed throughout the survey area with concentrations off Black Head, Co Clare and towards the middle of the bay.

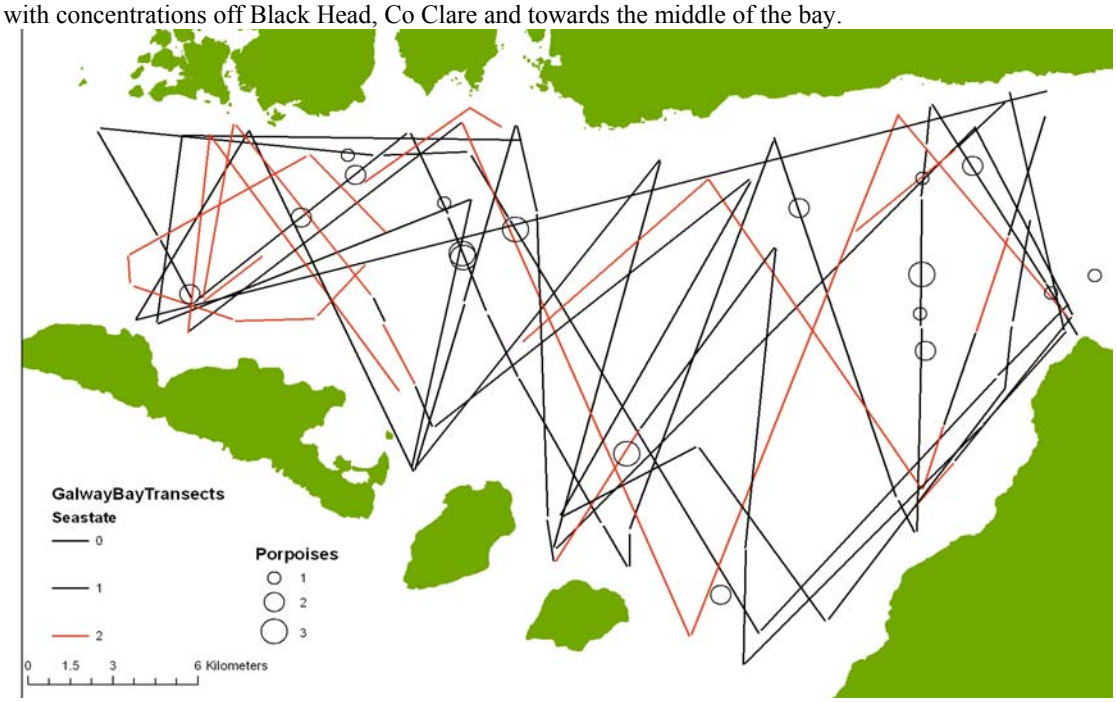

Figure 16. Map showing location of all track lines surveyed and harbour porpoise observed

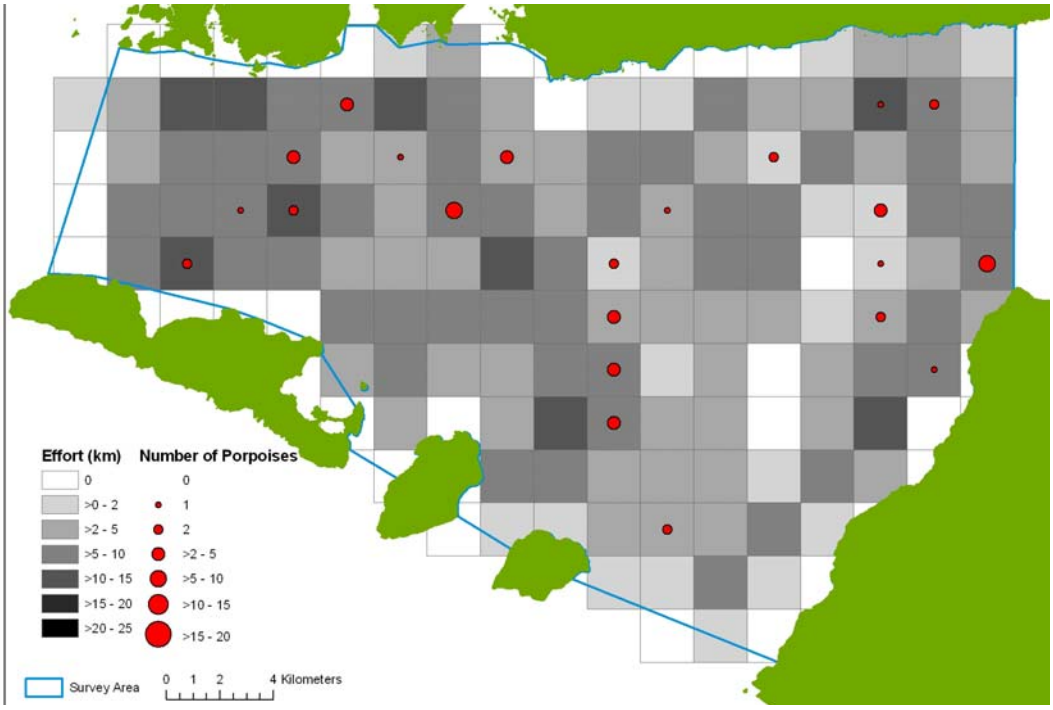

Figure 17. Map of Galway bay with effort and harbour porpoise sightings shown within a 2km^2 grid

The detection function is shown in Figure 18. There was evidence of evasive reaction, with a peak in sightings at 20-40m from the track-line. The proportion of the variability accounted for by the encounter rate was 50.2%, with 34.3% attributed to detection probability and 15.3% due to group size. This is somewhat different to other sites where the variation due to encounter rate was higher and due to smaller group sizes. This indicates there was more variability in the number of sightings recorded per track-line and a greater range in group size. This may reflect the larger area of this site.

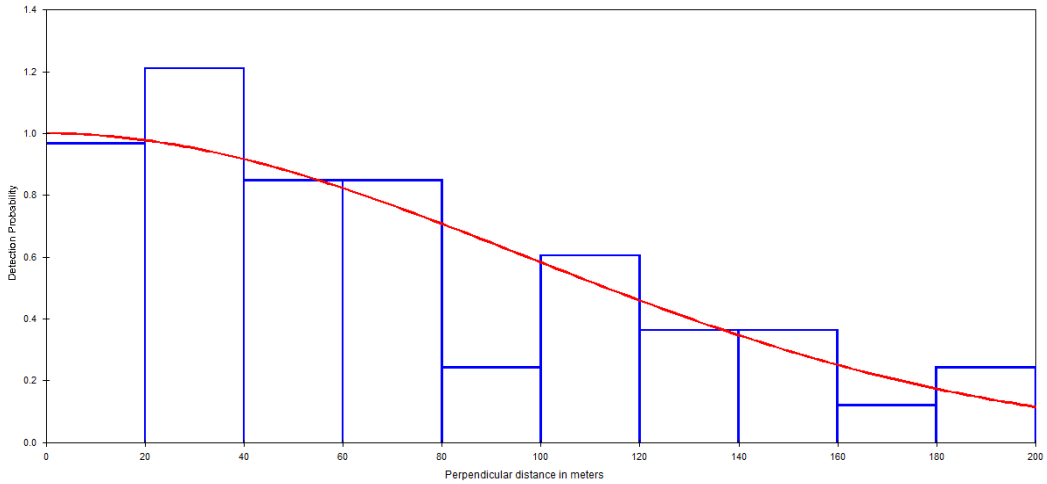

Figure 18. Detection function for harbour porpoise in the Galway bay (X^2 = 3.88, 8df, p=0.09)

The density estimate ranged from 0.31 to 1.80 harbour porpoise per km^2. As indicated earlier there was a large range in group size per day and within each survey day (Table 13). This has influenced the abundance

estimate with a large range in group size on Day 3 (21 August) contributing to the high Confidence Intervals (408-2406) in the final abundance estimate. Data for 4 September was truncated at 300m, which reflects the good sea-state recorded during this survey. The overall density estimate was 0.73 (CV=0.21) giving an abundance ±SE of 402±84 and 95% Confidence Intervals of 267-605. Galway bay is 547km^2 in area and even though the density estimate was low the overall abundance was high.

Table 13: Mean density and abundance of harbour porpoise per track line per day in Galway bay

Sample Day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
1	173 (41- 721)	126.0	0.73	0.31	1.50 (1.00-4.21)
2	348 (161-753)	137.3	0.40	0.64	2.25 (1.57-3.23)
3	991 (408-2406)	446.0	0.45	1.80	3.11 (2.18-4.45)
4	-	-	-	-	-
5	546 (271-1090)	193.4	0.35	0.99	1.94 (1.52-2.37)
6	254 (86-747)	142.7	0.56	0.46	1.63 (1.11-2.38)
Overall	**402 (267-605)**	**84.1**	**0.21**	**0.73**	**2.15 (1.84-2.51)**

Proportion of adult to young

An important criteria for consideration of a site as a potential SAC is a "*high ratio of young to adults during certain periods of the year*". There are no guidelines as to what is considered "high". The present surveys were carried out during the estimated time of peak calving (excluding June). We have calculated the proportion of adults to young (combining records of those animals described as juveniles or calves) for each site. No calves or juveniles were observed off the Cork coast. The proportion of juveniles and calves in sites which observed young are remarkably consistent with a percentage of 6-8% (Table 14).

Table 14. Proportion of adult to young harbour porpoises for all sites

Site	No. of sightings	No. of animals	No. of adults	No. of juveniles	No. of calves	% young
North County Dublin	82	111	102	1	8	8
Dublin bay	56	69	65	1	3	6
Cork coast	28	72	72	0	0	0
Roaringwater bay	47	110	102	8	0	7
Galway bay	62	134	124	2	8	7

Acoustic detections

Acoustic data was recovered from five of the six locations, with only one site (Muglins on the south side of Dublin bay) with no data. This was due to the T-POD being lost between the initial deployment and the first recovery. No data was recovered from the T-POD off the Old Head of Kinsale during the first deployment period but over 21 days was recovered during the second deployment. Only three days were recovered during the second deployment off Sherkin Island in Roaringwater bay but 16 days were recovered during the first deployment resulting in nearly 20 days in total. Over 39 days of data were recovered from the T-POD at Castlepoint in Roaringwater bay during the first deployment and nearly 31

days off Galley Head during the second deployment period. Generally T-POD performance was very good with an accumulated total of around 214 days acoustically monitored days.

We can see that the number of clicks and the detection rate from Howth Head, Co Dublin was much greater than at any other site. During the second deployment period, porpoises were detected for 14.7% of the time. At other sites the proportion is typically around 1-2% with the lowest (0.3%) recorded off Sherkin Island during the second deployment period. However the duration of deployment was very low (3.5 days) so these data should be treated with caution.

Table 15. Summary of acoustic data from T-PODs with (c) indicating the Correction Factor is applied

Site	Location	Deployment date	Deployment duration	Total clicks "*cet all*"	Clicks per hour	Total *DPM*	Mean *DPM* per h^{-1}	Mean *DPM* per h^{-1}(c)
Dublin bay	Howth Head	13.07.2008	18d 06h 21m	220,089	501	2882	6.6	8.9
		21.08.2008	27d 22h 07m	581,478	867	7280	10.9	14.7
Dublin bay	Muglins	13.07.2008		T-POD LOST				
Cork coast	Old Head	14.07.2008	06d 19h 39m	NO DETECTIONS LOGGED				-
		21.08.2008	21d 08h 28m	20,334	39	360	0.7	0.8
Cork coast	Galley Head	11.07.2008	29d 21h 34m	18,807	26	355	0.5	0.8
		21.08.2008	30d 23h 33m	34,084	48	707	1.0	1.4
Roaringwater bay	Sherkin Island	11.07.2008	16d 06h 24m	57,432	294	853	2.2	2.6
		20.08.2008	03d 18h 35m	2,110	23	24	0.3	0.3
Roaringwater bay	Castlepoint	11.07.2008	39d 16h 26m	44,554	46	818	0.9	1.1
		20.08.2008	20d 21h 29m	16,274	32	268	0.5	0.7

Acoustic data from all sites are presented by month in Table 16. The proportion of days with detections was remarkable with only one site for one month (Sherkin Island in August) reporting less than 100% days with detections. As one would expect, there was more variability in the proportion of hours with porpoise detections. There was a decrease in the number of encounters per month off Castlepoint in Roaringwater bay and an increase off Galley Head, with other sites consistent from July through to September. This may indicate some seasonal component to the presence of harbour porpoises at these two sites.

A summary of the data are presented in Figure 19, which shows after Howth Head the second highest detection rate was off Galley Head in the Cork coast site and Castlepoint in Roaringwater bay. The total number of days monitored acoustically off Sherkin Island and the Old Head of Kinsale were low and this was matched with low detection rates. The rate is corrected for the number of days deployed so this may have been a coincidence, however the longer the data-set the more robust are the data so this must be taken into account when interpreting data from these sites.

Table16. Monthly distribution of acoustic data from T-PODs (with Correction Factor applied)

County	Location	Month	No. days deployed	Encounters per month	% of days with porpoise detections	% Porpoise Positive Hours	Total Porpoise Positive Minutes	Porpoise Positive Minutes per hour
Dublin	Howth Hd	July	19	852	100	81	3891	8.9
		Aug	12	969	100	79	4336	15.6
		Sept	16	911	100	74	5491	13.5
Cork	Castlepoint	Jul	22	231	100	33	540	1.0
		Aug	31	296	100	29	667	0.9
		Sept	10	84	100	24	172	0.8
	Sherkin Island	July	9	154	100	48	109	0.6
		Aug	14	193	71	39	598	2.1
		Sept	-	-	-	-	-	-
Cork	Galley Head	July	22	151	100	25	372	0.8
		Aug	20	209	100	32	550	1.2
		Sept	21	257	100	34	692	1.4
	Old Head of Kinsale	July	-	-	-	-	-	-
		Aug	11	76	100	27	130	0.6
		Sept	11	135	100	39	266	1.0

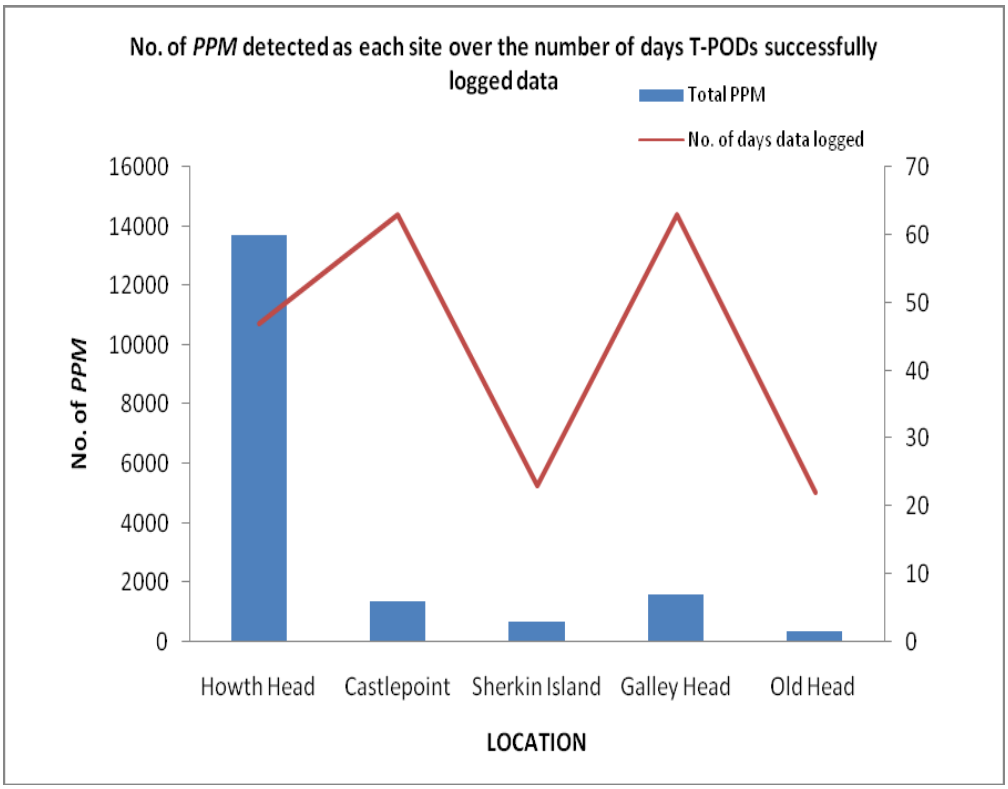

Figure 19. Graph showing detection rate and the number of days with acoustic data at five locations

Other species recorded during survey

In addition to harbour porpoise we recorded three other species of cetacean during this survey (Table 17). Common dolphins (*Delphinus delphis*) were the most frequently recorded other species with 13 sightings. Minke whales (*Balaenoptera acutorostrata*) were observed on eight occasions and bottlenose dolphins (*Tursiops truncatus*) on one occasion. All three species were seen in Galway bay and common dolphin and minke whale at two sites (Cork coast and Roaringwater bay) but no species other than harbour porpoises were observed in North County Dublin or Dublin bay. Dolphins not identified to species level were recorded on five occasions at three sites and were likely to have been common dolphins.

Images of bottlenose dolphins, suitable for photo-identification, were obtained from Galway bay on 31 August and one of these individuals was matched to Dublin bay from 2 June 2008 a distance of around 600km and duration between sightings of 90 days (see O'Brien *et al.* submitted).

Table 17. Cetacean species, other than harbour porpoise, recorded during the Harbour Porpoise Survey 2008

Site	Date	Species	Number of individuals	Location		Behaviour
				Latitude	Longitude	
Cork Coast	14 July	MW	1	51.51812	-9.109324	Feeding
Cork Coast	08 August	CD	5	51.51017	-8.913161	Feeding
Cork Coast	08 August	UID	1	51.50389	-8.828057	Leap/Splashing
Cork Coast	08 August	UID	2	51.53943	-8.802708	Fast Swim
Cork Coast	08 August	UID	1	51.50163	-8.863037	Slow Swim
Cork Coast	22 August	CD	2	51.50738	-8.942343	Fast Swim
Cork Coast	22 August	CD	5	51.51528	-8.908553	Feeding
Cork Coast	22August	MW	1	51.52896	-8.819016	Slow Swim
Cork Coast	18 September	CD	10	51.57340	-8.497319	Bow Riding
Roaringwater Bay	06 August	MW	1	51.48756	-9.54976	Slow Swim
Roaringwater Bay	06 August	CD	12	51.47057	-9.61479	Feeding
Roaringwater Bay	06 August	CD	8	51.44431	-9.553460	Slow Swim
Roaringwater Bay	21 August	MW	1	51.47571	-9.595358	Slow Swim
Roaringwater Bay	21 August	UID	10	51.43408	-9.558451	Feeding
Roaringwater Bay	21 August	MW	1	51.44814	-9.450918	Slow Swim
Roaringwater Bay	17 September	MW	1	51.42002	-9.48856	Slow Swim
Roaringwater Bay	17 September	CD	10	51.43005	-9.44369	Slow Swim
Roaringwater Bay	17 September	MW	1	51.43783	-9.448132	Feeding
Roaringwater Bay	17 September	CD	6	51.44397	-9.430395	Slow Swim
Galway Bay	23 July	CD	30	53.17540	-9.431225	Fast Swim
Galway Bay	28 July	CD	15	53.13667	-9.482608	Leap/Splashing
Galway Bay	28 July	CD	20	53.15618	-9.272897	Slow Swim
Galway Bay	21 August	UID	4	53.16734	-9.693048	Leap/Splashing
Galway Bay	31 August	BND	20	53.22858	-9.552546	Bow Riding
Galway Bay	04 September	CD	8	53.16701	-9.465578	Fast Swim
Galway Bay	04 September	CD	40	53.13361	-9.557377	Fast Swim
Galway Bay	24 September	MW	1	53.15731	-9.635653	Slow Swim

CD=Common dolphin
BND=Bottlenose dolphin
MW=Minke whale
UID=Unidentified dolphin

Discussion

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. To minimise the effect of movement it is recommended that the speed of the observer is at least twice the speed of the object and if this is the case then movement of the object causes few problems in line transect sampling (Buckland *et al.,* 2001).

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. If this was the case with the present survey then we could double the density estimates. Without a double-platform methodology it is not possible to accurately determine the numbers missed on the track-line. The detection functions for most sites also suggest there was evasive movement from the boat. These factors will reduce the density estimates. However these sources of variability were constant throughout the present survey and methods were consistent with the methods used by Berrow *et al.* (2007; 2008), which allows direct comparison of the data between surveys and within each survey.

The ability to detect harbour porpoise visually at sea and thus the accuracy of density and abundance estimates is extremely dependent on sea-state. During the present study, transects were carried out, whenever possible, in sea-state 2 or less as the ability to detect harbour porpoise decreases significantly in sea-state ≥3 (Teilmann, 2003). Berrow *et al*. (2007) recommended that all harbour porpoise surveys should only be carried out in sea-state 0 or 1 to ensure all animals are detected and g(0)=1. This is rarely possible and given the poor weather throughout the summer in 2008 we were fortunate to be able to carry out as many surveys as we did in relatively good sea-state (sea-state ≤2). The data can be stratified by sea-state if necessary if further monitoring in the future records any changes in density estimates. Acoustic monitoring is much less weather dependent.

During 28 survey days a total of 354 track-lines were surveyed for a total distance of nearly 20,000 km in seastate 0-3. From the 269 sightings a total of 496 individual harbour porpoise were recorded. There were 13 sightings of a total of 171 common dolphins (*Delphinus delphis*), eight sightings of single minke whales (*Balaenoptera acutoratrata*) and one sighting of 20 bottlenose dolphins (*Tursiops truncatus*). Five sightings of a total of 18 dolphins were not identified to species level.

Comparison of harbour porpoise density estimates

The Habitats Directive states a site which "*corresponds to the ecological requirements of the species*" may be designated as an SAC. The Directive states that the selection of sites eligible for identification as of Community importance are those "*for aquatic species which range over wide areas, such sites shall be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction*". It has proved difficult for member states to identify sites based on these criteria due to insufficient data and other criteria have been proposed including the regular or continuous presence of the species, good population density (in relation to neighbouring areas) and high ratio of young to adults during certain periods of the year (Johnston *et al.,* 2002).

A comparison of density estimates and associated statistics at eight sites are shown in Table 18. The CVs at the five sites were low which suggests the estimates were good. However, Englund *et al.* (2007) recommended that abundance estimates for monitoring bottlenose dolphins in the Shannon estuary should be as low as 0.12 if changes in abundance are to be detected within reasonable time-frames. If we want to achieve lower CVs for harbour porpoise density estimates then more surveys will be required each year at each site. The mean group sizes of harbour porpoise varied considerably between sites with larger groups recorded on the south and west coasts compared to the east coast.

Results from a similar survey of the Blasket Islands cSAC in 2007 were used as a reference with which to compare density estimates. Only North County Dublin (2.03) had a higher overall density than the Blasket Islands cSAC (1.33). Density estimates in Roaringwater bay cSAC (1.24), which is also designated for harbour porpoises, and Dublin bay (1.19) were slightly lower than the Blasket Islands cSAC. Densities in Galway bay were just over one-half of the reference density but this site is over twice the area.

There was a high standard error and wide confidence intervals in the estimates from North County Dublin, Roaringwater bay cSAC and Donegal bay sites in 2008 and the Blasket Islands cSAC in 2007. North County Dublin and Roaringwater bay cSAC sites are small in area which makes them sensitive to even small local movements of harbour porpoises in the adjacent area. This supports the recommendations to, where possible, increase the size of present and potential SACs. Densities in the Cork coast were lower than might have been expected. This site was chosen as there have been concentrations of harbour porpoise sightings off the Old Head of Kinsale and Galley Head (Berrow *et al.* 2002). Sightings inshore for many species of small cetacean were considered very low by local wwhalewatch operators and attributed to a dense plankton bloom at 20-30m caused by high rainfall and run off (Colin Barnes *pers. comm.*). These variables should be taken into account when short-duration surveys are conducted in a single season and year to identify sites suitable for designation as SACs.

We have provided a minimum density estimate for harbour porpoises within each site. These surveys should be repeated for a number of years to provide a measure of variability between years to obtain robust reference values from which changes in the populations at each site can be monitored.

Table 18. Density estimates of harbour porpoise during dedicated sighting surveys in 2007 and 2008

Location	Year	Area (km^2)	Mean group size	% young	Density (per km^2)	Abundance ± SE (95% Confidence Intervals)	CV	Reference
North County Dublin	2008	104	1.41	8	2.03	211±47.1 (137-327)	0.23	This study
Dublin bay	2008	116	1.19	6	1.19	138±33.2 (86-221)	0.24	This study
Cork coast	2008	326	2.67	0	0.53	173±56.6 (92-326)	0.33	This study
Roaringwater bay	2008	128	2.21	7	1.24	159±42 (95-689)	0.27	This study
Galway Bay	2008	547	2.15	7	0.73	402±84.1 (267-605)	0.21	This study
Carnsore Point	2008	151	1.91	14	0.58	87±36.3 (39-196)	0.42	Berrow *et al.* (2008)
Blasket Islands	2008	227	1.76	18	1.65	372±105.3 (216-647)	0.28	Berrow *et al.* (2008)
Donegal bay	2008	281	2.40	8	0.88	249±111.5 (106-586)	0.45	Berrow *et al.* (2008)
Reference								
Blasket Islands	2007	227	2.32	2	1.33	303±76 (186-494)	0.25	Berrow *et al.* (2007)

Proportion of adult to young harbour porpoise

An important criteria for consideration of a site as a potential SAC is a "*high ratio of young to adults during certain periods of the year*". There are no guidelines as to what is considered "high". The proportion of adults to young at the four sites with young reported was very consistent at between 6 and 8%. The proportion was consistent in small sites (North County Dublin = 8%) and large sites (Galway bay = 7%). In west Greenland the proportion of porpoises less than 1 year old in the population, as determined from Growth Layer Groups in teeth, was reported as 7% (Lockyer *et al.,* 2001) and 12-13% in NE Canada (Reid and Hohn, 1995). Sonntag *et al.* (1999) summarized data from 13 aerial surveys and 10 ship-based surveys throughout the North Sea and Kattegat area including data from SCANS (Hammond *et al*. 2002). The proportion of calves ranged from 5.1% (Inner Danish waters) to 17.9% (Isle of Sylt) from aerial surveys

and 2.2-6.7% from ship-based surveys. Data from the Irish Sea recorded 5.1% calves and only 3.3% in British coastal waters.

The 6-8% presented in this survey (Table 18) is likely to be higher than the data from SCANS as the sites are all small and coastal compared to the results presented by Sonntag *et al.* (1999). Sonntag *et al*. (1999) suggested the high proportion of calves of the Isle of Sylt in Germany (9.6-17.9%) indicated that it was a preferred calving ground for harbour porpoise in the southern North Sea. Our data do not suggest such elevated levels but proportions are probably typical of Irish coastal waters (Table 18).

Table 19. Proportion of adult to young for all sites surveyed in 2008

Site and date of survey	No. of sightings	No. of animals	No. of adults	No. of juveniles	No. of calves	**% young**
North County Dublin	82	111	102	1	8	**8**
Dublin bay	56	69	65	1	3	**6**
Cork coast	28	72	72	0	0	**0**
Roaringwater bay	47	110	102	8	0	**7**
Galway bay	62	134	124	2	8	**7**
Carnsore Point	12	22	19	3	0	**14**
Blasket Islands	30	55	45	0	10	**18**
Donegal bay	18	40	37	0	3	**8**

Acoustic detections

To compliment the boat-based surveys, which could only be carried out during daylight hours, Passive Acoustic Monitoring (PAM) was used at three sites through the use of T-PODs. This provided complimentary data to sightings for site assessment. There are a number of ways of displaying acoustic data but we have used mean Detection Positive Minutes (DPM) per hour as an index in order to allow comparisons with similar studies previously carried out in Ireland (Table 19).

Results from the present study have emphasized that Howth Head is an area of high importance for harbor porpoises, especially since the mean DPM/h^{-1} recorded here is over three times greater than the highest index reported from other sites around the country and nearly seven times the reference from the Blasket Islands in 2007 (Table 19). The second highest index was reported by Leeney (2007) who recorded a mean DPM/h^{-1} of 3.58 off Sherkin Island, Roaringwater bay in 2005. This compares to 1.5 mean DPM/h^{-1} recorded in the present study.

If detection rates from the Blasket Islands cSAC in 2007 were used as a reference then, apart from Dublin bay, only Roaringwater bay cSAC had comparable detection rates. All other sites had generally lower detection rates. Galley Head in the Cork coast site returned a detection rate of 1.1 mean DPM/h^{-1} over a 60 day period which was similar to Inishtooskert in the Blasket Islands cSAC. Detections from the Cork coast were less than Roaringwater bay which reflected the poor sighting rate from this site.

Acoustic data can provide a measure of presence and absence of harbor porpoises within an area, although it cannot provide information on numbers, it does provide information when other methods of surveying cannot be carried out e.g. during darkness and adverse weather conditions. Therefore, the importance of this type of monitoring is vital for the effective assessment and monitoring of a site.

Table 19. Comparison between acoustic indices from similar studies in Irish waters

Year	General area	Location	Deployment duration	Mean PPM per hour	Reference
2008	Dublin: Dublin bay	Howth Head	46d	11.8	This study
2008	Cork: Cork coast	Old head of Kinsale	27d	0.8	This study
2008	Cork: Cork coast	Galley Head	60d	1.1	This study
2008	Cork: Roaringwater Bay	Sherkin Island	20d	1.5	This study
2008	Cork: Roaringwater Bay	Castlepoint	60d	0.9	This study
2007	Kerry: Blasket Islands	Wildbank	29d	1.99	Berrow *et al*. (2007)
2007	Kerry: Blasket Islands	Inishtooskert	29d	1.04	Berrow *et al*. (2007)
2006-07	Galway: Galway Bay	Spiddal	333d	0.40	O'Brien *et al.* (2008a)
2006-07	Mayo: Clare Island	Clare Island	234d	0.90	O'Brien *et al.* (2008b)
2005	Cork: Roaringwater Bay	Calf Islands	66d	0.63	Leeney (2007)
2005	Cork: Roaringwater Bay	Sherkin Island	71d	3.58	Leeney (2007)
2005	Cork: Roaringwater Bay	Long Island	55d	0.23	Leeney (2007)

In summary:

North County Dublin
Only harbour porpoise were recorded in this site, which was the smallest surveyed. Mean group size (1.4) was low and the proportion of young animals probably typical of Irish coastal waters (8%). Overall density estimate was the highest recorded at any site to date and above the reference value from the Blasket Islands cSAC.

Dublin bay
Only harbour porpoise were recorded in this site. Mean group size was the lowest recorded at any site and the proportion of young animals probably typical of Irish coastal waters (6%). Acoustic detections of harbour porpoises were much higher than recorded at any other site in Ireland. Overall density estimate was high but below the reference value from the Blasket Islands cSAC.

Cork coast
Harbour porpoise, common dolphin and minke whale were recorded in this site. No calves or juveniles were recorded. Mean group size of harbour porpoise was the highest recorded at any site but the overall density estimate was the lowest recorded at any site. Acoustic detections of harbour porpoises were good but below the values from the reference site and those reported from Roaringwater bay cSAC.

Roaringwater bay
Harbour porpoise, common dolphin and minke whale were recorded in this site. Mean group size of harbour porpoises was high and the proportion of young animals probably typical of Irish coastal waters (7%). Overall densities were high and higher than all other sites apart from North County Dublin and the reference site. Acoustic detections of harbour porpises were also high and nearly as high as the reference site

Galway bay
Harbour porpoise, common and bottlenose dolphin were recorded in this site, which was by far the biggest surveyed. Mean group size of harbour porpoises was high and the proportion of young animals probably typical of Irish coastal waters (7%). Overall densities good but around one-half of the reference site.

Recommendations

The following recommendations are made following the results of this survey:

Sighting surveys

The following recommendations are made:

1. The following sites have high densities of harbour porpoise and should be considered as Special Areas of Conservation:

    a. Dublin bay
    b. North County Dublin
    c. Galway bay

2. Further monitoring should be carried out of the Cork coast to see if harbour porpoise densities do meet the level consistent with designation as a Special Area of Conservation.

3. This survey supports the designation of Roaringwater bay as a cSAC and provides baseline density and abundance data.

4. Dublin bay and North County Dublin are both small sites (104 and 116 km^2). In order to create an SAC of an appropriate spatial scale we recommend these sites are joined to make one site.

5. The size of Roaringwater bay cSAC should be increased to include the outer bay to make a more appropriate spatial scale while still facilitating monitoring surveys to be carried out in a single day. We recommend a boundary from Baltimore to Fastnet and northwest to Mizen Head. This would increase the area from 128 km^2 to approximately 253 km^2.

6. Conventional single platform line-transect sighting surveys can be used to estimate densities of harbour porpoises in coastal sites. However in order to provide robust estimates sites should be of a sufficient spatial scale to obtain sufficient sightings (n=40-60) for use in the model.

7. For monitoring purposes monthly sampling should be carried out each year between April and October, in order to take advantage of good weather conditions and obtain a good dataset for creating a reference value for each site. If the encounter rate at a site was sufficiently large, one sample day per month may have been sufficient however this was rarely achieved (see Berrow *et al.*, 2008) and twice monthly sampling may be necessary to obtain sufficient sightings to derive a robust density estimate using distance sampling.

8. In order to determine seasonal variation in abundance we recommend single platform line-transect sighting surveys should be carried out in every month for at least one year at each site during the next reporting round of the EU Habitats Directive. These data will not only inform managers on the use of the site by harbour porpoise but will assist in management of the site by identifying times of year when the impacts of activities within the site may be minimized or identify seasonally important habitats or areas.

9. If surveys intend to use multiple observers it is important that these observers are trained and their ability to determine important variables such as distance and group size are tested and if necessary used to derive correction factors to field data.

Acoustics

With regard to passive acoustic monitoring we recommend:

1. One criteria set by the EU for site designation of mobile species is "*the continuous or regular presence of the species (although subjected to seasonal variation)*". The most efficient way of exploring seasonal occurrence is through PAM especially when it is complimented by visual monitoring (e.g. that currently carried out under ISCOPE II). PAM can detect trends such as seasonal variation much quicker that visual datasets. Therefore we recommend PAM is carried out for a minimum 12 months at each designated site.

2. Given the low detection distance of PAM equipment for harbour porpoises (100-150m) we recommend two units may only be sufficient for sites of up to 250km^2 but for sites larger recommend three or four units, however consideration should be given to the geography of each site. Sites with a convoluted coastline and islands may require more PAM units for a given area than sites with a more uniform geography.

3. In designated sites an array of PAM units could be deployed to provide good data on how porpoises use the site. An intensive PAM study could provide high quality data on feeding areas and movements.

4. All PAM equipment should be calibrated before deployment. In order to be able to calibrate between researchers and across years we suggest a reference unit is used as a standard from which all other units can be calibrated. This reference unit should not be deployed in case it is lost. A T-POD reference can also be used to calibrate against the new C-PODs to allow comparisons between studies using these two different PAM devices.

5. Mean Detection Positive Minutes (DPM) per hour is used an acoustic index for comparing between sites and within sites between months and years.

Acknowledgements

We would like to thank all the boat operators: Colin Barnes, Joe Brady, Jeff Brownlee, William van Dyke, Séan McDonogh, Michál O'Chonneile, and Fachtna O'Driscoll, who have been extremely tolerant of late changes to plans and some early starts. This survey was funded by the Department of Environment, Heritage and local Governments' National Parks and Wildlife Service and we thank Dr David Lyons for his support during this project.

References

Berrow, S. D. and Rogan, E. (1997) Cetaceans stranded on the Irish coast, 1901-1995. Mammal Review 27(1), 51-76.

Berrow, S. D., Whooley, P. and Ferriss, S. (2002) *Irish Whale and Dolphin Group Cetacean Sighting Review (1991-2001).* Irish Whale and Dolphin Group**,** 1-34.

Berrow, S.D., O'Brien, J., O'Connor, I. and McGrath, D. (2007) Abundance Estimate and Acoustic Monitoring of Habour Porpoise *Phocoena phocoena* in The Blasket Islands Candidate Special Area of Conservation. Biology and Environment. Final Report to the National Parks and Wildlife Service.

Berrow, S.D., Hickey, R., O'Connor, I. and McGrath, D. (2008) Small Cetacean Site Investigations Survey 2008. Report to the National Parks and Wildlife Service. Irish Whale and Dolphin Group. pp 24.

Buckland, S.T., Anderson, D.R., Burnham, K.P.,Laake, J.L., Borchers, D.L. and Thomas, L. (2001) An Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Dawson, S., Wade, P., Slooten, E. and Barlow, J. (2008) Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. Mammal Review 38(10), 19-49.

Englund, A., Ingram, S. and Rogan, E. (2007) Population status report for bottlenose dolphins using the Lower River Shannon SAC, 2006-2007. Final Report to the National Parks and Wildlife Service. University College, Cork. pp35.

Hammond, P. S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jorgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. and Oien, N. (2002) Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* 39, 361-376.

Hammond, P.S. and MacLeod, K. (2006) SCANS-II-Report on Progress. Document for ASCOBANS Meeting of Partis, Egmond aan Zee, September 2006.

Ingram, S. N., Englund, A. and Rogan, E. (2004) Methods of best practice for the use of T-POD passive acoustic detectors for cetacean research in Irish waters. Report to the Heritage Council, Ireland.

Johnston, C.M., Turnbull, C.G. and Tasker, M.L., (2002) Natura 2000 in UK Offshore Waters, JNCC Report 325, ISSN 0963 8091.

Leeney, R. (2007) Distribution and abundance of harbor porpoises and other cetaceans in Roaringwater Bay, Co. Cork. Report to the National Parks and Wildlife Service, 1-23.

Leeney, R. and Tregenza, N.J.C. (2006) Static Acoustic Monitoring of Cetaceans. European Cetacean Society Newsletter No 46 – Special Issue. July 2006.

Lockyer, C., Heide-Jørgensen, Jensen, J., Kinze, C.C. and Sørensen, T.B. (2001) Age, length and reproductive parameters of harbour porpoises *Phocoena phocoena* (L.) from West Greenland. ICES Journal of Marine Science 58, 154-162.

O'Brien, J., McGrath, D. and Berrow, S. (2008a) Distribution and abundance of cetaceans in Galway bay: an evaluation of monitoring techniques and assessment of site suitability for future SAC designation. Unpublished Report to the National Parks and Wildlife Service. pp 17.

O'Brien, J., McGrath, D. and Berrow, S. (2008b) Distribution and abundance of cetaceans in Clew bay: an evaluation of monitoring techniques and assessment of site suitability for future SAC designation. Unpublished Report to the National Parks and Wildlife Service. pp 17.

O'Brien, J., Berrow, S.D., Ryan, C., Whooley, P., McGrath, D. and O'Connor, I. (submitted) Long-distance movements of bottlenose dolphins (*Tursiops truncatus*) around the Irish coast using photo-identification. Journal of Cetacean Research and Management.

Reid, J. B., Evans, P.G.H. and Northridge, S.P. (2003) Atlas of Cetacean distribution in north-west European waters. Joint Nature Conservation Committee, 1-75.

Reid, A.J. and Hohn, A.A. (1995) Life in the fast lane: the life history of harbour porpoises from the Gulf of Maine. Marine Mammal Science 11(4), 423-440.

Rogan, E. and Berrow, S.D. (1996) Review of Harbour porpoises *Phocoena phocoena* L. in Irish waters. Report of the International Whaling Commission 46**,** 595-605.

Sonntag, R.P., Benke, H., Hiby, A.R., Lick, R. and Adelung, D. (1999) Identification of the first harbour porpoise (*Phocoena phocoena*) calving ground in the North Sea. Journal of Sea Research 41, 225-232.

Teilmann, J. (2003) Influence of sea state on density estimates of harbour porpoises (*Phocoena phocoena*). Journal of Cetacean Research and Management. 5(1), 85-92.