Abundance estimate and acoustic monitoring of harbour porpoise *Phocoena phocoena* in the Blasket Islands candidate Special Area of Conservation

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Report to the National Parks and Wildlife Service

November 2007

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Summary

A survey of harbour porpoises (*Phocoena phocoena*) was carried out within the Blasket Islands candidate Special Area of Conservation (cSAC) to derive density and abundance estimates and carry out static acoustic monitoring. Single platform line-transect surveys were carried out on six days between 16 July and 1 October 2007. Distance sampling was used to derive g(0), which is the density of harbour porpoises on the track of the vessel. Passive acoustic monitoring was carried out through the deployment of self-contained click detectors called T-PODs, which identify and log the echolocation clicks of harbour porpoises. T PODs were deployed at four locations within the cSAC. T-PODs were calibrated against each other prior to deployment to account for different sensitivities of the equipment.

A total of 74 tracks were surveyed of a total distance of 460km. A total of 44 sightings of 102 individual harbour porpoise were recorded. Sightings of 25 common dolphins (*Delphinus delphis*), five minke whales (*Balaenoptera acutoratrata*) and two basking sharks (*Cetorhinus maximus*) were also recorded.

Abundance estimates were calculated using the day and the track line as the samples and the sighting as the observation. Density estimates ranged from 0.71 to 3.39 porpoises per km^2. This gave abundance estimates from 162±120 to 768±198 depending on the number of sightings per day. The most robust estimate was using all the data from each track-line combined, which gave an estimate of 303±76 (CV=0.25: (5% Confident intervals 186-494). However there are indications of a strong seasonal increase in abundance from July through to September.

An analysis of the effect of sea-state on density estimates was carried out and showed similar estimates were derived in sea-state 0 and 1 but there was a 50% decline in density for track lines surveyed in sea-state 2. No porpoises were observed in sea-state 3. This indicates harbour porpoise surveys within the Blasket Islands cSAC should only be carried out in sea-state 0 or 1 for accurate density estimates.

Two months of acoustic data were acquired, one month each from the Wildbank and off Inishtooskert. Gear loss prevented additional data to be collected. Data were extracted as Detection Positive Minutes (*DPM*) per day and per hour for analysis. Detections were logged every day of deployment at both sites. Nearly twice as many *DPM* per day were recorded off Wildlbank compared to Inishtooskert. Acoustic data from the Wildbank showed harbor porpoises to be more acoustically active during the day. The opposite occurred at Inishtooskert with porpoises more acoustically active during the night.

Density estimates from the Blasket Islands cSAC were compared to other similar surveys carried out in Irish and European waters. The densities in the Blaskets were much higher than other published studies. When acoustic data were compared to other sites, the mean DPM per hour was greater in the Blaskets Islands cSAC than sites in Galway and Clew Bays and two out of three sites surveyed in Roaringwater Bay. Only off Sherkin Island in Co Cork were higher DPM per hour recorded. These two comparisons support the designation of the Blaskets islands as a cSAC for harbour porpoise. A crude calculation estimates that around 0.5% of the total Irish harbour porpoise population may occur within the Blasket Islands cSAC.

More sighting surveys should be carried out to provide a robust dataset from which to inform the design of a long-term monitoring protocol. We recommend two replicate samples within each season are required, in parallel with an extensive acoustic dataset (minimum one year) to explore seasonal variation in harbour porpoise densities and abundance.

Citation: 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. Report to the National Parks and Wildlife Service.

Introduction

The Blasket Islands are comprised of a group of six main islands situated at the end of the Dingle peninsula in County Kerry. They are well known for their rich literature and archeological heritage (Sayers, 1974; O'Crohan, T. 1978). The islands support one of the most important seabird colonies in Ireland, with at least 11 species of seabird breeding regularly (Brazier and Merne, 1989; Smiddy *et al*., 2000). The Blasket Islands are one of the most important breeding sites for grey seals (*Halichoerus grypus*) in Ireland with pup production in 2005 estimated at 185 giving a minimum population size of 648-833 (Ó Cadhla *et al.,* 2007).

Published information on the cetaceans of the Blasket Islands is limited. Berrow (1993) carried out timed watches from 26 headlands around the Irish coast and recorded the highest sighting rate from Slea Head overlooking the Blasket Islands where harbour porpoise (*Phocoena phocoena*) and minke whales (*Balaenoptera acutorostrata*) were observed. Smiddy *et al.,* (2000) reported a single sighting of two harbour porpoises in Blasket sound in 1989 and a single bottlenose dolphin (*Tursiops truncatus*) in 2001. Five cetacean species were reported off Slea Head overlooking the Blasket Islsnds by Berrow *et al.* (2002). These included harbour porpoise, bottlenose, common (*Delphinus delphis*) Risso's dolphin (*Grampus griseus*) and minke whale. The presence of small cetaceans was known to islanders living on Great Blasket as O'Crohan (1978) describes driving sea-hogs ashore in 1890 where they were killed and eaten during the winter. These could refer to harbour porpoises (muc mhara or sea-pigs) or small dolphins.

The harbour porpoise is probably the most widespread and abundant cetacean species in Irish waters (Rogan and Berrow 1997). 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 consistently the most frequently recorded species stranded on the Irish coast (Berrow and Rogan, 1997). The life history of harbour porpoise in Irish waters is poorly understood. Rogan and Berrow (1996) reported that 95% of prey items recovered from the stomachs of stranded and bycaught harbour porpoise were either gadoids and clupeids, with *Trisopterus* spp., whiting, *Merlangius merlangus,* and poor cod, *T. minutus,* contributing most of the prey items. Walton (1997) showed there were significant genetic differences between harbour porpoise from the northern North Sea and the Celtic/Irish Sea, but these differences were predominantly due to variation among females. Abundance estimates for the Celtic Sea were determined in 1994 (Hammond *et al.,* 1999) and for all Irish waters to the shelf edge and including the Irish Sea in 2005 (Hammond and MacLeod, 2006).

Threats to harbour porpoise in Irish waters are also poorly understood. Tregenza *et al.* (1997) estimated 2,200 harbour porpoises were killed by bottom set gillnets in the Celtic Sea in 1993/94. This accounted for 6.2% of the estimated number of harbour porpoise in that region and there was serious concern about the ability of the population to sustain this mortality. Studies of persistent pollutants have shown radio-nuclide levels are low in harbour porpoises in the Irish Sea (Berrow *et al.,* 1998) whilst levels of organochlorine pesticide contamination are among the lowest recorded in the north-east Atlantic (Smyth *et al.,* 2000).

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 were designated as a candidate Special Area of Conservation (cSAC) in 2000 for a number of marine and terrestrial habitats as well as the grey seal and harbour porpoise. Roaringwater Bay cSAC in Co Cork is also designated for harbour porpoise and the Lower River Shannon is the only cSAC in Ireland designated for bottlenose dolphin.

Objectives

The objectives of the present survey were to:

1. survey the Blasket Island cSAC for harbour porpoise
2. calculate the density of harbour porpoise within the cSAC
3. derive an abundance estimate of harbour porpoises within the cSAC
4. carry out acoustic monitoring within the cSAC
5. record other species of interest within the cSAC

Methods

<u>Sighting Survey</u>

Single platform line-transect surveys were carried out within the boundaries of the Blasket Island cSAC (Fig 1) along pre-determined routes. Transect lines were determined to cross depth gradients and provide good coverage of offshore waters and around the islands. Distance sampling was used to derive g(0), the density estimate and calculate abundance estimates.

Figure 1. Map of Ireland showing location of Blasket Islands cSAC

The 13m long MV Blasket Princess was chartered for this survey and traveled at a speed of 12km hr^{-1} (7knts). Two observers (SB and JO'B) were positioned on the flying bridge, which provided an eye-height of 3.5m above sea-level and watched with naked eye from dead ahead to 90º to port or starboard depending on which side of the vessel they were stationed. Observers were alternated between port and starboard between surveys. During each survey a strip 200m wide was surveyed either side of the vessel thus giving a total surveyed width of 400m. Sightings outside this distance were recorded but 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 g(0).

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 angular distance of the sighting from the vessel recorded. These data were communicated to the recorder in the wheelhouse via a 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. To assist in estimating distance, tests were carried out prior to the start of each survey by estimating distances to objects which could be verified using a Leica Rangemaster 1200. This range finder was accurate to within ±2m over 800m or ±0.5% over 600m. 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 within 200m of the observer.

During this survey we assumed g(0) was equal to one, i.e. that all the harbour porpoise on the track-line were observed. To test this assumption we carried out a double-platform survey on 27 August 2007. Two trackers, one on each side of the flying bridge scanned ahead of the vessel and up to 30º either side with 10x50 binoculars. Once one of these experienced cetacean surveyors observed a group of harbour porpoises, they tracked the group until either it was observed by the primary platform, as determined by hearing a sighting being called out to the recorder through the VHF, or the group passed beyond 90º to the track of the vessel.

Abundance estimate

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 trackline 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 trackline 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).

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.

There were two broad approaches to data analysis. Either *survey day* could be used as the sample with sightings as observations or *track-line* treated as the sample with sightings used as observations. The advantage of the latter method is that the sample size is much greater which should reduce the variance. One possible disadvantage is the high number of zero observations within each sample (i.e. no porpoise sighted on the track line).

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 intervals of 0-20, 20-40 up to 180-200. Cluster size was analysed used 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; the map of the SAC was obtained from National Parks ands 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, in the study area. The T-POD units were manufactured by Chelonia Ltd in the UK. They consist of a self-contained computer and hydrophone and can log the times and duration of clicks which resemble the echolocation 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 is B, 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 harbor 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 1).

Harbour porpoise are known to produce echolocation signals that are narrowband, high frequency clicks within 110-150 kHz (Møhl and Andersen, 1973). An example of the output is shown in Figure 2.

Table 1. TPOD settings used for porpoise monitoring in the Blasket Islands cSAC (Ver 5 T-POD)

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	++	++	++	++	++	++
Sensitivity	16	16	16	16	16	16

Scan Limit on N of clicks logged	240	240	240	240	240	240

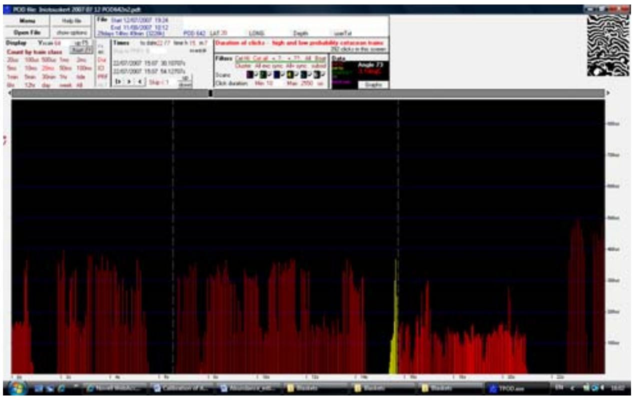

Figure 2. Screen print of the T-POD software after analyzing click trains present in the logged data from Inishtooskert. The clicks in red are classed as high probability cetacean clicks, while those in yellow are classed as lower probability cetacean clicks. There are several clicks present in a click train and range up to 500µs (as shown on the Y axis).

T-POD Calibration trials

In order to facilitate the comparison of acoustic data collected by different units, simultaneously recording from different sites, it is necessary to carry out calibration trials to assess the variability in sensitivity between units. Calibrations trials were carried out in Galway Bay, from a site two miles east of Spiddal, Co. Galway between 12 June and 10 July 2007. Two T-PODs (Nos 642 and 658) were deployed in close proximity to each other for a duration of 29 days. Both T-PODs were set to detect harbour porpoises only. Upon recovery of both devices, data were extracted as total detection positive minutes (*DPM)* per day.

Results from these trials showed that T-POD 658 detected 4,243 more clicks (56 more *DPM*) than T-POD 642 (Table 2). A correction factor was applied to data collected from T-POD 642, which was the less sensitive device. The mean detection rate of each T-POD over the 29-day deployment (X) was used to calculate the correction factor (C) as shown below:

Table 2. Summary of acoustic data logged during calibration trials in Galway Bay

T-POD Number	Duration of deployment	Total clicks "*cet all*"	Clicks Per hour	Total *DPM*	Mean DPM per h^{-1}
642	29d 3h 39m	20,587	30	372	0.53
658	29d 3h 39m	24,830	36	428	0.61

After the correction factor was applied a non-parametric Kruskal Wallis test was carried out in order to test for significant differences between the corrected data. No significant difference was found when expressed as Detection Positive Minutes (*DPM*) per day (P=0.401). It was planned to carry out similar calibration trials at the end of the study, to explore any changes in sensitivity between T-PODs over the duration of the study, but due to loss of gear this task could not be completed.

Moorings

The mooring system used at each location is shown in Figure 3. This system was designed to withstand adverse weather condition. The T-POD is attached to the lighter weight, which can be pulled by hand from the surface. This is attached to a heavier weight, which acts as the main mooring. Providing the distance between the weights is greater than the depth of water recovery was relatively straight forward. A similar but lighter mooring system was used by O'Brien (unpubl. data) in Galway

Bay. She used 40kg instead of 60kg on the main mooring and it stayed in position for the duration of a winter, ever during gale force winds. Written on each main mooring buoy was "*The Irish Whale and Dolphin Group Harbour Porpoise Survey. Please leave alone. Phone 086 8545450*".

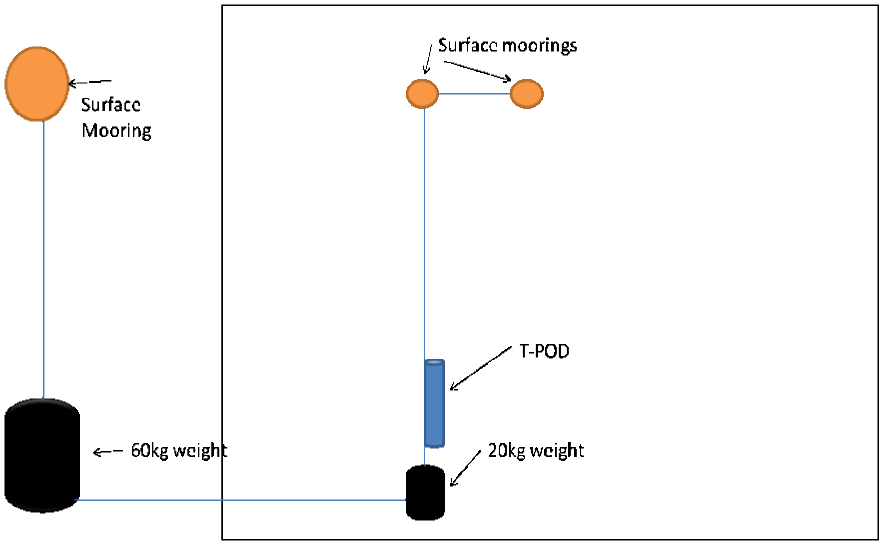

Figure 3. Design of the mooring system used for deployment of T-PODs

Deployment positions of T-PODs

Four locations were used for T-POD deployments throughout this study (Fig. 4). Two units were deployed at any one time. From the four sites, data were only successfully recovered from units at two sites (Inishtooskert and Wildbank). At the end of the study period, neither surface mooring-buoys could be found at their locations off Inishtearaght and Inishtooskert.

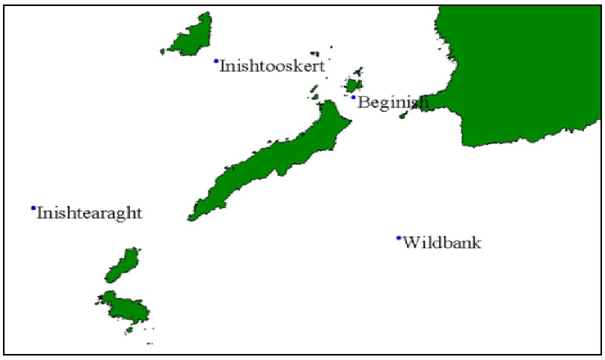

Figure 4. Map of locations where T-PODs were deployed

Results

<u>Sighting Surveys</u>

Harbour porpoise surveys were carried out on six days between July and October 2007 (Table 3). Individual track-lines for each survey are shown in Appendix I. The track-lines were chosen to provide as complete coverage of the cSAC as possible in order to identify any high-density areas. The whole cSAC was covered on each survey day to enable individual abundance estimates for each survey day to be calculated. No track-line was surveyed more than once (apart from in restricted areas such as Blasket sound) which provided good coverage of the whole cSAC (Fig 5).

Table 3. Date, sea-state and number of sightings of harbour porpoises within the Blasket Island cSAC during 2007

Sample	Date	No. of track lines	Total distance (km)	Sea-state (% of total survey time)				Number of sightings	Total Animals
				0	1	2	3		
1	16 July 2007	8	65.947	0	81.4	12.2	6.4	10	20
2	24 July 2007	17	83.045	0	55.7	35.3	9.0	5	12
3	11 August 2007	19	92.380	0	71.2	27.3	6.0	4	8
4	27 August 2007	18	83.180	7.1	57.0	24.0	11.9	9	26
5	11 September 2007	12	64.675	53.0	44.3	1.0	1.6	16	36
6	1 October 2007	8	67.429	0	15.8	66.7	17.5	0	0
Total		74	460.399					44	102

Transects were carried out within the cSAC boundary but on two occasions the route passed a maximum of 830m to the west of the western boundary (Fig 5). A total of 460 km of track-line was surveyed over the six survey days, ranging in length from 66km on 16 July to 92km on 11 August. A total of 44 sightings of harbour porpoise were recorded consisting of 102 individual animals.

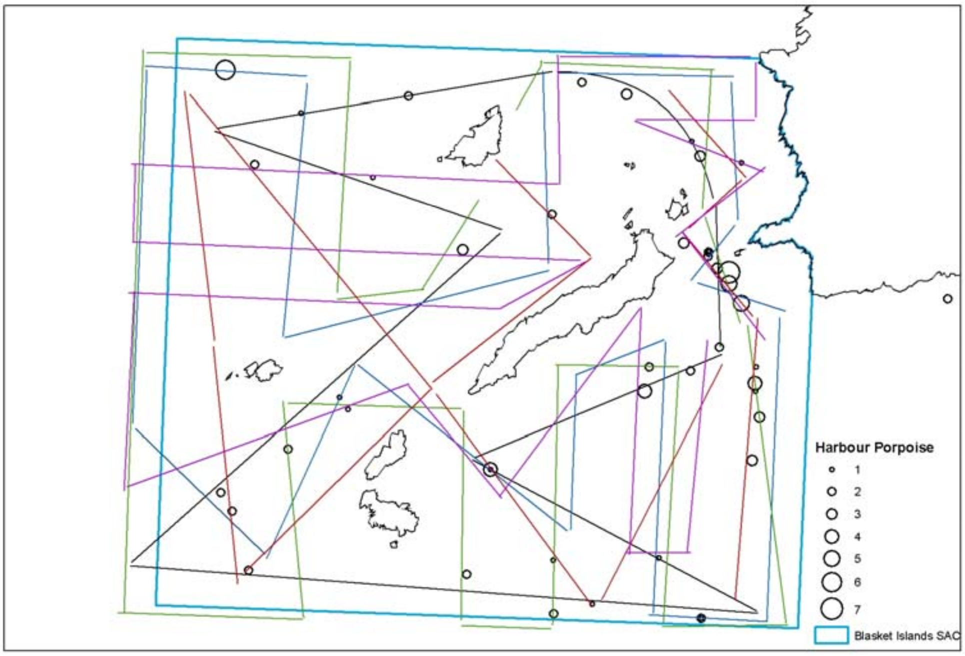

Figure 5. Map showing location of all track lines surveyed and harbour porpoise observed

Sea conditions varied over the survey period (Table 3). Although sea-state was less than 3 for over 88% of the track lines surveyed during five of the six days, a significant proportion of time with sea-state 0 was only recorded during the fifth transect on 11 September. Sea-state one or less was recorded on 97% of track lines surveyed on 11 September but under 65% on three of the six transect days. Sea-state was 2 or greater on 84% of the track lines surveyed on 1 October and no cetacean sightings were recorded. Data from this survey day was removed from all the subsequent analysis.

<u>Harbour porpoise distribution</u>

Harbour porpoise were distributed throughout within the cSAC with highest densities (harbour porpoise per km traveled) in Blasket Sound. High concentrations were also recorded to the south of Great Blasket and east of Inishvickillane and to the northwest of the cSAC (Fig 6). Only two calves were reported, both in September, which means gives an adult/calf ratio of 50:1 or 2% of total was recorded.

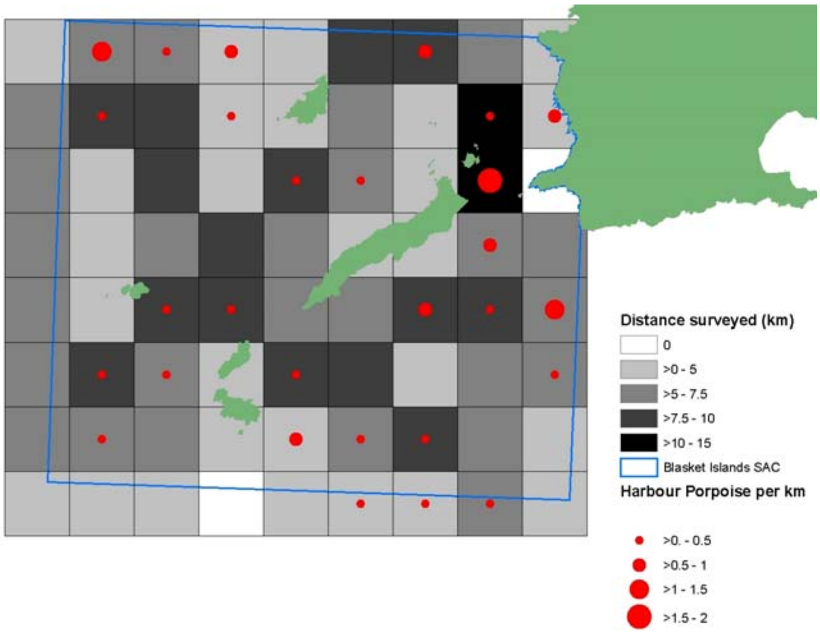

Figure 6. Map of Blasket cSAC with effort and harbour porpoise sightings shown within a 2km grid

Harbour porpoise abundance

Harbour porpoise density and abundance estimates are presented using day as the sample and the track-line as the sample (Tables 4 and 5). The Detection Function is shown in Figure 7, which had a goodness of fit of χ^2=3.39, 6df, p=0.76. The data are spiked at 40-80m, which is most likely caused by evasive movement of harbour porpoises from the track of the vessel prior to detection. This will cause the density estimate to be biased low.

The component of the variation of the density estimate (D) that was contributed by the Detection Probability was 12.3% and that from the Encounter Rate 80.0%, the remaining 7.7% contributed by variability in the Cluster Size. This is typical of line transect data and shows that the variability in encountering harbour porpoise on each track-line contributes to most of the overall variability.

Results from the double-platform survey on 27 August showed that all harbour porpoise sightings made by the trackers were also reported by the primary platform. On two of the nine sightings the primary platform actually recorded the sighting before the tracker platform. This suggests that few if any harbour porpoise within the 200m strip were not recorded by the observers strengthening the case that on this survey day at least g(0) was equal or close to 1.

Figure 7. Detection function for harbour porpoise in the Blasket Islands cSAC (χ^2=3.39, 6df, p=0.76)

Day as sample

Using this detection function we have derived density estimates for each sampling day. The estimate for sample days two and three are the lowest as the number of sightings and the total number of animals observed was also low. This also manifests itself in the confidence of the abundance estimate with a high CV and wide confidence intervals (Table 4). The CV for sample day five was the lowest (CV=0.26) as the number of sightings was high and the total track length sampled (64.7km) relatively short compared to other days. This has resulted in the highest density estimate (D=3.38 per km^2) during the survey and thus the highest abundance estimate of 768 (95% CI=457-1291) harbour porpoises. Abundance estimate for sample day 4 was also high due to a large mean group size of 3.15 compared to 2.25 on survey day 5 (11 September). The overall abundance estimate using data from all surveys combined was 303±106 (95% CI 133-691).

Table 4. Mean density and abundance of harbour porpoise per sample day

Sample day	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)	Effective strip width (m)
1	265 (120-586)	102	0.39	1.17	2.00 (1.37-2.91)	166
2	162 (29-909)	120	0.74	0.71	2.40 (1.00-6.76)	102
3	185 (45-763)	105	0.56	0.82	1.75 (1.00-4.11)	78
4	764 (451-1294)	200	0.26	3.37	3.15 (2.33-4.26)	88
5	768 (457-1291)	198	0.26	3.38	2.25 (1.62-3.12)	80
Overall	303 (133-691)	107	0.35	1.33	2.29 (1.89-2.78)	106

Track-line as sample

A total of 393km of track-line was available for analysis from the five survey days. The 74 track-lines ranged from 1.54km to 14.39km in length. For 45 of these track-lines (60.8%) there were no sightings. One sighting was made on 18 (24.3%), two sightings on 7 (9.5%) track-lines and 3 and 4 sightings on two each (2.7%).

The overall density estimate (D) is the same as in the previous analysis (D=1.33) resulting in a similar abundance estimate (303) with 95% Confidence Intervals of 186-494 (Table 5). The CV for each estimate is a measure of the amount of variation within each sample and figures as high as 0.76 and 0.95 result in very wide confidence intervals. The largest CV and thus the widest confidence intervals match those survey days with fewest sightings (5 sightings of 12 individuals and only 4 sightings of 8 individuals) but the highest number of sightings (Day 5) have a lower co-efficient of variation (CV=0.25) and less range in the confidence interval. The overall abundance estimate using data from all surveys combined was 303±76 (96% CI 186-494).

Table 5: 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)	Effective strip width (m)

1	265 (77-910)	167	0.63	1.17	2.00 (1.37-2.91)	166
2	162 (28-938)	154	0.95	0.71	2.40 (1.00-6.76)	102
3	205 (50-832)	155	0.76	0.90	2.05 (1.05-3.80)	78
4	356 (144-876)	165	0.46	1.57	2.89 (1.81-4.59)	113
5	769 (329-1799)	330	0.42	3.39	2.25 (1.62-3.12)	81
Overall	303 (186-494)	76	0.25	1.33	2.32 (1.92-2.79)	107

Influence of sea-state of density estimates

The DISTANCE model was run again with the data stratified by sea-state to explore the influence of sea-state on density and abundance estimates. There were no sightings during the 37km surveyed in sea-state 3, thus the density estimate is zero. There were seven sightings in sea-state 0, which provided an abundance estimate with the highest standard error and a CV of 0.52 (Table 6). The estimate with the lowest CV was in sea-state 1 where 30 sightings were made during 45 track lines of total length 203km. The density estimates in sea-state 0 and 1 were similar suggesting that the detection rate is similar in these sea-states. However the density estimate declined by 49% in sea-state 2 compared with the mean of seas-states 0 and 1. Thus the data suggests that, if possible, surveys should not be carried out in seas-state 2 as this will strongly affect the detection function.

Table 6. Mean density and abundance of harbour porpoise per track line in different sea-states

Sea-state	Distance surveyed (km)	N (95% CI)	SE	CV	Density (per km^2)	Group size Mean (95% CI)
0	46	320 (115-890)	166	0.52	1.41	1.28 (1.00-1.82)
1	203	369 (194-701)	122	0.33	1.62	2.27 (1.78-2.88)
2	107	179 (49-656)	126	0.70	0.78	2.40 (1.02-3.80)
3	37	-	-	-	0.00	-

Temporal changes in harbour porpoise abundance

The data suggest that was an increase in the abundance of harbour porpoises within the cSAC from July through to September. Densities increased around three-fold from around 1 porpoise per km in July and early August to 3 porpoise per km during late August and September. Large concentrations of harbour porpoises were recorded to the south of Blasket sound. This is in an important factor in the design of monitoring protocols as abundance estimates would have to be stratified by season to ensure any recorded changes in abundance are not due to shifts in seasonal changes rather than long term trends.

Acoustic detections

During the six potential acoustic months of deployment (3 months x 2 T-PODs) we only acquired 2 months of acoustic data from the Blasket Islands cSAC. Initially, one T-POD was deployed off Inishtooskert and one off the Wildbank and data was successfully downloaded from these two devices at the end of a 28-day deployment period.

Table 7. Summary of acoustic data from T-PODs recovered from Wildbank and Inishtooskert

Location	Deployment date	Deployment duration	Total clicks "*cet all*"	Clicks per hour	Total *DPM*	Mean *DPM* per h^{-1}

Inishtooskert (642)	12.07.07	28d 14h 49m	33,389	46	619	0.9
Wildbank (658)	12.07.07	29d 6h 28m	89,984	120	1394	1.99

After recovering the T-POD on the Wildbank it was re-deployed off Beginish Island. T-POD 658 was re-deployed off Inishtooskert with an extra small surface mooring attached. When the T-POD was recovered from Beginish on 11 September 2007, the unit had only logged for 10 hours, 48 minutes after which the angle switch showed the T-POD had moved into an off position. The T-POD off Inishtooskert could not be located on the 11 September, despite visiting the site at extreme low-water. After recovering the T-POD from Beginish, the mooring was then moved to a position on the eastern side of Inishtearaght. On the final transect on the 1 October the surface mooring could not be located. Results from the two full months of acoustic data are shown in Table 7.

Figure 8. Total *DPM* per day from Inishtooskert and Wildbank

Detection Positive Minutes (DPM) per day from Inishtooskert and Wildbank

Data were extracted from both units as total *DPM* per day (Fig. 9). T-POD 642 at Inishtooskert only detected 44% of the total *DPM* logged by T-POD 658 at the Wildbank. After the correction factor of 1.15 was applied to data from Inishtooskert (T-POD 642) these data were still significantly different (Kruskal Wallis, P=0.002).

Diel Variation

In order to compare this study with previous work carried in Roaringwater Bay cSAC, we then extracted the data as *DPM* per hour (including the 1.15 correction factor), similar to Leeney (2007). Meridians were calculated by assessing the times of sunrise and sunset over the deployment period and these were used to set day and night-time parameters. This was calculated using the software WXTide 32 for Dingle Harbour. Daylight was classified as between 05:00 and 19:00 and night-time as between 20:00 and 04:00. The data were then summed over these day and night-time periods. In order to select an appropriate statistical test, a Levene test was carried out to examine the homogeneity of variance between data from Inishtooskert and Wildbank. This showed that the variances between the two sites were not equal (P<0.05), therefore non-parametric Mann-Whitney U test was chosen to test for significant difference between the two sites.

Initially, diel variation was examined within sites. Random day and night samples (n=12) were chosen from each site (using random number tables), in order to assess if animals were using a site more often at a specific time of day or night Statistical analysis showed that harbour porpoises were more active during the day at Wildbank (P=0.02) when compared with nightime data from the same site. Porpoises were found to be more active during the nigh-time at Inishtooskert (P=0.0005) when compared against day-time.

Figure 9. Summed *DPM* per hour classed as day-time

We then examined variation between sites. Non-parametric Mann-Whitney U tests were carried out to determine any differences in the *DPM* logged during daylight. Again a random sample of 12 days was used, which showed there was a significant difference showing that harbour porpoises were more active during the day at Wildbank when compared with Inishtooskert (P=0.0014) (Fig. 9). The same trend was evident when the data were analyzed from both sites during night-time hours (Fig. 10). As above, a random sample of 12 nights was chosen from each site. Mann-Whitney U tests were used to test for significant difference. A significant difference (Mann-Whitney, P=0.0001) was found between the sites during night-time, with porpoises off the Wildbank most active.

Figure 10. Summed *DPM* per hour classed as night-time

Tidal Influence

When *DPM* per hour is presented over a tidal cycle it is clear that there are no trends on the Wildbank (Fig. 11) while off Inishtooskert there was some variation between low and high water, with the highest peaks ocurring during the ebbing tide (Fig. 11) however these were not significant (Kruskal Wallis test, P=0.234, NS).

Figure 11. Distribution of *DPM* over completer tidal cycles at Wildbank and Inishtooskert

<u>Other species recorded during survey</u>

In addition to harbour porpoise we recorded two other species of cetacean and two basking sharks (*Cetorhinus maximus*) (Table 8). Common dolphins (*Delphinus delphis*) were the most frequently recorded other species with seven sightings of 25 individuals. They were mainly observed to west and north side of cSAC area and at the south side of Blasket sound. The five minke whale sightings were all to the south of Blasket sound and on two occasions were observed in the same feeding aggregate as harbour porpoise.

Table 8. Species of marine megafauna, other than harbour porpoise, recorded during this survey

Date	Species	Number of individuals	Location		Behaviour
			Latitude	Longitude	
16 July	Basking shark	1	52.11169	10.49249	Feeding
16 July	Minke whale	1	52.10072	10.48638	
24 July	Common dolphin	2	52.09688	-10.70317	Traveling
24 July	Common dolphin	4	52.13765	-10.70197	Travelling
11 August	Common dolphin	5	52.11261	-10.6931	Travelling
11 August	Common dolphin	1	52.07759	-10.68857	Travelling
27 August	Minke whale	1	52.09896	-10.47663	Feeding
27 August	Common dolphin	2	52.09661	-10.47656	Feeding
27 August	Minke whale	1	52.09326	-10.47704	Feeding
27 August	Common dolphin	3	52.14727	-10.55287	Travelling
27 August	Minke whale	2	52.10154	-10.48637	
11 September	Minke whale	1	52.10227	-10.49079	Feeding
11 September	Common dolphin	8	52.14052	-10.51583	Feeding

11 September	Basking shark	1	52.10151	-10.53803

Discussion

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 (Teilman, 2003). Palka (1996) found that the sighting rates of this species decreased by 20% from Beaufort 0 to 1 and by 75% from Beaufort 0 to 2-3. We have shown the differences in abundance estimates with sea-state can vary as much as 100% between sea-state 0-1 and sea-state 2. 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 July and August 2007 we were fortunate to be able to carry out as many surveys as we did in relatively good sea-state. Acoustic monitoring is much less weather dependent.

Little was known about the distribution of harbour porpoise within the Blasket Islands cSAC prior to this study. The results suggest that all, or most of the site, is used by harbour porpoise. Concentrations, especially in Blasket sound, were recorded which might indicate an important foraging area as currents are very strong through the sound. Pierpoint *et al.* (1994) observed porpoises in tidal races surfacing repeatedly at the same location, always orientated so as to face into the tidal stream, which they intercepted as foraging activity. Other concentrations may correlate with reefs (e.g. Wildbank) or other typographic or oceanographic features.

Mean harbour porpoise group size recorded during this study ranged from 1.75 to 3.15 (actual: 1-7 individuals). O'Cadhla *et al.,* (2003) reported a mean of 1.92 (range: 1-4) from Broadhaven Bay, Co Mayo and Pierpoint (2001) 1.74 (range: 1-8) in the coastal water of southwest Wales. Thus the group sizes recorded are typical for the British Isles.

Comparison of harbour porpoise density estimates

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 estimate. Without a double-platform methodology it is not possible to accurately determine the numbers missed on the track-line. An attempt to test this assumption was carried out during this survey and all animals tracked were detected by the primary platform but some groups were not detected immediately and demonstrated evasive movement from the boat. This is also indicated by the detection function. These factors will reduce the density estimates however as density estimates were similar in sea-state 0 and 1 we can be confident that they are relatively accurate. We have provided minimum density estimates for harbour porpoises within the Blasket Islands cSAC and provided a baseline from which to monitor changes in the population.

We compare the density estimate from the present survey to those recorded for other harbour porpoise surveys in Irish and other European waters (Table 9). The density estimate recorded in the present study (1.33 harbour porpoise per km^2) was much higher than other published surveys. Only Leopold *et al*. (1992) reported densities greater than 0.5 harbour porpoise per km^2 in Irish waters. The highest densities in other European waters were from The East Danish coast (0.81) and in the Northern North Sea and around Orkney and Shetland (0.78)

We might expect density estimates to be high in the Blasket Islands cSAC given that densities of harbour porpoise are thought to be greater off the southwest coast compared to other parts of Ireland (Rogan and Berrow, 1996; Reid *et al.,* 2003) and this survey was restricted to the coast and offshore islands, which are considered preferred habitats for harbour porpoise (Santos and Pierce, 2005).

Table 9. Density estimates of harbour porpoise in Irish and EU waters as determined from dedicated sighting surveys

Location	Year	Area (km^2)	Method	Density (per km^2)	CV	Reference
Irish waters						
Galway - Cork[1]	1989	-	SPL	0.77		Leopold *et al.* (1992)
Celtic Sea	1994	201,490	DPL	0.18	0.57	Hammond *et al.* (2002)
Celtic Sea	2005	197,400	DPL	0.41	0.50	Hammond and MacLeod (2006)
Irish Sea	2005	45,417	Aerial	0.34	0.35	Hammond and MacLeod (2006)
Coastal Ireland	2005	31,919	Aerial	0.28	0.37	Hammond and MacLeod (2006)
Offshore shelf edge[2]	2005	149,637	DPL	0.07	1.24	Hammond and MacLeod (2006)
Blasket Islands	2007	227	SPL	1.33	0.25	This study
Other EU waters						
Northern North Sea	1994	118,985	DPL	0.78	0.25	Hammond *et al.* (2002)
Orkney and Shetland	1994	31,059	Aerial	0.78	0.34	Hammond *et al.* (2002)
East Danish coast	1994	7,278	Aerial	0.81	0.27	Hammond *et al.* (2002)
South Central North Sea	2005	156,972	DPL	0.56	0.23	Hammond and MacLeod (2006)
Coastal NW Denmark	2005	20,844	Aerial	0.56	0.43	Hammond and MacLeod (2006)

SPL = Single platform line transect, DPL = Double platform line transect, Aerial=Aerial survey
[1] not a dedicated survey but a platform of opportunity
[2] includes offshore waters to the west of Scotland

Comparison of harbour porpoise abundance estimates

The overall abundance estimate from this study suggests around 303 harbour porpoise occurred within the cSAC between July and September. Immigration into the site may have occurred through the summer and into the autumn increasing abundance to a maximum of 760 porpoises in September.

In the NPWS Conservation Assessment recently submitted to the EU as part of the governments reporting requirements the total population estimate for harbour porpoises in Irish waters was around 100,000 individuals. If this is accurate then the Blasket Islands cSAC may contain around 0.5% (0.3%-0.7%) of the total Irish population of harbour porpoise. The results present here provide a good baseline from which to compare similar surveys in other locations and from which to monitor changes in densities through time.

Acoustic detections

To compliment the boat-based surveys which could only be carried out during daylight hours, Static Acoustic Monitoring (SAM) was used through the use of T-PODs. This provided a robust means to explore factors such as site usage, diurnal and tidal factors influencing the distribution of harbour porpoises within this cSAC.

These data showed that there were significant differences in detections between the two sites surveyed (Inishtooskert and Wildbank). A significant difference was also found in the number of detections during day-time and night-time parameters within sites. This showed that harbour porpoise were more vocally active at Inishtooskert during the night, but were more active during the day-time at Wildbank. These results were similar to that reported by Carlström (2005) who found significantly higher inter-click intervals at night than during the day.

Further analysis examined the effect of tidal cycle on the number of DPM/h^{-1}, but no significant effect on the number of DPM/h^{-1} was found. This is in contrast to that reported by (Pierpoint and Baines, 2000), who found that tide had a strong influence on harbor porpoise activity at some Welsh coastal sites. However, a longer dataset is required to determine whether this relationship is consistent throughout the year or perhaps due to the seasonal occurrence of potential prey.

When compared with data from Roaringwater Bay cSAC (Leeney, 2007) the mean DPM/h^{-1} was greater at the Blaskets when compared with sites off Long and Calf Islands. However the mean value for Sherkin island was much greater than both sites in the Blaskets (Table 10). When the mean DPM/h^{-1} from the Blasket Islands was compared with Galway Bay (O'Brien, J. unpublished data) from the same month there was a large difference in this acoustic index. However, there was less of a difference when these data are compared to Clew Bay in County Mayo (Table 10).

Table 10: Comparison between acoustic indices from similar studies in Irish waters

County	General area	Location	Deployment duration	Mean DPM per hour	Reference
Kerry	Blasket Islands	Wildbank	29d	1.99	This study
Kerry	Blasket Islands	Inishtooskert	29d	1.04	This study
Galway	Galway Bay	Spiddal	22d	0.20	O'Brien (unpubl.)
Mayo	Clare Island	Clare Island	93d	0.68	O'Brien (unpubl.)
Cork	Roaringwater Bay	Calf Islands	66d	0.63	Leeney (2007)
Cork	Roaringwater Bay	Sherkin Island	71d	3.58	Leeney (2007)
Cork	Roaringwater Bay	Long Island	55d	0.23	Leeney (2007)

In this study we present a brief acoustic snapshot of harbour porpoise activity in the Blaskets cSAC. The results have shown that detection rates were high when compared with other sites in Ireland. It also demonstrates how the harbour porpoise activity can vary considerably between sites. Wildbank had higher acoustic detections and was used more during the day. Results suggest this site may be an important foraging area during the day and night when compared with Inishtooskert. Higher detection rates at night have been reported elsewhere (Pierpoint, 2001; Carlstrom, 2005) which were also attributed to availability of prey items, and the fact that harbor porpoises used their echolocation to explore the environment at greater distances during darkness.

A long-term monitoring scheme in this area would greatly increase our knowledge of the use and any seasonal variations in abundance or behaviour within the cSAC. Given the strong influence of sea-state on visual surveys a long-term monitoring programme involving extensive use of SAM may be the preferred option. This would be very beneficial during winter months, when sea conditions rarely support boat-based observations. Having a long-term acoustic dataset from a cSAC would provide a good reference for other sites where acoustic monitoring may take place during assessment for future designations.

It was hoped that a larger acoustic dataset would have been generated over the study period. Calibration trials planned for the end of the survey could not be carried out due to equipment loss. It is suggested that future deployment of acoustic equipment in this area should consider the use of very large chained moorings, with navigation lights and marine notices to minimise interference. The use of acoustic release systems should be considered, thereby eliminating the use of surface mooring-buoys. This could prove especially beneficial in areas where trawling does not take place.

Conclusion

The EC Habitats Directive states a site which "*corresponds to the ecological requirements of the species*" may be designated as a Special Area of Conservation (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. Elevated population density (in relation to neighbouring areas) is one of the recent criteria recommended for SAC selection according to Johnston *et al.,* (2002).

This study shows densities of harbour porpoise within the Blasket Islands cSAC were high relative to other areas, which supports its designation as a candidate Special Area of Conservation. These elevated density estimates are supported by acoustic data, which although limited, suggests acoustic detection rates are also high compared to other sites in Ireland.

The limited time-series presented here (3 months, July-September) suggests there could be a strong seasonal component to the abundance of harbour porpoise within the Blasket Islands cSAC. We recommend this factor is fully investigated through a replicated, seasonally stratified, sampling programme for at least one year. Simultaneous acoustic monitoring should also be carried out. As part of the recently funded Marine Institute SeaChange Marine Megafauna Research Project it is planned to acquire two years of acoustic data from within the Blasket Islands cSAC through the use of static acoustic monitoring. We suggest that this provides a cost-effective opportunity to fully explore seasonal variation in porpoise abundance if visual surveys are carried out during this period. These would then inform the design of a long-term monitoring protocol.

Recommendations

<u>Sighting surveys</u>

1. Single platform sighting surveys should be carried out to establish a robust dataset from which to inform the design of a long-term monitoring protocol. We recommend two replicate samples within each season (16 visits) to be carried out within the next reporting round of the Habitats Directive.
2. All sighting surveys should only be carried out in sea-state 0-2 and preferably 0-1.
3. Tracks should be randomized within each season to ensure good coverage of the cSAC
4. In distance analysis we recommend the track-line is used as the sample to reduce the coefficient of variation and confidence interval.
5. Ongoing land-based watches should be continued from Slea Head to compliment the dedicated surveys and acoustic monitoring

<u>Acoustics</u>

With regard to passive acoustic monitoring we recommend:

1. An extensive acoustic dataset (minimum 12 months) would assist in determining seasonal changes in detection rates and behaviour within the cSAC. This recommendation will be carried out under the Marine Institute SeaChange marine megafauna research project.
2. Site selection for Static Acoustic Monitoring (SAM) is important due to significant differences in acoustic detections over relatively short distances.
3. The use of more sophisticated mooring systems in order to eliminate loss of gear. Acoustic release systems could prove useful as they would eliminate the need for surface mooring buoys, and therefore long-term deployments of gear could go unnoticed.

Acknowledgements

We would like to thank Michael Sheeran of Blasket Islands Ferry and Tours for his commitment to ensuring the success of this survey. We would also like to thank Randall Counihan, Eugene McKeown, Mick O'Connell and Pádraig Whooley for help in the field. We would like to thank Professor Steve Buckland from the Centre for Research into Ecological and Environmental Monitoring at the University of St Andrews on advice on DISTANCE analysis. 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. 1993. Constant effort cetacean sighting survey of Ireland. Irish Naturalists' Journal. 24(8) 344.

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

Berrow, S. D., Long, S.C., McGarry, A.J., Pollard, D., and Rogan, E. 1998. Radionuclides (Cs-137 and K-40) in Harbour porpoises Phocoena phocoena L. from British and Irish Waters. Marine Pollution Bulletin **36**(8), 569-576.

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.

Brazier, H., and Merne, O.J. 1989. Breeding seabirds on the Blasket Islands, Co Kerry Irish Birds 4, 43-64.

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.

Carlström, J. 2005. Diel variation in echolocation behavior of wild harbor porpoises. Marine Mammal Sacience, 21(1); 1-12.

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.

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 Roaringwarer 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.

Leopold, M. F., Wolf, P.A. and Van de Meer, J. 1992. The elusive harbour porpoise exposed, strip transect counts off southwestern, Ireland. Netherlands Journal of Sea Research 29(4), 395-402.

Møhl, B. and Anderson, S. 1973. Echolocation: high-frequency component in the click of the Harbour Porpoise (*Phocoena* ph. L.). Journal of the Acoustical Society of America 54(5), 1368-1372.

O'Cadhla, O., Englund, A., Philpott, E., Mackey, M. and Ingram, S. 2003. *Marine mammal monitoring in the waters of Broadhaven Bay and northwest Mayo: 2001-2002*. Report to Enterprise Energy Ireland, Ltd., 1- 74.

Ó Cadhla, O., Strong, D., O'Keeffe, C., Coleman, M., Cronin, M., Duck, C., Murray, T., Dower, P., Nairn, R., Murphy, P., Smiddy, P., Saich, C., Lyons, D. and Hiby, A.R. 2007. Grey seal breeding population assessment in the Republic of Ireland: 2005. *Irish Wildlife Manuals (In press)*. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland. 50pp.

O'Crohan, T. 1978. The Islandman. Oxford: Oxford University Press. (First Published as Ó Criomhthain, T. 1929. An Toileánach. Baile Átha Cliath: Oifig an Tsoláthair).

Palka, D. 1996. Effects of Beaufort Sea State on the Sightability of Harbour Porpoises in the Gulf Of Maine. Report of the International Whaling Commission 46, 575-582.

Pierpoint, C. 2001. Harbour porpoise distribution in the coastal waters of SW Wales. Unpublished Report to the International Fund for Animal Welfare.

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.

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.

Santos, M.B., and Pierce, G.J. (2003) The diet of Harbor porpoises (*Phocoena phocoena*) in the Northeast Atlantic. Oceanography and Marine Biology: An annual review 2003, 41, 355-390.

Sayers, P. 1974. Peig: The Autobiography of Peig Sayers of The Great Blasket Island. Dublin: Talbot Press. (First Published as Sayers, P. 1936. Peig. Baile Átha Cliath: Clólucht an Talbóidigh).

Smiddy, P., O'Halloran, J. and O'Mahony, B. 2000. The birds and mammals of Beginish and Young's Island (Blaskets), Co Kerry (1988-2001). Irish Birds 6(4), 593-596.

Smyth, M., Berrow, S.D., Nixon, E. and Rogan, E. 2000. Polychlorinated biphenyls and organochlorines in by-caught harbour porpoises *Phocoena phocoena* and common dolphins *Delphinus delphis* from Irish Coastal Waters. Biology and Environment. *Proceedings from the Royal Irish Academy* 100B(2), 85-96.

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

Tregenza, N.J.C., Berrow, S.D., Leaper, R. and Hammond, P.S. 1997. Harbour porpoise *Phocoena phocoena* L. bycatch in set gill nets in the Celtic Sea. *ICES Journal of Marine Science* 54: 896-904.

Walton, M. J. 1997. Population structure of harbour porpoises *Phocoena phocoena* in the seas around the UK and adjacent waters. *Proceedings of the Royal Society*, London B 264: 89-94.

Appendix I: Routes of transect lines and harbour porpoise sightings for each day in the Blasket Islands cSAC

Day 1: 16 July 2007

Day 2: 24 July 2007

Day 3: 11 August 2007

Day 4: 27 August 2007

Day 5: 11 September