BOTTLENOSE DOLPHIN STUDIES IN CARDIGAN BAY, WEST WALES

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INTRODUCTION

Cardigan Bay in West Wales is home to a population of bottlenose dolphins, a portion of which at least occurs here year-round (Baines *et al*., 2000). A marine Special Area of Conservation (SAC) has been proposed by the UK government specifically to protect the bottlenose dolphins, under the EU Species and Habitats Directive, and a management plan has been drawn up (Ceredigion County Council *et al*., 2001).

Our knowledge of the status, distribution and ecology of the bottlenose dolphins of Cardigan Bay remains rudimentary, and one important objective of the Atlantic *Tursiops* project under the EU INTERREG Programme has been to gather new information specifically on population size, spatial and temporal variation in abundance, and habitat preferences for bottlenose dolphins within the Cardigan Bay cSAC. This report summarises the results of fieldwork undertaken over the summer of 2001 to address those objectives, and puts it in the context of management of the local bottlenose dolphin population.

METHODS

Study area

The main study area was the Cardigan Bay cSAC, which is bounded by the coordinates (expressed as decimal degrees) given below:

Corner	Lat	Long
S	52.0783	4.7650
W	52.2186	5.0042
N	52.4300	4.3967
E	52.2500	4.2333

Fieldwork started and ended on each day at Fishguard, which lies approximately 15 km from the south-western boundary of the cSAC. Therefore some survey effort was applied outside the main study area.

The cSAC was divided into an inshore and an offshore zone along a median line approximately 11 km (6 nm) from the coast. The area of the cSAC and its main subdivisions are given below (in km sq):

Total area	1039
Inshore	517
Offshore	522

Boat

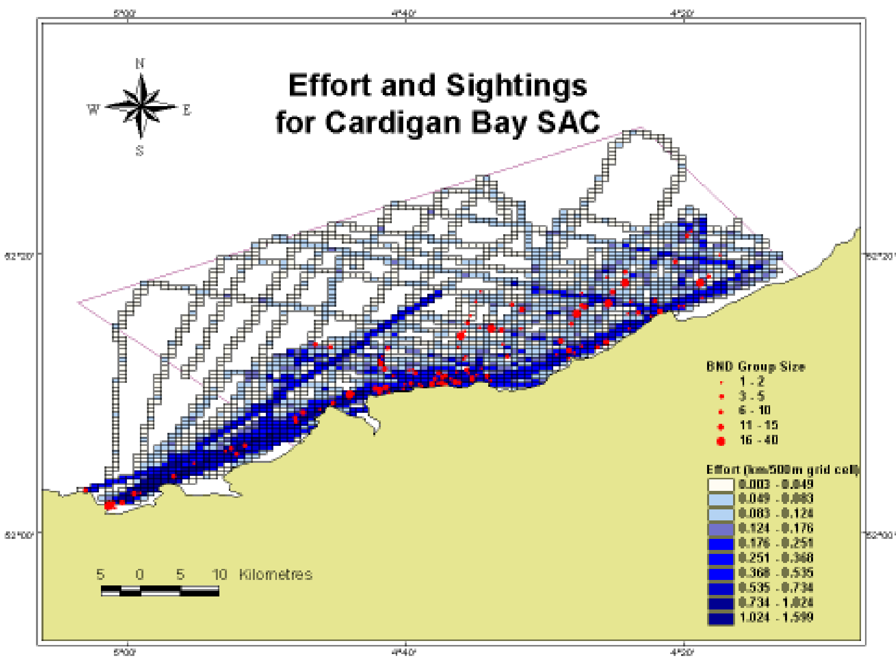
The vessel used was a 9 m boat of GRP construction, 'Ocean Breeze', powered by a 200 hp inboard diesel engine. The boat has a forward wheelhouse, on the roof of which a single observer could sit with an eye height of approximately 3.5 m above sea level. The speed of the boat through the water was maintained at approximately 12.5 km/h, however, the speed of the boat over ground was determined by the strength and direction of tidal flow.

Position data were relayed from a GPS receiver into a laptop PC running the navigation software Maptech 'Offshore Navigator'. In addition to displaying the position of the vessel overlaid on an Admiralty chart, together with transect lines and the boundaries of the study area, the program also automatically logged position, speed and course over ground every 12 seconds.

Line transect methods.

Field methods

Two sets of transect routes were drawn up at the beginning of the field season. 'Inshore transects' followed a zigzag pattern between the coast and the median line running parallel to the coast approximately 6 nm offshore. 'Offshore transects' followed a similar pattern between the coast and the outer boundary of the cSAC. A transect close inshore and parallel to the coast ('coastal') was carried out on the return from the end point of the zig-zag transect or to the start point if the zig-zag transect was carried out from east to west. The transect followed on any given day was selected at random. Transects were conducted only in sea states less than 3. Weather conditions on some occasions prevented work in the offshore zone and therefore influenced the choice of transect routes on those days. Start coordinates and bearings of each transect leg are given in an appendix.



Map showing Transect Lines and Bottlenose Dolphin Sightings from Boat Surveys, Cardigan Bay SAC, April-September 2001

A minimum of two observers took part in every survey, although on most occasions three or four observers were present. However, only one main observer was on watch at any one time.

Effort status was assigned to one of two categories: when 'on effort' the observation platform on the wheelhouse roof was manned. If no observer was present on the observation platform then effort status was 'off effort'. Effort was usually commenced before the cSAC boundary and was maintained for varied distances between the cSAC and Fishguard on the return journey. Effort was maintained throughout the survey period in the cSAC unless sea state increased to 3 or more, or photo identification mode was entered following an encounter with dolphins.

Effort was recorded on a form designed for this survey (form in appendix). An entry on the form was completed at any change in effort status, at every sighting event, at every change of course in the boat's track, and otherwise at approximately 15 minute intervals. The data recorded on the form were: time, position (latitude and longitude in degrees and decimal minutes), effort status, wind direction and force, sea state and swell height, visibility, cloud cover, precipitation, and the angle subtended by any glare in the observer's field of view. When an entry was made in response to the signal from the observer indicating a sighting, a unique reference number for the sighting was recorded in association with the effort data. The same reference number was recorded on the sightings form completed by the observer on the wheelhouse roof.

The survey vessel was out of commission for approximately 3 weeks, including the last 2 weeks of July and the first week of August. This resulted in some differences in the methods used for the 13 survey days prior to the boat being out of commission, and subsequent surveys.

For the first 13 survey days the vessel was equipped with a SIMRAD EY200 Scientific Echosounder and colour printer. The sounder was run continuously from the start to the end of effort. On each occasion when an effort record was made on the effort recording form, a button was pressed on the echosounder, causing it to print a vertical line through the trace together with an incrementing reference number. The echosounder reference number was recorded in the appropriate column in the effort recording form.

The observer continuously scanned through the forward 180°, but paying particular intention to the track line and the forward 90°. The observer searched with the naked eye but had binoculars available to examine cues if necessary. As soon as a sighting was made the effort recorder in the wheelhouse was signalled (by a knock on the roof). The observer then completed an entry in the sightings recording form (see appendix). The first priority was to check the time, estimate and record the distance and bearing of the sighting in the position at which it was first seen. For the first 13 surveys the bearing of sightings was obtained by using an electronic hand-held compass. Subsequently bearings were estimated to the nearest 5° using a compass rosette painted on the wheelhouse roof, taking the boat's heading as 0°.

Data recorded on the sightings recording form included: sightings reference number, time, species, group size best estimate and range, and number of any juveniles or calves present. Behaviour was recorded as one or more of the following categories: slow or normal swim, fast swim, feeding, leaping/splashing, tail-slaps, bow-riding, resting/milling, and sexual. The species of any associated sea birds was recorded.

If photography of dolphins appeared possible during a sighting, then the effort status changed to 'off effort' and photo identification mode was entered. When line transect effort was resumed, the boat was returned to the point at which effort had ceased before continuing on effort.

Distance estimation experiment.

In order to calibrate the distances estimated by the main observers, a distance estimation experiment was carried out in Fishguard Bay. Two black 25 litre plastic containers were tied together and moored in a fixed position, which was recorded using a GPS receiver with 5 m accuracy. The boat then approached the moored containers from a range of different directions and distances while the observers periodically estimated the distance to the target. On every occasion when a distance estimation was made, the position of the boat was recorded from the GPS. A total of 90 estimations was made (45 by each of the two main observers) from each of two observation platforms, one on the wheelhouse roof and the other from the driving position in the wheelhouse. The data obtained from the observation platform on the wheelhouse roof were used to derive a correction factor for distances estimated during sightings events.

Line transect data analysis.

Data collected in the field were prepared for analysis using the Distance software package. Initially the transects were divided into legs between turning points. During offshore transects, the legs were also divided at the points where they crossed the midline, such that individual legs were entirely within either the inshore or offshore sub-divisons of the cSAC. In addition, transects parallel to the coast within the cSAC which were carried out on the way to the start point or on the return from the end point, were classified as 'coastal'. Transect legs outside the cSAC were classified as 'extra'. The length of each leg in kms was calculated from the coordinates of the start and end points. Thus transect legs were classified as one of four types: offshore, inshore, coastal and extra.

The distances estimated in the field were corrected using a model derived from the distance estimation experiment. The model was obtained by fitting a regression line to a plot of actual against estimated distances, using a Microsoft Excel chart plotting function.

Before analysis by Distance, the data were pooled first by day and then by month, in order to test for the most appropriate level of pooling. Abundance was estimated only for the inshore sub-divison of the cSAC (no dolphins were encountered in the offshore area) although density was also estimated for the coastal and extra zones. The selection of appropriate detection functions was carried out on the basis of testing for the function resulting in the lowest coefficient of variation, as an indicator of the best fit to the data.

Photo-identification methods.

Field methods

The camera used was a 35 mm auto-focus Nikon F4, fitted with either an 80-200 mm zoom lens or a 300 mm fixed focal length lens. Colour transparency film was used, mainly Fuji 100 and 200 ASA although some Fuji 50 ASA, Kodak Ektachrome 100 ASA and Kodak Kodachrome 200 ASA were also used.

When it was considered possible to take photographs of dolphins following an initial sighting, line transect effort status was ceased, and the photographer took up a position on the bow of the boat.

Photographs were taken of the dorsal fins and backs of the animals at a perpendicular angle. Photography was attempted if the animals appeared to be approachable, irrespective of group size. Attempts were made to photograph every dolphin present in an encounter irrespective of how well marked individual dolphins were.

If photography was carried out during any encounter, a note to that effect was made on the sightings recording form. In addition, a photo identification recording form was used to record the film and frame numbers of photographs taken during particular encounters. The subject matter of 'spacer' frames exposed at the beginning and end of encounters was also recorded on the form.

Photo-ID data analysis.

The processed films were examined on a light box using a 10x magnifier. For each encounter photographed, the pictures were compared in order to identify all individual animals that had been successfully photographed. Each picture of every animal photographed was identified and the film and frame numbers together with an animal number for that encounter were entered into a spreadsheet. The best pictures of the left and/or right side of each animal from each encounter were scanned using a Nikon Coolscan II and the images stored in JPEG format.

The next step was to compare photographs between encounters and to compile a catalogue of identified individuals. Each individual identified was given a reference number, prefixed by 'L' if only a left side had been identified, an 'R' if only the right side had been identified, but without prefix if both sides of the same animal had been identified. In this way an encounter history was compiled for each identified individual. At the same time, photographs were graded for quality and assigned to one of four categories:

Photo quality grade	Criteria
0	Poor quality, not usable.
1	Below average quality, only distinctive animals identifiable.
2	Average quality, both distinctive and undistinctive animals identifiable.
3	Excellent quality photograph.

Individual animals were also assessed for distinctiveness. Animals with clearly visible nicks that would permit identification of the individual no matter which side was photographed, were considered to be distinctive or 'well marked'. All other animals, even if they had apparently distinctive white marks, rake marks or skin lesions, were assigned to the undistinctive category.

For each encounter the number of distinctive and undistinctive animals was counted and these counts were summed over all encounters in order to derive an estimate of the proportion of well marked animals in the population.

The capture histories of well marked animals were used to calculate a population estimate using program CAPTURE, run through the Windows interface of program MARK. Due to the relatively short time period of the study, births and deaths were not considered to be a significant factor and a closed population was assumed. However, it was thought that there were time differences through the field season affecting the probability of individual dolphins being photographically captured, because some animals were seen only in the early part of the season while others were seen only in the latter part of the season, when there appeared to be an influx of 'new' animals coincident with the herring spawning season in Fishguard Bay. Also there appeared to be individual heterogeneity in the probability of capture due to behavioural differences between dolphins, and between the same dolphins when seen in different encounters. Therefore the M(th) model of Chao *et al*. (1992) was selected which estimates populations with time variation and individual heterogeneity in capture probabilities. The result was multiplied by the factor derived from the proportion of well marked animals in order to derive an estimate of overall population size.

RESULTS

Effort

Number of days at sea

Surveys were conducted on 30 days between 21/05/2001 and 21/10/2001, spending a total of 287 hours at sea, of which 212 hours were on effort. However, line transects were completed on only 24 days, between 21/05/2001 and 22/09/2001 and the photographic data analysed here were collected in the period 21/05/2001 to 22/09/2001.

Distance travelled on effort

The total distance travelled on line-transect effort is given in the table below for each transect type and for all effort combined.

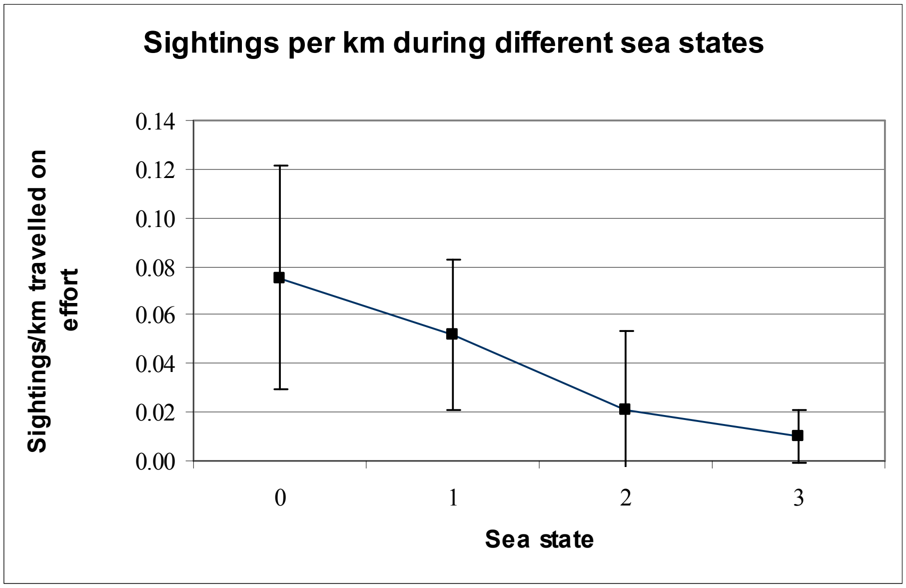
Transect type	Total distance (km)
Inshore	1026
Offshore	281
Coastal	672
Extra	202
Total	2180

The total number of kilometres travelled on line-transect effort in each month and for each transect type is given in the table below.

Line transect and Distance estimation

Sea state and detection rate

The sightings rate on line transects, expressed as the number of sightings per km travelled, declined with increasing sea state (see chart below, in which error bars indicate standard deviation). The table below shows the level of effort expressed as kilometres of line transects for each sea state; 78% of effort was in sea states 0 or 1.



Sea state	Effort (km)
0	465
1	1238
2	377
3	100
All sea states	2180

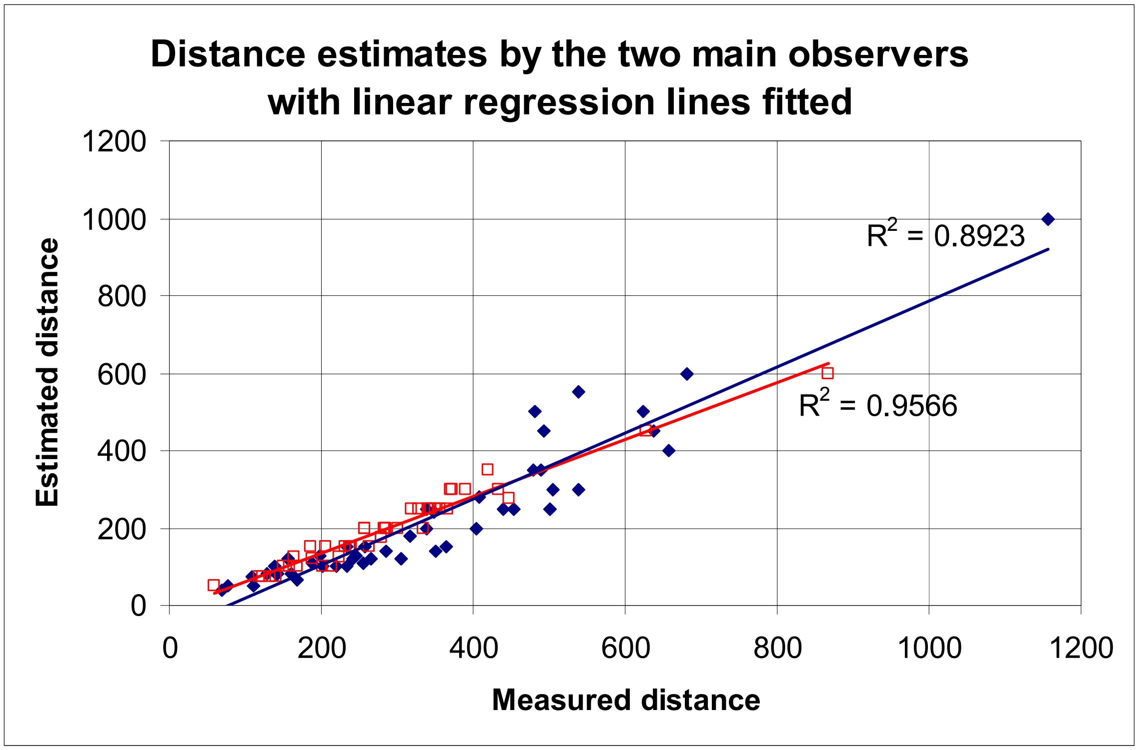
Distance estimation experiment

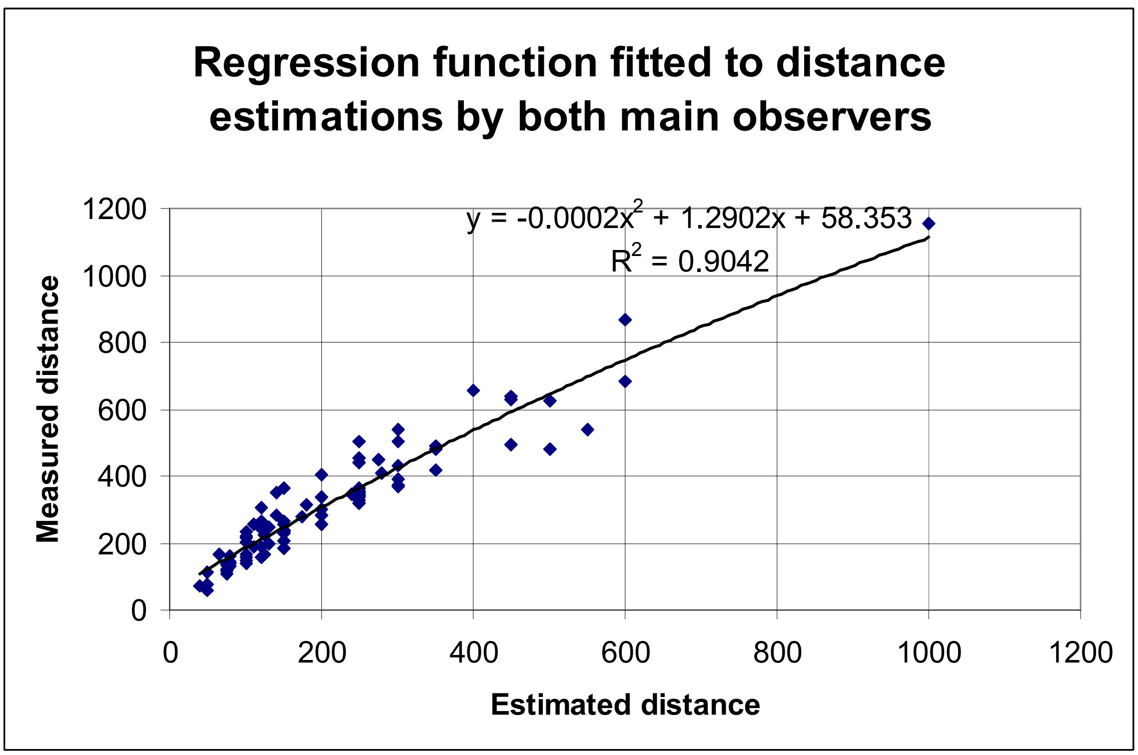
The first chart below shows a scatter plot of the results of 90 distance estimations made by the two main observers, against the actual distance measured, using a GPS receiver with 5 m accuracy. Regression lines have been fitted to the data from each of the two principle observers, together with the coefficient of determination (r^2) calculated by Excel for each regression line. Linear regression lines provided the best fit to the data of each observer, selected on the basis of the highest r^2 values.

Distances were consistently underestimated by both observers, by an average of 36% (SD = 13%). There was little difference in the accuracy of distance estimation between the two main observers, so a regression line fitted to the data from both observers combined was used to derive a factor to compensate the estimated distances recorded throughout the survey. A polynomial function provided the best fit:

$$Dc = -0.0002De^2 + 1.2902De + 58.353$$

where Dc is the corrected distance and De is the estimated distance.


Distance estimates by the two main observers
with linear regression lines fitted
Estimated distance
Measured distance
R2 = 0.8923
R2 = 0.9566
0
200
400
600
800
1000
1200


Regression function fitted to distance
estimations by both main observers
y = -0.0002x2 + 1.2902x + 58.353
R2 = 0.9042
Measured distance
Estimated distance
0
200
400
600
800
1000
1200

Sightings rates per km

The first table below shows the rates of encounters with dolphin groups, expressed as encounters per kilometre of line transect effort in each zone and for each month. The second table gives the same information for the numbers of animals per kilometre.

Abundance estimate

The tables below show density estimates (expressed as the number of clusters (i.e. groups) or of animals per square kilometre) and abundance estimates calculated by program DISTANCE, from the line-transect data. Only data from Inshore transects have been used, as no sightings were obtained from the Offshore half of the cSAC. Only data from transects carried out in sea states 0 – 2 have been used. Distance estimations were first corrected using the factor derived from the distance estimation experiment. A uniform detection function with cosine adjustment was used, as this model produced the lowest coefficient of variation and was therefore assumed best to fit the data.

The first table compares results for three different levels of pooling (not pooled, pooled by survey day and pooled by month). There was no significant difference between these estimates (each estimate fell within the 95% confidence intervals of the other two estimates), however the coefficient of variation (CV) increased with each level of pooling. The unpooled data, which produced the result with the lowest CV, were therefore used to provide the final results, indicating a mean abundance of 135 dolphins (95% CI: 85 – 214) in (the inshore half of) the cSAC between May and September of 2001.

The second table compares density and abundance estimates for two periods, the early part of the field season from May to July, and the latter part from August to September.

Inshore zone of the cSAC	**Estimate**	**%CV**	**df**	**Lower 95% CI**	**Upper 95% CI**
Unpooled					
Density of clusters	0.0759	19.68	108	0.0515	0.1117
Density of animals	0.2607	23.73	168	0.1642	0.4138
Abundance	135	23.73	168	85	214
Pooled by day					
Density of clusters	0.0765	23.11	26	0.0478	0.1222
Density of animals	0.2628	26.65	44	0.1550	0.4455
Abundance	136	26.65	44	80	230
Pooled by month					
Density of clusters	0.0835	41	4	0.0279	0.2494
Density of animals	0.2869	43.09	5	0.0993	0.8287
Abundance	148	43.09	5	51	428

Inshore zone of the cSAC	**Estimate**	**%CV**	**df**	**Lower 95% CI**	**Upper 95% CI**
May - July					
Density of clusters	0.0769	27.81	58	0.0445	0.1328
Density of animals	0.2483	33.52	90	0.1298	0.4747
Abundance	128	33.52	90	67	245
August - September					
Density of clusters	0.0746	27.78	49	0.0431	0.1290
Density of animals	0.2932	32.88	75	0.1549	0.5550
Abundance	152	32.88	75	80	287

Density estimates, sightings rates and group size for strata

Data from coastal and extra transects were used to calculate the density of dolphins, although they could not be used to produce abundance estimates because the area sampled was not known and the transects were not laid out to sample a defined area. The density of both bottlenose dolphins and harbour porpoises calculated from the four transect types are plotted in the chart below.

Coastal transects	Estimate	%CV	df	Lower 95% CI	Upper 95% CI
Density of clusters	0.0625	27.94	4	0.0292	0.1337
Density of animals	0.2128	32.01	7	0.1017	0.4452

Extra transects	Estimate	%CV	df	Lower 95% CI	Upper 95% CI
Density of clusters	0.0413	29.14	3	0.0166	0.1024
Density of animals	0.1120	35.82	6	0.0479	0.2622

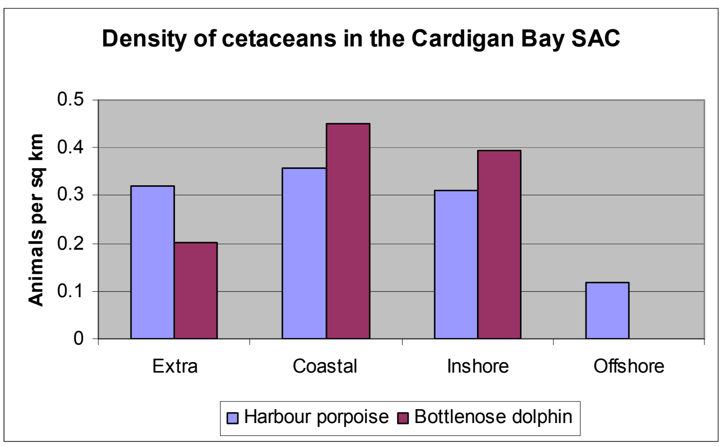


Photo-Identification

Number of films and frames exposed

Sixty-one films were used during the course of fieldwork, from which 1143 frames included usable images of bottlenose dolphins. This resulted in 443 capture events, i.e. occasions on which one or both sides of a bottlenose dolphin were photographed (an average of 7.26 individuals captured per film).

Proportions of animals photographed and of well marked animals

For each encounter, the number of individuals photographed was counted and subdivided into two groups, comprising well-marked or distinctive animals (with nicks that would allow identification from either side) and poorly marked animals (see table below, in which 'Animals photographed' is the sum of the number of different individuals photographed in each encounter). Overall, 62% of the estimated total number of animals sighted, were photographed. At first sight the data suggest that 98% of animals were photographed during those encounters when at least some photographs were obtained. However, on some occasions the number of dolphins photographed exceeded the group size estimated in the field, giving a slight positive bias to the apparent proportion of animals photographed.

The overall proportion of well-marked animals was 0.48. The proportion of well-marked animals varied however, between the early part of the field season from May to July (0.57) and the later period from August to September (0.45). These factors have been used to scale the results of analyses carried out on the sub-set of well-marked animals, in order to estimate the total population comprising both distinctive and poorly marked animals.

Period	Sum of group size estimates (all encounters)	Sum of group size estimates (encounters photographed)	Animals photographed	Distinctive animals	Poorly marked animals	Proportion of distinctive animals
May - July	228	110	96	55	41	0.57
August - September	305	230	237	106	131	0.45
May - September	533	340	333	161	172	0.48

Minimum number of animals photographically identified

The table below shows the number of individual dolphins photographed from the left or right sides only and from both sides. This suggests that the minimum number of dolphins photographed was 148 (i.e. the number of animals photographed from both sides plus the number photographed from the left side only). The number of different animals identified was estimated by a second, independent method, using the number of distinctive animals identified (74) and the overall proportion of distinctive animals (0.48), which indicates a total of 154 animals identified.

Side	Dolphins photographed
Both	64
Left	84
Right	65

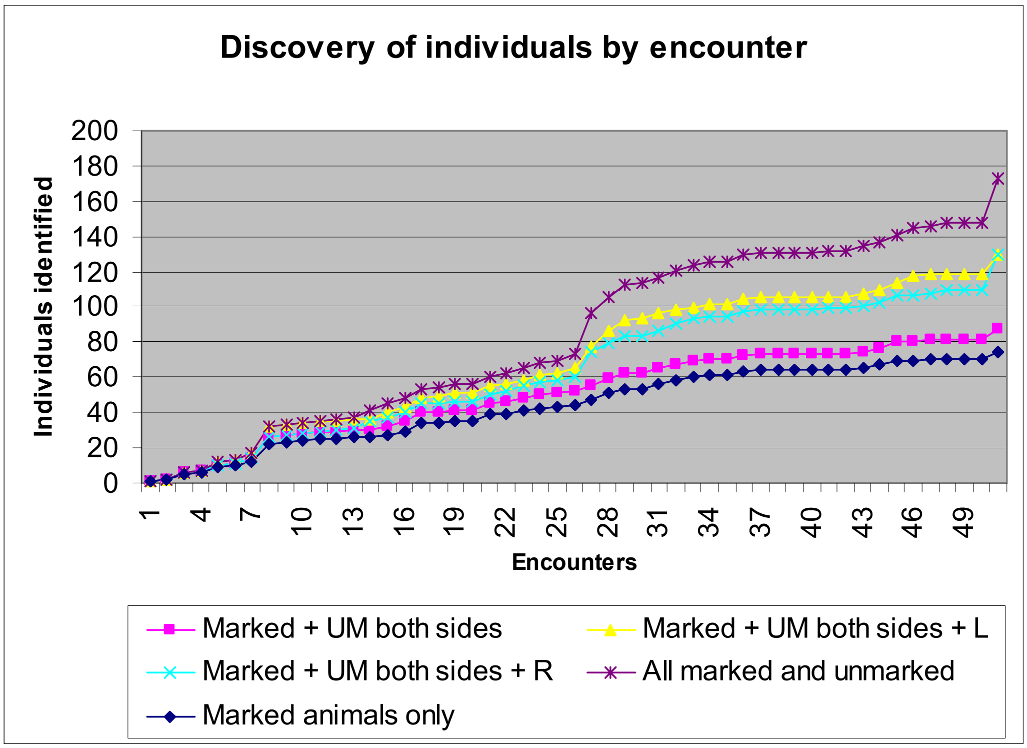
Discovery curves

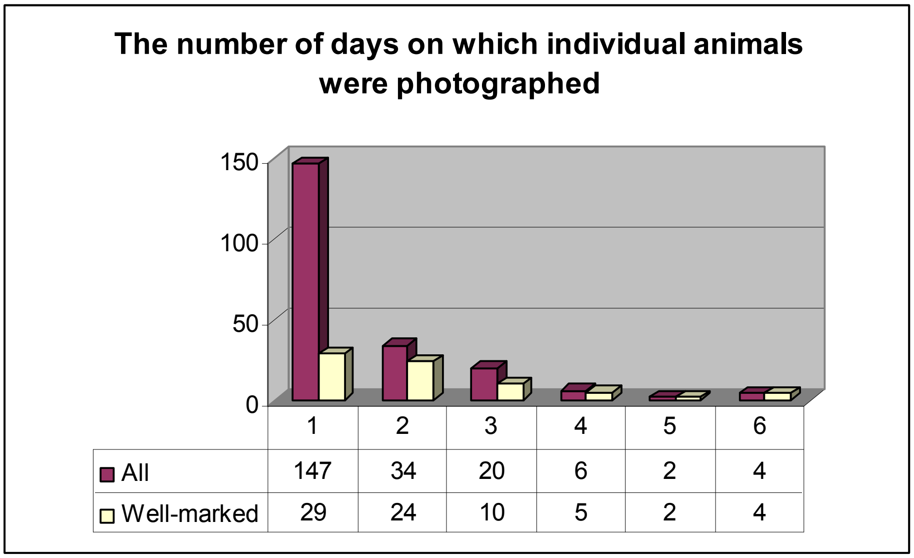
A series of discovery curves was plotted using the following sets of data: well-marked animals (WM); WM and un-marked (UN) animals photographed on both sides; WM and UN both sides and UM left side only; WM and UN both sides and UM right side only; and all marked and un-marked animals. Note that the last category is likely to contain duplicates, of un-marked animals photographed from different sides that could not be matched. The curves were plotted against an x-axis of successive encounters.

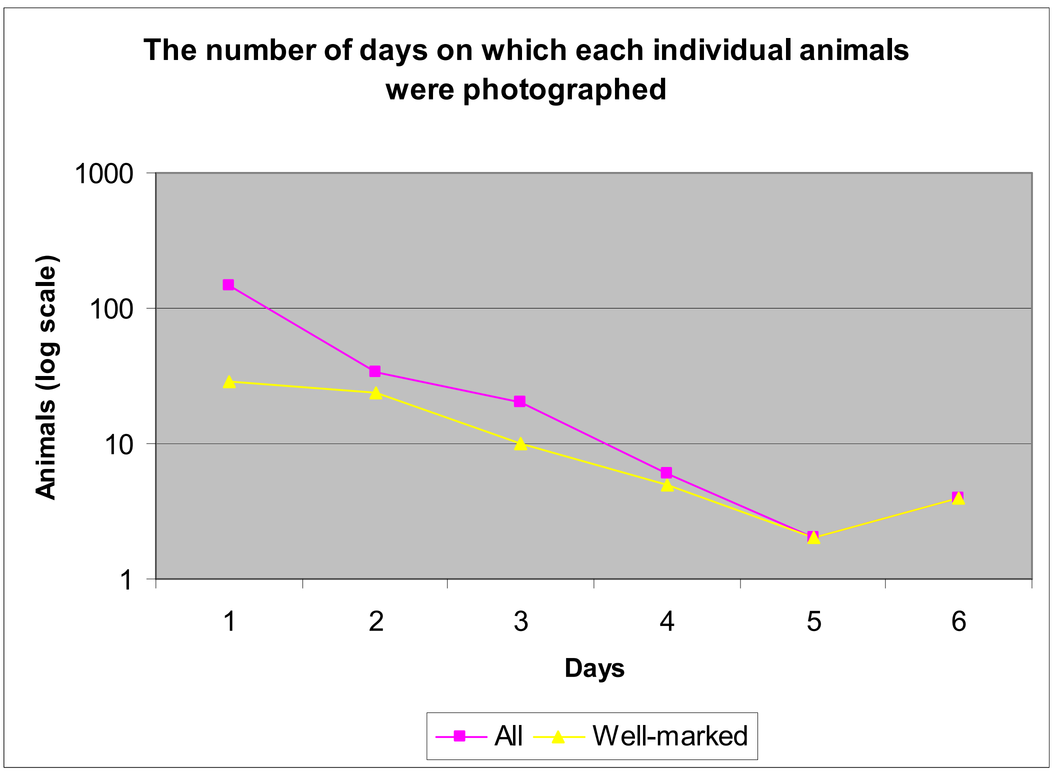
Frequency of recaptures

The table below shows the number of days on which individual dolphins were photographed; these data are plotted as a histogram below, also on a log scale in a second chart below.

Days seen	All animals	Well-marked animals
1	147	29
2	34	24
3	20	10
4	6	5
5	2	2
6	4	4







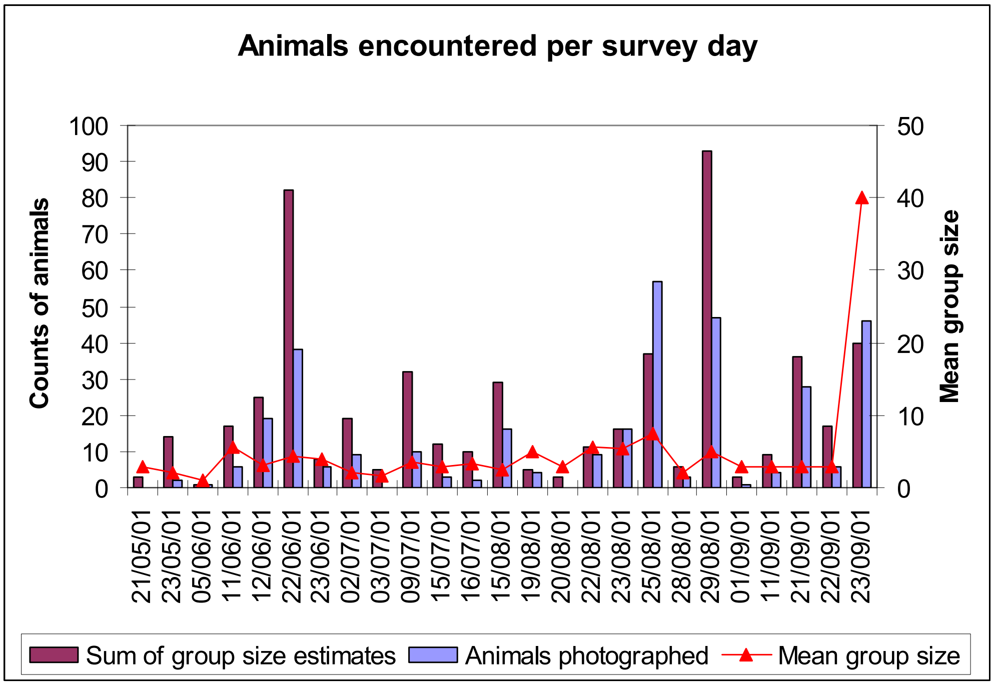
<u>Population estimate</u>

Program CAPTURE applied to data from well marked animals only, using the M(th) model of Chao et al. (1992), was used to calculate bias-corrected population estimates for the periods May to July, August to September, and for the entire field season from May to September (see table below). The proportion of well-marked animals photographed during the same time period was used to calculate estimates of the overall population sizes.

These analyses were applied to data collected from both within the cSAC, and from the area between the cSAC and Fishguard. When the data were restricted to only those encounters within the cSAC, an almost identical population estimate of 103 well marked animals for the period May to September was calculated by CAPTURE, however the standard error (12.95) was slightly higher than for the estimate made using all the data.

Period and area	Estimate	Standard error	Lower 95% CI	Upper 95% CI
Data from cSAC & west to Fishguard May - July				
Well marked animals	64	14.18	47	106
All animals	112		82	186
August - September				
Well marked animals	95	14.91	76	137
All animals	211		169	304
May - September				
Well marked animals	102	11.35	88	134
All animals	213		183	279
Data from cSAC only				
May - September				
Well marked animals	103	12.99	86	139
All animals	215		179	290

Peak daily counts of dolphins



The chart above plots the total of the group size estimates of dolphins seen on each survey day, together with the number of different individuals photographed and the mean group size for the day. The highest number of dolphins counted was on 29/8/01, when the animals were seen to be heading for the vicinity of river estuaries, especially the Teifi, but also the smaller Nyfer and Gwaun rivers, where they were observed to be feeding on sea trout or sewin, *Salmo trutta*. Note that photographic identification demonstrated that the animals seen earlier in the day heading towards the estuaries, were later encountered again in or close to the estuarine habitats. Therefore the number of different animals photographed was approximately half of the cumulative group size total for the day. The date of this event corresponds to the point on the discovery curve (point 29 on the x-axis of the discovery curve) at which the curve stepped up, indicating an influx of new animals.

The maximum group size recorded was on 23/09/2001 in Fishguard Bay, outside the SAC. Group size was conservatively estimated in the field at 40 animals, however 46 different individuals were photographed. When first encountered at approximately 8 am the dolphins were observed feeding on herring, *Clupea harengus*, that are known to concentrate close inshore in Fishguard Bay at that time of year when they spawn.

Summary of main results

Mean abundance of bottlenose dolphins in (the inshore half of) the cSAC between May and September of 2001 was estimated using program DISTANCE, at 135 dolphins (95% CI: 85 – 214). No dolphins were recorded in the offshore half of the cSAC.

The minimum number of dolphins photographed was 148 and the total number of individuals identified was estimated at 154, from the number of well-marked individuals identified and the proportion of animals photographed that were well-marked.

The overall population size was estimated at 213 dolphins (95% CI: 183 – 279), using capture-recapture statistical methods applied to photographs of well-marked individuals. The inclusion of data collected between Fishguard and the cSAC did not significantly change the population estimate, but it slightly improved the precision of the estimate.

The rate of discovery of previously unidentified individuals suggested a relatively stable ‘population’ using the study area in the first part of the field season, followed by an influx of new individuals in the period August to September. Application of the same capture-recapture model to the data from May to July, indicated a population size of 112 dolphins (95% CI: 82 – 186) for that period. Similarly, the estimates of abundance calculated by program DISTANCE suggested an increase in abundance during the latter part of the field season, although with considerably reduced precision.

The abundance values estimated for different periods and by the two different methods are summarised in the table below.

Area	Period	Method	Abundance	Lower 95% CI	Upper 95% CI
Inshore cSAC	May - July	DISTANCE	128	67	245
Inshore cSAC	August - September	DISTANCE	152	80	287
Inshore cSAC	May - September	DISTANCE	135	85	214
Inshore cSAC - Fishguard	May - July	CAPTURE	112	82	186
Inshore cSAC - Fishguard	August - September	CAPTURE	211	169	304
Inshore cSAC - Fishguard	May - September	CAPTURE	213	183	279
Inshore cSAC	May - September	CAPTURE	215	179	290

DISCUSSION

In this survey we used a combination of line transect and photo-identification methods. These two methods were used to give measures or estimates of two different parameters. Photo-identification of individual dolphins was used to estimate the size of the population using the study area, whereas the line transect data were used to estimate the mean abundance of animals in the cSAC. Because the population ranges over an (unknown) area that is greater than that enclosed by the cSAC boundaries, these two measures of abundance differ considerably.

The population estimate derived from the photo-identification data was more precise than the abundance estimated by DISTANCE sampling. However, the line transect method had the advantage of recording distribution, and by ensuring a uniform spread of effort in the study area, provided useful data for spatial analyses using a GIS system.

More individual dolphins were identified by this survey than in any previous study in any one year. The results provide the first annual estimates of abundance and population size with 95% confidence intervals for the bottlenose dolphin population in Cardigan Bay.

No dolphins were seen in the offshore half of the cSAC. Previous studies, which provided the data on which the cSAC boundaries were based, did not survey the offshore half of the cSAC (the offshore boundary was probably set at 12 nm for political/administrative convenience).

The overall population size was estimated at 213 animals, while the abundance of dolphins in the cSAC was estimated at 135 animals. This implies that the cSAC was estimated to hold only 63% of the population on average during the summer of 2001. Therefore it could be argued that the cSAC boundaries are inappropriate, both by including offshore habitats that are unimportant for dolphins and by excluding inshore habitats that do appear important. Specifically, the area between the cSAC and Fishguard should be considered for inclusion in the SAC: the largest group size encountered during the survey was in Fishguard Bay and the density of dolphins in the ‘extra’ area was comparable to the cSAC inshore zone. The exclusion of Fishguard Bay has arisen because the designation of the cSAC was based on previous fieldwork carried out from New Quay which did not extend as far west as Fishguard, and no comprehensive survey was commissioned with the aim of identifying appropriate boundaries.

The results suggest that a sub-set of the population, numbering around 112 animals, occupied the study area during the first part of the field season, and that there was an influx of animals during August, raising the size of the population in the study area to an estimated 213 dolphins. There was evidence to suggest that this influx was associated with the exploitation of seasonally available coastal food resources, i.e. sewin and herring.

Habitat use by bottlenose dolphins in Fishguard Bay reaches a peak in the autumn, coincident with the onset there of spawning by herring. Harbour porpoise numbers also peak at this time. In the days immediately following the observation of the large group of bottlenose dolphins apparently feeding on herring in Fishguard Bay, volunteer observers at Strumble Head reported groups of common dolphins and Risso's dolphins heading past Strumble Head from the direction of Fishguard Bay, early in the morning, suggesting that these species may also have been attracted to the concentration of spawning herring. The spawning stock of herring in Fishguard Bay and its ecological relationship with coastal cetacean species deserves further investigation, especially as it is currently not exploited by any commercial fishery.

The ratio of population size to cSAC area could be used to compare the Cardigan Bay SAC with the other protected areas in the Moray Firth and Brittany. Here we have a protected area of 1039 km^2 for a population of 213 dolphins, i.e. 4.88 km^2 per dolphin. However, as only the inshore half of the cSAC appears to contain habitats that are important for dolphins, we could argue that the effective ratio provides only 2.43 km^2 of protected habitat per dolphin in the population.

REFERENCES

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Western start points for offshore line transects

No.	start lat. (deg:min:sec)	start long. (deg:min:sec)	No. legs	Bearing from start (deg)	subsequent bearing (deg)
1	52:13:22	4:59:10	3	20	106
2	52:12:30	4:57:50	2	106	20
3	52:12:10	4:57:25	3	20	106
4	52:11:00	4:55:35	3	20	106
5	52:10:30	4:54:50	3	106	20
6	52:09:46	4:53:40	3	20	106
7	52:08:40	4:52:00	3	20	106
8	52:08:29	4:51:40	3	106	20
9	52:07:26	4:50:12	2	20	106
10	52:06:25	4:48:30	3	106	20
11	52:06:20	4:48:25	2	20	106
12	52:05:05	4:46:38	2	20	106
13	52:06:54	4:43:00	2	20	106

Eastern start points for offshore line transects

No.	start lat. (deg:min:sec)	start long. (deg:min:sec)	No. legs	Bearing from start (deg)	subsequent bearing (deg)
1	52:22:15	4:20:55	3	200	286
2	52:24:01	4:22:50	2	200	286
3	52:20:40	4:19:26	3	200	286
4	52:19:12	4:17:38	3	200	286
5	52:24:50	4:23:45	3	286	200
6	52:17:37	4:16:10	3	200	286
7	52:16:10	4:14:30	3	200	286
8	52:23:01	4:21:45	3	286	200
9	52:14:36	4:16:45	2	286	200
10	52:21:15	4:19:52	3	286	200
11	52:15:36	4:13:47	2	286	200
12	52:17:27	4:15:48	2	286	200
13	52:19:20	4:17:52	2	286	200

Western start points for inner shore line transects

No.	start lat. (deg:min:sec)	start long. (deg:min:sec)	No. legs	Bearing from start (deg)	subsequent bearing (deg)
1	52:08:40	4:52:01	4	106	20
2	52:08:17	4:51:23	5	20	106
3	52:07:26	4:50:05	4	20	106
4	52:07:02	4:49:31	4	106	20
5	52:06:31	4:48:47	4	20	106
6	52:05:45	4:47:35	4	20	106
7	52:05:36	4:47:25	4	106	20
8	52:04:48	4:46:20	4	20	106
9	52:06:52	4:43:23	4	20	106

Eastern start points for inner shore line transects

No.	start lat. (deg:min:sec)	start long. (deg:min:sec)	No. legs	Bearing from start (deg)	subsequent bearing (deg)
1	52:16:58	04:15:20	4	200	286
2	52:15:47	04:14:10	5	200	286
3	52:14:40	04:16:30	4	286	200
4	52:18:15	04:16:36	4	200	286
5	52:15:10	04:13:25	4	286	200
6	52:16:27	04:14:46	4	286	200
7	52:19:18	04:17:45	4	200	286
8	52:17:46	04:16:15	4	286	200
9	52:19:10	04:17:32	4	286	200