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Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation

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Sea Watch Foundation

sea watch FOUNDATION

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EXECUTIVE SUMMARY

In this report we summarise the field research conducted by the Sea Watch Foundation in 2012 on behalf of the Countryside Council for Wales. Our research goal is to monitor bottlenose dolphin and harbour porpoise populations in Cardigan Bay. The aims of this research were: to provide information on the condition of bottlenose dolphins and harbour porpoises in Cardigan Bay including both the Cardigan Bay and Pen Llyn a'r Sarnau Special Areas of Conservation (SACs) and offshore areas; to use photographic ID techniques to evaluate dolphin movements, distribution and abundance; to assess population structure; and to gather evidence of anthropogenic activities within the site. A series of boat-based surveys were conducted in Cardigan Bay using both line-transect and Photo ID techniques in order to collect data that would achieve these objectives.

Line-transect surveys in Cardigan Bay commenced in April and continued throughout the summer until late October. Twenty-seven line-transect surveys were conducted in Cardigan Bay, amounting to 3109 km travelled in favourable conditions. In addition, 101 *ad libitum* surveys took place in Cardigan Bay amounting to 1308 km travelled in favourable conditions. Bottlenose dolphin abundance estimates were calculated using Distance v. 6, and revealed a very low number (70) for Cardigan Bay SAC itself whereas a much higher estimate (330) was obtained for the entire Bay. The estimate for the Cardigan Bay SAC is lower than that calculated in 2011. This may represent a trend, although it is too early to say with confidence. Numbers in the entire Bay have not declined, so it may represent a shift in usage by the dolphins in the Bay. Along with numerous bottlenose dolphin sightings in North Wales during the summer months, particularly around the Isle of Anglesey, extending east into Liverpool Bay and north to at least the Isle of Man, dolphins may be inhabiting these more northerly waters during the summer months whereas in previous years they were observed there mainly in the winter. We experienced some exceptionally bad weather this summer which prevented us from reaching our recommended effort goals and for that reason some caution is needed when interpreting the results since the number of encounters was relatively low. Nevertheless, the results should represent a good assessment of the current status of the population in Cardigan Bay. The harbour porpoise population appears to be stable in Cardigan Bay SAC, with an estimate of 169 individuals but was lower than in 2011 for the entire Bay, with an estimate of 565 individuals. However, this may be due to effort coverage being wider and spread more evenly throughout the season than in 2011. Sightings numbers are higher and CV's are lower, leading us to believe that the estimates for Cardigan Bay SAC and the entire bay in 2012 are more accurate than those previously reported.

Photo-identification was conducted whenever possible during line-transect surveys, whilst dedicated photo ID surveys were conducted throughout the season, mainly in Cardigan Bay SAC. No new dolphins were added to the catalogue in 2012, which currently holds 248 marked, 131 left side and 132 right side individuals. Analyses were completed using the mark-recapture method, and taking into consideration a total of 52% of marked individuals in the SAC and 54% in the whole of Cardigan Bay. These are relatively low percentages of

marked individuals, most probably due to high numbers of young individuals recorded during photo ID encounters in 2012. The average marked population between 2001 and 2012 is 59% for Cardigan Bay SAC and 62% for the entire Bay. Overall population estimates for Cardigan Bay, when using a robust open population model, were 203 individuals, and 154 individuals for Cardigan Bay SAC. These estimates suggest that the population using the Bay and within the SAC, were relatively stable, with similar numbers observed in previous years. These results, combined with the lower line-transect abundance estimates; (primarily in Cardigan Bay SAC) suggest that although a similar number of animals have been visiting the bay, they may have been spending less time there. A slight increase has occurred since 2011. Immigration and emigration rates in Cardigan Bay SAC are higher than those calculated for Cardigan Bay as a whole. These are presented as gamma" - probability of an animal emigrating out of the study area; and gamma' - probability of an animal staying out of the study area. Gamma'' and gamma' trends in Cardigan Bay are relatively stable throughout the years (with the exception of 2009) whereas no real trends can be seen in the SAC suggesting a larger and more stable proportion of the population is using the entire Bay and not only the SAC.

Photo-identification surveys off the coast of Anglesey commenced in 2007, and along with data provided from the Isle of Man, these have continuously provided evidence that the bottlenose dolphins from Cardigan Bay extend their home ranges to the northern Irish Sea at least as far as the Isle of Man. 102 dolphins were identified in 2012 during surveys around Anglesey. Over 90% of those (n=93) were photographed previously in Cardigan Bay. In addition, over 90% of identified individual dolphins analysed through photos taken during 2012 in the Isle of Man were also recorded previously in Cardigan Bay. As in previous years, these data provide evidence confirming that the full geographic range of this population includes all of the coastal waters of West and North Wales, and possibly the entire Irish Sea.

More than half of the marked population is considered resident in Cardigan Bay, which also forms an important calving area. Females in Cardigan Bay SAC exhibit a relatively healthy crude birth rate of 5.3% for a closed population model, and 7.8% using an open population model. Even higher birth rates are seen for all of Cardigan Bay with values of 7.15% and 9.5% for closed and open models respectively, suggesting that the entire Bay is an important calving ground for this population. Home ranges of females with and without calves have in the past highlighted the importance of Cardigan Bay SAC as a calving ground. However, our analyses indicate that at least two more significant calving areas exist – in Pen Llŷn a'r Sarnau SAC and around the Isle of Anglesey, North Wales.

A proportion of the population (12%) was sighted only ever in Cardigan Bay SAC. A larger proportion (42%) were re-sighted in that area in at least six years of the study period and 59% were seen more than 12 times in the SAC. Although some proportion of the population still shows high residency to Cardigan Bay SAC, there is increasing evidence that the population using this SAC is declining. Potential explanations for this trend include a change in prey availability and/or increased anthropogenic disturbance. In addition, since this population is known to range much further than Cardigan Bay, it is also necessary to consider potential impacts elsewhere. Off the North Welsh coast towards Liverpool Bay, there is more offshore

renewable energy activity and pollutants are likely to be of greater significance, whilst water sports also occur more intensively in some areas there. Other offshore activities such as net fisheries and oil & gas exploration have taken place in recent years in the Irish Sea, where bottlenose dolphins occur regularly.

In order to accurately assess population trends through distance sampling and photo ID methods, a long-term and consistent data set is required. Further monitoring in Cardigan Bay and other potential areas is needed to further investigate the reasons for the trends recently observed.

1. INTRODUCTION

Cardigan Bay is one of the two main areas of UK territorial waters where there are semi-resident groups of bottlenose dolphins, the other being the Moray Firth, Scotland (Wilson *et al.*, 1997, Thompson *et al*., 2004). This population is the largest of semi-resident bottlenose dolphins in the UK (Evans and Pesante, 2008b). Two marine Special Areas of Conservation (SACs) were established in Cardigan Bay to conserve bottlenose dolphins as the species is protected under the EU Species and Habitats Directive. There is also a resident population in the Shannon Estuary, Ireland (Ingram and Rogan, 2002, 2003; Mirimin *et al*., 2011). Bottlenose dolphins are also recorded off other coasts of the UK including Cornwall, Devon, and the Hebrides, as well as in offshore waters along the Northwest European shelf edge (Evans *et al*., 2003; Reid *et al*., 2003; Hammond, 2008).

Cardigan Bay has long been known for its population of bottlenose dolphins (Morris, 1991; Mayer *et al*., 1991; Lewis and Evans, 1993) with sightings going back at least to the 1920s (Evans and Scanlan, 1989). During the late 1980s, Bob Morris started drawing the fins of bottlenose dolphins that he saw at close quarters from the town of New Quay, Ceredigion. Then in 1989, Sue Mayer and Holly Arnold from Greenpeace UK teamed up with Peter Evans and Emily Lewis-Brown from the UK Mammal Society Cetacean Group (later to become Sea Watch Foundation) to initiate a study of the Cardigan Bay dolphins using photo-identification techniques. However, it was not until 2001 that intensive photo ID surveys were started within Cardigan Bay, through a project funded jointly by the EU Interreg Programme and CCW (Baines *et al*., 2002).

From the 1990s until 2007, photo-identification effort was concentrated upon the Cardigan Bay Special Area of Conservation in the southern part of Cardigan Bay (Baines *et al*., 2002; Ugarte and Evans, 2006; CBMWC, 2007; Pesante *et al*., 2008b). Two photo ID projects stemmed from these efforts during the early 1990s (Arnold *et al*., 1997; Lewis, 1999), and a land-based study on marine mammal disturbance from 1994 (Ceredigion County Council, 1998; Pierpoint *et al*., 2009).

Since 2007, photo ID has been conducted also in the northern part of Cardigan Bay including Tremadog Bay, encompassing the Pen Llyn a'r Sarnau SAC (Pesante *et al*., 2008b). These were *ad-libitum* surveys, whilst additional important information from the region has come

from Alan Gray of Shearwater Coastal Cruises, operating out of Pwllheli. In 2011, line-transect surveys were commenced across all of northern Cardigan Bay, thus also providing photo ID information for the entire Bay (Veneruso and Evans 2012a).

From 2001 to the present day, Sea Watch Foundation (SWF) has been regularly monitoring the bottlenose dolphin population within Cardigan Bay, incorporating abundance estimates, and studies of ranging patterns, population structure and life-history characteristics from Photo ID (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al*., 2008b; Feingold *et al.*, 2011; Veneruso and Evans, 2012a, b).

There is some evidence for an overall increase in abundance since 2001, with summer population estimates ranging from 150-250 individuals (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al*., 2008b; Feingold *et al.* 2011). Cardigan Bay, and particularly Cardigan Bay SAC, is thought to be important in the summer months. However, a proportion of the population is known to remain in the region year-round (Baines *et al.*, 2002; Pesante *et al*., 2008b). It has become increasingly evident that a significant number of animals leave Cardigan Bay in winter months, moving northwards. High concentrations of individuals have been reported off the north coast of the Isle of Anglesey, in Liverpool Bay and around the Isle of Man involving animals that have been previously and often regularly identified by Photo ID within Cardigan Bay (Pesante *et al.*, 2008a; Veneruso and Evans, 2012b). At present, the waters around the Isle of Man represent the northern range limit of this population confirmed by photo ID (although bottlenose dolphins are seen regularly in the Solway Firth, no photographs exist suitable for matching), and, as of yet, Photo ID catalogues from Ireland, Hebrides, Moray Firth, Cornwall, or the English Channel have yielded no matches with the SWF Photo ID catalogue, showing no evidence of exchange outside of the Irish Sea (Pesante e*t al.*, 2008b; Sea Watch, unpublished data).

In addition to winter sightings of the species in the northern Irish Sea, bottlenose dolphins have recently been recorded off the North Wales coast and across to Liverpool Bay also in summer. Due to the intensive anthropogenic pressures resulting from industry and pollution in these regions, which are currently unprotected for bottlenose dolphins, there is some concern as to what impact these pressures may have on the population. In Cardigan Bay, scallop dredging has intensified in recent years (Woolmer, 2009; Evans and Hintner, 2010) and the effects of this activity on bottlenose dolphins are currently unknown. Further monitoring encompassing the whole of Cardigan Bay, including offshore areas, is necessary to assess potential impacts.

With several areas of the Irish Sea currently being targeted for offshore renewable energy projects and with scallop dredging ongoing, it is imperative that we accurately identify where and when particular localities are used by bottlenose dolphins so that CCW can advise on appropriate mitigation measures to minimise threats to their conservation status. Different types of measurements are required to characterise features (species presence, densities and habitat use); monitor impacts (numbers disturbed/displaced/ injured; reduction in densities); and determine significant changes in populations (time-series).

It is important for nature conservation management and measurement of the achievement of Favourable Conservation Status that reliable estimates of the number of dolphins, their trends, and the effects of human activity on the population in the SACs, are made. The UK's Common Standards Monitoring (CSM) programme led by the Joint Nature Conservation Committee (JNCC) requires monitoring of mandatory attributes in SACs across Britain. For bottlenose dolphins, the mandatory attribute is 'numbers of bottlenose dolphins using the SAC'. Population dynamics, physiological health, natural range and distribution, supporting habitat and management of human activities are valuable indicators identified as attributes for monitoring bottlenose dolphins in Welsh SACs.

An attribute considered essential to assessing the condition of the feature is the 'number of individual dolphins using the SAC' and is assessed for all sites. Monitoring, using Photo ID techniques, of individual animals by vessel will build on previous research to determine bottlenose dolphin abundance, seasonal habitat use, range, distribution and reproductive success. (Also, it is important that opportunistic monitoring occurs for other other marine mammals that inhabit the study area, notably the harbour porpoise (*Phocoena phocoena*) and grey seal (*Halichoerus grypus*), but also common dolphin, Risso's dolphin and minke whale that occasionally visit the Bay).

Annual assessments of absolute abundance in southern Cardigan Bay, have been made by Sea Watch Foundation from 2001 to 2007, mostly funded by CCW as part of a systematic monitoring programme. Since then, a scaled back programme of monitoring, which concentrated on Photo ID, along the coastal strip of the Cardigan Bay SAC with limited coverage elsewhere has been continued by Sea Watch Foundation up to 2010. This provides an estimate of the numbers of animals using that area but is insufficient to determine overall trends or whether some areas of Cardigan Bay are being used less now than others. Thus, there has been a gap of three years in monitoring this primary feature of Cardigan Bay SAC and qualifying feature of Pen Llŷn a'r Sarnau SAC. A mixture of line-transect and photo-monitoring undertaken by SWF has given a systematic and scientifically robust means of assessing changes in status and distribution. The current project combines vessel-based surveys and Photo ID throughout Cardigan Bay on a regular basis (minimum once a month) and equally spaced out in time throughout 2012.

1.1 *General Aims*

- To record, document, statistically analyse and report indicators of the condition of bottlenose dolphins and harbour porpoises in both the Cardigan Bay and Pen Llyn a'r Sarnau SACs.
- To collect images and refer to those from established catalogues, at sites within and outside the key study areas, using photographic ID techniques, to evaluate dolphin movements, abundance estimates and distribution.
- To monitor the number of bottlenose dolphins using the sites, and to assess the supporting habitat and estimate population structure (age and sex).

- To gather evidence of any anthropogenic activities within the sites, while monitoring bottlenose dolphins. This will contribute to the determination of the effect of scallop dredging on bottlenose dolphins in Cardigan Bay SAC through a measure of how the population is faring in terms of use of the area, population size and structure, and production, and will support the impact assessment.

1.2 *Objectives*

a) Record, document, and report numbers of bottlenose dolphins in Cardigan Bay SAC and Pen Llyn a'r Sarnau SAC, and more widely in Cardigan Bay in order to determine the total population using the SACs and Cardigan Bay.

b) Report on fine- and broad-scale distribution patterns of bottlenose dolphins and the relative temporal use of different parts of this range.

c) Document and report on the presence of calves and young juveniles in order to estimate the number of calves born annually by the population.

d) Measure both juvenile and calf survival rates for the population on an annual basis by monitoring the proportion of animals still alive and recording known deaths.

e) Record numbers of juveniles, female and male bottlenose dolphin adults, in order to report on population structure parameters (age and sex ratios) and site use, e.g. by family groups or bands.

f) Identify the home range sizes of individual identifiable animals, including determination of ranging movements and core areas.

g) In order to investigate the nature of the supporting habitats, e.g. estuary, headland or reef, record the number of bottlenose dolphins in each of the respective habitats and the location of each habitat within the site if necessary. Record all environmental and physical parameters at the time of recordings, e.g. tides, beach aspect, wind direction & speed, sea state, air temperature, and relevant biological information, e.g. aggregations of feeding birds or shoaling fish. The combination of information on habitat type and some of the above list will allow a preliminary assessment of habitat in the SACs. Results from this work will inform more targeted evaluation of both habitat and prey species.

h) Categorise bottlenose dolphin behavioural activities in the region (areas and proportion of time spent in resting, socialising, travel and feeding), and analyse yearly and seasonal behavioural patterns.

i) Whilst conducting the above, quantitatively record, document and report all observed incidents of:

- anthropogenic activity at each site at time of survey;
- evidence of any recent change in anthropogenic use of sites. This should be evaluated in light of any historical records changes in use or otherwise;

- bottlenose dolphin disturbance by anthropogenic or other factors, its cause and outcome;
- bottlenose dolphin absence from historically used sites that can be attributed to an activity (human or otherwise) whether the activity is present or not at the time of observation;
- entanglement of cetaceans in anthropogenic debris, e.g. fishing gear;
- significant fresh injuries commensurate with propeller or boat collision;
- evidence of body condition/health e.g. lesions.

j) To interpret past and current data, in order to provide a reasoned opinion on the status of bottlenose dolphins in the SACs and Cardigan Bay and develop targets for monitoring. A recommendation of condition should be made but CCW reserves the right to accept or reject. All available data should be integrated at the appropriate level.

k) Critically review the methodologies used and report on best scientific and fieldwork practice for monitoring of bottlenose dolphins in Wales. To include a cost benefit analysis concentrating on abundance and life history parameters but covering all attributes listed in Section 1. Alternative sampling strategies should be explored.

l) Along with CCW staff and relevant contractors, attend a meeting to discuss guidance for generic bottlenose dolphin monitoring in Wales.

2. METHODOLOGY

2.1 *The Study Area*

Cardigan Bay is the largest bay in the UK, measuring over 100 km (60 miles) across its westernmost extent and encompassing a total area of 4986.86 km^2 from the western tip of the Llyn Peninsula in the north (52˚ 47’ 45’’ N, 004˚ 46’ 00’’ W) to St David’s Head in the south (51˚ 54’ 10’’ N, 005˚ 18’ 54’’ W, Fig. 1). It is a shallow bay, with waters nowhere deeper than 60 metres and very gentle slopes (Evans, 1995). A population of bottlenose dolphins forms a primary interest of the Bay and it was for this that the Bay was first selected as a Special Area of Conservation. Early surveys by Sea Watch Foundation, Greenpeace and others in the 1990’s identified the importance of the Bay for bottlenose dolphins. Two Special Areas of Conservations (SACs) were proposed for the protection of the bottlenose dolphin, an Annex II species (designated as candidates in 2001, with full status in 2004) under the 1992 EU Habitats and Species Directive.

Cardigan Bay SAC is located in the south of the bay and encompasses 958.65 km^2, with the boundaries 52.08°N to 4.76°W; 52.22°N to 5.00°W; 52.43°N to 4.40°W and 52.25°N to 4.23°W (Figure 1). As well as being recognised as important for bottlenose dolphins, it is also thought to be a key area for Atlantic grey seals (*Halichoerus grypus*) as well as important for some fish and invertebrate species. It is a multiple interest site which has been selected for various interest features that qualify under Annex I and Annex II of the Habitats Directive such as reefs, submerged or partially submerged sea caves, sandbanks which are

slightly covered by seawater all the time, grey seals (*Halichoerus grypus*), river lampreys (*Lampetra fluviatilis*) and sea lampreys (*Petromyzon marinus*) (Ugarte and Evans, 2006; Evans and Pesante, 2008; Pesante *et al*., 2008b).

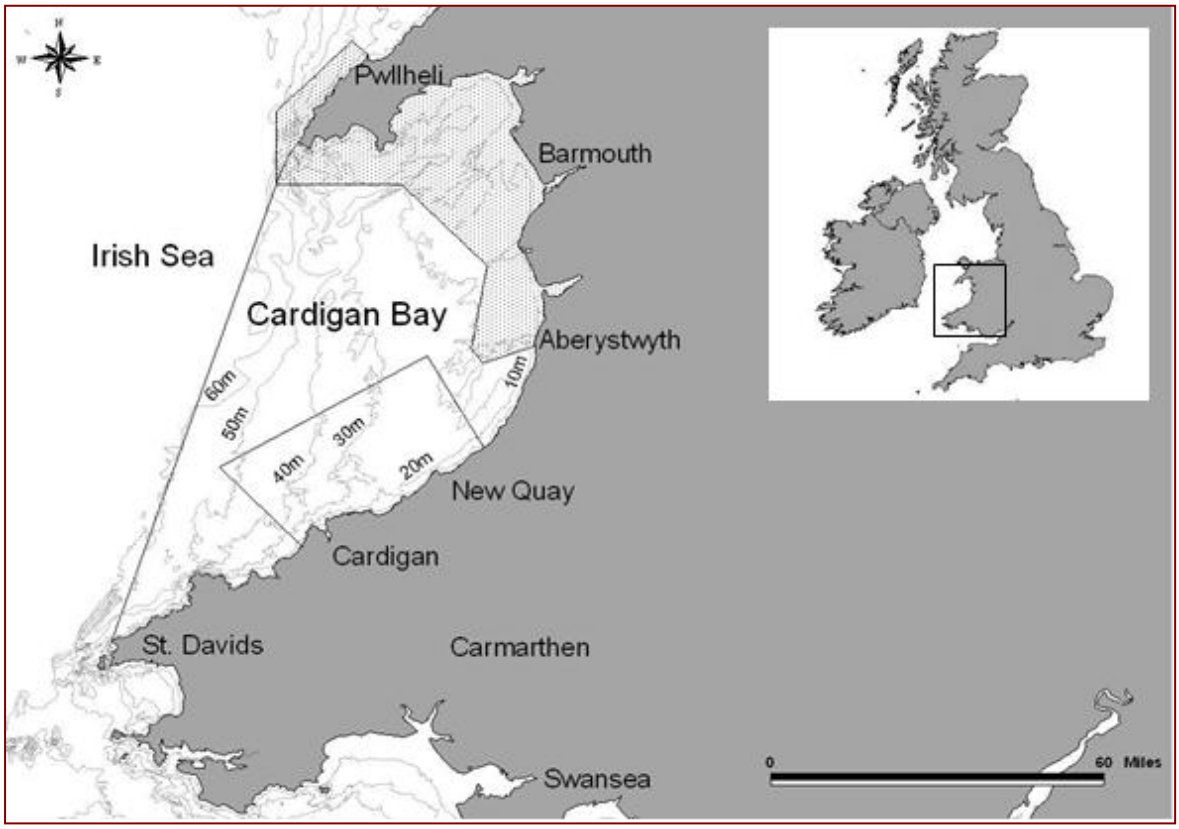


Figure 1: The study area: Cardigan Bay in West Wales. The rectangle in the south of the bay represents Cardigan Bay SAC. The hatched polygon situated in the northern half of Cardigan Bay illustrates Pen Llŷn a'r Sarnau SAC

The Pen Llŷn a'r Sarnau SAC encompasses areas of sea, coast and estuary that support a wide range of different marine habitats and wildlife. It is situated in the north of Cardigan Bay and covers an area of 1460.35 km^2. The latitudinal range of the SAC is 52.43˚N to 52.97˚N. Some additional features that are of importance in this SAC include coastal lagoons, estuaries, mudflats and the otter (*Lutra lutra*). *Ad libitum* surveys have taken place in the northern SAC since 2006 although not to the same extent as in Cardigan Bay SAC (Evans and Pesante, 2008; Pesante *et al*., 2008b; Feingold *et al*., 2011). Line-transect surveys extending throughout the Bay commenced in the summer of 2011 and have been carried out in summer 2012.

There is a significant area remaining in Cardigan Bay that is not covered by the SACs (Figure 1). Few boat-based surveys have been conducted here in the past. Winter aerial surveys, conducted in Cardigan Bay in 2007, detected bottlenose dolphins, harbour porpoise and grey seals, in the outer area. Bottlenose dolphins appeared to show a strong preference for this offshore area in winter (Pesante *et al.*, 2008b). Due to this we have included these areas in our research, and have conducted a number of boat-based surveys in areas that have not been covered in the past.

2.2 *Line-transect surveys*

Line-transect surveys were used as the data collection method from which population estimates can be derived for bottlenose dolphin and harbour porpoise. Line-transect surveys in Cardigan Bay SAC have been performed successfully in previous years, providing abundance estimates for bottlenose dolphins but also harbour porpoise and Atlantic grey seals that are known to be abundant in the region (Baines *et al.*, 2002; Ugarte *et al.*, 2006; Pesante *et al.*, 2008b, Veneruso and Evans, 2012a). The methodology used in 2012 was comparable to surveys performed in previous years in order to ensure consistency between monitoring periods.

Commencing in April 2012, dedicated line-transect surveys were conducted by SWF staff and a team of trained volunteers. These were all undertaken in favourable conditions: Beaufort sea state <3, visibility >1.5 km, and no precipitation. The surveys were conducted in Cardigan Bay SAC, Pen Llyn a'r Sarnau SAC and outer Cardigan Bay. Vessels used during these surveys are listed in Table 1.

Table 1: Vessels used for line-transect surveys in Cardigan Bay in 2011
(* Cardigan Bay SAC; ** Pen Llyn a'r Sarnau SAC)

Vessel name	Length	Eye Height (m)	Speed (kn)	Engine Type	Area surveyed
Dunbar Castle II	9.7	3.5	5-6	120 hp diesel	CB SAC*
Ma Chipe Seabrin	10	4.5	10	Twin 220 hp diesel	PL SAC**
Pedryn	11	3.0	10	350 hp diesel	PL SAC** & offshore

The same survey design that was used in previous years in Cardigan Bay SAC was adopted. Transect lines previously used by Ugarte *et al*. (2006) and Pesante *et al.* (2008b) were also used in 2012 (Figure 2). Transects were divided into two strata - inner and outer transects (split at 52.15°N, 4.89°W and 52.33°N, 4.31°W), since bottlenose dolphin density within Cardigan Bay SAC has been shown to be highest in inshore waters (Baines *et al.*, 2002; Ugarte *et al*., 2006; Pesante *et al*., 2008b; Feingold *et al*., 2010). Continuing the efforts of 2011, line-transects were conducted in Pen Llyn a'r Sarnau SAC and outer Cardigan Bay. Transects drawn up in 2011 were used, and transects were added to give greater coverage across the Bay (Figure 3).

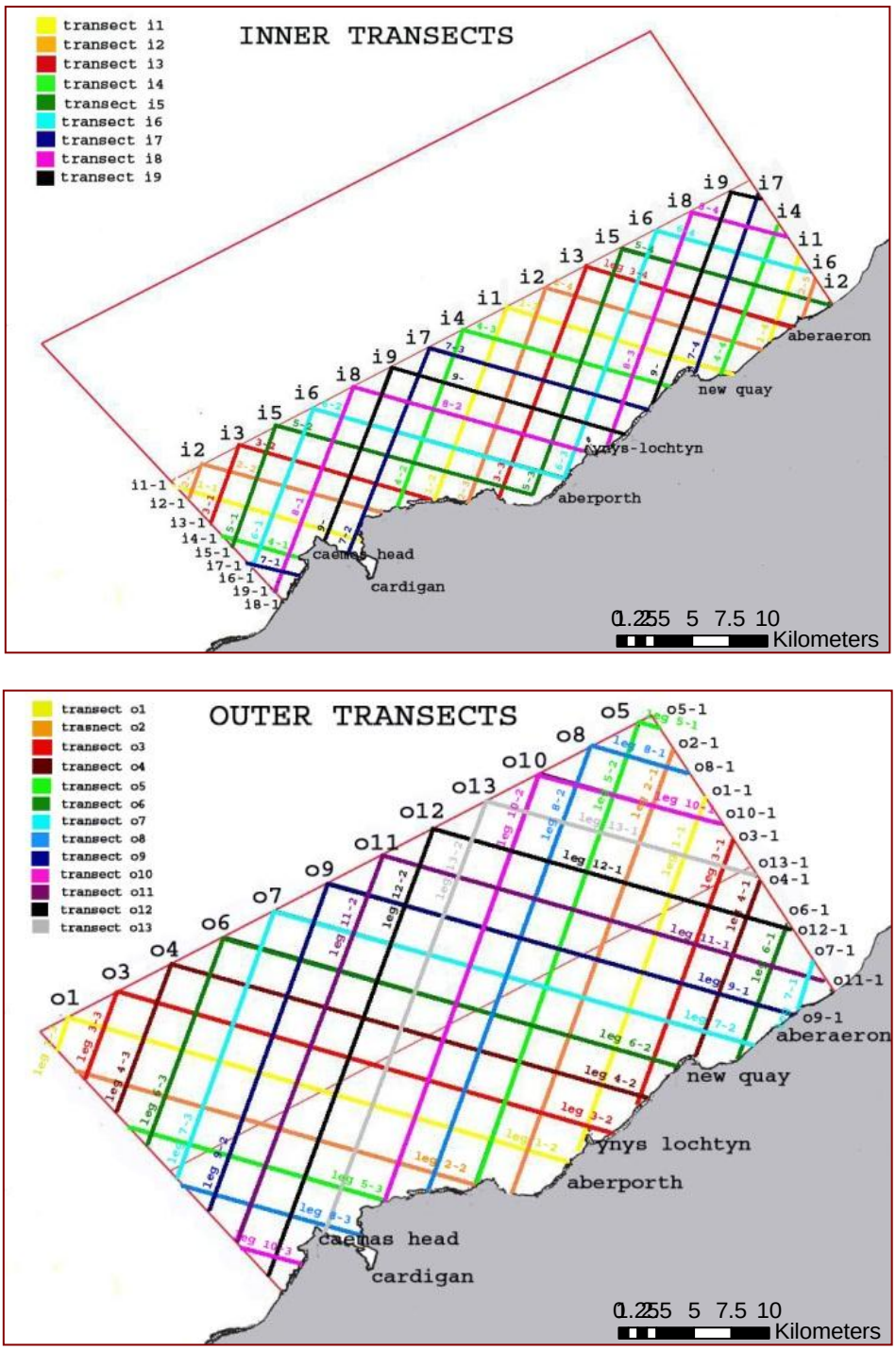


Figure 2: Transect lines (inner and outer) used for line-transect surveys in Cardigan Bay SAC

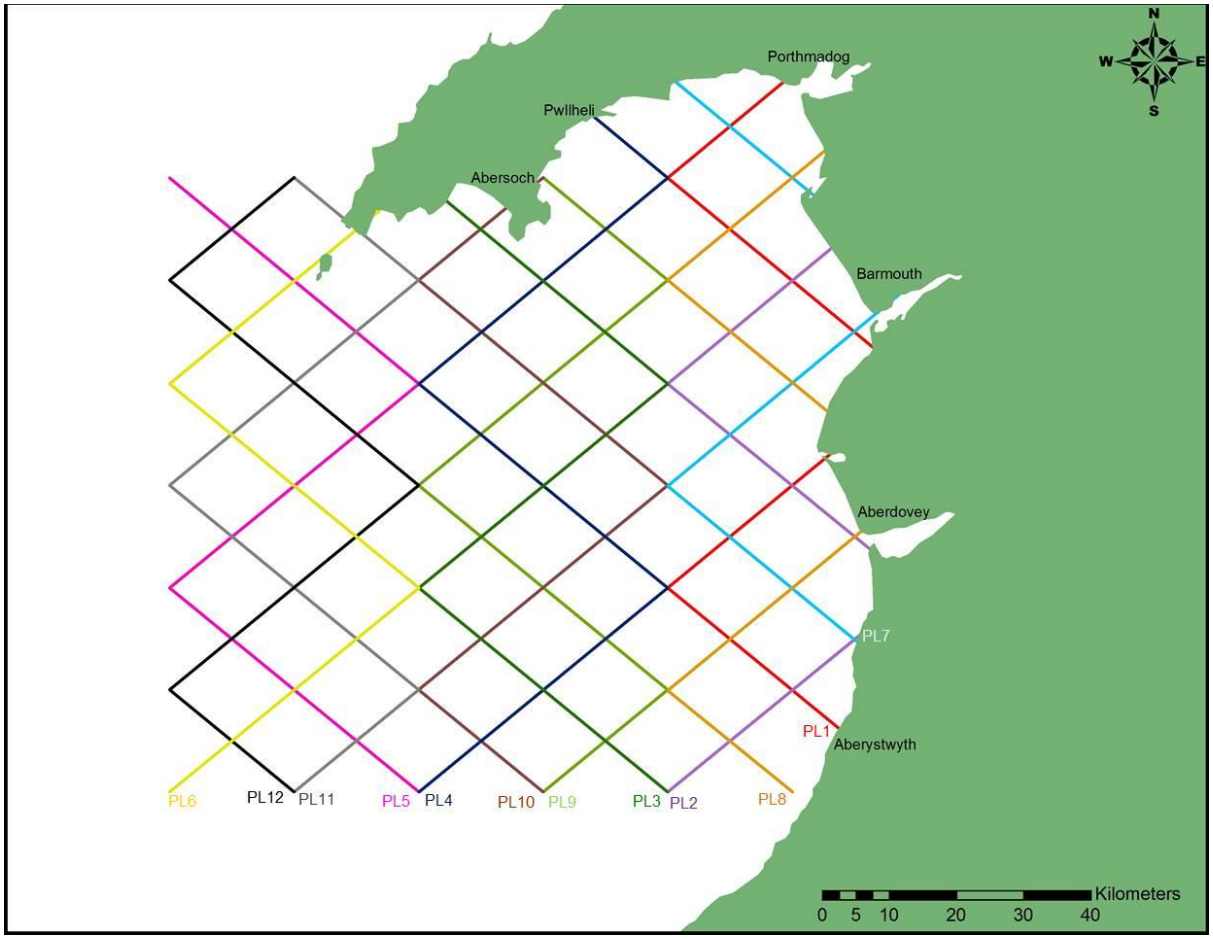


Figure 3: Transect lines designed for Pen Llyn a'r Sarnau SAC and outer Cardigan Bay (Transect numbers: PL1- red; PL2- purple; PL3- green; PL4- blue; PL5- pink; PL6- yellow; PL7-light blue; PL8-orange; PL9-light green; PL10-brown PL11-grey; PL12-black)

Transect numbers was chosen at random, and these were followed for the duration of the survey. In some cases, when weather deteriorated or when a transect could not be completed for some other reason, a different transect was chosen while in the field. Apart from one offshore survey, transects aboard *Ma Chipe Seabrin* were restricted to the inshore transects in Pen Llyn a'r Sarnau SAC (PL1, PL2, PL7, PL8, Figure 3). The route of *Pedryn* surveys was chosen before departure in order to maximise coverage. Bad weather conditions prevented us to undertake as many offshore surveys as we would have liked,

When on transect, the vessel travelled at a constant speed. This speed, of necessity, varied between vessels (Table 1). Any significant change in speed was noted on the effort form (Appendix 4), as was any movement away from the transect line, such as to conduct Photo ID. When this occurred, the vessel returned as close as possible to the position where the track line was left and the transect was resumed.

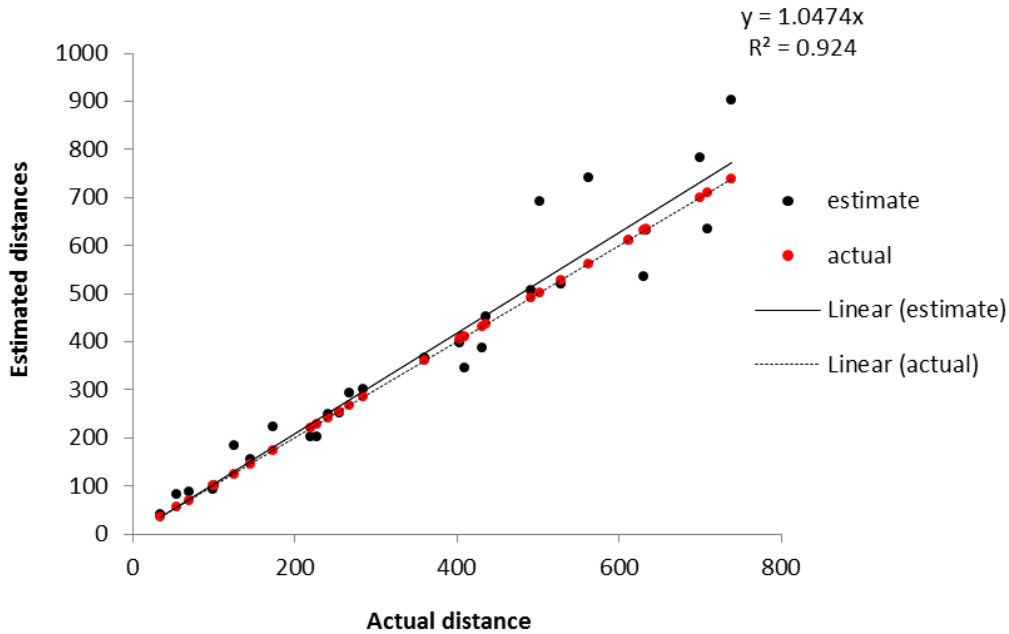
During the majority of the surveys, a double platform of observers was used, consisting of two pairs of observers. Observers were paired so that at least one was experienced with a minimum of 20 hours of survey time achieved.

Two primary observers (POs) were positioned on the roof of the vessel for one-hour shifts. These observers scanned from abeam (90°) on their side to 10° on the opposite side. POs scanned with the naked eye and used binoculars only to investigate possible sightings. Observations of marine mammals were recorded on a standardised 'sighting form' (see Appendix 2).

Line-transect surveys for abundance estimation make a number of assumptions. The first assumption is that every school (animal) is detected on the transect line itself; in other words, the detection function referred to as g(0) equals one. This assumption is very rarely if ever satisfied, so various methods have been developed to try to provide an independent estimate of g(0), the most common of which are to use double platforms and/or double observers. Another assumption is that animals do not move prior to detection. However, cetaceans, of course, do move. Random movement with respect to the survey platform causes a negative bias in abundance estimates, but this bias is small so long as the survey platform travels quickly relative to the animals. A survey speed of 10 knots is typically taken as a minimum, whilst unless sea conditions are calm, speeds of 15 knots or greater introduce problems of perception bias (i.e. animals are available to be detected but are missed by the observer). Movement in response to the survey vessel can be a greater problem. It is not uncommon for some cetacean species (e.g. bottlenose dolphin) to be attracted to survey ships, and others to avoid them (e.g. harbour porpoise). The obvious solution is to search sufficiently far ahead of the vessel that animals do not respond before they are detected. This is best achieved by having a high platform, and by using powerful binoculars. Typically, two observers look either side of the track-line (out to 90°), a third observer independently (i.e. isolated from the other two both visually and audibly) looks at a distance along the track-line, and a fourth person coordinates sightings and records these, together with effort & environmental information.

In our surveys, two independent observers (IOs) were positioned where they could have the best view of the track line without being seen by the POs and thus obtaining information about g(0). –the detection function - when g(0) < 1. The key to distance sampling analyses is to fit a detection function to the observed distances, and use this fitted function to estimate the proportion of objects missed by the survey. On *Dunbar Castle II*, IOs could only be positioned near the stern of the vessel, where the view of the track line was partially blocked by the wheelhouse. IOs aboard *Ma Chipe Seabrin* and *Pedryn* were positioned further forward and had a clear field of view. IOs concentrated their effort on the track line, scanning from 45° on their side to 10° on the other, for one-hour shifts. Scanning was conducted entirely with binoculars in an attempt to detect sightings at a distance, mainly to spot the animals before any potential responsive movement. Sightings were reported on an 'independent observer' form (Appendix 3). It was important that the IO did not communicate their sightings to the POs. Once the sighting had passed the beam, the person dedicated to effort checked with the POs whether they had detected that particular sighting and recorded

this on the IO form as a duplicate sighting. Duplicates were then removed from the database for analytical purposes to avoid over estimating sighting rates.



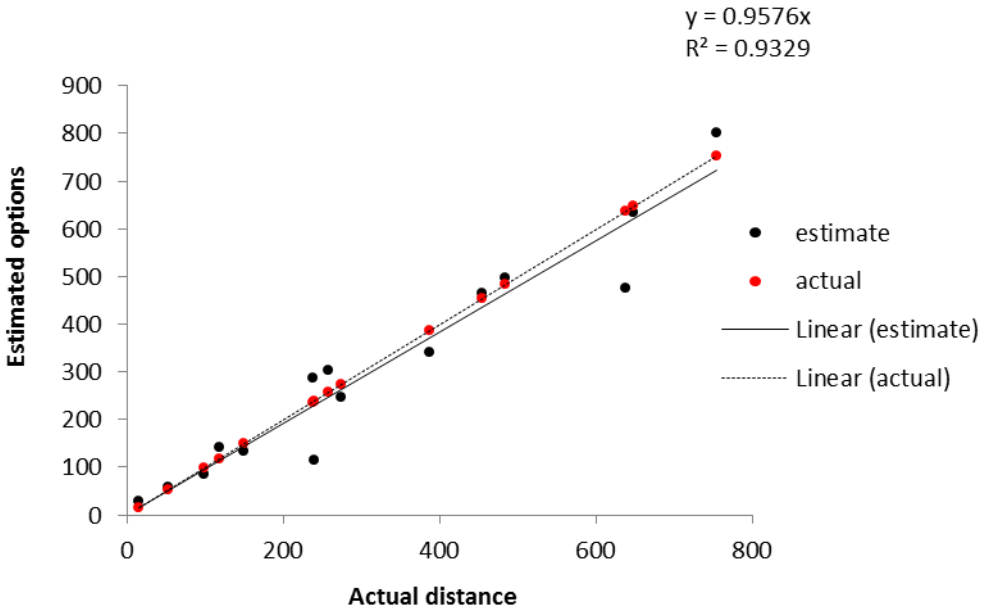


Figure 3.2: Plot of distance to the buoy measured by the GPS, against the distance estimated by two experienced observers

Both POs and IOs estimated the distance to the animals when first detected. The survey team was given regular distance training sessions by testing them with objects at known ranges. For the majority of sightings, distances were checked by SWF staff. The distances from the boat to an anchored buoy were estimated using a handheld GPS. During these trials, the boat stopped at different distances from the buoy, ranging from only a few metres to nearly 800

metres. At each point, the observers estimated the distance to the buoy and wrote it down without communicating with each other. A plot of the distance to the buoy measured by the GPS against the distance estimated by two experienced observers (Monitoring Officer and Research Assistant) are presented in Figure 3.2. A regression line fitted to these data and set to intercept at the origin, had an average slope of 0.928. Slopes revealed no significant differences and before analysis, all the distances estimated during the study were transformed by multiplying them by the inverse of 0.928, or 1.07.

The angle between the vessel bow and sightings when first detected was recorded using an angle-board. Rounding was avoided for both distance and angle readings.

One person was dedicated to recording effort using the 'effort form' (Appendix 4), which logged the vessel journey and environmental variables throughout the survey. One line was filled on the form each time any of the variables collected changed (sea state, visibility, swell height, boat course, end of transect leg, etc). Otherwise, if none of these variables had changed, a line of effort was recorded every 15 minutes by default. The track of the vessel was recorded continuously using GPS. The number and type of boats in view was recorded during every line of effort in order to have a record of boat traffic in the vicinity of the location. Four types of effort were considered during the survey: a) line-transect, where the vessel travelled along the pre-defined transect line with dedicated observers scanning for sightings; b) dedicated search, where POs were on duty but the boat was not following a transect line. This occurred when leaving the transect line to conduct Photo ID, or once the transects for the day had been completed and the vessel returned to port; c) casual watch, with no dedicated observers scanning for cetaceans (e.g. when weather conditions turned bad or the boat had to stop for any reason); d) photo identification, when the boat approached and persisted with a group of dolphins at close range in order to obtain images used for Photo ID.

When dolphins were detected, where possible, the line-transect survey was paused and the vessel left the track line in order to approach the animals for photo identification. The method used for Photo ID is explained in section 2.3. Once the group had been comprehensively photographed, the vessel travelled to the point that the vessel last left the transect line and resumed the line-transect survey (Figure 4).

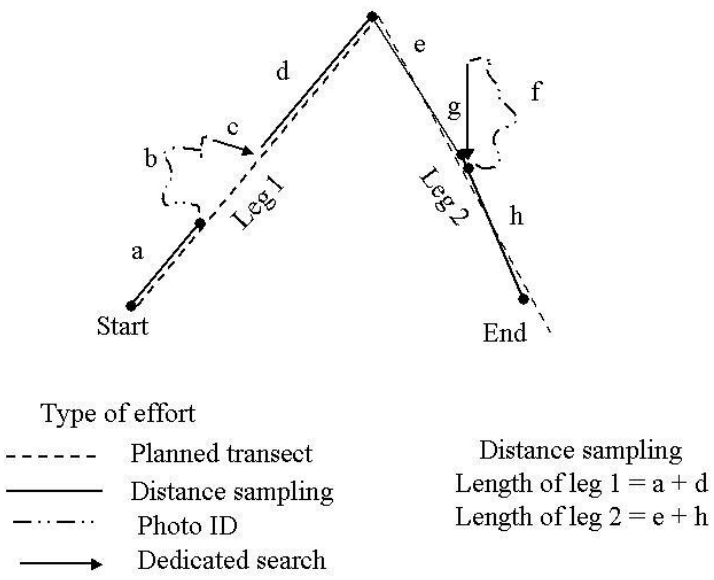


Figure 4: Schematic representation of two transect legs temporarily interrupted in order to take Photo ID pictures

2.3 *Data Analysis - Line-transect surveys*

Effort and sightings data were entered into Microsoft Excel, and plotted using ArcGIS v. 10.1. Following Ugarte and Evans (2006), the distance of each sighting was adjusted according to the results of the distance test and calibration experiment taken by SWF staff. Perpendicular distances of animals from the track-line are calculated from measures of the angle and distance of each sighting from the observer, so that the effective strip width can be calculated (since this varies with observation height and sea conditions prevailing at the time), using version 6.0 of the software program Distance (Buckland *et al*., 2001, 2004; Thomas *et al*., 2010). For that, the length of each effort leg, sea state, the radial distance, angle and group size of each sighting, and the area of each stratum were imported into the program. In our case, the platform heights of all three vessels used were very similar. Abundance estimates were calculated for bottlenose dolphin and harbour porpoise using sightings recorded only by the PO's. A half normal cosine Multi Covariates Distance Sampling model was used, sampling the data for sea state, and truncating all observations to 600 m, which usually provided the lowest AIC value, as recommended by Buckland *et al*. (2001, 2004). Previous data from 2005-07 and from 2011 were treated similarly. For some previous years, however, it was not possible to truncate to 600 m due to low sample size of sightings, and in those cases a 700 m truncation was used instead.

Effort and sightings data were examined to investigate temporal variation in sightings and group composition, and to assess activity budgets. Statistical analyses were performed using SPSS v. 21. To test for significance between group size and month, a Kruskal-Wallis test was used.

2.4 *Ad libitum surveys*

In addition to the line-transect surveys, *ad libitum* surveys were conducted within Cardigan Bay SAC and Pen Llyn a'r Sarnau SAC using two vessels, *Boat Gallois* and *Pedryn* (Table 2). Trained SWF volunteers also joined local dolphin-watching trips kindly provided by two commercial boat operators, 'New Quay Boat Trips' and 'SeaMor'. During these trips, SWF staff and volunteers collected effort and sightings data, and when dolphins were sighted close to the vessel, took photographs for Photo ID purposes.

Table 2: Vessels used during *ad libitum* surveys in Cardigan Bay in 2012

Vessel name	Length	Eye Height (m)	Speed (kn)	Engine Type
Ermol V	11.5	2.5	6	Twin 128 hp diesel
Ermol VI	10.9	2.5	6	350 hp diesel
Islander	7	2.5	6	Twin 60 hp petrol
Boat Gallois	5	1.5	8	60 hp petrol

2.5 *Data Analysis - Ad Libitum surveys*

Effort and sightings data were entered into Microsoft Excel and along with data collected from line-transect surveys, we investigated temporal variation in sightings, group composition, and activity budgets, and to test for significance between group size and month.

2.6 *Photo Identification*

Photo ID is a mark-recapture method that makes use of naturally produced markings. Bottlenose dolphins are an ideal study species for this technique since many acquire nicks and scratches on the dorsal fin and body from interactions with other individuals. These are unique to individual animals and, with good quality photographs, are recognisable. In the early 1990's, Sea Watch Foundation began its own catalogue of images collected in Cardigan Bay. Since 2001, this has grown and been maintained to the present day by regular dedicated Photo ID surveys. In 2007, the catalogue was extended to include data from surveys conducted in North Wales and around the Isle of Man, resulting in a catalogue of individuals reported for the wider Irish Sea. This non-invasive method has proved very successful and has been used to assess abundance and population trends, define habitat use and fidelity, and home ranges, as well as to investigate social structures and study life history (such as birth and death rates) (Ugarte *et al.*, 2006; Pesante and Evans, 2008; Pesante *et al.*, 2008b; Feingold *et al.*, 2011, Veneruso and Evans 2012a, b).

In 2012, images used for Photo ID were collected during dedicated surveys (line-transect and *ad libitum*), onboard passenger trips and during land-based watches from New Quay Harbour. In some cases, images were also provided from others including Janet Baxter (Friends of Cardigan Bay), Alan Gray (Shearwater Cruises) and Tom Felce (Manx Whale and Dolphin Watch). Members of the public were also encouraged to send in their photos, taken during

sightings from passenger trips or from New Quay Pier, so long as some basic sightings information was provided, including date, location and group size.

Photographs obtained by SWF were taken using a Canon 40D and a Canon 7D camera body with 18-200 mm, 18-300 mm or 75-300 mm telephoto zoom lens. During dedicated surveys, dolphins were approached to 20-50 metres. Photographs were obtained under CCW licence, following their protocols.

Information on behaviour of bottlenose dolphins was collected during sightings onboard every survey, both line-transect and *ad-libitum.* A dolphin group was defined as any group of dolphins observed in apparent association, moving in the same direction and often, but not always, engaged in the same activity (Shane, 1990). Behaviours were recorded on a standardised 'sighting form' (see Appendix 2). Four main behaviours were collected:

Feeding - Characterised by individuals moving in various directions without an obvious pattern. Performing deep dives often preceded by fluke up or peduncle arches. Definite feeding is noted only when animals are seen directly pursuing a fish (e.g. fish jumping at the surface) or with fish in their mouth. 'Suspected feeding' was also noted when all the characteristics are seen apart from the actual fish.

Resting - Characterised by slow movements with no apparent direction. Dolphins are usually seen, either floating on the surface or surfacing slowly, exhibiting low activity levels.

Travelling – Dolphins are seen moving in a persistent and directional manner, exhibiting regular patterns of surfacing and diving.

Socialising – Characterised by dolphins swimming in close proximity, showing high levels of close interaction and often breaking the surface.

2.7 *Data analysis - Photo ID*

Photo ID matching was performed using ACDSee Pro. All matched encounters were confirmed by a second person. Software programs MARK 6 and CAPTURE were used to calculate population estimates using mark-recapture analysis. A closed population model (Chao Mth) was used for Cardigan Bay, and separately for Cardigan Bay SAC. A Robust Design Method was also conducted for the open population model on data acquired from both areas. Having a long data set for Cardigan Bay SAC (2001-12) has enabled us to run the robust model and let it estimate all parameters. Then for the second model, a mean survival rate (S) value calculated from all years was taken and constrained to a constant value for each year. MARK cannot distinguish between permanent emigration and mortality, and without constraining survival rates some unreasonable estimates for S may occur suggesting a high mortality in the winter between field seasons, whereas in fact it may just be that animals have moved away permanently. The data set for wider Cardigan Bay is not as large, containing data from 2005-12, and, therefore, S values were not constrained to a constant value for the robust model in this case.

Behaviour data were analysed by comparing percentages of all behaviours recorded. Behaviour analyses were combined for all surveys in Cardigan Bay SAC (line-transects and *ad-libitum*), and also analysed separately for line-transect surveys in Cardigan Bay overall. Only two *ad-libitum* surveys were made in Pen Llyn a'r Sarnau SAC (since most effort there was now by line-transect), hence analyses were not conducted for all surveys in Cardigan Bay. Sightings in which behaviours were not recorded or unidentified, were omitted.

3. RESULTS

3.1 *Line-transect surveys*

A total of 27 line-transect surveys took place between April and October 2012, covering 3109.54 km of survey effort. Of these, 1864.79 km were conducted in line-transect mode (Table 3). A total of 101 bottlenose dolphin, 87 harbour porpoise and 115 grey seal sightings were recorded. Of these, 48 bottlenose dolphin sightings were detected from the transect line, as well as 75 harbour porpoise and 76 grey seals (Table 4).

As anticipated, our surveys indicate that bottlenose dolphins have a strong preference for inshore waters, as seen in previous years. Although much lower effort was invested in offshore surveys, five bottlenose dolphin sightings were recorded outside of Pen Llŷn a'r Sarnau SAC, and an additional five bottlenose dolphin sightings were recorded within the gap between the two SACs (Figure 6). No sightings of this species were recorded south of Cardigan Island.

Harbour porpoises and grey seals were relatively widely distributed, with detections in both inshore and offshore waters (Figure 6). Harbour porpoise clusters were observed in the southern part of Cardigan Bay SAC around Cemaes Head and regularly spotted offshore in both SACs. Grey seals were recorded throughout the study area both inshore and offshore.

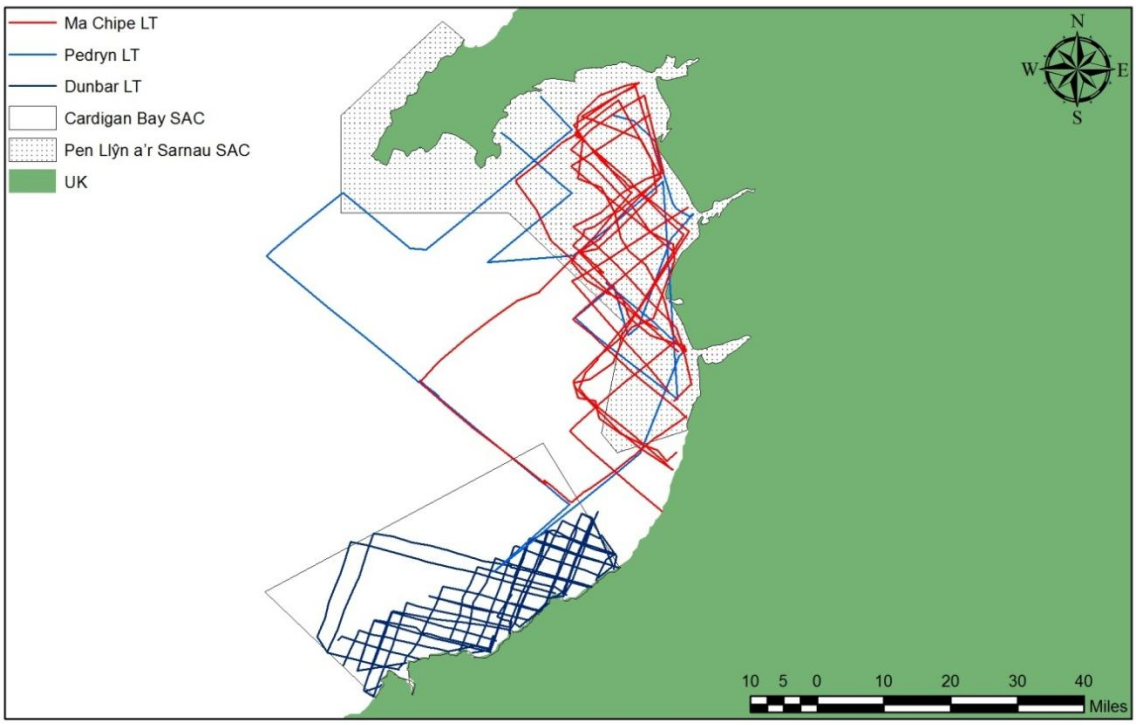


Figure 5: Tracks of line-transect (LT) surveys conducted in Cardigan Bay in 2012. Coloured lines represent tracks from different vessels

Table 3: Line-transect (LT) survey effort conducted in Cardigan Bay in 2012

Vessel	No. surveys	Km travelled	Km travelled in LT mode	Km in inner transects	Km in outer transects
Dunbar Castle II	18	1364.04	686.05	565.52	120.52
Ma Chipe Seabrin	7	1222.74	852.36	699.69	152.67
Pedryn	2	522.74	326.36	172.21	154.15
TOTAL	27	3109.54	1864.79	1437.43	427.35

Table 4: Marine mammals sightings yielded from line-transect (LT) surveys conducted in Cardigan Bay in 2012 (BND - bottlenose dolphin; HP - harbour porpoise; GS - Atlantic grey seal)

Vessel	No. BND sightings	No. BND in LT mode	No. HP sightings	No. HP in LT mode	No. GS sightings	No. GS in LT mode
Dunbar Castle II	84	31	47	39	76	39
Ma Chipe Seabrin	13	13	32	29	33	32
Pedryn	4	4	8	7	6	5
TOTAL	101	48	87	75	115	76

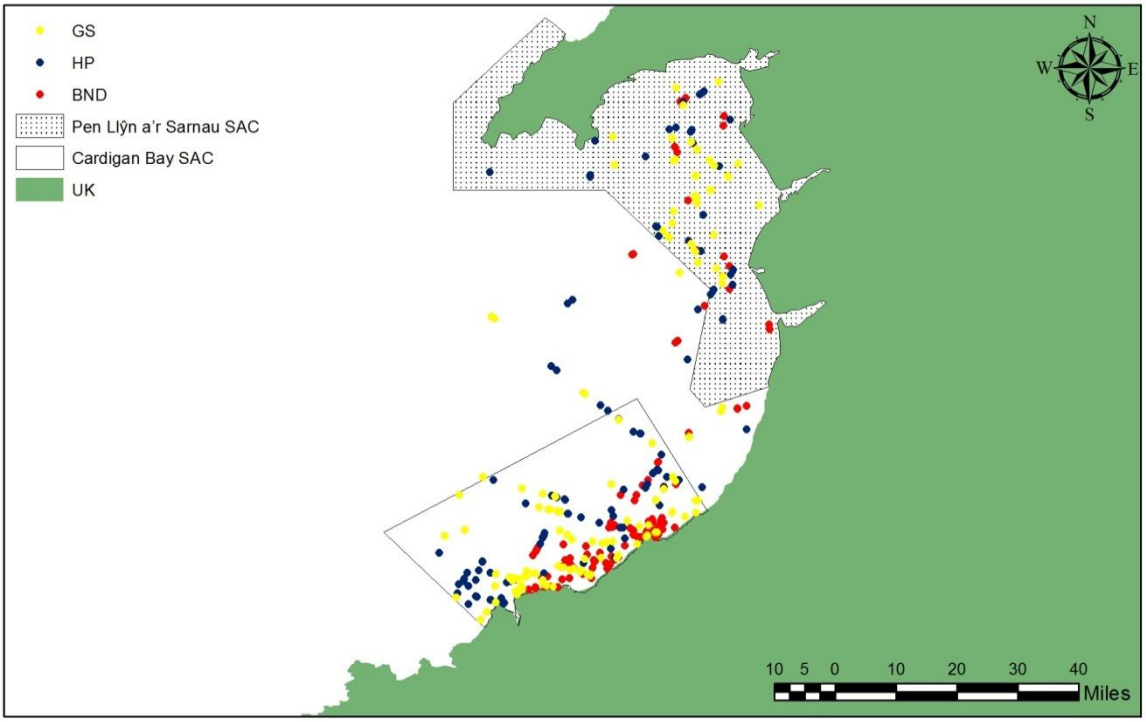


Figure 6: Sightings recorded during line-transect surveys in Cardigan Bay in 2012
(BND = bottlenose dolphin - red; HP = harbour porpoise - blue; GS =Atlantic grey seal - yellow)

Table 5: Abundance estimates of bottlenose dolphin (BND) and harbour porpoise (HP), from line-transect surveys in Cardigan Bay 2011-12

Definition	BND 2011	BND 2012	HP 2011	HP 2012
Abundance	309	330	1074	565
95% CI	179-353	203-534	634-1821	379-840
CV	0.28	0.24	0.28	0.20
Observations	27	32	42	57

Abundance estimates for the whole of Cardigan Bay were calculated using Distance v. 6, and are presented in Table 5. All calculations were made using a 'Multiple Covariate Distance Sampling test (MCDS)' sampled for 'Sea State' (cf. Buckland *et al*., 2001, 2004; Thomas *et al*., 2010). The mean abundance estimate for bottlenose dolphins was 330 individuals, slightly higher than in 2011 (309 individuals). However, CV values remain higher than we would desire (where possible, one aims for CVs of 0.15-0.20, although few of the estimates during the international SCANS surveys achieved this level of precision). Harbour porpoise abundance estimates were 565 individuals in the wider Cardigan Bay, a much lower value to that estimated in 2011 (1074 individuals). Detection functions for both species are presented in Figure 7.

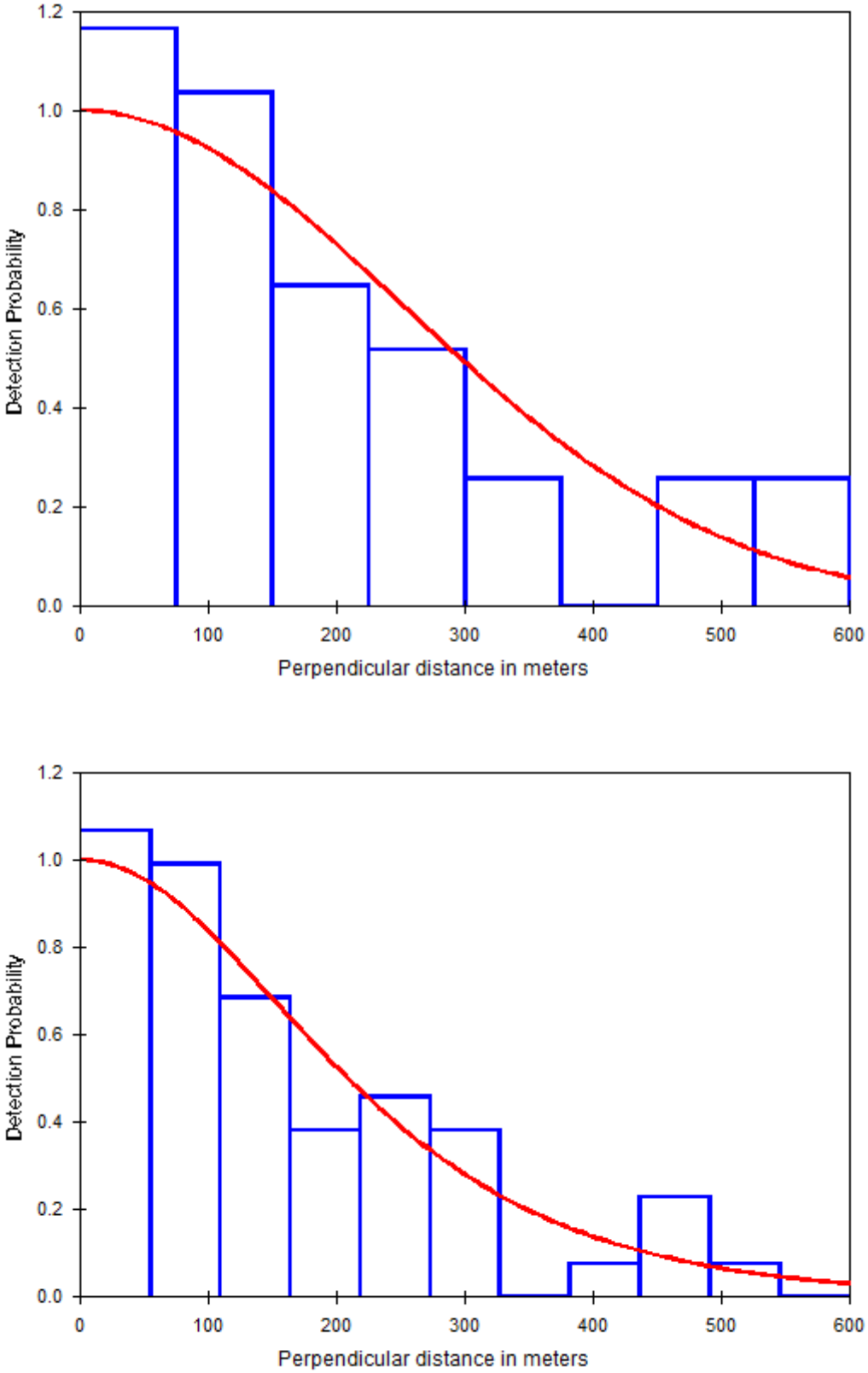


Figure 7: Detection function of bottlenose dolphins (top) and harbour porpoise (bottom) in Cardigan Bay 2012

Initial efforts during the first years of the Cardigan Bay monitoring programme was concentrated primarily in Cardigan Bay SAC, contributing to a long-term population estimate data set for this area. Therefore, abundance estimates were also calculated for Cardigan Bay SAC alone (Table 6). An estimate of 70 bottlenose dolphins was calculated for this SAC. In previous years, when regular line-transect surveys were undertaken (Ugarte *et al.*, 2006; Pesante *et al.*, 2008b), a general increase in abundance was observed between 2003 (N=140) and 2006 (N=214), but in 2007, numbers dropped markedly (N=109). An estimate of 114 individuals was obtained in 2011 (Veneruso and Evans, 2012a), although further modelling truncating the detection function to 600 m revises this value to 133 individuals. The estimate of 70 individuals for 2012 represents a very low number of dolphins for Cardigan Bay SAC (Table 7). The harbour porpoise population estimate (169) for Cardigan Bay SAC is much lower than that exhibited in 2011 (340). However, the CV value in 2011 was very high and the number of encounters was low (n=20) whereas the estimates for 2012 are relatively similar to those presented in previous years (2005-07) suggesting the harbour porpoise population in the SAC is relatively stable (Table 8). Detection functions for both species are presented in Figure 7.

Table 6: Abundance estimates of bottlenose dolphin (BND) and harbour porpoise (HP), from line-transect surveys in Cardigan Bay SAC in 2012

Definition	BND	HP
Abundance	70	169
95% CI	37-131	96-296
CV	0.32	0.29
Observations	19	32

Table 7: Comparison of abundance estimates between years of bottlenose dolphins in Cardigan Bay SAC

Year	Abundance	95% CI	CV	Observations
2003	140	69-284	0.36	19
2004	-	-	-	-
2005	139	88-218	0.23	49
2006	214	108-422	0.35	30
2007	109	49-239	0.41	24
2011	133	75-235	0.29	29
2012	70	37-131	0.33	19

Table 8: Comparison of abundance estimates between years of harbour porpoise in Cardigan Bay SAC

Year	Abundance	95% CI	CV	Observations
2003	236	148-337	0.24	50
2004	215	136-339	0.23	46
2005	170	121-240	0.17	81
2006	161	109-238	0.20	57
2007	182	123-269	0.20	49
2011	340	140-828	0.46	20
2012	169	96-296	0.29	32

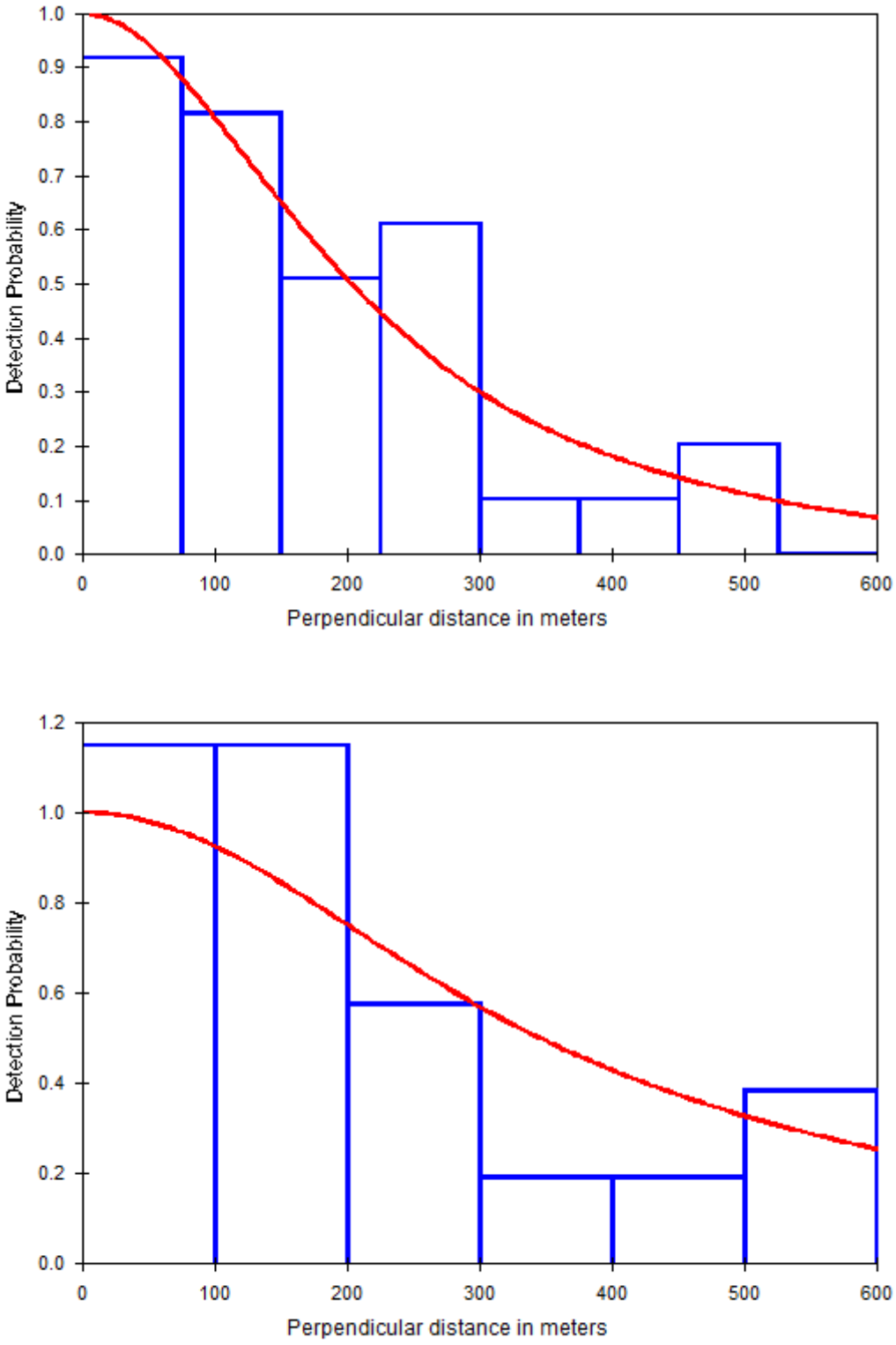


Figure 8: Detection functions of bottlenose dolphins (top) and harbour porpoise (bottom) in Cardigan Bay SAC

Seasonal patterns of sightings occurrence (sightings per km effort travelled) were collected during line-transect surveys in Cardigan Bay. There was a peak in sightings in June and July, particularly the latter month (Figure 9). Average group sizes, on the other hand, were relatively constant throughout the summer in Cardigan Bay (Figure 10). Most group sizes here varied between 1-5 individuals, with few groups numbering over ten individuals (Figure 10a), and those were mainly during June and October (Figure 10b). However, no significant differences in group size were observed between April and October 2012 (X^2 = 4.44, df = 6, p = 0.617).

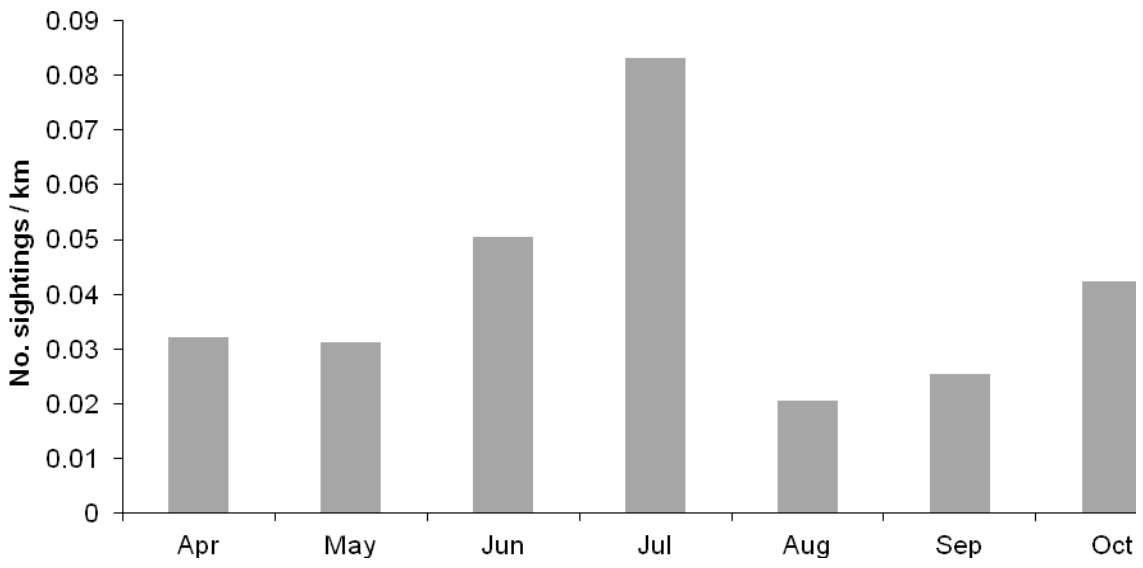


Figure 9: Number of bottlenose dolphin sightings per kilometre travelled, recorded from line-transect surveys each month in Cardigan Bay 2012

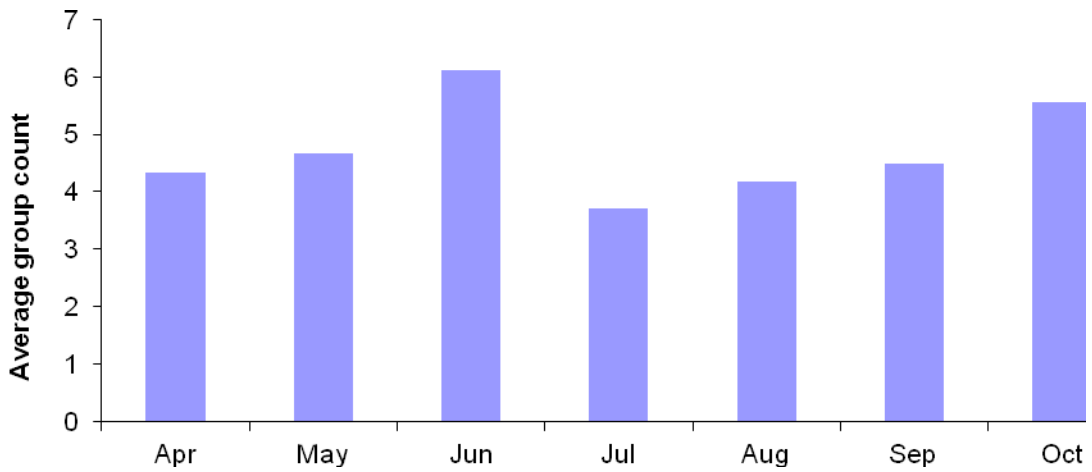


Figure10: Average group size of bottlenose dolphins recorded from line-transect surveys each month in Cardigan Bay 2012

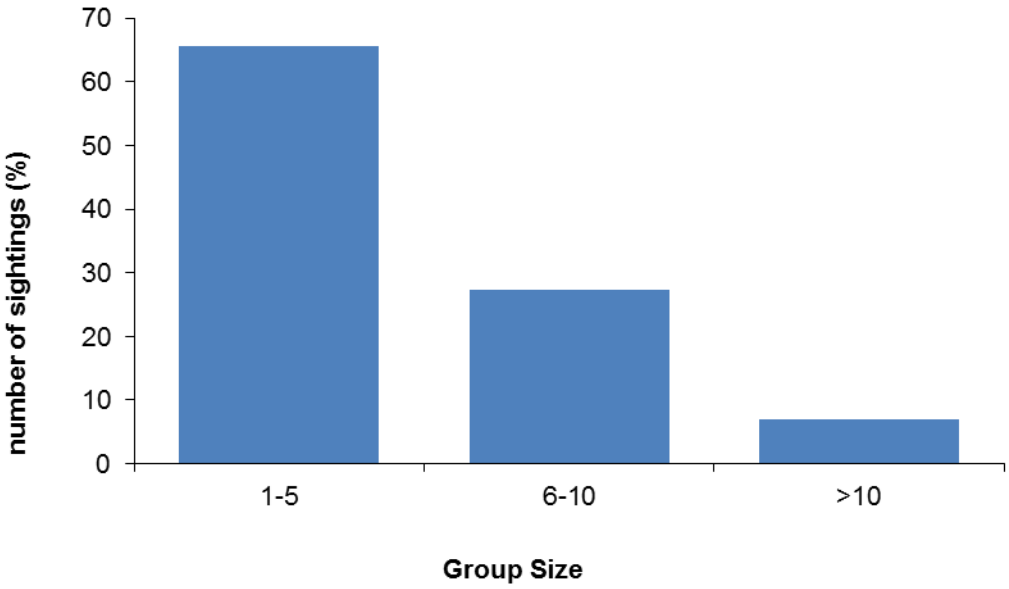


Figure10a: Bottlenose dolphins group sizes recorded from line-transect surveys in Cardigan Bay 2012

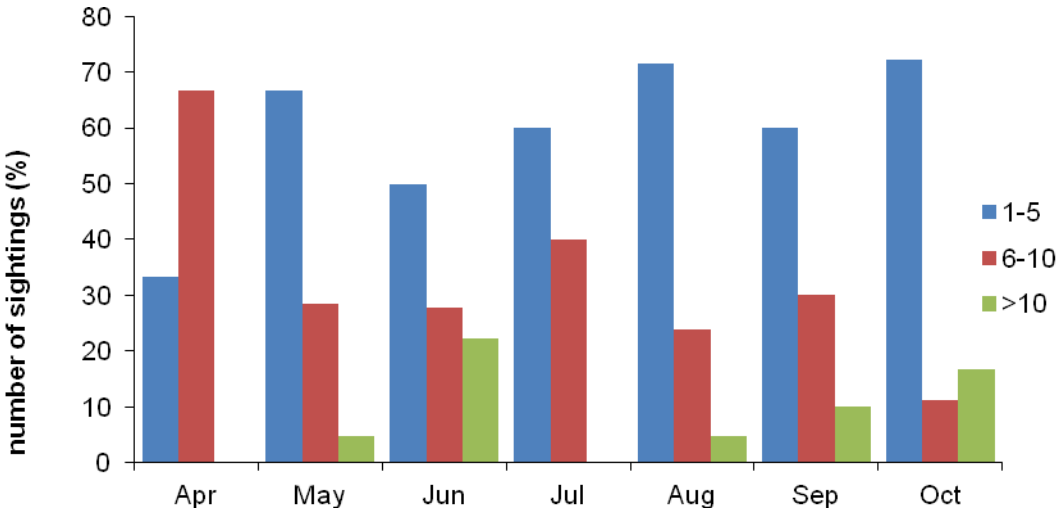


Figure10b: Bottlenose dolphins group sizes recorded from line-transect surveys in Cardigan Bay 2012

3.2 *Ad Libitum surveys*

Ad libitum surveys were conducted regularly throughout the season mainly in Cardigan Bay SAC on board *Boat Gallois*. Two surveys also took place on board *Pedryn* in Pen Llyn a'r Sarnau SAC. In addition, a number of dolphin-watching boats in the region were used as platforms of opportunity to collect regular effort, sightings, and Photo ID data (Table 9).

Table 9: Total effort and sightings recorded during *ad libitum* surveys in Cardigan Bay in 2012

Vessel	No. surveys	Km of effort	BND sight.	BND sight/km	HP sight.	HP sight/km	GS sight.	GS sight/km
Ermol V	33	633.51	51	0.08	0	0	53	0.083
Ermol VI	34	288.94	41	0.14	1	0.003	29	0.1
Islander	20	138.38	38	0.27	0	0	12	0.086
Boat Gallois	12	280.24	22	0.07	8	0.028	12	0.042
Pedryn	2	99.56	1	0.01	2	0.02	0	0
TOTAL	101	1440.65	153	0.58	11	0.052	106	0.313

All marine mammal sightings recorded in Cardigan Bay SAC from *ad-libitum* boat based surveys were widely distributed in coastal waters with a hotspot off New Quay. However, effort was highest at New Quay since all vessels, except *Pedryn*, departed from this location. Harbour porpoise and grey seals were also widely distributed along the coast. Grey seal sightings occurred particularly between New Quay and Ynys Lochtyn, but since this was also the most common route taken by commercial boat operators, effort was most intense in this part of the SAC, so that seals may be over-represented on this route compared to the rest of the SAC.

3.3 *Activity Budgets*

Bottlenose dolphins were recorded in four main behaviour activities: feeding, travelling, resting, and socialising. An additional category of 'suspected feeding' was noted when dolphins were seen performing deep dives often preceded by fluke up or peduncle arches although no visible prey was seen. 'Suspected feeding' may indicate that feeding activities are taking place below the surface or that dolphins are engaging in behaviours related to searching for food though not necessarily being successful, otherwise termed 'foraging'. In most cases, 'suspected feeding' is a combination of foraging and successful feeding. Behaviours collected during line-transect and *ad-libitum* surveys in Cardigan Bay SAC in 2012 illustrate activity budgets of 55% travelling, 41% suspected feeding, 22% feeding, 14% socialising, and 2% resting (Figure 11). Since dolphins feed under the surface, and underwater visibility in the Bay rarely enables a clear sight of animals to any depth, the dolphins may be using the area for feeding more than these estimates suggest. Since prey is not actually visible during 'suspected feeding', it is possible that the dolphins are spending more time foraging for food but not necessarily consuming fish. An increase in the proportion of time foraging implies a shortage of food, whereas an increase in successful feeding implies the opposite. As expected, a large proportion of the budget in 2012 (55%) is used for

travelling, and the lowest proportions recorded are socialising (14%) and resting (2%). A comparison of activity budgets with previous years within Cardigan Bay SAC was made between 2005 and 2012 (Figure 12). Travelling is the predominant behaviour recorded in Cardigan Bay SAC, with similar percentages throughout the years, whereas socialising and resting activities are the least recorded. Feeding activities show no apparent trend throughout the years although a peak in feeding activities is seen in 2012 (Figure 12a). A rising trend in 'suspected feeding' is seen since 2006, suggesting dolphins are spending more time foraging for food, although not necessarily with success. It may well be that dolphins are spending more time searching for food as it is less abundant in the SAC. Further spatial analysis will demonstrate whether this is also taking place in Pen Llyn a'r Sarnau SAC or if this is a local occurrence. Seasonal behaviour budgets (April-October) confirm that travel is the predominant behaviour throughout the season with resting and socialising being the least recorded in all months (Figure 13). When examining trends for feeding and 'suspected feeding' (Figure 13a), inverse trends are apparent with feeding activities declining and 'suspected feeding' rising, suggesting dolphins are spending more time searching for prey though not necessarily consuming it in the latter part of the season. April was omitted from this analysis due to low sample size (n=8).

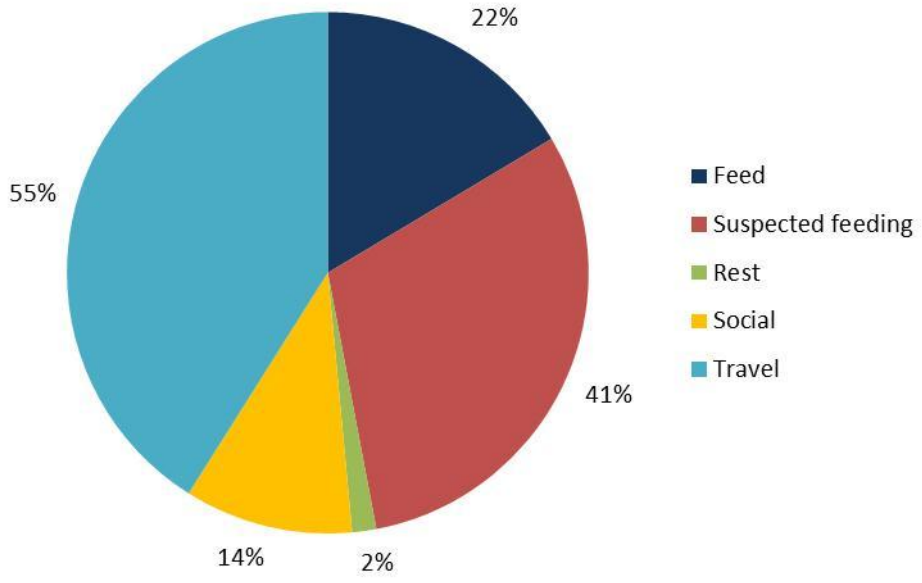


Figure 11: Behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC in 2012 (n=99)

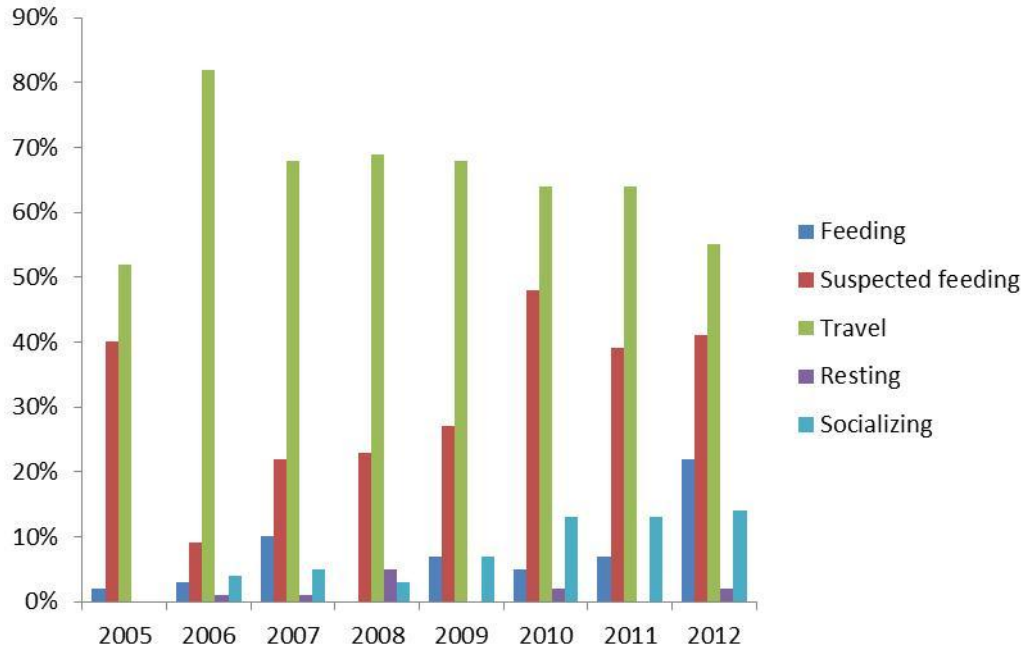


Figure 12: Comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-12 (all behaviours) (n=87,77,88,39,59,56,83,99 respectively for each year)

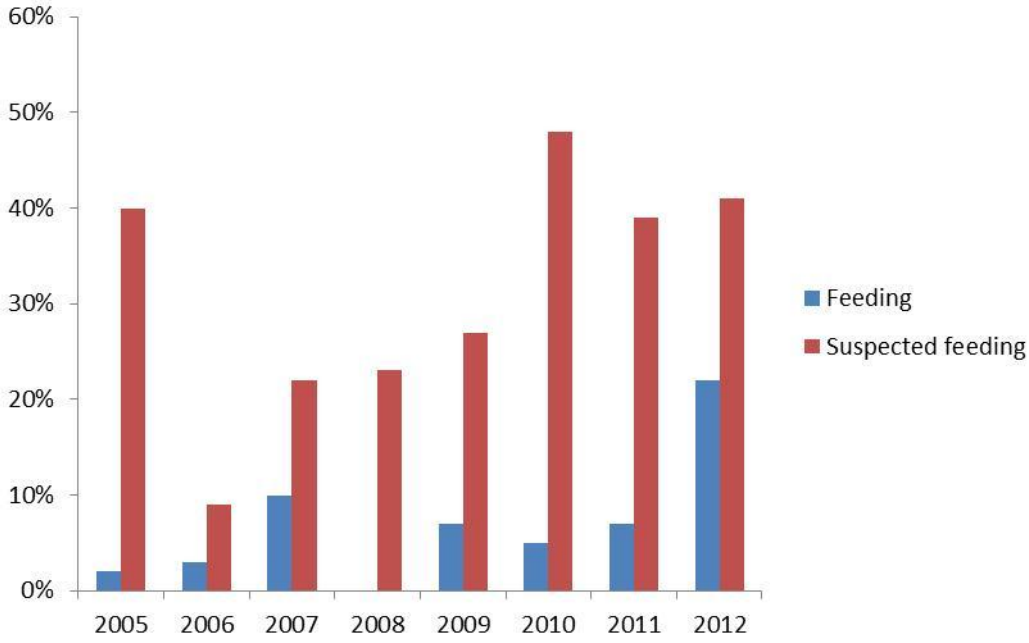


Figure 12a: Comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-12 (feeding and suspected feeding only) ($n_{feeding}$=2,2,9,0,4,3,6,22 respectively for each year; $n_{suspected\ feeding}$=35,7,19,9,16,27,32,41 respectively for each year)

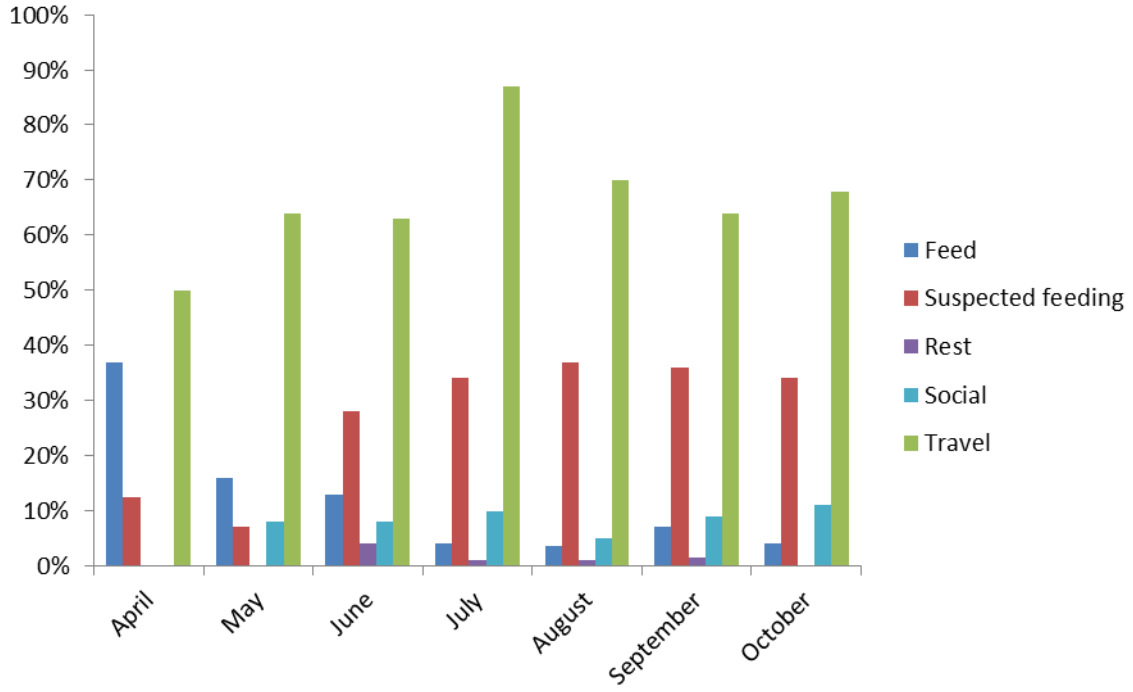


Figure 13: Seasonal **c**omparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-12 (all behaviours)

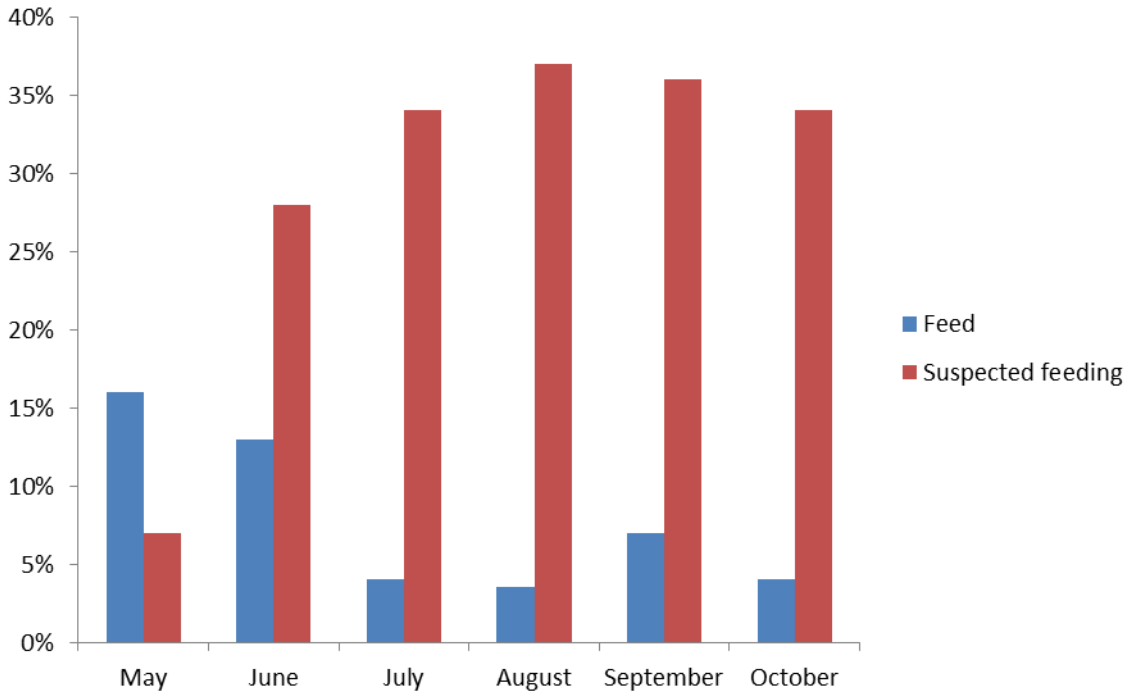


Figure 13a: Seasonal **c**omparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-12 (feeding and suspected feeding only)

3.4 *Reproductive & Mortality Rates*

It has previously been reported that Cardigan Bay SAC serves as a nursery ground and is thus an important area for mothers and calves (Ugarte and Evans, 2006; Pesante, 2008b; Veneruso and Evans, 2012a). In 2012, 45% of groups encountered within Cardigan Bay SAC had one or more calves present, once again confirming the importance of this area, with 11 newborns recorded this year alone (Table 10). This number will in fact be an underestimate as some newborns born after October or those which have not been seen this year, will be seen as young calves in 2013, and therefore designated as newborns of the previous year. An average of ten newborns were born per year between 2001-12, with peaks in 2005 and 2011, but low numbers in 2008-09 corresponding to years of low survey effort (Figure 14). Crude birth rates were calculated in Cardigan Bay SAC, averaging 5.3% per annum using mark-recapture population estimates with a closed model, and 7.8% per annum using an open population model (Table 10). Birth rates estimated with the closed model show an increase between 2001 and 2004, peaking at 8.4%. They then steadily declined, reaching their lowest value in 2009, at 1.5%. An increase in birth rates can be seen in recent years since 2010 (6.1%), with highest rates reaching 8.8% in 2011. Birth rates in 2012 show a slight decline (4.1%) although these rates will probably increase, after further evaluation of young in 2013. Birth rates calculated using the open model population estimates show large peaks in 2005 (11.4%) and 2011 (11.4%). A similar decline occurred between 2005 and 2009, with very low rates that year (0.5%). Data in recent years, however, have shown an increase to 11.4% in 2011 and a decline to 7.1% in 2012 (Table 10, Figure 14).

Crude birth rates for all of Cardigan Bay were calculated for the years 2005-12 when effort was extended to the entire Bay, also including Pen Llŷn a'r Sarnau SAC. Average annual birth rates using a mark-recapture open population model, is 9.4%. A steady decline from 11.6% in 2005 to 5.6% in 2009 is apparent, with birth rates increasing since then, peaking to 12.4% in 2011 and then declining to 9.4% in 2012 (Table 11). Higher birth rates for the whole of Cardigan Bay indicate that additional individuals to those within the Cardigan Bay SAC use only the northern part of the Bay as a calving ground, and that the entire Bay should be viewed an important site for mothers and calves (Table 11, Figure 15). Data analysis of females and calves sighted between 2007 and 2012 in Cardigan Bay SAC, Pen Llŷn a'r Sarnau SAC, and North Wales show no significant differences in calf sightings, once corrected for effort, between the three areas, strengthening the hypothesis that several locations, including some outside of Cardigan Bay serve as calving grounds for this population.

Inter-birth intervals in Cardigan Bay were calculated using data from 29 definite females all of which produced at least two calves between 2001 and 2012. Females, which were not seen in successive years, were excluded from the analysis. Inter-birth intervals varied between two and six years, with most mothers giving birth to a new calf every three years (Figure 16).

Female reproductive success was analysed for 45 confirmed females giving birth to at least one calf between 2001 and 2012. Analysis included calculating the number of offspring surviving to the age of three within a three-year time period. Most females (84%) had one or

no calves surviving (18 and 20 respectively). Six females (13%) had two and only one female (2%) had three calves surviving to the age of three within a three-year period (Figure 17).

The calving season in Cardigan Bay between 2001 and 2012 was analysed by estimating birth dates based on the last sighting of a female without a calf and the first sighting of a female with a newborn (n=62). Birth dates were estimated for females who were seen with and without a calf within a three-four month period. These were corrected for the number of identified females each month. Calves are born in all months of the main field season (March-October), with the exception of October. Some newborns have also been observed during the winter months off north Anglesey, and although few surveys take place during this time, group sizes are larger and include many sightings of females. Hence, winter birth rates are most probably well represented. Peak calving season in Cardigan Bay occurs between July and September, when 76% of all births are recorded (Figure 18).

Calf mortality rates were calculated from a sample of 60 mother-calf pairs born between 2001 and 2012. Higher mortality rates were found in the first two years (18% in both years) with lower rates in the third year (8%) (Figure 19), and a total of 55% of calves survived into their fourth year.

Table 10: Number of newborns recorded in the Cardigan Bay SAC and birth rates calculated for the sites using mark-recapture population estimates for closed and open population models

Year	No. newborns	Population estimate (closed)	Population estimate (open)	Birth rate (closed)%	Birth rate (open)%
2001	7	129	99	5.54	7.07
2002	8	166	77	4.82	10.39
2003	10	150	135	6.67	7.41
2004	12	143	126	8.39	9.52
2005	12	198	105	6.06	11.43
2006	13	229	144	5.68	9.03
2007	10	225	166	4.44	6.02
2008	5	260	125	1.92	4.00
2009	3	205	18	1.46	0.54
2010	14	228	152	6.14	9.21
2011	15	171	132	8.77	11.36
2012	11	268	154	4.10	7.14

Table 11: Number of newborns recorded in the Cardigan Bay and birth rates calculated for the sites using mark-recapture population estimates for closed and open population models

Year	2005	2006	2007	2008	2009	2010	2011	2012
No. newborns	15	18	16	14	12	21	23	19
Population estimate (closed)	182	217	252	291	295	282	209	270
Population estimate (open)	129	178	222	191	213	182	186	203
Birth rate (closed)%	8.24	8.29	6.34	4.81	4.06	7.44	11.00	7.03
Birth rate (open)%	11.63	10.11	7.21	7.33	5.63	11.54	12.37	9.36

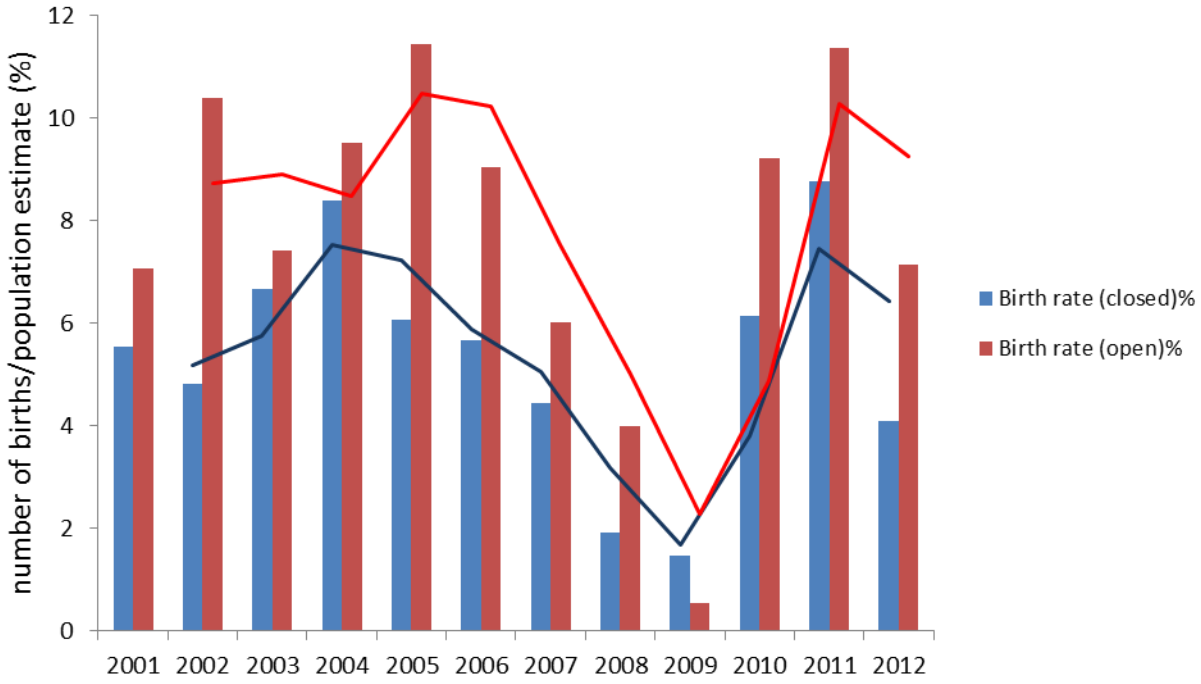


Figure 14: Birth rates of bottlenose dolphin calves in Cardigan Bay SAC calculated using closed and open population estimates.

Figure 15: Birth rates of bottlenose dolphin calves in Cardigan Bay vs. Cardigan Bay SAC, calculated using open population estimates

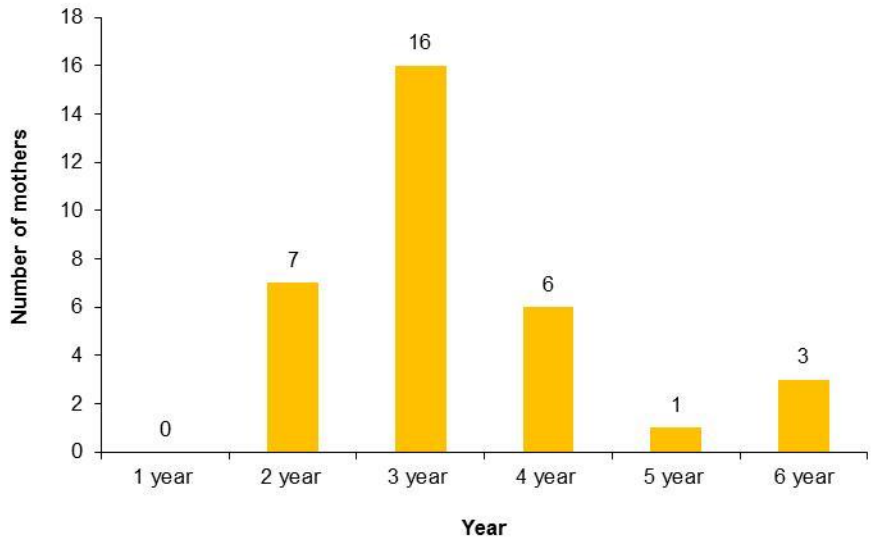


Figure 16: Inter-birth intervals of 29 known mothers in Cardigan Bay between 2001 and 2012

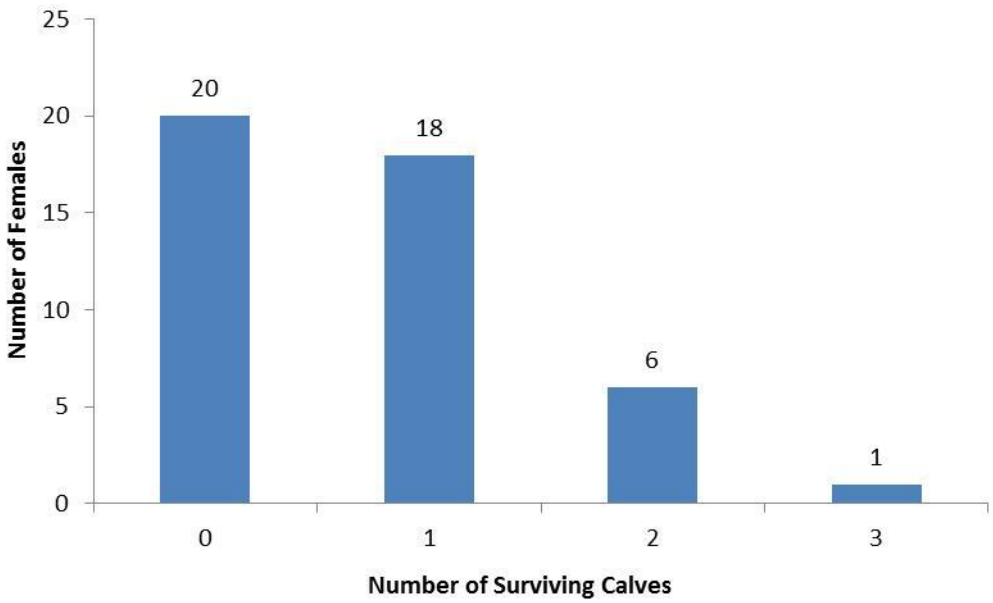


Figure 17: Female reproductive success: number of calves surviving to the age of three within a three-year time period, in Cardigan Bay between 2001and 2012

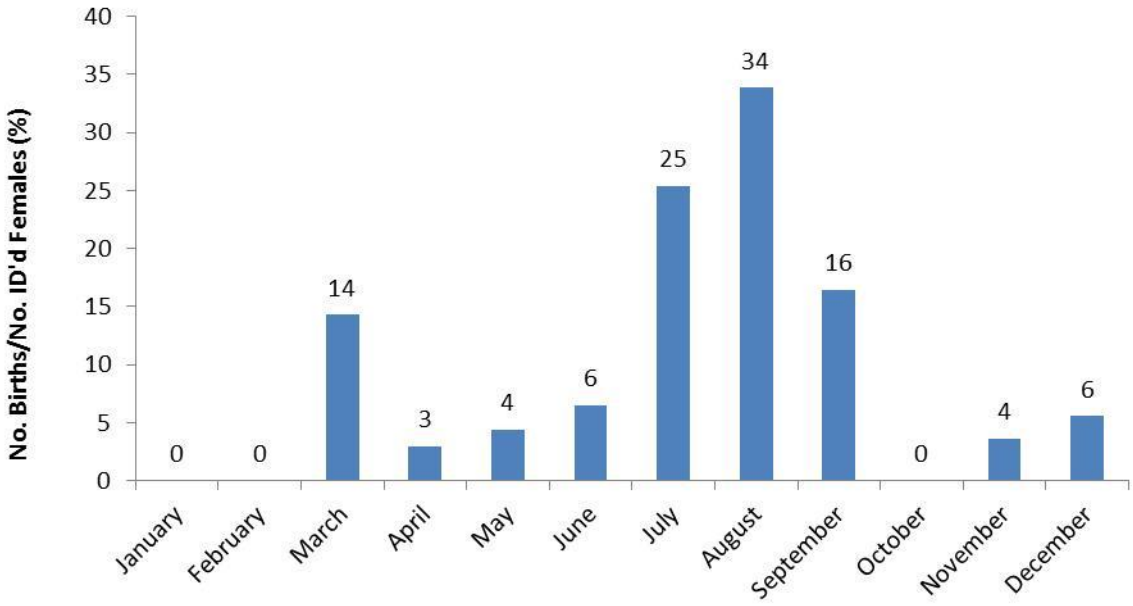


Figure 18: Number of births recorded by number of identified females each month in Cardigan Bay, between 2001 and 2012 (expressed as percentages)

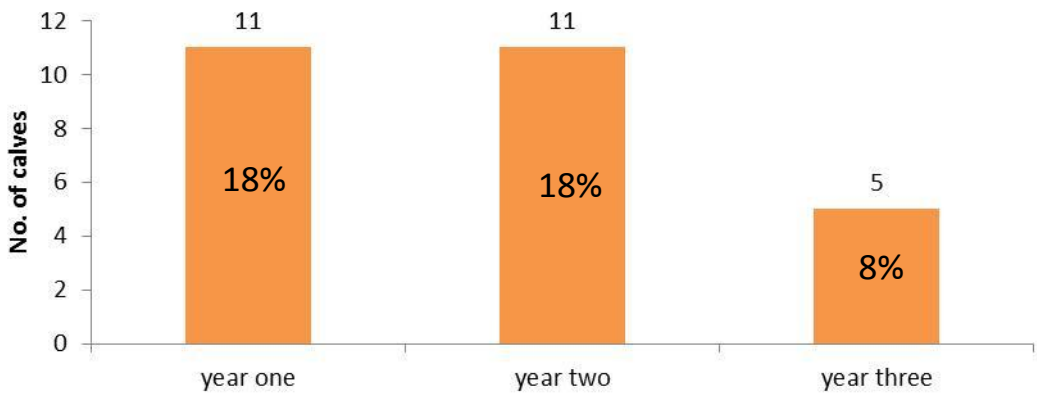


Figure 19: Number of calves that have died between age 1 and 3 years, between 2001-2012

3.5 *Photo ID*

A total of 194 bottlenose dolphin encounters were made in 2012 throughout Cardigan Bay and off North Wales. From these, 184 individual dolphins were identified (Table 12). The Photo ID catalogue content remained fairly stable since 2011, as no new individuals were added to the catalogue in 2012. On the contrary, some animals were removed as some errors in identifications were found. The Welsh Photo ID catalogue now holds a minimum of 379 individuals (Table 13).

Table 12: Bottlenose dolphin encounters in 2012

Total no. encounters	194
Total no. dolphins identified	184
No. marked dolphins identified	153
No. unmarked dolphins (left) identified	30
No. unmarked dolphins (right) identified	31

Table 13: SWF catalogue content in 2012

Well marked (WM)	105
Slightly marked (SM)	143
Left (L)	131
Right (R)	132
WM+SM+L	379
WM+SM+R	380

A discovery curve of marked individuals plotted from encounters between 2001 and 2012 confirms that new dolphins are regularly being identified in all areas. This is particularly true for the beginning of the study when all dolphins were considered ‘new’. Two other steeper increases in the detection curve are seen in 2005 when surveys expanded to Pen Llŷn a’r Sarnau SAC, and in 2007 when extended effort into North Wales commenced. The detection curve is expected to rise regularly anyway, due to transient dolphins entering the study area, and juveniles and calves gaining their first dorsal fin marks, and thus being added to the marked category. The curve appears to have reached a plateau in recent years, suggesting that the majority of the marked dolphins in the region have been photographed and identified (Figure 20).

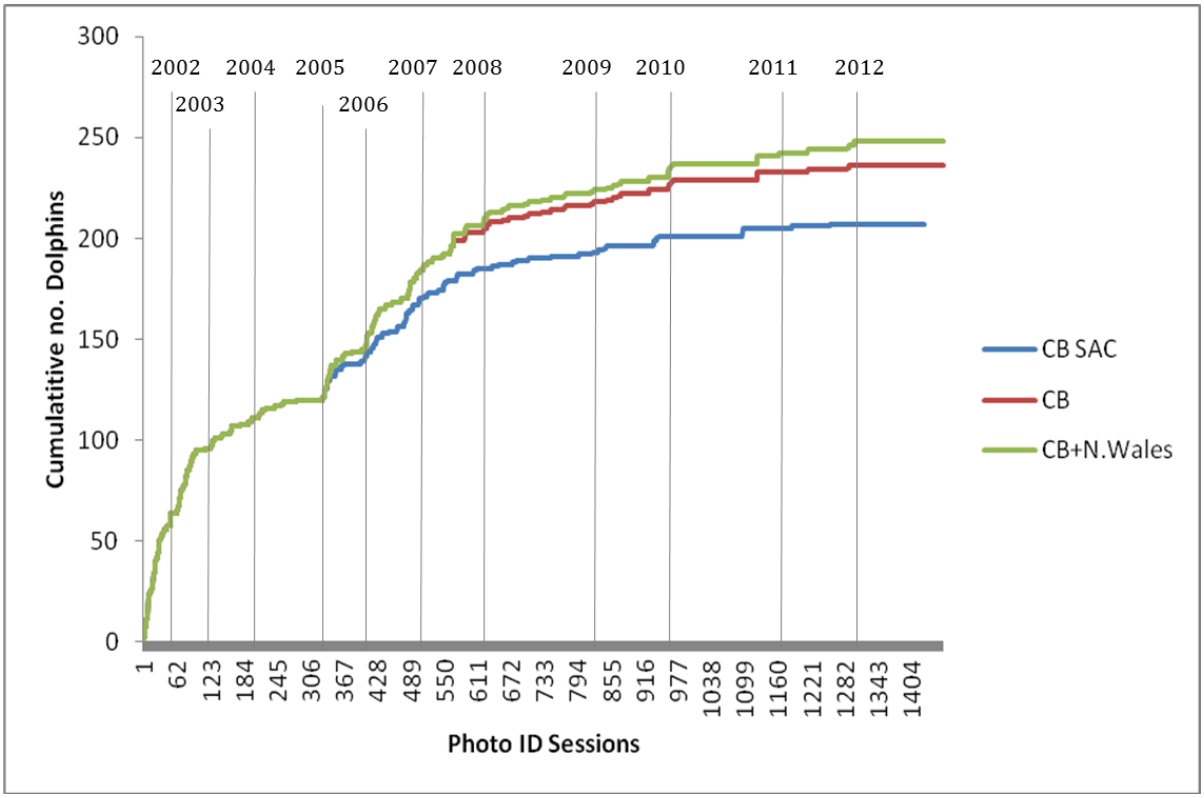
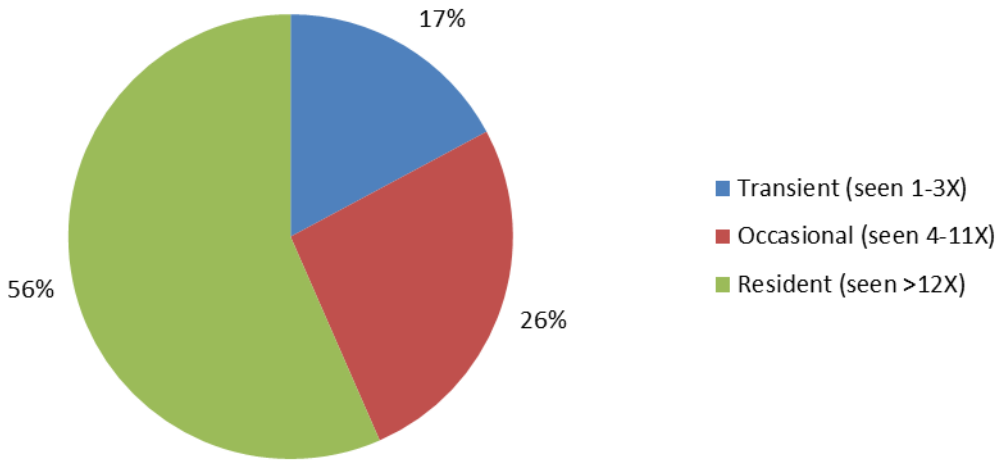


Figure 20: Discovery curve for marked bottlenose dolphins from 2001-2012
(CB SAC - Cardigan Bay SAC, CB - all Cardigan Bay; CB + N Wales - Cardigan Bay and North Wales)

It has been reported previously that the bottlenose dolphin population in Cardigan Bay SAC can be described as a combination of transients, occasional visitors, and resident animals (Pesante, 2008b). Extended surveys across Pen Llŷn a'r Sarnau SAC and adjacent areas in 2012 enable us to evaluate whether this hypothesis applies also for the entire Bay. Between 17 and 21% are considered transient, being seen less than four times and in only one or two years; between 25 and 26% are considered occasional, spotted between 4-11 times and in 3-5 years; and between 49 and 56% are considered resident inhabitants of the Bay, having been seen on more than 12 occasions throughout the study period and in more than six years, with three individuals being seen as many as 112, 121 and 133 times (017-03W, 074-03W and 004-90W respectively) and seven individuals seen in all twelve years of the study period (Figures 21a, b). Frequencies of re-sightings ranged from 1 to 15 (mean = 4.64, SD = 3.6; Figure 22). Multiple sightings per day for any individual were omitted and new individuals added in 2011 were not included in this analysis. Comparing these results with those for Cardigan Bay SAC alone, the percentages are rather similar (Figures 21a, b), suggesting that transient dolphins entering Cardigan Bay SAC originate from areas outside Cardigan Bay, although further analysis of the individual dolphins comprising each of these groups, is needed.



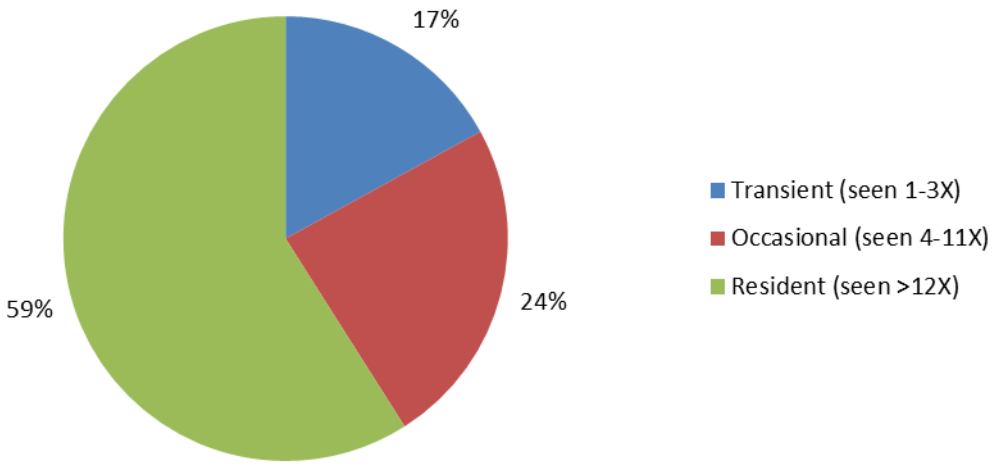
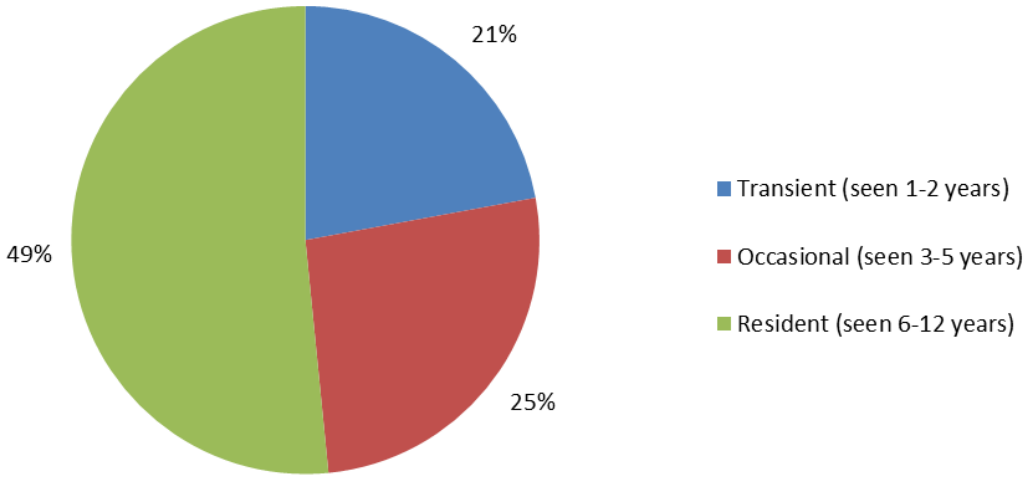


Figure 21a: Percentage of individual re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)



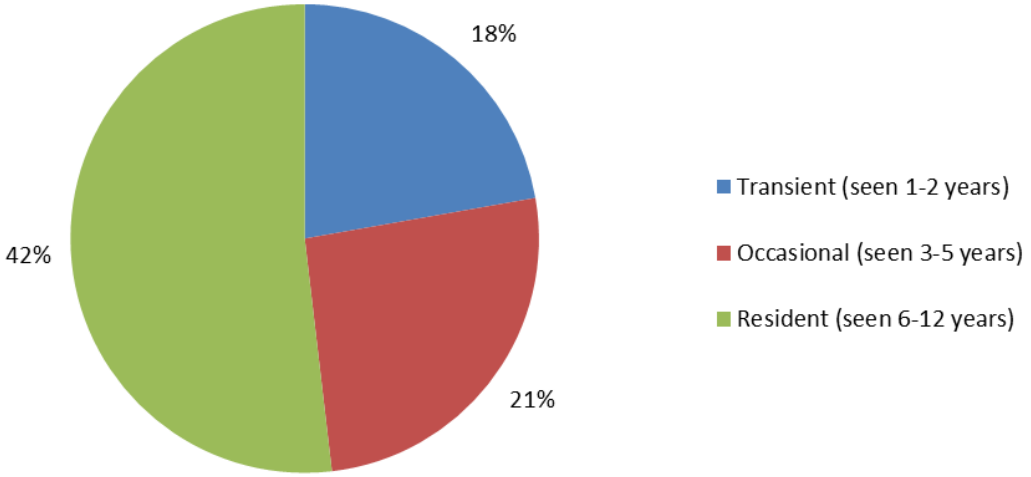


Figure 21b: Percentage of yearly re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)

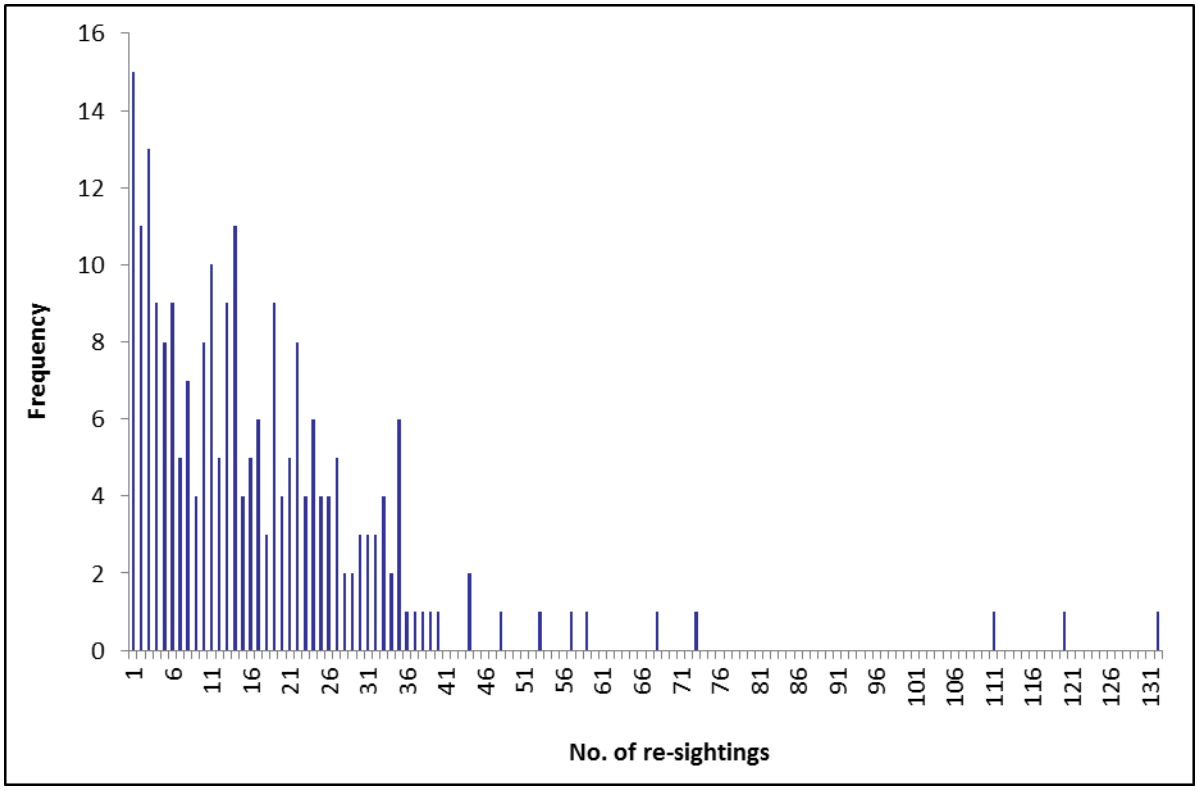


Figure 22: Frequency of re-sightings of individuals in Cardigan Bay, 2001-12

Cardigan Bay SAC has had regular and relatively even coverage over the last 12 years, which therefore provides more accurate population estimates for this area. Population estimates using a robust open population model between 2001 and 2012 reveal no apparent long-term trend, reaching a peak of 166 individuals in 2007. A slight increase to 154 individuals can be seen in 2012 compared with the previous year (Table 14, Figure 23). The open model also considers emigration, immigration, and birth & death rates. The probability of emigration from Cardigan Bay SAC between 2011 and 2012 has decreased to 26%, and the probability of dolphins remaining out of the study area entirely decreased to 53%, probably due to individuals returning to the SAC after one or more years of absence. Major fluctuations between years are visible, disguising any clear pattern (Figure 24, Table 15), and probably reflecting variation in usage of the area. These results suggest that a proportion of the population uses Cardigan Bay SAC on an irregular basis.

Table 14: Population estimates for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-12, obtained using an open population model and considering the marked proportion of individuals

Year	Population estimate	Standard Error	Proportion of marked
2001	**99**	5.85E-04	0.64
2002	**77**	8.59E-05	0.48
2003	**135**	1.70E-04	0.65
2004	**126**	0	0.64
2005	**105**	1.92E-05	0.63
2006	**144**	0	0.60
2007	**166**	5.13E-05	0.55
2008	**125**	0	0.62
2009	**118**	1.81E-04	0.64
2010	**152**	1.96E-05	0.62
2011	**132**	2.96E-04	0.55
2012	**154**	0	0.52

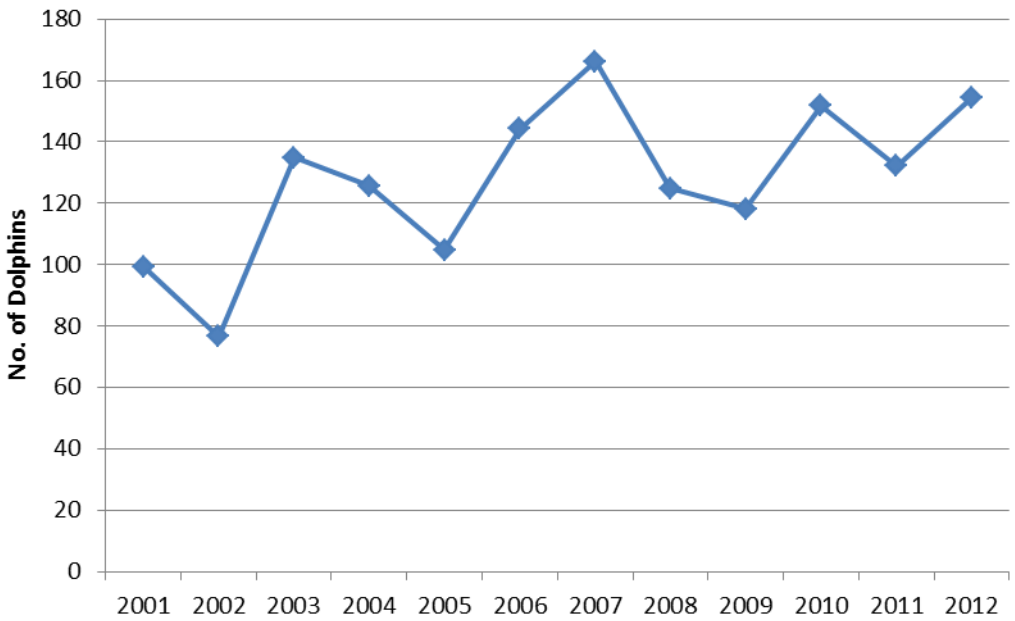


Figure 23: Population trend for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-12, obtained using an open population model

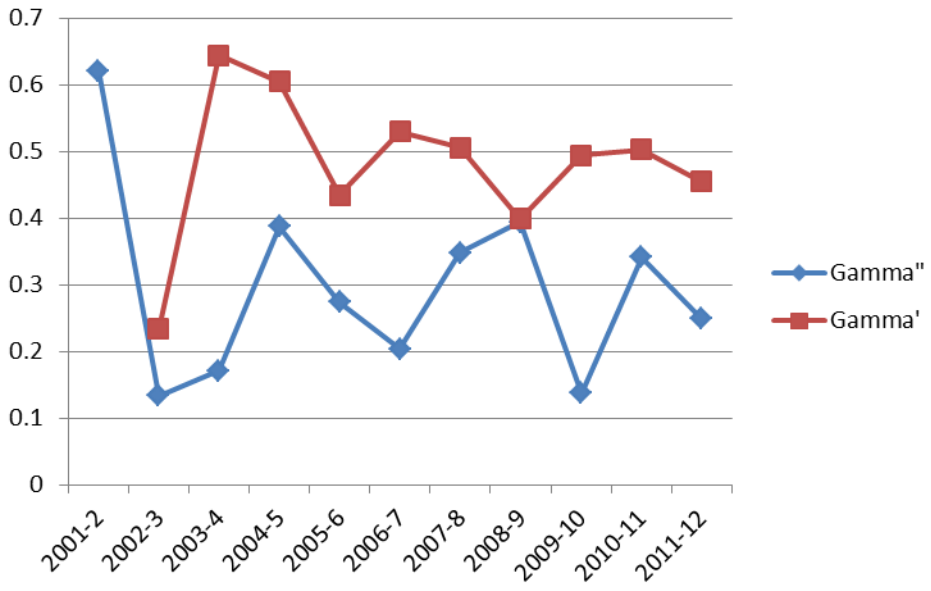


Figure 24: Bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model; (gamma”-probability of an animal emigrating out of the study area; gamma’- probability of an animal staying out of the study area)

Table 15: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model; (gamma”-probability of an animal emigrating out of the study area; gamma’- probability of an animal staying out of the study area)

Period	Gamma"	Standard Error	Gamma'	Standard Error
2001-2	0.621	6.47E-02		
2002-3	0.134	6.08E-02	0.23	0.08
2003-4	0.171	4.24E-02	0.64	0.15
2004-5	0.388	0.0573946	0.60	0.11
2005-6	0.274	5.84E-02	0.43	0.08
2006-7	0.204	0.0528058	0.53	0.09
2007-8	0.348	5.36E-02	0.51	0.10
2008-9	0.394	0.0589053	0.40	0.08
2009-10	0.137	4.50E-02	0.49	0.08
2010-11	0.341	5.47E-02	0.50	0.11
2011-12	0.248	5.88E-02	0.45	0.10

Population estimates for all of Cardigan Bay were made using the robust open model. Only data from 2005-12 were analysed for this purpose since coverage in Pen Llŷn a’r Sarnau SAC was more regular during these years. A peak of 222 individuals was reached in 2007 with a similar estimate in 2009 (Table 16). A general decline in the population size appears to have occurred from 2007-10, most probably due to much lower effort (with a more restricted area

surveyed) between 2008 and 2010. This is then followed by a small, though consistent rise to 203 individuals in 2012 (Figure 25).

Emigration and immigration rates in Cardigan Bay between 2005 and 2012 are relatively stable, with the exception of 2009, a year with low survey effort (Figure 26, Table 17). Lower values of gamma'' and gamma' apply to Cardigan Bay as a whole compared with the SAC alone, suggesting that the Bay generally is used more evenly by the population, with a larger proportion staying within this wider area (Figure 27). However, there remains a portion of the population that has not yet been recorded within Cardigan Bay, most probably inhabiting mainly more northerly parts of the Irish Sea. It is important that survey effort in all of Cardigan Bay, including off-shore areas, is implemented regularly and consistently throughout the season, in order to evaluate trends relevant to the entire Bay and not only to Cardigan Bay SAC.

Table 16: Population estimates for bottlenose dolphins in Cardigan Bay for the years 2005-2011, obtained using an open population model, and considering the marked proportion of individuals

Year	Population estimate	Standard Error	Proportion of marked
2005	**129**	1.99E-07	0.66
2006	**178**	7.963E-05	0.65
2007	**222**	5.13E-05	0.60
2008	**191**	6.01E-05	0.69
2009	**213**	1.04E+01	0.67
2010	**182**	3.96E-05	0.63
2011	**186**	2.19E-05	0.58
2012	**203**	1.96E-06	0.54

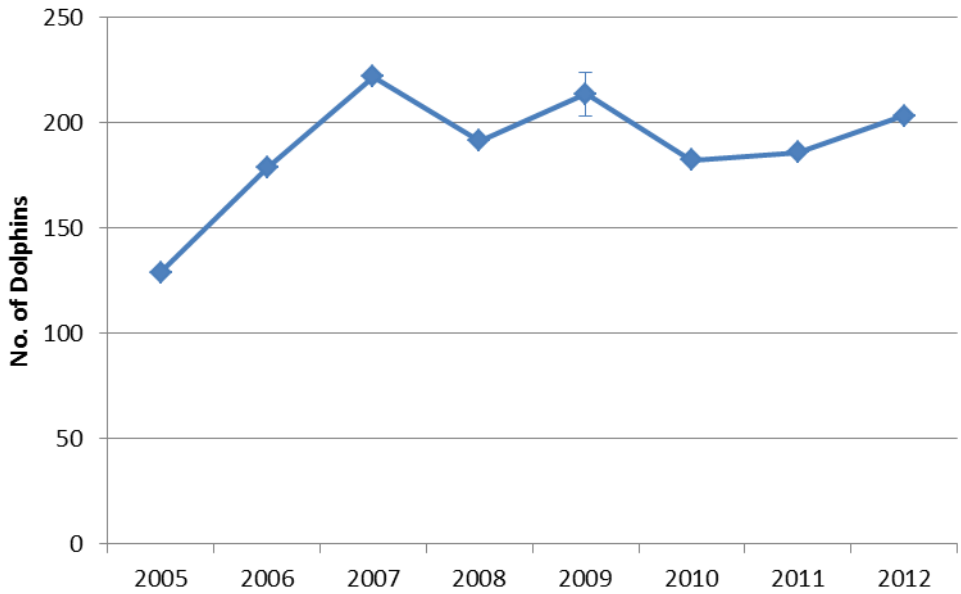


Figure 25: Population trend for bottlenose dolphins in Cardigan Bay for the years 2005-12, obtained using an open population model, and considering the marked proportion of individuals

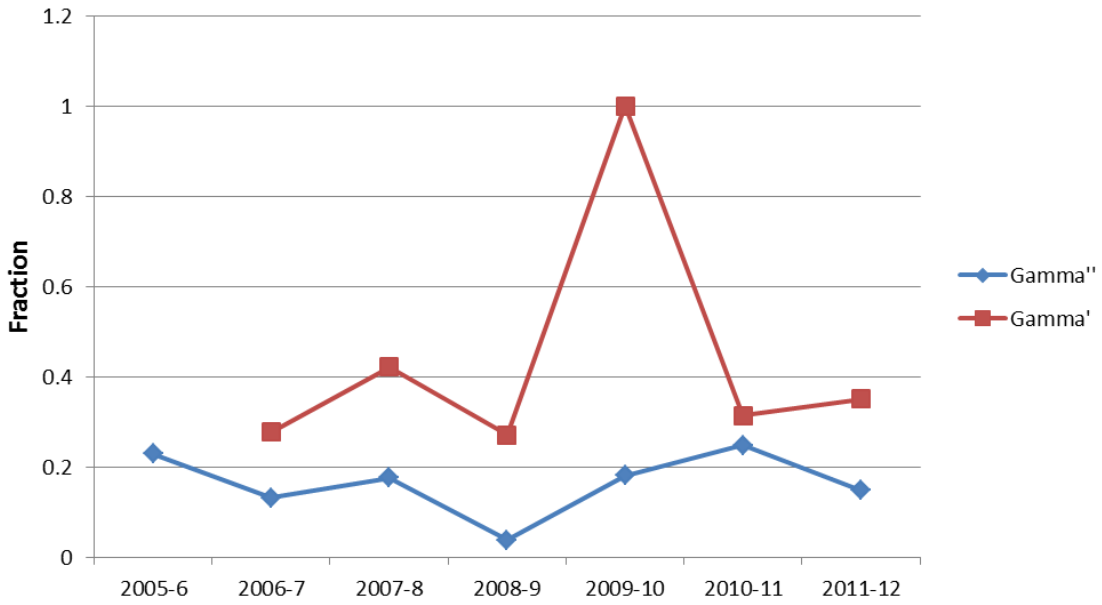


Figure 26: Bottlenose dolphin residency patterns in Cardigan Bay using an open population model (gamma" is the probability of an animal emigrating out of the study area; gamma' is the probability of an animal staying out of the study area)

Table 17: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay using an open population model
(gamma" is the probability of an animal emigrating out of the study area; gamma' is the probability of an animal staying out of the study area)

Period	Gamma"	Standard Error	Gamma'	Standard Error
2005-6	0.229	5.02E-02		
2006-7	0.132	0.0422512	0.277	0.123
2007-8	0.176	1.25E-01	0.421	0.237
2008-9	0.037	1.30E-01	0.270	0.704
2009-10	0.181	6.38E-01	1.000	0.000
2010-11	0.248	1.24E+01	0.313	14.258
2011-12	0.148	2.37E+01	0.351	41.142

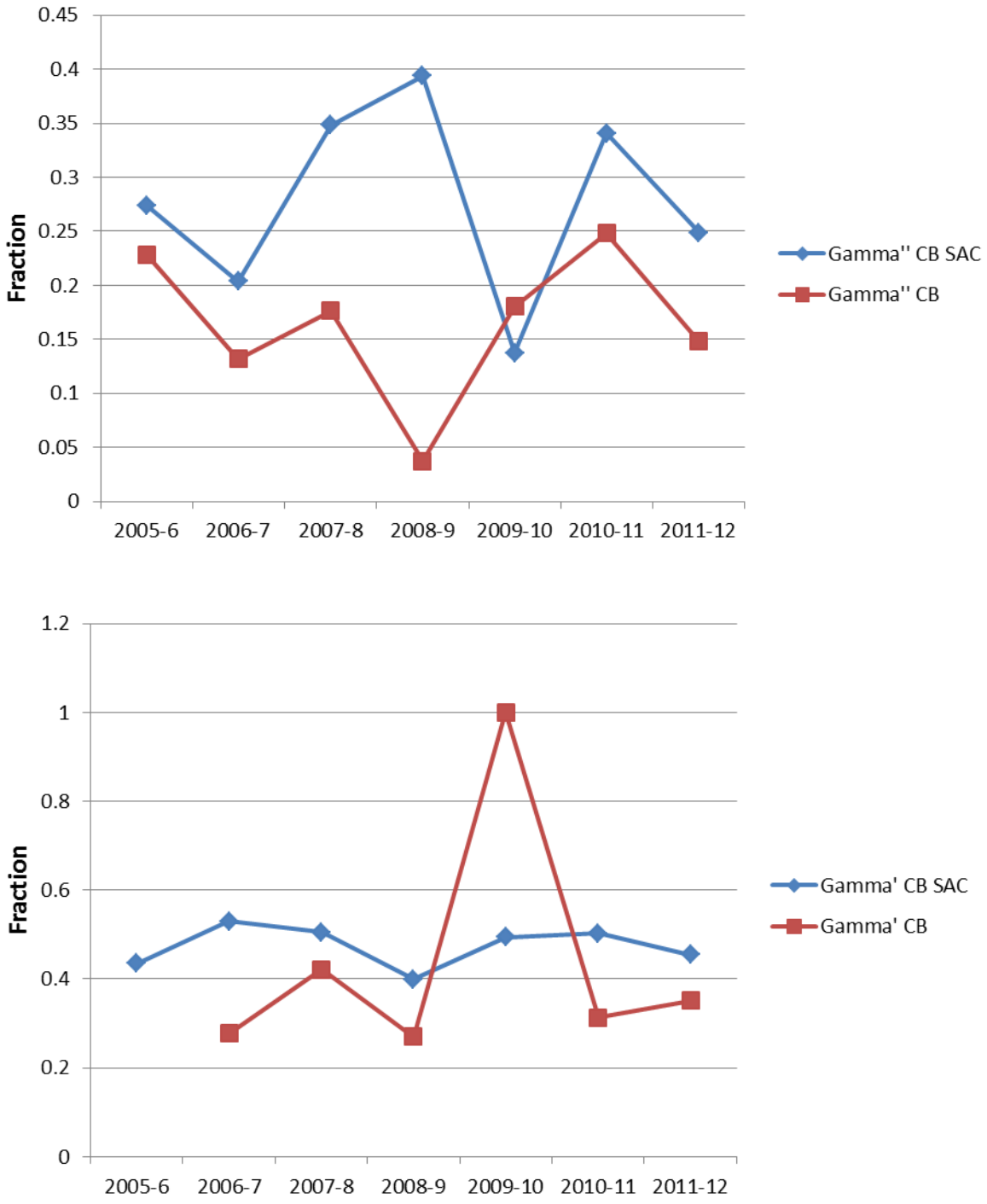


Figure 27: Bottlenose dolphin residency patterns in Cardigan Bay and Cardigan Bay SAC, using an open population model. gamma" is the probability of an animal emigrating out of the study area (top graph); gamma' is the probability of an animal staying out of the study area (bottom graph)

We analysed population estimates for all of Cardigan Bay using the mark-recapture closed population model, which resulted in an estimate of 270 individuals in the Bay for 2012, broadly similar to earlier years. Nearly 50% of bottlenose dolphin encounters during line-transect surveys in Cardigan Bay have included calves, and nearly 25% of encounters included juveniles. A high number of young dolphins, which are not yet marked utilising the Bay, along with low average group sizes, may result in the low proportion of marked individuals obtained for 2012 (just under 52%; Table 18, Figure 28). When estimating the population in 2012 using the average marked population (61%), the estimate for 2012 is reduced to 229 individuals, and this value may more accurately reflect the overall size of the population inhabiting Cardigan Bay in summer 2012. Recent years have shown that dolphins emigrate out of Cardigan Bay SAC throughout the summer consequently, a closed population model for this SAC alone will be misleading and the open population is most probably the more accurate one.

Table 18: Population estimates of bottlenose dolphins occupying Cardigan Bay, calculated using the mark-recapture method, and a closed population model, taking account for the marked proportion of individuals

Year	Capture events	Animals captured	Population estimate	Lower 95% CI	Upper 95% CI	Standard error	Proportion well-marked
2005	141	83	**182**	153	242	14.55	0.661
2006	219	117	**217**	197	260	9.97	0.649
2007	286	129	**252**	237	288	7.49	0.583
2008	239	122	**291**	248	370	19.80	0.646
2009	187	107	**295**	234	405	28.04	0.661
2010	245	110	**282**	237	363	19.35	0.620
2011	162	85	**209**	182	273	12.30	0.549
2012	219	104	**270**	122	175	13.12	0.518

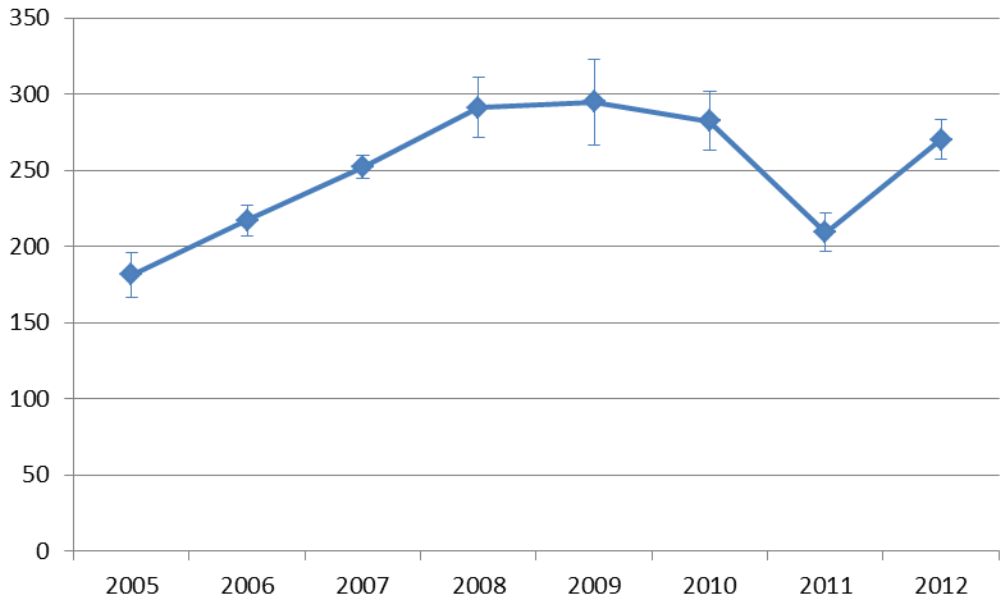


Figure 28: Population trend for bottlenose dolphins in Cardigan Bay for the years 2005-12, obtained using a closed population model, and considering the marked proportion of individuals

3.6 *Home ranges*

Since 2007, extended effort has taken place in North Wales, particularly around the Isle of Anglesey, and it is now well established that individually identifiable bottlenose dolphins from Cardigan Bay can be seen regularly at least on a seasonal basis off North Wales and the Isle of Man (Pesante *et al.*, 2008a, b; Veneruso and Evans, 2012b). A preliminary analysis of bottlenose dolphin home ranges was completed using photo ID data from 279 dolphins seen between 2007 and 2012. Dolphins which were not sighted during this time period, were excluded. Nearly 30% of individuals have been identified in both SACs and north of the Llŷn Peninsula, around the Isle of Anglesey. Nearly 25% were seen in Cardigan Bay SAC and North Wales, but not in Pen Llyn a'r Sarnau SAC. This is most probably due to lower coverage in this SAC, particularly in the offshore area. Some individuals exhibited localised home ranges, with 12% of individuals sighted only in Cardigan Bay SAC, just under 8% solely around the Isle of Anglesey, and 7% seen only in the Pen Llyn a'r Sarnau SAC. These results suggest that the majority of the population have large home ranges encompassing all of Cardigan Bay and North Wales, and possibly also all of the northern Irish Sea, although a proportion of the population appears to be relatively site faithful with small home ranges. These more sedentary animals may occur in any part of the study area, and are not found only in Cardigan Bay SAC.

3.7 Body condition

No underweight dolphins were encountered during Sea Watch Foundation research surveys in 2012. However, photo ID data provided to us by Janet Baxter (Friends of Cardigan Bay) showed one underweight dolphin on the 19 June 2012 while on board the *Bay Explorer*, a commercial boat operating out of Cardigan in the south part of Cardigan Bay SAC. We have identified this individual to be 038-90W, a well-marked female seen regularly in the area since 1990. This female was photographed in Cardigan Bay SAC in 2010 and 2011 and was seen in a healthy condition. As with our findings in 2011, this underweight individual was a female with a dependent calf (Figures 29, 30).

Figure 29: Underweight dolphin (038-90W) recorded during an encounter in Cardigan Bay SAC on 19th June 2012 (Photo: Janet Baxter)

Figure 30: Dolphin 038-90W photographed in June 2010 (left) and July 2011 (right) in Cardigan Bay SAC (photos: Sea Watch Foundation)

Two injured dolphins were encountered during 2012. One individual, which is well known to us, has been recorded inhabiting the area since 2003 (035-03W). It appears that the injury, first recorded in 2007, has had little impact on this individual's mobility or reproductive capability as she has been seen accompanied by a calf, and regularly throughout the study period. During 2012, she was photographed in Cardigan Bay, off Anglesey and the Isle of Man (Figures 31,32). The second individual is a very young calf, only one month old, spotted in Pen Llŷn a'r Sarnau SAC on 22 Sept 2012. This is the first calf we have recorded for this particular female, first recorded by us in 2009. The female was sighted one month previously, on 19 Aug 2012, without a calf present, suggesting the injury to the calf took place sometime within the first month of its life. Since this is quite rare, it may be that the calf was born with the disfiguration on its fin. During this encounter, the two animals were observed bow riding for long periods of time, which is also uncommon for a young calf. The mother of this young calf may have been inexperienced, and, allowed it to get too close to one of the many vessels that uses the northern part of Cardigan Bay during the summer months. Both mother and calf have been seen since, on 30 Nov 2012, around Anglesey in North Wales (Figure 33).

Figure 31: An individual with a long-lasting injury recorded in Cardigan Bay SAC. Injury first recorded in 2007 (left) and on the 18th June 2012 (right)

Figure 32: An individual with a long-lasting injury accompanied by a calf recorded in Cardigan Bay SAC in 2007

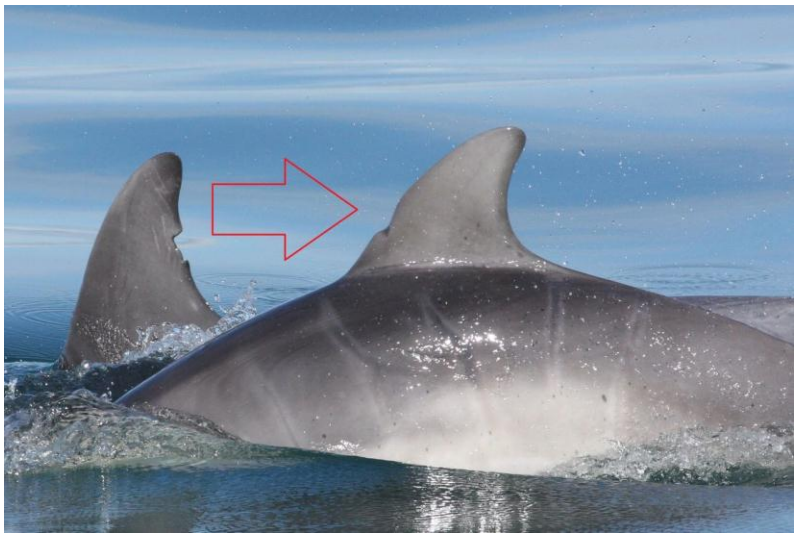


Figure 33: A young calf injured on his dorsal fin, recorded in Pen Llŷn a'r Sarnau SAC on 22nd September 2012

4. DISCUSSION

4.1 *Line-transect surveys*

2012 was the first year in which surveys took place throughout Cardigan Bay during the entire field season (April-October), with the aim of obtaining absolute abundance estimates for bottlenose dolphin and harbour porpoise. Additional transects were undertaken in Pen Llyn a'r Sarnau SAC and adjacent waters, enabling better coverage of the northern part of Cardigan Bay than in any previous year. The overall Cardigan Bay abundance estimate was 330 (CV 24.9) for bottlenose dolphin, and 565 (CV 20.4) for harbour porpoise. The harbour porpoise is known to be more abundant and widespread in the Irish Sea than bottlenose dolphin (Hammond, 2008; Pesante *et al*., 2008b; Baines and Evans, 2009, 2012). An increase in overall abundance for bottlenose dolphin in the Bay was observed in 2012 compared with 2011 (309; CV 28.3), possibly due to increased spatial coverage throughout the season. The harbour porpoise abundance estimate for Cardigan Bay was much lower in 2012 than in 2011 when 1074 individuals (CV 28.7) were estimated. Given that, in 2012, the number of porpoise encounters were higher, resulting in lower CV values, these estimates should be more accurate than those previously reported.

Harbour porpoise population estimates in Cardigan Bay SAC also showed a decline compared with 2011, although the CV value in 2011 was very high (46.4) due to the number of sightings being very low (n=20). The ability to detect a trend in a monitoring project depends upon the precision of the survey estimates (Gerrodette, 1987; Barnes 2002), and generally the goal is to build up a sample size that reduces the CV to c. 15-20%. With cetacean line-transect surveys, this is rarely feasible. The SCANS II survey, for example, obtained a CV of 27% for bottlenose dolphin across the entire ASCOBANS Agreement Area (P.S. Hammond, *pers. comm.*), and once regional estimates are obtained, the CV goes up further. Clearly, from a conservation point of view, it is desirable to have as small a CV as possible. This can be challenging if the number of sightings is reduced by the population not using the area so much. Harbour porpoise estimates for Cardigan Bay SAC in 2012 were similar to those estimated in previous research seasons of line-transect surveys during the years 2005-07 (Pesante *et al.*, 2008b), suggesting that the population in the SAC is relatively stable. Further line-transect surveys in upcoming years will enable a more accurate and viable estimation for the whole of Cardigan Bay. Bottlenose dolphin population estimates in Cardigan Bay SAC were very low in 2012 (70 individuals), resulting in the lowest estimate since the beginning of the monitoring programme. Very low numbers of sightings (n=19) and a relatively high CV value (32.98%) indicates this may not be an accurate estimation of the population in the area. However, since bottlenose dolphins were seen quite regularly in North Welsh waters as well as in Liverpool Bay this past summer, this may indicate a shift in dolphin presence from the SAC. Unfortunately, the gap in line-transect surveys between 2008 and 2010 does not give us a clear idea of the population status in those years. Total population estimates require a long-term study using line-transect techniques, and identifying a statistically significant change in total population size requires several years of data collection obtained on an annual basis. To understand these trends, annual monitoring will

need to be maintained. Population estimates in the entire Bay seem to have increased since 2011 strengthening the hypothesis that this decline in the SAC alone may represent a strong shift in how the dolphins used this SAC during this last year, which could be either due to shifts in prey availability or a more direct effect of human activity, for example the increase in recreation in this area. Some evidence that the latter may be taking place is provided in section 5.9.

Low numbers of detection (n=19) may contribute to this low estimate, although it suggests a trend of population decline.

The wider coverage in 2012 resulted in ten sightings of bottlenose dolphins recorded outside of the two designated SACs. Five of these were recorded in the gap between the two SACs, and five were recorded offshore outside the Pen Llŷn a'r Sarnau SAC. No bottlenose dolphin sightings were observed outside the SACs in 2011, despite offshore effort (aboard *Pedryn*) was wider, particularly beyond the Pen Llyn a'r Sarnau SAC, emphasising the difference in how the dolphins appear to have been using the Bay in summer 2012, and possibly serving as an additional explanation for the low estimates within Cardigan Bay SAC. Aerial surveys conducted in 2007 confirmed that bottlenose dolphins do use the outer area of Cardigan Bay, at least in the winter months (Pesante et al., 2008b). Here we conclude that in some years, bottlenose dolphins may utilise the outer area of Cardigan Bay in summer months as well. Further effort coverage should take place targeting those areas. Sightings of grey seals and harbour porpoise were made throughout the study area, in both inshore and offshore waters.

Sighting frequencies were highest in June and July with a slight increase towards the end of the season, most likely due to aggregations of pelagic prey, such as herring, in the area. Average group size was relatively constant throughout the summer with no significant differences in group size by month; however, group sizes were mainly of 1-5 individuals with very few encounters of groups above ten individuals.

4.2 *Ad libitum surveys*

Ad libitum surveys were conducted regularly throughout the season mainly in Cardigan Bay SAC on board *Boat Gallois*. Two surveys also took place on board *Pedryn* in and around Pen Llyn a'r Sarnau SAC. However, effort mainly concentrated on line-transect surveys, thus reducing the number of *ad-libitum* trips undertaken. *Boat Gallois* was mainly used for recording bottlenose dolphin whistles and grey seal photo ID data. Sightings of bottlenose dolphins and grey seals from *ad libitum* surveys were concentrated particularly between New Quay and Ynys Lochtyn, which is the route undertaken by the passenger vessels Ermol V and Ermol VI. Very few (n=11) harbour porpoise sightings were recorded from these surveys, with the majority (8) recorded on board *Boat Gallois* which usually ventured further along the coast than the local boat trips. Previous studies have also shown that bottlenose dolphins exhibit a strong preference for the inshore waters in Cardigan Bay SAC, whereas harbour porpoise and grey seals are more widely distributed (Baines *et al*., 2002; Pesante *et al.*, 2008b).

4.3 *Activity budgets*

Dolphin behaviour is often difficult to measure since most activities take place out of sight below the surface. Furthermore, encounters are often brief when made during line-transect surveys, and so may not reflect the true behaviour of the individual or group. The recording of behaviours is also prone to inconsistencies when different observers are engaged in the data collection. Previous behavioural budgets recorded in Cardigan Bay SAC (along with T-POD acoustic monitoring) have confirmed that a high proportion of dolphins are feeding in the coastal strip of the SAC, particularly at certain locations such as New Quay Head, Ynys Lochtyn, Aberporth Head, and Mwnt (Lewis and Evans, 1993; Baines *et al*., 2000; Pesante *et al*., 2008b). Between April and August, bottlenose dolphins in Cardigan Bay are thought to be feeding in this region mainly on bottom-dwelling fish and crustaceans (Evans *et al*., 2000; Pesante *et al*., 2008b; Pierpoint *et al*., 2009), although in late summer, salmonids from the River Teifi in the southern end of the SAC and pelagic species like herring may also be attracting dolphins (Baines *et al*., 2000). Feeding activities can be verified only if prey is visible during the encounter. However, dolphins are regularly witnessed taking prolonged vertical dives where they are thought to be foraging close to or on the bottom. This behaviour is defined here as 'suspected feeding'. Data collected on board line-transect and *ad-libitum* surveys serve as a potential source for both spatial and temporal behaviour analysis, so long as they are collected in a consistent manner. In this study, all such data collected were validated by the Monitoring Officer or another experienced researcher.

A comparison of activity budgets in 2012 during line-transect and *ad libitum* surveys in Cardigan Bay SAC showed a large proportion of encounters involving 'feeding' or 'suspected feeding' activities (63%), indicating the importance of the SAC as a foraging and feeding ground. A large proportion of the activity budget takes the form of 'travel' (55%). However; it is likely that a significant portion of travel is in fact "forage-travel", where animals are searching for prey. Resting and social behaviours are rarely observed and we believe the presence of the many vessels in the area, including our own research vessel, may be affecting the frequency of these behaviours. Yearly comparisons of activity budgets between 2005 and 2012 in Cardigan Bay SAC confirm that travelling is the predominant activity recorded in the SAC while socialising and resting activities are the least recorded throughout these years. Although yearly feeding activities show no apparent trend, a peak in feeding activities is seen in 2012 suggesting low availability of prey may not be the main reason for the low population estimates for this year. A rising trend in 'suspected feeding' is seen since 2006, however, suggesting dolphins are spending more time foraging for food, though not necessarily consuming it.

A seasonal declining trend in feeding activities is seen between April and October along with a rising trend in 'suspected feeding', activities suggesting prey availability is lower in the latter part of the season. It may well be that in recent years, dolphins are generally spending more time searching for food as it is less abundant in the SAC. However, we do not believe this is the only reason for the possible trend of population decline (indicated from the line-transect surveys), and that increasing anthropogenic activities in the SAC may be

contributing as well, as indicated also by our recent studies examining social networks in areas of high *vs* low vessel traffic (see section 5.9). It is important that codes of conduct are implemented throughout Cardigan Bay and that licences to approach dolphins are brought to a minimum, although our preliminary findings are that dolphins are affected more by the number of vessels they encounter than whether or not the behaviour of those vessels is regulated.

4.4 *Reproductive & Mortality Rates*

It has previously been reported that Cardigan Bay SAC is considered to be an important nursery area for bottlenose dolphins (Veneruso and Evans, 2012a). This continues to be the case, with 45% of groups encountered in the SAC in 2012 including mother-calf/newborn pairs. A higher than average number of births, as seen in 2006 (13), 2010 (14) and 2011 (15) may be a result of a number of females becoming reproductively mature at the same time, creating a "baby boom". This has been seen in other studies of bottlenose dolphin (Bearzi *et al.*, 1997; Haase and Schneider, 2001), and also in Atlantic spotted dolphins (*Stenella frontalis*) (Herzing, 2007). Here we present data indicating that the whole of Cardigan Bay is an important area for mothers and calves, with some females with calves being sighted only in the northern part of the Bay.

Table 19: Crude birth rates from studies of bottlenose dolphins around the world

Location	Crude birth rate	Source
Eastern Australia	1.2	Lear & Bryden, 1980
North Adriatic, Croatia	4.9	Bearzi *et al*., 1997
Cardigan Bay SAC (closed)	**5.3**	**This study**
Sado Estuary, Portugal	5.4	Gaspar, 2003
Sarasota Bay, Florida	5.5	Wells & Scott, 1990
Moray Firth, Scotland	6.0	Wilson *et al*., 1999
Doubtful Sound, New Zealand	6.6	Haase & Schneider, 2001
Cardigan Bay, Wales (closed)	**7.15**	**This study**
Southern California	7.2	Hansen, 1990
Northern Gulf of Mexico	7.7	Leatherwood, 1977
Cardigan Bay SAC, Wales (open)	**7.8**	**This study**
Florida	8.2	Irvine *et al*., 1981
Cardigan Bay, Wales (open)	**9.4**	**This study**
Argentina, South Atlantic Coast	9.6	Würsig, 1978
Tampa Bay, Florida	9.7	Weigle, 1990

Mean birth rates were calculated for Cardigan Bay SAC using a closed and open model (5.3%, 7.8% respectively) and for the whole of Cardigan Bay (7.15% for a closed model and

9.4% for an open model). The estimated mean birth rate of the resident population of bottlenose dolphins in the UK, in the Moray Firth, is 6.0% (Table 19; Wilson *et al.*, 1999; Grellier, 2000; Thompson *et al*., 2004), situated in between those estimated for Cardigan Bay and the SAC both calculated with the closed population estimate. Birth rates using the open population model estimate present higher numbers, especially for Cardigan Bay (9.4%) due to a large number of females and newborns observed in Pen Llyn ar Sarnau SAC suggesting the entire Bay serves as an important calving ground.

Table 20: Inter-birth intervals from studies of bottlenose dolphins around the world

Location	Mean (years)	Range (years)	Source
North Carolina, USA	2.9	2-7	Thayer, 2008
Doubtful Sound, New Zealand	3.0	2-5	Haase & Schneider, 2001
Natal, South Africa	3.0	2-6	Cockcroft & Ross, 1990
Cardigan Bay, Wales	**3.0**	**2-6**	**This study**
Moray Firth, Scotland	3.2	3-6	Mitcheson, 2008
Shark Bay, Australia	4.1	3-6	Connor *et al*., 2000
Sarasota Bay, Florida	5.4	2-11	Wells & Scott, 1999

Table 21: Juvenile mortality rates from studies of bottlenose dolphins around the world

Location	First year	Second Year	Third Year	Source
North Carolina, USA	11%	-	-	Thayer, 2008
Indian & Banana rivers, Florida	11%	-	-	Hersh *et al*., 1990
Sarasota Bay, Florida	19%	-	-	Wells & Scott, 1990
Cardigan Bay, Wales	**18%**	**18%**	**8%**	**This study**
Doubtful Sound, New Zealand	20%	-	-	Haase & Schneider, 2001
Natal, South Africa	22%	-	-	Cockcroft *et al*., 1989
Shark Bay, Australia	29%	18%	3%	Mann *et al*., 2000

The mean inter-birth interval in Cardigan Bay between 2001 and 2012 is estimated to be three years, similar to other studies of the species (Table 20) suggesting that the female population of Cardigan Bay is healthy and reproducing offspring regularly. Calving season between 2001 and 2012 (corrected for the number of identified females per month) occurred mainly in the summer months with the majority of newborns (76%) observed between July

and September. Calf mortality rates between 2001 and 2012 were calculated as highest in the first two years (18%), similar to records from Sarasota Bay, Florida for the first year and to Shark Bay, Australia for the second year (Table 21). Mortality rates then reduce to 8% in the third year with a majority of calves surviving into their fourth year (55%).

4.5 *Photo ID & Home Ranges*

The Photo ID catalogue of bottlenose dolphins in the Irish Sea has not changed much since 2011, with no new dolphins added in 2012. New dolphins tend to be juveniles that were previously unmarked. However, some dolphins added to the catalogue in recent years were those inhabiting North Welsh waters, specifically the Anglesey area. Ten surveys took place in Anglesey in 2012, and two further encounters were documented by Jon Shaw, although none of these produced new identifications, suggesting that the catalogue may now represent the majority of dolphins inhabiting Welsh waters. This is also apparent in our detection curve which has flattened off in the last few years.

Through individual re-sightings of bottlenose dolphins in Cardigan Bay, the population can be described as a combination of residents (56%), occasional visitors (26%) and transients (17%) with 48% of individuals seen over more than six years of this study. Previous residency patterns in 2001-07 were calculated for Cardigan Bay SAC, and indicated a 58% residency for dolphins within the SAC (Pesante *et al.*, 2008b). Similar percentages are calculated here at 59%, suggesting the resident population in the SAC is stable. Further surveys in the entire Bay will allow a long-term trend assessment of residency for the entire Bay.

Overall population size estimates for bottlenose dolphins within Cardigan Bay have been made since 2005, when coverage was extended to Pen Llŷn a'r Sarnau SAC. Estimates derived from an open population model indicate a general increase until 2007, peaking at 222 individuals, with a lower estimate (191) in 2008. Estimates in 2009 and 2010 should be viewed with caution since, due to lack of funding, there was low effort in the northern part of the Bay. The population estimate in 2011 also revealed a relatively low number (186), although slightly higher than 2010 (182). This may be a result of 2011 being a poor year for sightings with fewer animals in the area (Veneruso and Evans, 2012a). The Cardigan Bay population estimate for 2012 was 203 individuals, suggesting that the lower values in the preceding years may have been due due to fewer surveys and more restricted coverage imposed by lack of funding over that period. This highlights the need for consistent monitoring throughout the years.

A longer dataset was used to estimate the population for Cardigan Bay SAC, which has had regular and relatively even coverage over a period of 12 years. The open model reveals no apparent trends over those years, with the latest estimate being 154 dolphins in 2012.

There are reasons why estimates derived from Photo ID (Mark-Recapture) and line-transect (Distance) analyses in 2012 (and any other year) might differ. Line-transect estimates present the average number of animals estimated to occur in the study area at the time of the surveys

(a snapshot view) whereas Photo ID estimates the number of different individuals occurring in the study area over the particular study period (in this case usually April-October). If some individuals are visiting the SAC only briefly, they should still appear in the Mark-Recapture population estimate but by chance may not be reflected in the mean abundance estimate from the line-transect surveys. We believe the low estimate from the line-transects suggests a lower usage of the SAC in 2012, although the number of dolphins visiting the SAC was not reduced. Further monitoring efforts will elucidate whether or not this inference is correct.

Immigration and emigration rates in Cardigan Bay SAC are higher than those calculated for Cardigan Bay as a whole. These are presented as gamma" - probability of an animal emigrating out of the study area; and gamma' - probability of an animal staying out of the study area. Gamma'' and gamma' trends in Cardigan Bay also show a relatively stable trend throughout the years (with the exception of 2009) suggesting a larger and more stable proportion of the population is using the entire Bay. This emphasizes the need for regular surveys throughout the Bay thus monitoring a larger proportion of the Cardigan Bay population.

In 2007, survey coverage expanded to include the waters off NE Anglesey, and since then these have recorded significant numbers of bottlenose dolphins, particularly in winter. Many of the dolphins encountered in Cardigan Bay have now been identified off the Isle of Anglesey and some also around the Isle of Man (Pesante *et al.*, 2008a, b; Veneruso and Evans, 2012b). Nearly 30% of individuals have been identified in both SACs as well as north of the Llŷn Peninsula, around the Isle of Anglesey, indicating a large home range that most probably extends further into the northern Irish Sea. On the other hand, a small proportion of the population shows a much more local residency pattern with small home ranges. Twelve percent of individuals were sighted only within Cardigan Bay SAC, nearly 8% solely around the Isle of Anglesey, and 7% only within the Pen Llyn a'r Sarnau SAC, suggesting a proportion of the population shows strong site fidelity, although the area which they frequent can be anywhere around the coast of West and North Wales.

4.6 *Body condition*

On the 19th of June, one underweight female was recorded by Janet Baxter (Friends of Cardigan Bay) in Cardigan Bay SAC. Bottlenose dolphins in the UK tend to have a thick layer of blubber, which makes this recent occurrence unusual. This female has been seen in the region since 1990, has been recorded having two previous calves, and is currently accompanied by a third suckling calf. Two similar underweight females, also accompanied by calves, were recorded in 2011 (Veneruso and Evans, 2012a). Although it is possible that a mother suckling her young may lose weight, this has never been evident in other mothers recorded in Cardigan Bay in previous years. These unusual observations may suggest that currently there is low prey availability in the region, or that disease or parasite burdens are affecting them. Although neither of these explanations can be confirmed, the relatively low usage of the SAC in 2012 and the high percentages of foraging activities accords with the first hypothesis.

Two injured individuals were also recorded in 2012. One of these was a female well-known to us since 2003. Her injury has been recorded previously, and has had no apparent effect on her, as she has been seen in both SACs as well as off Anglesey. She has also been recorded having two calves throughout the study period. The second individual is a very young calf, only one month old, recorded in Pen Llŷn a'r Sarnau SAC on 22 Sept 2012. The injury resembles a boat collision wound, and since this is the first calf recorded for this mother, it is possible that her inexperience and the high boat traffic in the northern part of the Bay may have resulted in the injury.

5. REVIEW OF OBJECTIVES AND CONCLUSIONS

In this section, the original list of objectives will be reviewed, and conclusions reached from the current study will be presented.

5.1 *Record, document, and report numbers of bottlenose dolphins in Cardigan Bay SAC and Pen Llŷn a'r Sarnau SAC, and more widely in Cardigan Bay in order to determine the total population using the SACs and Cardigan Bay.*

Estimates of population size have been assessed using two different methods: line-transect surveys and Photo ID. Line-transect analysis estimates the average number of animals in the study area during the surveys. Population estimates in Cardigan Bay SAC present similar numbers for 2003 and 2005, peaking at 214 individuals in 2006 and then declining to 109 individuals in 2007. Estimates rose again slightly to 133 individuals in 2011, before dropping considerably, to 70 individuals in 2012. Unfortunately, funding ceased in 2008 and no line-transect surveys were undertaken until 2011, limiting our ability to assess long-term trends. 2012 was the only year when a large part of Cardigan Bay was surveyed by line-transect, and resulted in an overall abundance estimate of 330 individuals. These results suggest that the species uses Cardigan Bay SAC differently in different years with no obvious long-term trend.

Population estimates, calculated using the mark-recapture method based on Photo ID within Cardigan Bay SAC, also show no clear trend although there is some indication of a general increase in population size since 2001. However, when examining estimates for the whole of Cardigan Bay using a mark-recapture open model between 2005 and 2012, a relatively stable trend is observed, with a possible slight increase in recent years. The probability of dolphins leaving, and remaining outside the study area, is higher for Cardigan Bay SAC than for the wider region, emphasising that Cardigan Bay SAC is only part of the dolphins' consistent range, and that there may be a recent net emigration. This should become clearer in future years should monitoring be maintained. It is recommended that the entire area of Cardigan Bay be included in such monitoring.

5.2 *Report on fine and broad-scale distribution patterns of bottlenose dolphins and the relative temporal use of different parts of this range.*

Bottlenose dolphins in Cardigan Bay have a predominantly inshore distribution. Evidence of much feeding in the area, and the frequent presence of mother-calf pairs suggests that prey availability is probably the leading factor for the observed distribution. Furthermore, the shallow nature of the Bay may make the area attractive for benthic feeding mothers with dependent young since it means the adults can forage without leaving the calf alone for more than a few minutes, whilst also enabling growing calves to learn to make shallow dives in order to capture prey for themselves. On the other hand, surveys conducted during 2012, recorded ten dolphin sightings outside of the SACs, five of those recorded offshore outside Pen Llyn a'r Sarnau SAC, confirming the species as using the offshore waters of Cardigan Bay in summer months as well as in the winter. Offshore sightings have been reported on occasions in previous years although these have still been within c. 10 nm of the coast. Areas further offshore have only recently been surveyed in summer. Two of the five offshore sightings in 2012 were recorded just over 10 nm from the coast. In addition, five sightings were recorded inshore in the gap between the two SAC's. It is recommended that a re-evaluation of the boundaries of the SACs be made, and that monitoring is continued in these "unprotected" areas.

The overall distribution of the population may also be changing, with increased summer activity in North Wales observed in recent years. In 2011 and 2012, groups of dolphins were recorded in that region several times during the summer months, and included individuals that have previously shown a strong site fidelity to Cardigan Bay at this time of year. It may be the case that prey availability has become greater off the waters off North Wales, and so dolphins do not make the journey into Cardigan Bay. Alternatively, there could be a prey shortage in Cardigan Bay, meaning that dolphins need to travel more widely, including outside of the study area, in order to find food. The observations of undernourished adults within Cardigan Bay over the last two years lend some support to the latter hypothesis. Information on the abundance of important prey species in Cardigan Bay, and other parts of the Irish Sea, would be useful in order to investigate this further. However, relatively stable population estimates for the entire Bay suggest that the shift has been less pronounced over the wider area than in Cardigan Bay SAC itself. This SAC is also considered a high-pressure area for boat traffic, with a continued increase in recreational boat activities occurring each year, which may be affecting bottlenose dolphin presence in the area (see section 5.9).

Local residencies, which were previously recorded only in Cardigan Bay SAC, are now apparent in other areas of Cardigan Bay and north of the Llŷn Peninsula. There is currently no targeted protection for bottlenose dolphins in the northern Irish Sea, which is subject to a number of anthropogenic pressures that currently do not exist in Cardigan Bay. If this trend of increased bottlenose dolphin activity north of Cardigan Bay continues, it would be wise to consider implementing appropriate conservation management actions for the species in this wider area and possibly setting up an additional long-term monitoring programme for that region.

5.3 *Document and report on the presence of calves and young juveniles in order to estimate the number of calves born annually by the population.*

Reproductive rates in Cardigan Bay SAC present healthy crude birth rates of 5.3% and 7.8% using closed and open population models respectively, confirming that this region serves as an important nursery ground for females and their young calves. Birth rates calculated for the entire Bay are even higher, especially when using an open population model (9.4%), suggesting there are additional females nursing their young within other areas of the Bay including Pen Llŷn a'r Sarnau SAC. It is clear that the whole region, quite possibly extending beyond the Bay, serve as regular calving grounds. High intensity of vessel activity has been shown to cause stress particularly on mother-calf pairs, and improved application of current codes of conduct for recreational vessel activities in the northern part of Cardigan Bay is needed.

5.4 *Measure both juvenile and calf survival rates for the population on an annual basis by monitoring the proportion of animals still alive and recording known deaths.*

Calf mortality rates calculated for Cardigan Bay SAC were 18% for each of the first and second years, decreasing to 8% in the third year. The first year mortality rate seems to be average compared with other populations of the species. There are few studies that show the mortality rate of calves in the second and third years. Our calculation is the same as that which others have presented for year two, although higher for year three.

A total of 55% of calves survived into their fourth year. Bottlenose dolphin calves in Cardigan Bay tend to leave their mother by the fourth year. Unfortunately, once they leave the mother's side, they are no longer recognisable as individuals until they have acquired markings useful for Photo ID. For this reason, it is difficult to report on juvenile survival rates beyond the age of 3-4 years.

5.5 *Record numbers of juveniles, female and male bottlenose dolphin adults, in order to report on population structure parameters (age and sex ratios) and site use, e.g. by family groups or bands.*

Our database currently holds records of 70 definite females and 16 definite males. However, at this stage, without moving into genetic sampling, it is not possible to provide an accurate assessment of sex ratios of this population. Animals can be positively sexed if the genital area of identifiable individuals is seen or, in the case of females, if a dolphin is recorded with a calf on several occasions (we use a minimum of three occasions as the criterion). Since there are many mother-calf pairs in the region, females can be identified much more easily and for this reason there is an under-representation of known males confirmed in the catalogue. Genetic sampling would allow us to sex individuals and also to identify related individuals both within and between groups. It would also provide information on population structure generally, enabling us to better differentiate sub-populations. If this aspect is to be addressed, genetic sampling of this population (by skin biopsy) will be necessary, as has been conducted with many other European populations, including those in Scotland and Ireland.

5.6 *Identify the home range sizes of individual identifiable animals, including determination of ranging movements and core areas.*

It is now clear that the home ranges of some dolphins that use Cardigan Bay extend to North Wales and the Isle of Man if not beyond. Despite comparison with other Photo ID catalogues around the UK and Ireland, however, no individual matches have yet been found with Welsh animals, suggesting that this population's range may be restricted to the Irish Sea.

Recent analysis shows that nearly 30% of individuals have been identified in both SACs as well as north of the Llŷn Peninsula around the Isle of Anglesey, indicating large home ranges that most probably extend to the northern Irish Sea and maybe beyond. On the other hand, a proportion of the population shows a more local residency pattern, with relatively small home ranges: 12% of individuals were sighted only within Cardigan Bay SAC, nearly 8% solely around the Isle of Anglesey, and 7% only in the Pen Llyn ar Sarnau SAC (Figures 34-37).

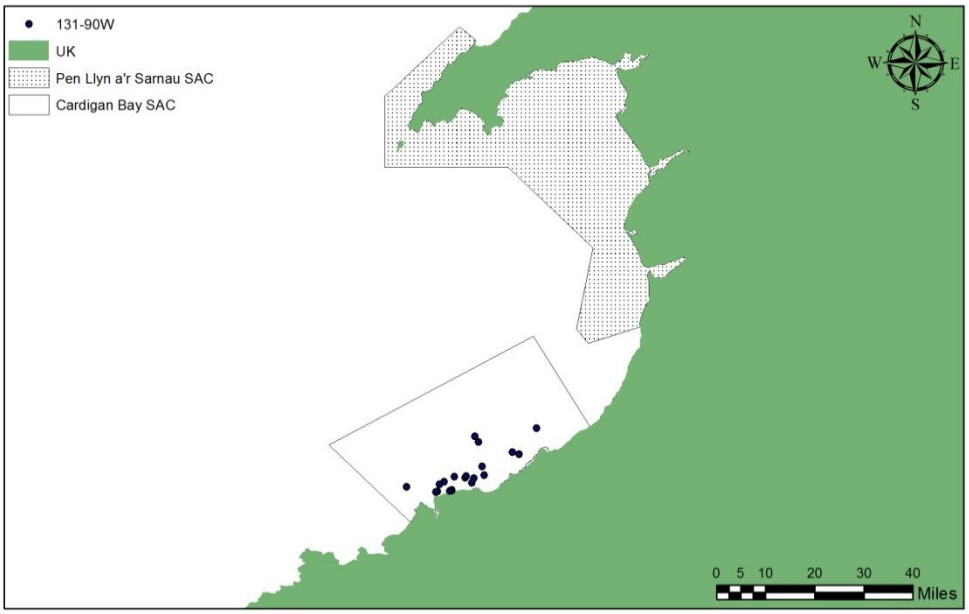


Figure 34: An individual (131-90W) recorded only in Cardigan Bay SAC between 2001 and 2012 (n=28)

Figure 35: An individual (004-90W) recorded in Cardigan Bay SAC, Pen Llyn a'r Sarnau SAC, and Anglesey between 2001 and 2012 (n=173)

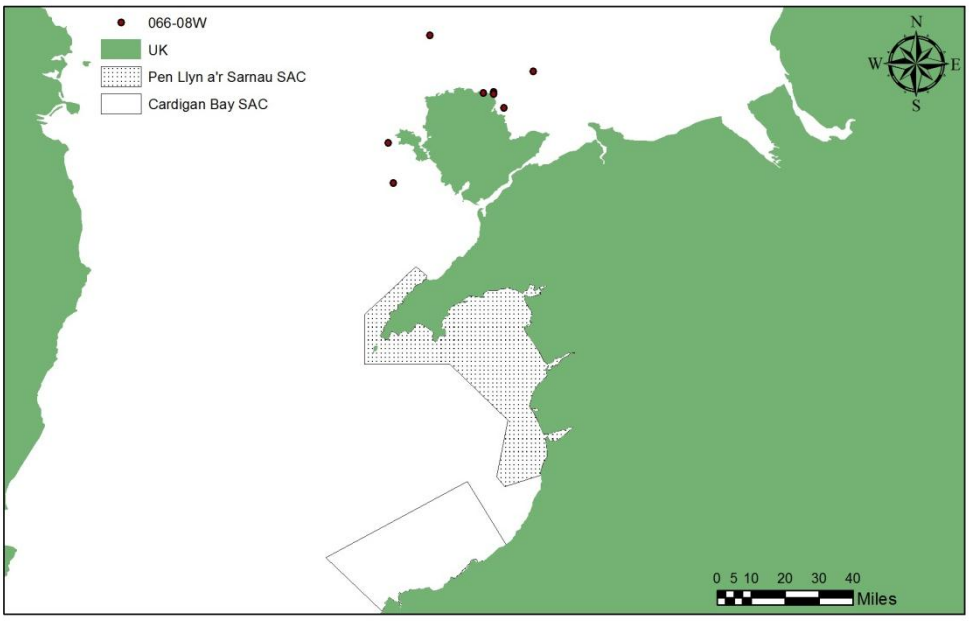


Figure 36: An individual (066-08W) recorded only in Anglesey between 2001 and 2012 (n=8)

Figure 37: An individual (005-90W) recorded in Cardigan Bay SAC, Anglesey and the Isle of Man between 2001 and 2012 (n=36)

5.7 *In order to investigate the nature of supporting habitats, e.g. estuary, headland or reef, record the number of bottlenose dolphin in each of the respective habitats and the location of each habitat within the site if necessary. Record all environmental and physical*

parameters at the time of recordings, e.g. tides, beach aspect, wind direction & speed, sea state, air temperature, and relevant biological information, e.g. aggregations of feeding birds or shoaling fish. The combination of information on habitat type and some of the above list will allow a preliminary assessment of habitat in the SACs. Results from this work will inform more targeted evaluation of both habitat and prey species.

The geographical location of each bottlenose dolphin sighting was recorded by latitude and longitude. A number of environmental parameters were recorded during surveys including sea state, swell height, and precipitation, and additional biological information (such as associated seabirds) was recorded if present.

5.8 *Categorise bottlenose dolphin behavioural activities in the region (areas, and proportion of time spent in resting, socialising, travel and feeding), and analyse yearly and seasonal behavioural patterns.*

Feeding and foraging have been recorded as the primary activities within the bottlenose dolphin budget in 2012 in Cardigan Bay SAC with feeding activities being the highest ever recorded since 2005. Assuming prey availability is a major factor influencing dolphin presence, we would expect higher population estimates in 2012. However, this is not the case with population estimates (from line-transect surveys) from Cardigan Bay SAC being the lowest this year since 2001, suggesting other elements might be the cause for this decline.

Further monitoring in future years would show whether this decline is part of a natural fluctuation, or represents a longer-term trend, with a decline in prey availability in the SAC. Other evidence (underweight dolphins, and an apparent decline in numbers using Cardigan Bay SAC) suggests this may be the case.

5.9 *Whilst conducting the above, quantitatively record, document and report all observed incidents of:*

- *Anthropogenic activity at each site at time of survey;*
- *Evidence of any recent change in anthropogenic use of sites. This should be evaluated in light of any historical records, changes in use or otherwise;*
- *Bottlenose dolphin disturbance by anthropogenic or other factors, its cause and outcome;*
- *Bottlenose dolphin absence from historically used sites that can be attributed to an activity (human or otherwise) whether the activity is present or not at the time of observation.*

Leisure boat activity around the UK has generally increased in recent years, and dolphin watching activities in particular have risen markedly (O'Connor et al., 2009; Lambert and Evans, 2012). Boat traffic is now recognised as an important factor affecting distribution and behaviour of coastal cetaceans. Many studies present the negative effects upon bottlenose

dolphins due to recreational activities, with behaviour responses ranging from moderate changes in behaviour to the avoidance of preferred habitats (see, for example, Gregory and Rowden, 2001; Hastie *et al*., 2003; Lusseau, 2005; Mattson *et al*., 2005; Lohrengel *et al*., 2012; Thompson, 2012). Boat traffic, including the number and type of surrounding boats, was recorded at regular intervals during all our surveys in Cardigan Bay as part of our effort collection. Previous studies in the area have concluded that boat presence is negatively linked to bottlenose dolphin sighting frequencies, and one of the busiest sites, around the town of New Quay within the Cardigan Bay SAC, has seen a steady decline in bottlenose dolphin occurrence since 1994, with the relative abundance of the species inversely related to the number of boats counted (Pierpoint *et al*, 2009). A recent study (Lohrengel *et al*., 2012) shows that boat traffic, primarily motorised vessel levels increased throughout Cardigan Bay from 2006 to 2011, with the highest rate of boat traffic in Tremadog Bay averaging at 11.5 boats per hour. Six sites within Cardigan Bay (Tremadog Bay, Barmouth, Aberystwyth, New Quay, Aberporth and Cardigan) had high levels of boat traffic coinciding in most cases (the only exception being Aberporth) with a decline in sightings after 2007.

A Masters project undertaken by Katy Thompson in 2012 (Appendix 1) investigated variation in whistle characteristics of bottlenose dolphins within Cardigan Bay, and found that frequency characteristics (peak, maximum and minimum frequency) increased in areas of high boating activity. These results suggest that increased excitement or distress due to the presence of boats appears to be linked with tighter group formations, in particular those with calves. Most whistles collected for this project were obtained within the vicinity of New Quay, where high levels of boat traffic are recorded although these are regulated through codes of conduct that were introduced in 2001. Analyses of whistles collected indicate that dolphins changed aspects of their whistle characteristics in this area irrespective of whether or not regulation was in place.

An additional study performed by a Masters student (Heidi Richardson) in 2012 (Appendix 1) examined the effect of boat disturbance on the social structure of bottlenose dolphins in Cardigan Bay. The results strongly indicate that vessel traffic does impact community structure. Group size was significantly smaller in areas of high vessel traffic, and results suggested individuals in high vessel traffic areas form moderately strong bonds with several other individuals, whereas those in areas of low vessel traffic formed very strong bonds with a smaller number of individuals. Very similar values between areas of regulated and unregulated vessel traffic indicated that dolphins modify their social behaviour when exposed to high levels of boat traffic, despite the regulating of boat behaviour.

It is suggested here that low population estimates for bottlenose dolphins derived from line-transect surveys in Cardigan Bay SAC have been partly affected by intense vessel traffic within the area. High levels of vessel traffic are also observed in the northern part of Cardigan Bay, with Tremadog Bay having the highest rate, although this comprises mainly sailboats. Since population estimates through line-transect surveys across the entire Bay appear to be relatively stable, it is suggested that the effects may be localised, as for example in Cardigan Bay SAC. Dolphins are recorded also in the outer parts of Cardigan Bay, an area that for the last few years has been subject to scallop dredging in winter months. Further

surveys of this region are necessary to assess the potential effects of this fishing activity upon the species.

Entanglement of cetaceans in anthropogenic debris, e.g. fishing gear

There were no observations by SWF of entanglement in anthropogenic debris in 2012, nor any incidents reported to us. Commercial fishing is at a relatively low level in Cardigan Bay, with most of the industry focused upon potting. To our knowledge, there is relatively few net fisheries operating in the area.

Significant fresh injuries commensurate with propeller or boat collision

Two injured dolphins were observed by Sea Watch Foundation researchers. One, which is a well known female (035-03W) recorded since 2003, carries an injury thought to be a propeller cut that was first recorded in 2007. It appears that this injury has had little impact on the animal's mobility and reproductive ability since she has been seen accompanied by a calf and has been seen regularly throughout the study period, and in 2012 was observed in Cardigan Bay, off Anglesey and the Isle of Man (Figure 28).

The second individual was a very young calf, only one month old, accompanied by a dolphin assumed to be its mother. This is the first calf we have recorded for this female, which was first spotted in 2009. During our encounter with the two animals, they were observed bow-riding for long periods of time, an activity that is uncommon for such a young calf. The inexperienced mother, along with her young calf may therefore have been subject to this injury from one of the many vessels that occur in the northern part of Cardigan Bay during the summer months. On the other hand, one cannot discount the possibility that the calf was born with this disfiguration on its fin (Figure 29).

Evidence of body condition/health, e.g. skin lesions

A single dolphin has been recorded as underweight in 2012 by Janet Baxter (Friends of Cardigan Bay), while on board a local boat tour in Cardigan Bay SAC (see Figure 27a). We have identified this individual to be 038-90W, a well-marked female seen in the area since 1990. This underweight female currently has a dependent calf. Although she was spotted relatively early in the season (June), she was not seen again so a further evaluation of weight could not be assessed. Underweight dolphins have been recorded in Cardigan Bay emphasising the need to further investigate prey availability in the area. A record of underweight dolphins should be kept in future surveys, and the individuals identified as underweight in 2012 should be monitored further.

Skin lesions were present on many individuals in 2012, although in no greater proportion than in previous years. No analysis of the presence and type of skin lesions has been made since Magileviciute's (2006) Masters thesis.

5.10 *To interpret past and current data, in order to provide a reasoned opinion on the status of bottlenose dolphins in the SACs and Cardigan Bay, and develop targets for monitoring. A recommendation of condition should be made but CCW reserves the right to accept or reject. All available data should be integrated at the appropriate level*

Sea Watch Foundation has been monitoring bottlenose dolphins using standardised procedures for the past 12 years. However, in order to provide a robust assessment of the status of bottlenose dolphins in the SACs and in the wider Cardigan Bay, long-term monitoring with consistent effort and coverage is required. Due to lack of resources, there have been some years with little survey coverage and no overall abundance estimates could be calculated, thus providing some gaps in our knowledge. Furthermore, the focus in the earlier years was Cardigan Bay SAC and so we have a longer series of estimates than from Pen Llyn a'r Sarnau SAC, whilst areas outside these SACs have only started to be surveyed in 2011 with this current contract. Despite this, some educated judgments can be made regarding abundance estimates for Cardigan Bay SAC and, at the present time,, for the whole of Cardigan Bay. Examination of the longest dataset we have, which is for Cardigan Bay SAC, both line-transect and photo ID data reveal no clear trend. The results for 2012 indicate a decline in abundance estimates in the SAC from the line-transect surveys, but a slight increase in estimates of population size from photo ID.

The apparent contradiction between the trends observed from line-transect surveys and those from Photo ID in Cardigan Bay SAC may be due to the different measures they make. Line-transect surveys estimate the average densities and hence abundance of the area being systematically surveyed. Photo ID, applying mark-recapture, provides an estimate of the number of individuals using the study area during the period of data collection. Some individuals may use the area regularly whereas others may do so only infrequently. If some individuals use the area less, the line-transect abundance estimate may not be affected but the mark-recapture estimate could be. This may be what occurred during 2012, and some of the additional information from the Photo ID effort supports that. Whether this is a temporary situation or part of a longer-term trend will become clearer with future monitoring.

When comparing estimates for the entire Bay, a relatively stable trend is observed from photo ID since 2007 when surveys over the wider area started. It is not possible to evaluate trends for the entire Bay from line-transect surveys as this is only the second year that these have taken place throughout the Bay, including Pen Llyn a'r Sarnau SAC. In addition, line-transect surveys commenced late in the season in 2011, and did not include as full a spatial coverage of the region. Taking all these aspects into consideration, it appears that the population inhabiting all of Cardigan Bay is more stable than within Cardigan Bay SAC itself. There is clearly movement of individuals between the SAC and other parts of the Bay, and some of these appear to be longer lasting such that some animals may not be seen within the SAC in a particular year. This is supported by the lower immigration and emigration rates in wider Cardigan Bay compared to the SAC itself.

In order to assess whether the above assessment is a true reflection of the status of the population, consistent monitoring needs to be maintained throughout the Bay.

5.11 *Critically review the methodologies used and report on the best scientific and fieldwork practice for monitoring of bottlenose dolphins in Wales. To include a cost benefit analysis concentrating on abundance and life history parameters but covering all attributes listed in Section 1. Alternative sampling strategies should be explored*

A combination of methods has been used to monitor this population of bottlenose dolphins, and to maximise the information collected. These techniques have both advantages and disadvantages, but when combined, are effective in assessing abundance and life history parameters.

Vessel-based line-transect surveys were conducted to calculate abundance estimates for both bottlenose dolphin and harbour porpoise. These surveys allow systematic coverage of the area, providing spatially unbiased population estimates for these species. Since photo ID is not practical for the harbour porpoise, line-transects have become the standard procedure for assessing abundance of this species. Another advantage of systematic surveys of this kind is that they provide information on distribution, allowing one to identify hot spots and determine whether these change seasonally or from year to year. One limitation of using the technique, however, is that a number of assumptions have to be made and some of these may be violated. They assume, for example, that animals are not responding to the survey vessel before being detected. If in fact they are moving towards the vessel before detection (as has been found on occasions for bottlenose dolphins, and some other social dolphin species) this will inflate the abundance estimates, whereas if they move away (as can occur with harbour porpoises), this will lower those estimates. Very little study has been made to date of those potential effects on small boat surveys. It may be that the lower engine noise of these small vessels reduces any potential effect. On the other hand, the invariably lower platform height may result in detections being confined to shorter ranges and thus made after any such movement has started. In order to assess this potential bias, the majority of line-transect surveys took place using a double-platform mode with independent observers focusing upon detecting animals at a distance along the track-line.

A further weakness is that in order to obtain precise abundance estimates with low CVs, unless the animals are very abundant, a high volume of effort must be conducted. The Welsh weather conditions often leave fewer opportunities for surveys than recommended. Therefore, a full field season is necessary in order to achieve the required volume of effort. For this reason, the recruitment of volunteers for the 2012 field season has been extended to include most of April and all of October, in the hope that funding for line-transects will allow SWF to begin surveys in spring. However, 2012 was an exceptionally bad year in terms of weather, and although we were able to cover all the inshore transects of the study area, there was lower effort offshore than we desired. There is also a limit to how much one can extend the field

season because the majority of the Cardigan Bay bottlenose dolphin population usually only returns to the Bay sometime in April, and may then depart again in October.

As noted above, line-transect surveys are the standard method for calculating abundance of harbour porpoise, and indeed the only technique available to provide robust estimates for the species. We believe that the harbour porpoise estimates obtained here represent an accurate picture of the status of this species. We continue to work to minimise the CVs for a more precise abundance estimate, ideally to achieve CV values of 15-20%. For relatively small areas like Cardigan Bay, that is challenging. Nevertheless, the CV around the harbour porpoise abundance estimate from the SCANS II survey conducted across all NW European waters was in fact the same as ours in 2012, at 20%.

Photo ID was another technique used in conjunction with line-transect surveys, in order to provide a separate assessment of abundance. Population estimates using Photo ID work best when most if not all of the population is aggregated in a small area over a short time period. The migration of individuals to other areas can cause difficulties. Since it is evident that an increasing number of dolphins are remaining outside Cardigan Bay, inhabiting the waters of North Wales (and probably beyond), we recommend that year-round systematic monitoring be established in North Wales.

One of the strengths of Photo ID is that it also provides information on life history parameters (birth rates, juvenile survival), social structure, individual movements and home ranges.

All dedicated surveys have additionally allowed the regular recording of boat traffic, as well as the collection of dolphin vocalisations and behavioural and environmental data, making these trips very cost-effective by combining these various research approaches within the same surveys.

For data collection related to sex ratios, genetic relatedness, connectivity between populations, and dietary preferences, biopsy sampling will be necessary, since current methods are not suitable to collect this information.

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APPENDIX 1: STUDENT PROJECTS – THESIS ABSTRACTS

Bird, A. (2012) Geographic variation in the whistle characteristics of bottlenose dolphins (*Tursiops truncatus*) between Cardigan Bay, Wales, the Shannon Estuary, Ireland, the Molène Archipelago, France and the Sado Estuary, Portugal. MSc thesis, University of Bangor Wales

The whistles of bottlenose dolphins can differ between geographic locations, but the reasons behind this variation remain unclear. It is important to study geographic variation in whistle characteristics of dolphins as it could be reflective of culture, genetic differences, and the importance of learning within different populations. In this study, the whistle characteristics of bottlenose dolphins (*Tursiops truncatus*) were compared between four different geographic locations (Cardigan Bay, Wales, the Shannon Estuary, Ireland, the Molene Archipelago, France and the Sado Estuary, Portugal). It was predicted that variation between populations would be greater than the variation within populations. Recordings from the four locations were collected using either hydrophones or bottom-moored autonomous recorders between 2001 and 2012. Whistles were extracted from the recordings, and nine whistle characteristics were measured from each whistle. One-way ANOVAs and Kruskal-Wallis tests were undertaken on each of the nine whistle characteristics to determine the ways in which whistles varied between location. The frequency and intensity variables of whistles from the Sado Estuary were significantly higher than in other areas. This variation could be due to differences in background noise levels, genetic differences, the openness of populations, or differences in body size. It seems most likely that differences in background noise levels between populations would explain the variation, due to the high levels of boat traffic in the Sado Estuary. Future studies should focus on more conclusively determining the reasons behind the existing variation between these four populations of bottlenose dolphins.

Britton, J. (2012) The impact of boat disturbance on the grey seal (*Halichoerus grypus*) around the Isle of Man. MSc thesis, University of Bangor Wales

Due to their coastal habitat and curious nature, grey seals (*Halichoerus grypus*) are often subject to anthropogenic disturbance from boat users and pedestrians. This can have many negative impacts upon the species, such as reducing the time they are able to spend resting and changing their haul-out patterns. Disturbance has been shown to be extremely detrimental during the breeding season, as it may interrupt lactation or cause separation of the mother and pup. This study examined the behaviour of grey seals whilst in the water and hauled-out, in order to gain a full picture of how the seals are impacted by boat disturbance. Observations were made at two sites on the Isle of Man, one that was subject to large amounts of boat disturbance, whilst the other received minimal disturbance. In---water surveys involved focal follows of individual seals in order to construct behavioural budgets, and to record the responses of focal seals to boat disturbance. Haul---out surveys were conducted to record general count data, levels of vigilance and response to disturbance. The proportion of time that seals in the water spent 'bottling,' (a form of rest at the surface of the water) was found to be significantly different between sites (U = 8.000, p = 0.04). On the other hand, the overall time spent resting was similar. A significant correlation was found

between boat speed and the distance at which hauled seals showed alert behaviour ($X2(14) = 0.55$, $p = 0.04$). There also appeared to be a similar association between boat speed and movement and flushing response (entering the water), but this was not tested due to small sample size. The duration of the boat interaction was found to be important, with flushing occurring in all interactions lasting four minutes or longer. Due to unusually poor weather during the study, seals at the disturbance site were not subject to as high a level of boat traffic as is normal. However, boat disturbance would likely be much higher during good weather, and this location is close to a breeding site where seals are particularly vulnerable. Therefore stricter enforcement is needed to protect seals from the effects of disturbance.

Cunningham, E.G. (2012) Advances in understanding of natural range and distribution of *Tursiops truncatus* in Cardigan Bay, Wales. MRes thesis, University of Bangor Wales

The Lagrangian photo-identification technique has been used exclusively to monitor the Cardigan Bay *Tursiops truncatus* population since 1986. However, understanding of natural range and distribution of the population is limited. Improved spatiotemporal coverage via the unification of existing photo-ID catalogues was analysed in order to improve understanding and to determine the suitability of the current monitoring programme. Photographs were cross-matched by eye, with any probable matches confirmed or rejected by an experienced second reader. Individual recapture rates, defined as the number of years out of all years with survey effort that an individual was positively sighted, disappearance rate and mortality rate were calculated. A high matching success rate between Cardigan Bay catalogues and between these and the Isle of Man catalogue was found. No matches between the Cardigan Bay/Isle of Man and Hebridean catalogue were made. Certain individuals were found to exhibit 15 to 20 year site fidelity to southern Cardigan Bay. The effect of markedness on recapture rate was found to be significant, biasing results towards well-marked individuals. Photo quality was highly variable. A minimum average disappearance rate of 3.37% and a minimum average mortality rate of 2.44% was calculated. Mortality rates are concurrent with existing literature. The population is likely closed, and its range probably encompasses the entire Irish Sea. It is suggested that although southern Cardigan Bay, Anglesey and the Isle of Man do constitute seasonally important habitats, existing conclusions on range and distribution are likely artefacts of spatiotemporally limited survey effort and biased analyses. Future work must strive to improve coverage, employing a more multi-faceted monitoring approach where possible.

Dencer Brown, A. (2012) Assessing the parameters affecting sighting detection rates of the bottlenose dolphin in the Cardigan Bay Special Area of Conservation, Ceredigion, West Wales. Diploma thesis. Department of Continuing Education, University of Oxford

Abundance and density data on the semi-resident population of bottlenose dolphins in New Quay, Cardigan Bay is integral to the conservation measures employed in this Special Area of Conservation. Responsive behaviour of the bottlenose dolphin *Tursiops truncatus* to vessels in the area may have an effect on abundance and density data leading to positive or

negative bias in the numbers recorded. The present study's main aim was to see whether responsive behaviour of *Tursiops truncatus* to vessels occurred, at what distances this behavioural response took place and whether this behaviour occurred before the observer on board the vessel had detected the bottlenose dolphin(s). The study period ran from the 24th June to the 31st July 2012. Bottlenose dolphins were tracked from the cliff-top and behaviour prior to interaction with vessels was noted as well as any behavioural changes. Observers on-board vessels also recorded the presence of bottlenose dolphins and the data was compared. Responsive behaviour occurred in 38% of total observations (n=95). However this was not significant with the type of vessel, group size and composition of the bottlenose dolphin or distance between the bottlenose dolphin and the vessel (Chi-squared tests, $P>0.05$). Comparison of data between the observer on the vessel and the cliff-top observer showed that responsive behaviour occurred in 43% of cases, all displaying behaviour away from the vessel. This change in behaviour was detected by the cliff-top observer before the observer on the vessel in 66% of observations, however sample size was very low (n=7). This study suggests that responsive behaviour of *Tursiops truncatus* may occur and that this occurrence may happen before the animal is detected by the observer on-board the vessel. This has important implications with regards to abundance and density estimates of *Tursiops truncatus* in the Cardigan Bay SAC and subsequent conservation measures implemented within the area.

Goulton, M. (2012) A comparison of visual and acoustic survey data collected from 2005 to 2008 in the Cardigan Bay SAC for the harbour porpoise and bottlenose dolphin. MSc thesis, University of Bangor Wales

Acoustic monitors are widely used to monitor the presence of cetaceans and have advantages over visual survey methods that include being able to monitor in all weather and lighting conditions, and recently acoustic techniques have been used to derive density estimates using arrays of passive acoustic detectors. Few studies have compared trends in acoustic and visual data in monitoring of bottlenose dolphins and the harbour porpoise. This study compared visual data (within areas around T-PODs and absolute abundance estimates for Cardigan Bay SAC) to the acoustic data (median number of detection positive minutes) produced across 12 sites in the inshore Cardigan Bay SAC during 2005-08. When data was combined across years, high correlations were found between the visual and acoustic data for the harbour porpoise ($rs= 0.6000$, d.f. = 12, $P<0.05$), and for the bottlenose dolphin ($rs= 0.6173$, d.f. = 12, $P<0.05$), when grid cells around T-PODs were 1650m and 1300m respectively. Lower, but still significant correlations existed as the data was separated into years for both cetacean both species. Bottlenose dolphin behaviour affected correspondence between visual and acoustic data, where in comparison to the visual data a lower number of detection positive minutes was found. Additionally, for the harbour porpoise, a significant correlation was found between line-transect survey absolute abundance estimate for the Cardigan Bay SAC and the and median detection positive minutes produced within the inshore Cardigan Bay SAC ($rs= 1.0$, d.f.= 3, $P<0.01$). No correlation was found between the line-transect or photo ID absolute abundance estimates and the median number of detective minutes for the bottlenose dolphin. A longer timescale of data collection be ideal to determine whether trends

do exist between absolute abundance data and acoustic T-POD data in the inshore Cardigan Bay SAC. The close correspondence between the acoustic (median number of detection positive minutes) and visual data (total number of animals per km travelled) around T-PODs, suggests that the derivation of density estimates using acoustic data loggers has potential, although behaviour of the bottlenose dolphin needs further consideration.

Kuepfer, A. (2012) Foraging patterns and home ranges of breeding razorbills (*Alca torda*) from two colonies in North Wales, UK, as revealed by GPS-tracking in the seasons of 2011 and 2012. MSc thesis, University of Bangor Wales

Razorbills *Alca torda* have experienced recent localised population declines with repeated breeding failure due to food shortage. An improved understanding of foraging behaviour would facilitate the implementation of appropriate at-sea protection measures. Using miniature GPS loggers, this study aimed to describe the foraging behaviour of breeding razorbills from two North Welsh colonies: Bardsey Island (2011) and Puffin Island (2011 and 2012). The study tested for inter-colony and inter-annual differences in maximum and total foraging trip distance and trip duration (using a GLM) and trip timing (using $\chi 2$-tests), and applied a fixed-kernel analysis to determine the 95% home-range and 50% core foraging areas, relating the latter to environmental parameters. Birds from Bardsey and Puffin Island travelled up to c. 40 and 60km from the colony, respectively. Overall, both colonies/years showed similar patterns with mean values of c. 13km maximum distance, 37km total distance and 6h trip duration. However, when diurnal and nocturnal trips were analysed separately, a significant colony difference was found, with birds from Bardsey having longer distance diurnal trips, and shorter nocturnal trips. In both years/colonies, diurnal trips occurred between sunrise and sunset, whilst nocturnal trips revealed a significant diel pattern, probably representing crepuscular foraging. At Bardsey, the home-range extended in a south-western direction, with core foraging areas located c. 10-20km SW of the colony. At Puffin Island, the overall home-range extended NW of the colony, with core foraging areas located around Puffin Island and along the E/NE Anglesey coast. However, diurnal and nocturnal home-ranges and foraging areas differed substantially at both colonies, with diurnal foraging areas mainly over sandy substrates. In both years at Puffin Island, the diurnal foraging areas occurred in much shallower waters (<20m) than in nocturnal foraging areas (≤80m depth), whereas at Bardsey, both diurnal and nocturnal foraging areas occurred in waters of 50-100m deep.

Richardson, H. (2012) The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus*) of Cardigan Bay in Wales. MSc thesis, University College London

The bottlenose dolphin is a widespread, iconic species and as such is protected by law throughout Europe. Cardigan Bay in Wales has two areas designated for the protection of the bottlenose dolphin. Legislation protecting the bottlenose dolphin requires Governments to ensure factors that may adversely affect populations are limited. With respect to the bottlenose dolphins of Cardigan Bay, this factor is likely to be disturbance. Boat disturbance within Cardigan Bay has been steadily increasing due to increases in the number of

recreational boats used and wildlife watching trips taken. Studies show that boat disturbance can negatively impact bottlenose dolphins, with responses ranging from moderate changes in behavior to the avoidance of preferred habitats. This study focuses on the effect of disturbance on dolphin community structure, community structure being important to increasing an individuals' fitness. Additionally, it examined the effectiveness of current management plans in decreasing the possible effects of disturbance. Cardigan Bay was split into areas of regulated and unregulated high vessel traffic and areas of low vessel traffic. The results strongly indicate that vessel traffic does impact community structure. Group size was significantly smaller in areas of high vessel traffic and results suggested individuals in high vessel traffic areas form many moderately strong bonds with many other individuals, whereas those in areas of low vessel traffic formed very strong bonds with a small number of individuals. Very similar values between areas of regulated and unregulated vessel traffic indicate that the current management plan is not being effective in reducing all of the impacts of disturbance on the dolphin population. This study recommends the continued monitoring of Cardigan Bay to increase the understanding of how disturbance may affect the bottlenose dolphins and to allow an effective management plan to be put in place.

Schop, J. (2012) Predicting spatial abundance of common demersal fish in the Irish Sea. MSc thesis, University of Bangor Wales

Knowledge of the spatial distribution of marine fish species is an important tool for the development of fisheries management plans. An example of the implementation of such management is the development of marine protected areas. Habitat suitability of species is a key feature in defining the spatial distributions. In this study the habitat suitability of dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), poor cod (*Trisopterus minutus*) and whiting (*Merlangius merlangus*) in the Irish Sea were investigated. Generalised additive mixed models were used to analyse the species response to chlorophyll *a*, shear stress and sediment type. It was hypothesised that all species prefer an area with a high chlorophyll *a* level and a low shear stress. These two factors might be indirectly linked to the food availability, because in general areas with high chlorophyll *a* concentrations tend to attract many marine species, and areas with high shear stress can disturb and even damage benthic invertebrates, which is the main food source the demersal fish. This hypothesis was accepted for *L. limanda*, *P. platessa* and *M. merlangus*, but rejected for *T. minutus*. *T. minutus* preferred areas with a high shear stress and a low concentration of chlorophyll *a*. It was also hypothesised that flatfish (*L. limanda* and *P. platessa*) have a stronger preference for a certain sediment type, compared to the two ganoids species (*T. minutus* and *M. merlangus*), because of their morphological shape and the ability to burry themselves in the sediment. No difference of the abundance of two flatfish was found between the different sediment types, while a preference was found for *T. minutus* and *M. merlangus*. *M. merlangus* preferred fine sediment types and *T. minutus* had a preference for a coarse substrate type.

Thompson, K. (2012) Variations in whistle characteristics of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, Wales. MSc thesis, University of Bangor Wales

Bottlenose dolphins have complex social structures which require a wide range of auditory communication. Whistles are long ranging vocalisations which vary within different social contexts. Whistle convergence has previously been seen in groups of strongly bonded individuals as a result of vocal mimicry, causing similarities in whistle characteristics such as frequency and whistle complexity variables. Other sources of whistle variation can be caused by differences in behaviour and the environment. Whistles of the Cardigan Bay population were investigated by comparing whistles characteristics produced by different groups of dolphins both within and between dolphin groups. The variation was then correlated to behavioural and environment contexts. This was completed via *ad libitum* and line-transect surveys and subsequent multi and univariate analysis. Whistle variation between groups was larger than within groups; this was attributed to shared whistle repertoires of different social groups. Frequency variables were responsible for the variation between groups whilst variation within groups was attributed to whistle complexity. Frequency characteristics of peak, maximum and minimum frequency increased in areas of increased boating activity, decreased depth and whilst in tighter group formations. The increased frequencies indicate incre ased excitement or distress due to the presence of boats, which may result in tighter group formations, in particular those with calves. Overall whistle rates were low which may also be resultant of high calf numbers in Cardigan Bay. Low whistle rates reduces the risk of adult male conspecifics locating calves and reduces energy costs for lactating females. In addition, the high familiarity between individuals of the sample area may indicate a large amount of vocalisation is not required. Despite the small dataset it can be concluded that whistle variation does occur in Cardigan Bay however increasing surveying effort will give a full representation of whistles of the dolphin population in the different environments within Cardigan Bay.

APPENDIX 2: Primary Observer Sighting Form

Entered into PC ☐ Checked by ____________

Date:________________ Type of trip: LT ☐ NLT ☐ Page:___of___

GMT or BST

Sight #	**Time** (hh.mm)	**Lat** (min.sec)	**Long** (min.sec)	**Effort type**	**An. Ang** (deg)	**Boat course** (deg)	**Dist** (m)	**Species**		**Tot num**	**A**	**J**	**C**	**NB**	**Cue**	**Beh**	**Reac. to Boat**		**Seen by**
																Dir			
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	
		N52º	W004º					BND	HP								A	T	
								GS									U	N	

Type of trip LT = line-transect surveys, NLT = other than line-transect surveys **GMT**=Greenwich Mean Time, **BST**=British Summer Time **Effort type** LT, DS, CW, ID **Species** BND=bottlenose dolphin, HP=harbour porpoise, GS=grey seal **A**=adult, **J**=juvenile, **C**=calf, **NB**=newborn **Cue** HE=head, F=fin/fluke, L=leaping, S=splash, B=blow, BA=back, BI=bird, R=reflection, O=other, U=unknown. **Behaviour** For BND & HP SS=slow swim, NS=normal swim, FS=fast swim, SF=suspected feeding, FF=feeding (fish seen), L=leaping, B=bowriding, R=resting/milling, S=socializing, O=other, U=unknown, N=not recorded. For GRS H=hauled out, W=in the water **Reaction to boat** A=swimming away, T=swimming toward us, U=unknown, N=none.

APPENDIX 3: Independent Observer Sighting Form

Date:________________ Type of trip: LT ☐ NLT ☐ Page:___of_ GMT or BST

IO #	**Time** (hh.mm)	**Lat** (min.sec)	**Long** (min.sec)	**An.Ang.** (deg)	**Boat course** (deg)	**Dist(m)**	**Species**		**Ind. #**	**Cue**	**Effort type**		**Seen by prim.platform?**		**If yes, sighting #**	**Seen by**	**Comments**
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			
		N52º	W004º				BND GS	HP			LT	DS	Y	N			

Type of trip LT = line-transect surveys, NLT = other than line-transect surveys; **GMT**=Greenwich Mean Time, **BST**=British Summer Time; **Species** BND=bottlenose dolphin, HP=harbour porpoise, GS=grey seal **Cue** F=fin/fluke, **L**=leaping (body out of water), **S**=splash, **B**=blow, **BA**=back, **BI**=bird, **R**=reflection, **O**= other, **U**=unknown. **Effort type** LT=line-transect, DS=dedicated search.

APPENDIX 4: Effort Form

Boat: ____________ Person responsible for data ______________ Crew:__________________________________ Page ___of ___

Date:__________________ Time start ___________ Time end ___________ GMT or BST Type of trip: LT ☐ NLT ☐

Time hh.mm	**Lat.** (min.sec)	**Long.** (min.sec)	**Transect**	**Leg num.**	**Tran. point**	**Boat act.**	**Speed** knots	**Course** Deg.	**Glare** degrees	**Effort type**		**Precipitation**				**Visibility** (km)	**Sea state**		**Sigh. ref.**	**Comments**
												Type		**Int.**			B	S		
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52º	W004º		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				

Type of trip LT = line-transect surveys, NLT = other than line-transect surveys; **Leg** S=start, C=continuation, E=end; **Boat activity** NB=none, YA=yatch or sailing, RB=kayak, JS=jet ski, SB=speed boat, MB=motorboat, FI=fishing boat, Fe=ferry, LS=>30m; **Glare** 0=no glare, 1=mild, minimal impact on sightability, 2=moderate, 3=severe **Effort type** CW=casual watch, DS=dedicated search, LT=line-transect, ID=photoid; **Precipitation type** N=none, R=rain, F=fog, I=intermittent, C=continuous, L=light, M=moderate, H=heavy; **Sea state** B=sea state in Beaufort scale, S=swell presence and height (L= <1m, M= ≥1 and <2, H ≥ 2m)

Entered into PC ☐by ________________ Checked by____________________

APPENDIX 5: Data Archive

Data outputs associated with this project are archived on external Hard Drive sent to National Resources Wales (NRW).

(A) This report is archived in Microsoft Word and Adobe Portable Document Formats along with .jpg formatted images of related photos, graphs and maps within the document;

(B) Photo ID images taken while conducting CCW funded surveys in current SWF folder structure in .jpg format (original and cropped photos);

(C) Photo ID Catalogue – a dataset of marked and un-marked fin images in .jpg format;

(D) Photo ID database –records in access .mdb format; files that are required to install the software; map and fin images in .jpg format

(E) Sighting and Effort data in .xls spreadsheet format and related GPS tracks in .xls format (projection WGS 84)