Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2015

Katrin Lohrengel and Peter G.H. Evans

Sea Watch Foundation

Paragon House, Wellington Place, New Quay, Ceredigion, SA45 9NR

Contents

List of Figures

Introduction

Cardigan Bay is home to the largest coastal bottlenose dolphin population in the UK (Evans and Pesante, 2008). It is one of two main areas within UK territorial waters that have semi-resident groups of bottlenose dolphins, the other being the Moray Firth, Scotland (Wilson et al., 1997, Thompson et al., 2004). There is also a resident population in Ireland in the Shannon Estuary (Ingram and Rogan, 2002, 2003; Mirimin et al., 2011). Within the UK, small groups of bottlenose dolphin are also recorded regularly recorded in Southwest England and the Hebrides, whilst larger numbers inhabit offshore waters along the Northwest European shelf edge (Evans et al., 2003, Reid et al., 2003; Hammond et al., 2014).

Bottlenose dolphins are listed as a species of Community interest under Annex II of the EU Habitats and Species Directive (Council Directive 92/43/EEC), requiring spatial protective measures where critical habitat can be identified. There are two marine Special Areas of Conservation (SACs) in Cardigan Bay: Cardigan Bay SAC, where dolphins are the primary reason for designation and Pen Llŷn a'r Sarnau SAC, where they are a qualifying feature. The species is also listed under Annex IV of the Directive which requires strict protection.

History of dolphin research in Cardigan Bay

Cardigan Bay is renowned for its population of bottlenose dolphins with sightings being recorded as early as the 1920s (Evans & Scanlan, 1989). The first projects to systematically utilise photo-identification techniques to study the population were initiated in 1989 by Sue Mayer and Holly Arnold of WDCS, and Peter Evans and Emily Lewis-Brown from the UK Mammal Society Cetacean Group (later to become the Sea Watch Foundation). 2001 marked the start of the first intensive photo-ID surveys within Cardigan Bay, through a project funded jointly by the EU Interreg Programme and CCW (Baines et al., 2002).

Most dedicated photo-identification surveys focused on the Cardigan Bay SAC in southern Cardigan Bay between the 1990s and 2007, including two projects during the 1990s (Arnold et al., 1997; Lewis & Evans, 1999) and a land-based study on marine mammal disturbance from 1994 (Ceredigion County Council, 1998; Pierpoint et al., 2009). Line transect surveys were conducted alongside photo-ID (Ugarte & Evans, 2006)

Since then, survey effort has expanded into northern Cardigan Bay, covering the Pen Llŷn a'r Sarnau SAC (Pesante et al., 2008b) While initial surveys were conducted on an *ad libitum* basis with additional data being obtained through a local boat operator Alan Gray running Shearwater Cruises out of Pwllheli, systematic line transect surveys commenced in this part of the Bay in 2011, and have continued to date.

From 2001 to the present day, the Sea Watch Foundation (SWF) has been systematically monitoring bottlenose dolphins in Cardigan Bay, deriving abundance estimates, and studies of home ranges, population structure, and life history characteristics from photo-ID as well as line-transect surveys (Baines et al., 2002; Ugarte & Evans, 2006; Pesante et al., 2008b;

Feingold et al., 2011; Veneruso & Evans, 2012a,b; Feingold & Evans, 2014a, b; Norrman et al., 2015).

Distribution and abundance of bottlenose dolphins in Cardigan Bay

Overall, abundance estimates between 2001 and 2008 indicated an increase in bottlenose dolphin numbers in Cardigan Bay with summer estimates of up to 250 animals. However, in more recent years this trend appears to have been reversed (Baines et al., 2002; Ugarte and Evans, 2006; Pesante et al. 2008a, b, Feingold et al., 2011; Veneruso and Evans 2012a, b; Feingold & Evans, 2014a, b; Norrman et al., 2015). Nevertheless, Cardigan Bay, and the Cardigan SAC in particular, remain important habitats for bottlenose dolphins, with large numbers of animals inhabiting the area in the summer months. While photo-iID surveys have suggested that a significant number of individuals leave Cardigan Bay in the winter, moving north towards the Isle of Man and Liverpool Bay, a proportion of the population is known to remain in Cardigan Bay throughout the year (Pesante et al., 2008a , b; Feingold & Evans, 2014a, b).

In the winter season, dolphins regularly sighted in Cardigan Bay in the summer are frequently spotted off the north coast of Anglesey, around the Isle of Man, and sometimes in Liverpool Bay. Although the Isle of Man is the northernmost known limit of this population's range, it is likely to extend further north than that (Pesante et al., 2008a; Veneruso & Evans, 2012b; Feingold & Evans 2013b). Bottlenose dolphins have been sighted in the Solway Firth, but there are to date no suitable photographs to attempt matching to the Cardigan Bay catalogue. The Cardigan Bay catalogue has also been compared to photo-ID catalogues from further afield, such as from the Hebrides, Moray Firth, western Ireland, Cornwall and the English Channel but so far no matches have been made (Pesante et al., 2008b) suggesting there is currently no exchange between these populations and Cardigan Bay. There is some anecdotal evidence of a well-marked solitary dolphin ('Clet') that has previously been sighted in Cornwall, Isle of Mull and France being seen in Fishguard, Pembrokeshire, but not within the southern Cardigan Bay SAC.

In recent years, bottlenose dolphins have also been increasingly sighted in Liverpool Bay and off the Northeast Wales coast in the summer, and a large proportion of these have been positively matched to the Cardigan Bay catalogue (Lohrengel et al, 2014, Sea Watch Foundation, unpublished data).

Pressures, impacts and the need for monitoring

Despite the presence of two SACs within Cardigan Bay, there are a number of anthropogenic pressures that have the potential to negatively impact the Cardigan Bay bottlenose dolphin

population. Recreational boat use has increased in Cardigan Bay in recent years and there are indications that heavy traffic can temporarily displace animals from an area (Pierpoint et al., 2009; Lohrengel et al., 2012) as well as impacting community structure (Richardson, 2012). Although there is a strict code of conduct regulating interactions with wildlife in the SACs in Cardigan Bay, a high volume of motorised boat traffic may nevertheless have detrimental long term effects and these need to be carefully monitored and assessed to mitigate more permanent negative impacts.

Cardigan Bay bottlenose dolphins also frequently range into areas that afford them no special protection, such as Liverpool Bay and along the North Wales coast, which are under pressure from offshore renewable energy projects and the development of a deep water container terminal, heralded as the UK's largest transatlantic deep-sea port by developers. Building activities such as pile driving and dredging of canals can be disruptive to marine mammals (Daehne et al., 2013), and the development of a deep water terminal will almost certainly increase ship traffic in the area, as it is set to be the most centrally located terminal in the UK with the capacity to accommodate more- and significantly larger -container ships than previously possible (Peel Ports, 2016)

Furthermore, a recent proposal to open Cardigan Bay to winter scallop dredging within the 3-12 nm coastal zone from November 2016 has been submitted for consultation to the Welsh Government. There is limited information available on the impact that dredging may have on bottlenose dolphins in Cardigan Bay; although previous periods of dredging within the SAC coincided with lowered birth rates and reduced use of this area, it is impossible to tell if these were directly related or coincidental (Feingold & Evans, 2014a; Norrman et al., 2015). Continued monitoring will be essential to assess any direct or indirect long term impacts of these activities on the bottlenose dolphin population in Cardigan Bay.

It is vital for effective conservation management and the assessment of Favourable Conservation Status that reliable estimates of the number of dolphins, population trends, and the effects of anthropogenic activities on the population in the SAC 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 indicators identified as attributes for monitoring bottlenose dolphins in Welsh SACs (JNCC, 2005).

The Sea Watch Foundation have been monitoring the Cardigan Bay population since 2001, using a combination of line-transect and photo-identification, aiming for a systematic and scientifically robust means of assessing the status and distribution of the bottlenose dolphin population. Funding by Natural Resources Wales (formerly Countryside Council for Wales) has enabled the systematic monitoring to take place, allowing for absolute abundance estimates for both bottlenose dolphins and harbour porpoise in most years between 2001

and 2015. The current project combines vessel based surveys, both line transect and *ad libitum*, and photo-ID, from dedicated vessel-based surveys, opportunistic platforms, and land based surveys throughout Cardigan Bay on a regular basis to collect the necessary data to reliably monitor the resident bottlenose dolphin population. Sea Watch also engages in some monitoring of other marine mammals in the study area, such as the harbour porpoise (*Phocoena phocoena*) and the grey seal (*Halichoerus grypus*), as well as occasional visitors such as common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*) and minke whale (*Balaenoptera acutorostrata*).

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 photographic identification images for comparison to established catalogues, at sites within and outside the key study areas in order to evaluate dolphin movements, abundance estimates, and distribution

- To monitor the number of bottlenose dolphins using the SACs 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 potential impacts of human activity, such as scallop dredging, on bottlenose dolphins in the Cardigan Bay SAC and threats to the population in terms of population size, structure and reproductive success as well as distribution, range and area use.

Objectives

The following were the main objectives of the monitoring project:

- Using Photo-ID protocols and Capture Mark Recapture (CMR) analysis, record, document and report numbers of bottlenose dolphins in Cardigan Bay SAC and Pen Llŷn a'r Sarnau SAC, and more widely in the Cardigan Bay area, in order to determine the total population using the SACs and Cardigan Bay

- Report on fine and broad scale distribution patterns of bottlenose dolphins and the relative temporal use of different parts of the range, where survey effort allows

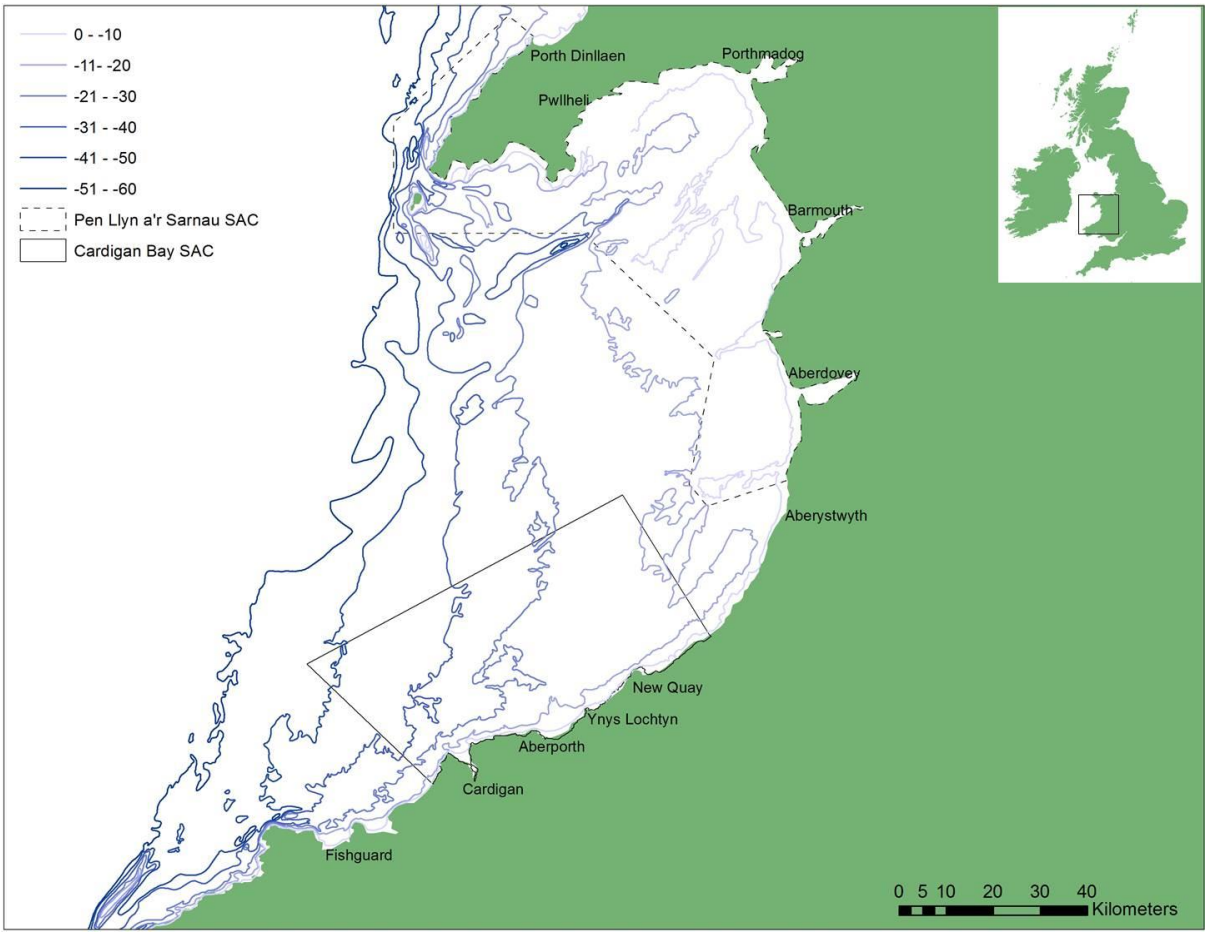
- Document and report on the presence of calves and young juveniles in order to estimate the number of calves born annually by the population
- Measure both juvenile and calf survival rates for the population on an annual basis by monitoring the proportion of animals still alive and recording known deaths
- Record numbers of juveniles, female & male bottlenose dolphin adults (on those occasions where gender can be determined), in order to report on population structure parameters (age and sex ratios) and site use (e.g. by family groups or bands)
- Identify the home range distributions of individual identifiable animals, including determination of ranging movements and core areas
- Investigate the nature of the supporting habitats, e.g. estuary, headland or reef, by recording 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
- 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
- Interpret past and current data in order to provide a reasoned opinion on the status of bottlenose dolphins in the study area. A recommendation of status should be made, but NRW reserves the right to accept or reject. All available data should be integrated at the appropriate level
- Along with NRW staff and relevant contractors, attend a meeting to discuss guidance for generic bottlenose dolphin monitoring in Wales

Methodology

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 4,986.86 km^2 from the western tip of the Llŷn 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, Figure 1). It is a shallow bay, with waters nowhere deeper than 60 metres and very gentle slopes (Evans, 1995).

Figure 1: The Study Area: Cardigan Bay in West Wales



The boundaries to Cardigan Bay SAC are indicated by continuous lines, and for Pen Llŷn a’r Sarnau SAC by hatched lines

There are two marine SACs within Cardigan Bay: Cardigan Bay SAC to the south and Pen Llŷn a’r Sarnau SAC to the north. The Cardigan Bay SAC was designated specifically to protect the local population of semi resident dolphins and encompasses 958.65 km^2 (Figure 1). In addition to being an area of critical importance to bottlenose dolphins, it is also thought to be a key habitat for Atlantic grey seals (*Halichoerus grypus*) as well as being important for some fish and invertebrate species (Anon, 2007; CCW, 2009). Furthermore, the SAC has a number of features and habitat types that qualify under Annexes I and 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, river lampreys (*Lampetra fluviatilis*),

and sea lampreys (*Petromyzon marinus*) (Anon, 2007; CCW, 2009). The Cardigan Bay SAC remains a prime habitat for bottlenose dolphin, and most research effort particularly prior to 2005, was focused within the southern SAC (Ugarte and Evans, 2006).

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˚ 25' 48" N to 52˚ 58' 12" N. Some additional qualifying features in this SAC include coastal lagoons, estuaries, mudflats and the otter (*Lutra lutra*) (Anon, 2007; CCW, 2009). The first dedicated marine mammal surveys of this area were conducted by SWF in 2006 on an *ad libitum* basis, with line transect surveys commencing in 2011 and continuing to the present.

Whereas the SACs cover much of the coastal area, there is a large proportion of Cardigan Bay, particularly offshore, that does not receive special protection. Survey effort in this area has been more limited; aerial surveys conducted during the winter season in 2006-07 suggested that this area was extensively used by bottlenose dolphins during that season, detecting also harbour porpoises and grey seals (Pesante et al., 2008b), but the first systematic coverage through boat based line-transect surveys did not occur until 2011.

Data collection

Surveys: Line transect surveys

Data for distance sampling based abundance estimates were collected during line transect surveys. Line transect surveys in Cardigan Bay SAC have been performed successfully in previous years, providing abundance estimates not only for bottlenose dolphins but also harbour porpoises and Atlantic grey seals (Baines et al., 2002, Ugarte and Evans, 2006, Pesante et al., 2008b, Veneruso and Evans 2012a; Feingold and Evans, 2013).

Table 1: Vessels used for line-transect surveys in Cardigan Bay in 2015
(*Cardigan Bay SAC, **Pen Llŷn 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**
Highlander	10	4	10	Twin 370 hp diesel	Offshore PL SAC**

Dedicated line-transect surveys were conducted between 2011 and 2015 by SWF staff and a team of trained interns, using vessels listed in Table 1. Surveys were subject to weather and

were only undertaken in favourable conditions: Beaufort sea state <3, visibility > 1.5 nm, and no precipitation.

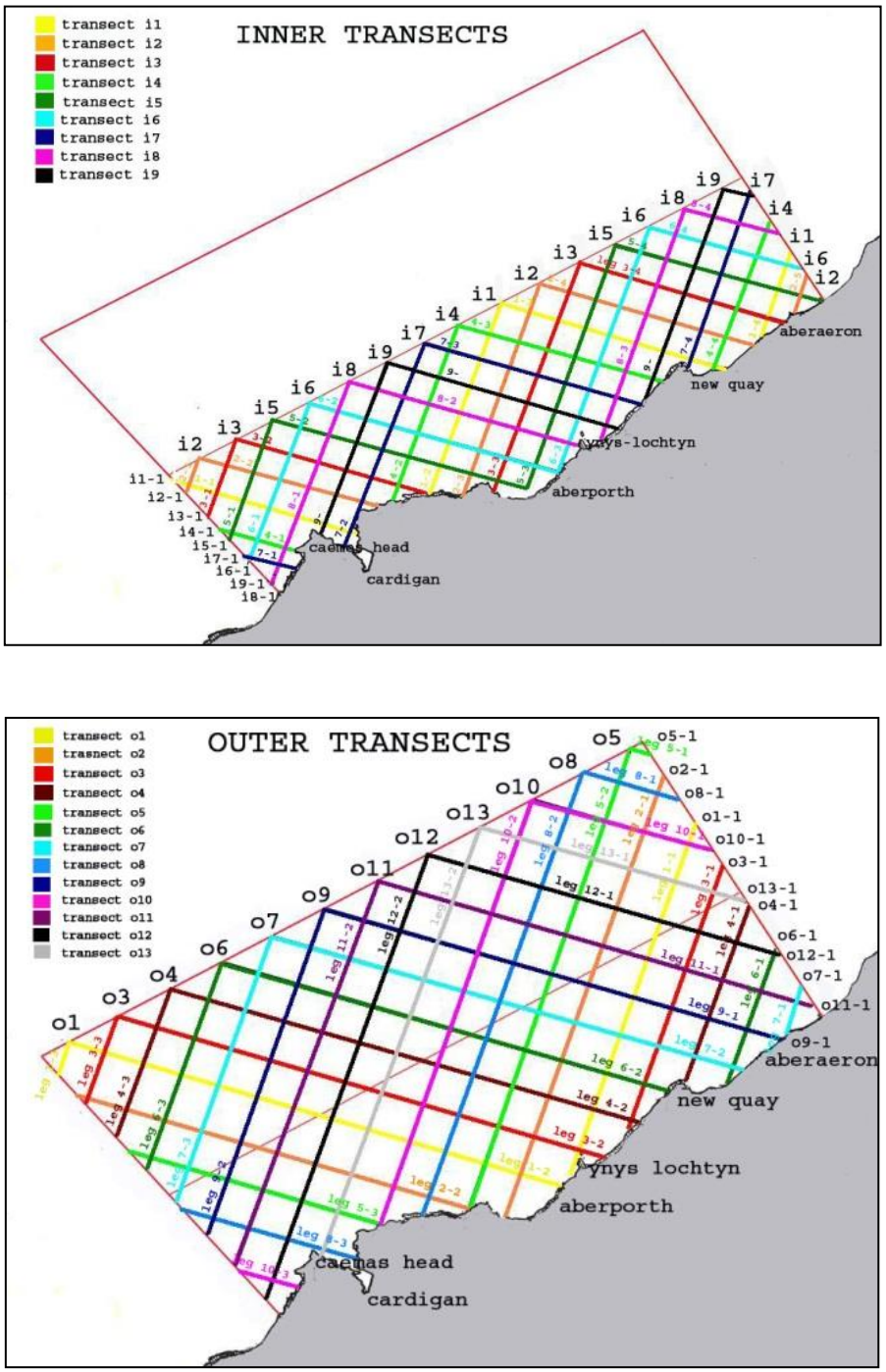


Figure 2: Transect lines used for line-transect surveys in Cardigan Bay SAC (inner-top and outer-bottom)

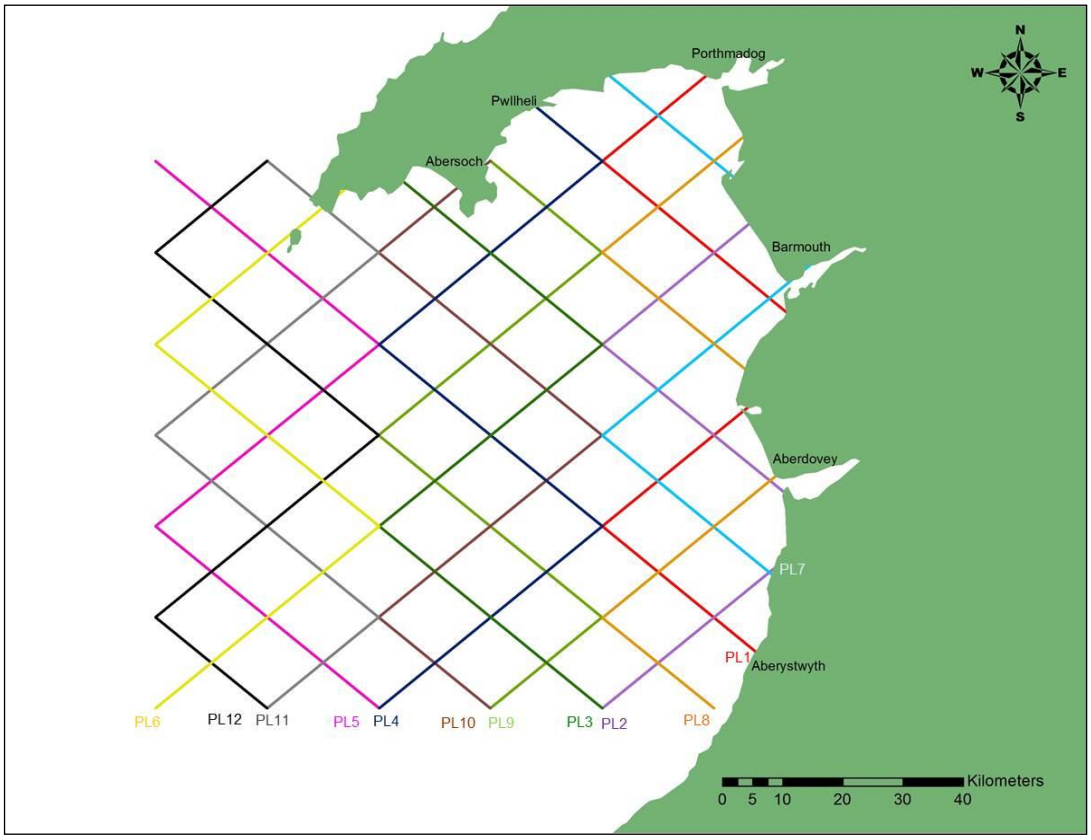


Figure 3: Transect lines designed for Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay (Transect numbers: PL1- red; PL2- purple; PL3- green; PL4- blue; PL5- pink; PL6- yellow; PL7-light blue; PL8-orange; PL9-light green; PL10-brown PL11-grey; PL12-black)

Transects were chosen at random prior to each survey and were followed for the duration of the survey. In the Cardigan Bay SAC, the transect number was selected at random from both inner and outer transect lines. Pen Llŷn a'r Sarnau transects were also randomly chosen but were restricted to inshore transect lines when surveying aboard *Ma Chipe Seabrin*. The outer transects in northern Cardigan Bay are usually covered using the NRW vessel *Pedryn* and no alternative vessel was available until the end of the season when a new charter boat, *Highlander*, was trialled for the first time. In some cases, if the weather significantly deteriorated while on survey, particularly offshore, an alternative transect line was chosen.

Vessels travelled at constant speed while on transect, although average speed varied slightly between survey vessels (see Table 1).

While on line transect, a double platform of observers, comprising two pairs of observers, was used to spot cetaceans. Each pair included at least one seasoned observer with at least 20 hours of prior survey experience.

The primary observers (POs) were positioned on the roof of the vessel, scanning with bare eyes from abeam (90°) on their side to 10° on the opposite side. Binoculars were only used to investigate or confirm sightings. Observations of marine mammals, as well as some other species such as basking sharks and sunfish, were recorded on a standardised primary observer sightings form.

Independent observers (IOs) scanned the track line ahead using binoculars, concentrating on 45° on their side to 10° on the other, in order to detect marine mammals before any responsive movement to the vessel had been made. IOs were positioned in such a way that POs were unable to see them but maintained the best possible view of the track line ahead. On *Dunbar Castle II*, IOs could only be positioned near the stern where part of their view was obscured by the wheelhouse. On *Ma Chipe Seabrin* and *Highlander*, they were positioned further forward on the bow and had a clear view of the track. IOs recorded their sightings on a separate sightings form and did not communicate at any point during the sighting with the POs. To avoid duplicate sightings, when IOs made a sighting, the person recording effort then checked with the POs whether they had made a sighting, and any duplicates were recorded on the IO sightings form.

On making a sighting, both POs and IOs immediately recorded the distance to the animals, the angle of the animals to the boat, and the position of the boat. The angle of the animal to the boat was recorded using an angle board, using the bow of the vessel as point 0. Distance to animals was estimated by individual observers and checked by Sea Watch staff for accuracy, and interns took part in distance training sessions, by testing them against objects with known ranges.

As well as four observers, one person was dedicated to recording effort data (Appendix 1), logging vessel position and environmental variables throughout the survey. Effort was recorded every 15 minutes or whenever any of the recorded variables changed (sea state, visibility, well height, boat coarse, transect leg). Position of the vessel was recorded using a handheld GPS which also automatically generated a track. For every line of effort, the number and type of boats were recorded in order to provide a record of boat traffic in the vicinity. Four types of effort intensity were considered during the survey: a) line-transect, where the vessel travelled along the pre-defined transect line with dedicated observers, both POs and IOs, 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 was returning to port (transit); 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); and d) photo identification, when the boat approached and remained with a group of dolphins at close range in order to obtain images used for Photo ID.

During summer 2014, for the first time, a data logger was additionally used, with a customised version of the Cybertracker application uploaded. This operated in addition to

completing the printed recording forms. The data logger had fields recording vessel, effort type, transect numbers, presence of other boats in the vicinity, and environmental conditions, as well as details of any sightings. The vessel tracks were recorded continuously. This was continued during 2015 but due to some restrictions such as battery and software problems, it has not completely replaced the paper forms.

When dolphins were encountered, the transect survey was paused and the survey vessel deviated from the transect line to approach dolphins and allow for photo-identification. The change in effort intensity, course and speed were noted as a new line of effort on the effort form. Dolphin photographs were taken using either a Canon EOS 40D or a Canon EOS 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 NRW licence, following their protocols. On completion of photo-identification, the survey was resumed as close as possible to the vessel's original position prior to commencing photo-ID.

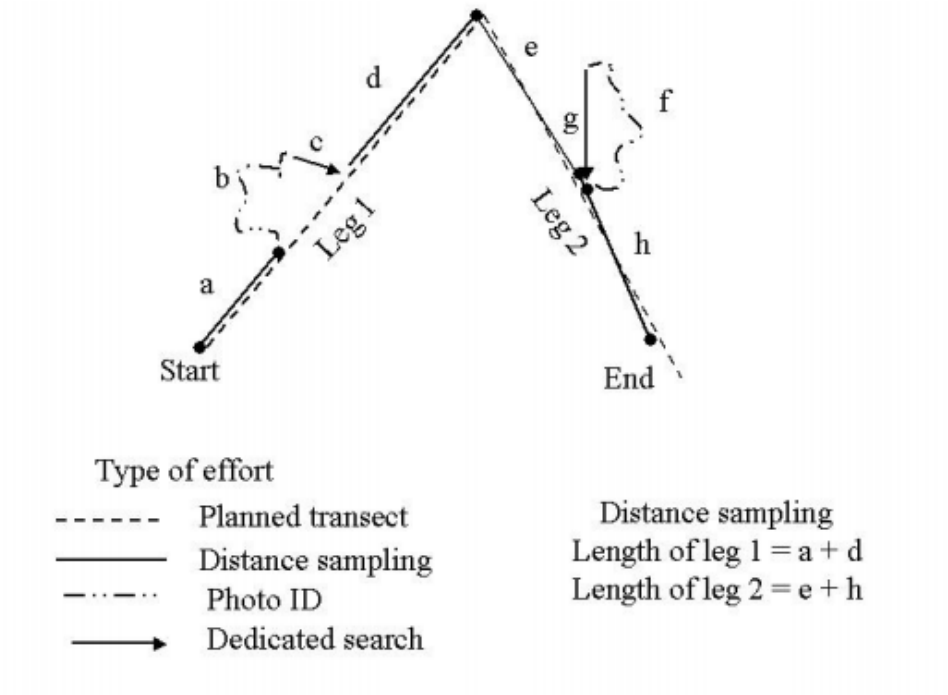


Figure 4: Schematic representation of two transect legs interrupted for photo-ID

Surveys: *Ad libitum* surveys

In addition to line transect surveys, a number of *ad libitum* surveys were conducted. These can be divided into two categories dedicated non line-transect surveys, and opportunistic observations.

Dedicated non-line transect surveys were carried out for the purpose of photo-identification using both *Dunbar Castle II* and *Ma Chipe Seabrin*. These surveys were undertaken when weather conditions were not sufficiently favourable to allow for a full day's survey. Data collection methods followed broadly the same methodology as described for line transect surveys but were usually carried out in dedicated search mode, utilising only primary observers.

Opportunistic observations were made aboard local wildlife watching tour operators, *Dolphin Spotting Boat Trips* in New Quay and *Bay to Remember* in Cardigan. This survey effort was increased substantially compared to previous years, following agreement with *Dolphin Spotting Boat Trips* to employ two dedicated 'dolphin guides' to record effort data in accordance with SWF protocols on daily trips, as well as allowing SWF interns on board trips that were not covered.

Table 2: Vessels used during *ad libitum* surveys in Cardigan Bay in 2014

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
Bay Explorer	10	2.5	Variable	Twin 200hp petrol

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 the standardised 'sighting form'. On line transect survey, an additional 'behaviour form' was filled in every 3 minutes, recording behaviours, group size and group composition. Four main behaviours were recorded:

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. '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

Resting - Characterised by slow movements with no apparent direction. Dolphins are usually seen 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.

Secondary behaviours such as leaping or tail slapping were also recorded.

Data analysis

Line transect surveys

Effort and sightings data were entered into Microsoft Excel and plotted using QGIS 2.4. Abundance estimates for bottlenose dolphins and harbour porpoise were calculated with a 'Multiple Covariate Distance Sampling test (MCDS)' sampled for 'sea state' (cf. Buckland et al., 2001, 2004) using a half cosine model in the program Distance 6.0; on the basis of data on the leg length of each effort leg, sea state, the radial distance, angle and groups size of each sighting, and the area of each stratum imported into the program.

Effort and sightings data were examined to investigate temporal variation in sightings and group composition, and to assess activity budgets

Ad libitum surveys

Effort and sightings data were entered into Microsoft Excel and plotted using QGIS 2.4. Although effort data from these surveys were not used in abundance estimates, data collected on *ad libitum* surveys were included in some aspects of analysis relating to temporal variation in sightings, group composition and activity budgets.

Photo-identification

Photo-ID matching was performed using ACDSee Pro. All matched encounters were confirmed by a second person. Software program Mark 6 Photo ID matching was performed using ACDSee Pro (ACD Systems International Inc.). All matched encounters were confirmed by a second person. Software programs MARK 6 and CAPTURE (Gary C. White, Dept of Fish, Wildlife, and Cons. Bio. Colorado State University, USA) were used to calculate population estimates using mark-recapture analysis. A closed population model (Chao Mth: Chao *et al*., 1992) was used for Cardigan Bay, and separately for Cardigan Bay SAC. A Robust Design Method (Kendall & Nichols, 1995; Kendall *et al*, 1997) was also conducted for the open population model on data acquired from both areas. Having a long data set for Cardigan Bay SAC (2001-14) 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 the wider Cardigan Bay is not as large, containing data from 2005-14, 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 (see section 5.3). Behaviour analyses were combined for all surveys in Cardigan Bay SAC (line-transects and *ad-libitum*), and also analysed separately for surveys in the wider Cardigan Bay area. Sightings in which behaviours were not recorded or unidentified, were omitted.

Results

Survey effort, sightings rates and spatial analysis

Survey effort was somewhat reduced this year, owing in part to extremely unfavourable weather conditions, 2015 being on record the windiest year for two decades (Met Office, 2015), and by uncertainty of funding at the start of the season. In total, 15 line transect surveys and a further six dedicated non-line transect surveys were carried out; covering a total of 2,028 km of which 996.13 km were conducted on line transect mode.

A total of 93 bottlenose dolphin sightings, 44 harbour porpoise sightings, and 76 grey seal sightings were made. Of these, 37 bottlenose dolphin sightings, 25 harbour porpoise sightings and 30 grey seal sightings were detected on the transect line (Table 4). The resultant sightings rates for bottlenose dolphins were an average 0.030 per km during line transects, slightly higher but broadly similar to the 2014 season when it was estimated at 0.028 (Norrman et al., 2015). There was, however, a significant difference between sightings rates in northern and southern Cardigan Bay, the average sightings rates for surveys conducted in the southern SAC at 0.060 being double that of the sightings rate recorded on northern surveys at 0.30 sightings/km (Figure 5).

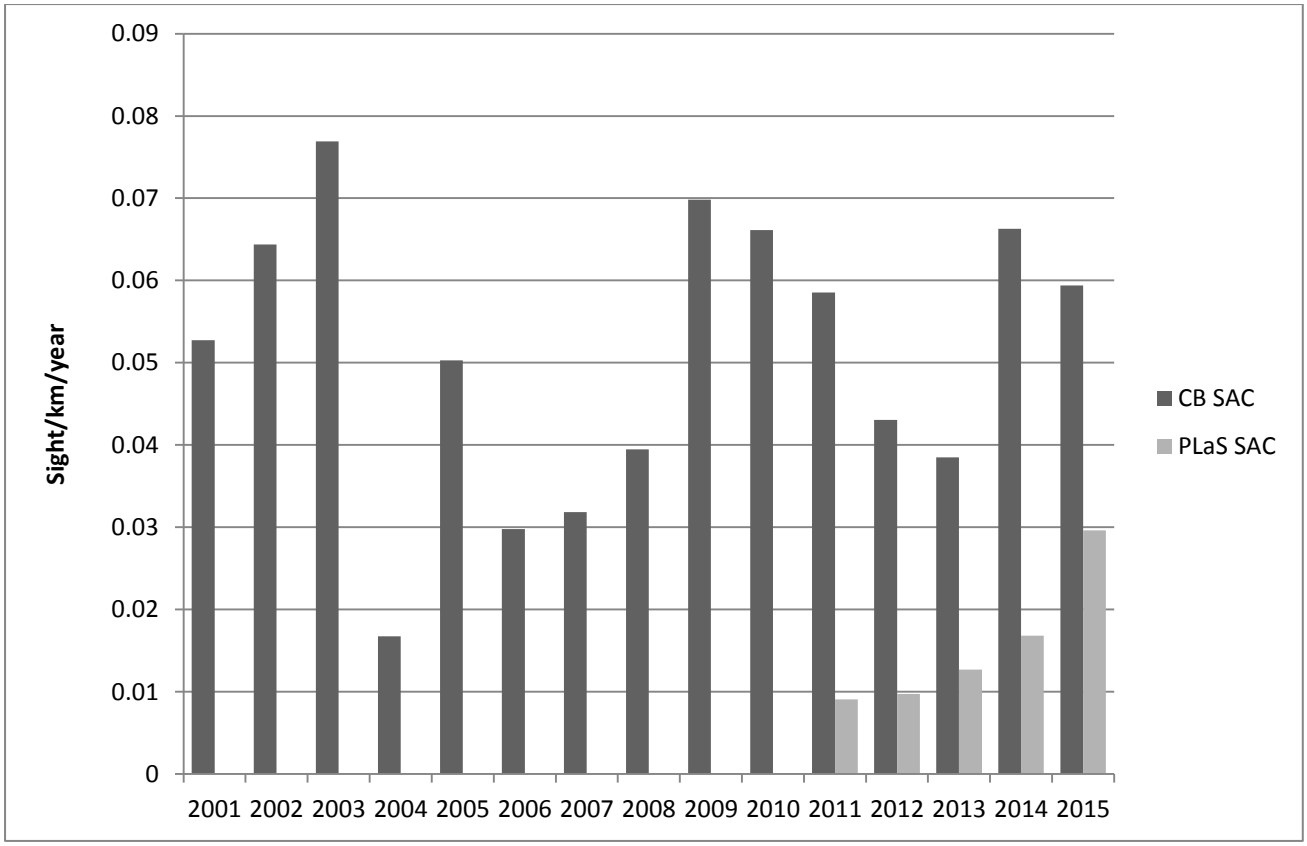


Figure 5: Bottlenose dolphin sightings per km per year, for Cardigan Bay SAC (CB SAC) and the Pen Llŷn a'r Sarnau SAC (PL SAC)

Harbour porpoise sightings on systematic surveys were considerably improved on 2014, with an average of 0.028 sightings per km (Table 3), compared to 0.011 in the previous year (Norrman et al., 2015). However, this is still lower than the average rate between 2005-07, at 0.045 sightings/km (Pesante et al., 2008b).

Grey seal sightings rate also increased compared to 2014, rising from 0.018 sightings/km to 0.024 sightings/km, but falling short of previous years when they were regularly above 0.030 sightings/km (Table 3)

Table 3: Line-transect (LT) survey effort conducted in Cardigan Bay 2011-2015 (BND- bottlenose dolphin, HP- harbour porpoise, GS – Atlantic grey seal)

	Vessel	2011	2012	2013	2014	2015	Total	Total 2011-15
No. of Surveys	Dunbar Castle II	10	18	26	10	13	77	122
	Ma Chipe Seabrin	2	7	8	3	7	27	
	Pedryn	3	2	7	5	-	17	
	Highlander	-	-	-	-	1	1	
Km travelled	Dunbar Castle II	897.42	1364.05	1843.54	709.57	724.89	5539.47	14105.47
	Ma Chipe Seabrin	382.82	1222.75	1201.90	380.12	797.17	3984.76	
	Pedryn	939.55	522.75	1632.80	1341.50	-	4436.60	
	Highlander	-	-	-	-	144.64	144.64	
Km travelled in LT mode	Dunbar Castle II	450.85	686.06	1019.26	412.17	347.45	2915.79	8653.05
	Ma Chipe Seabrin	258.71	852.37	896.57	175.36	539.96	2722.97	
	Pedryn	554.81	326.37	1115.00	909.39	-	2905.57	
	Highlander	-	-	-	-	108.72	109.72	
Total km travelled	All vessels	2219.79	3109.55	4678.24	2431.19	1666.7	144467.03	
BND sight/km	All vessels	0.025	0.024	0.018	0.028	0.030	0.025	
HP sight/km	All vessels	0.025	0.028	0.031	0.011	0.028	0.025	
GS sight/km	All vessels	0.033	0.037	0.035	0.018	0.024	0.029	

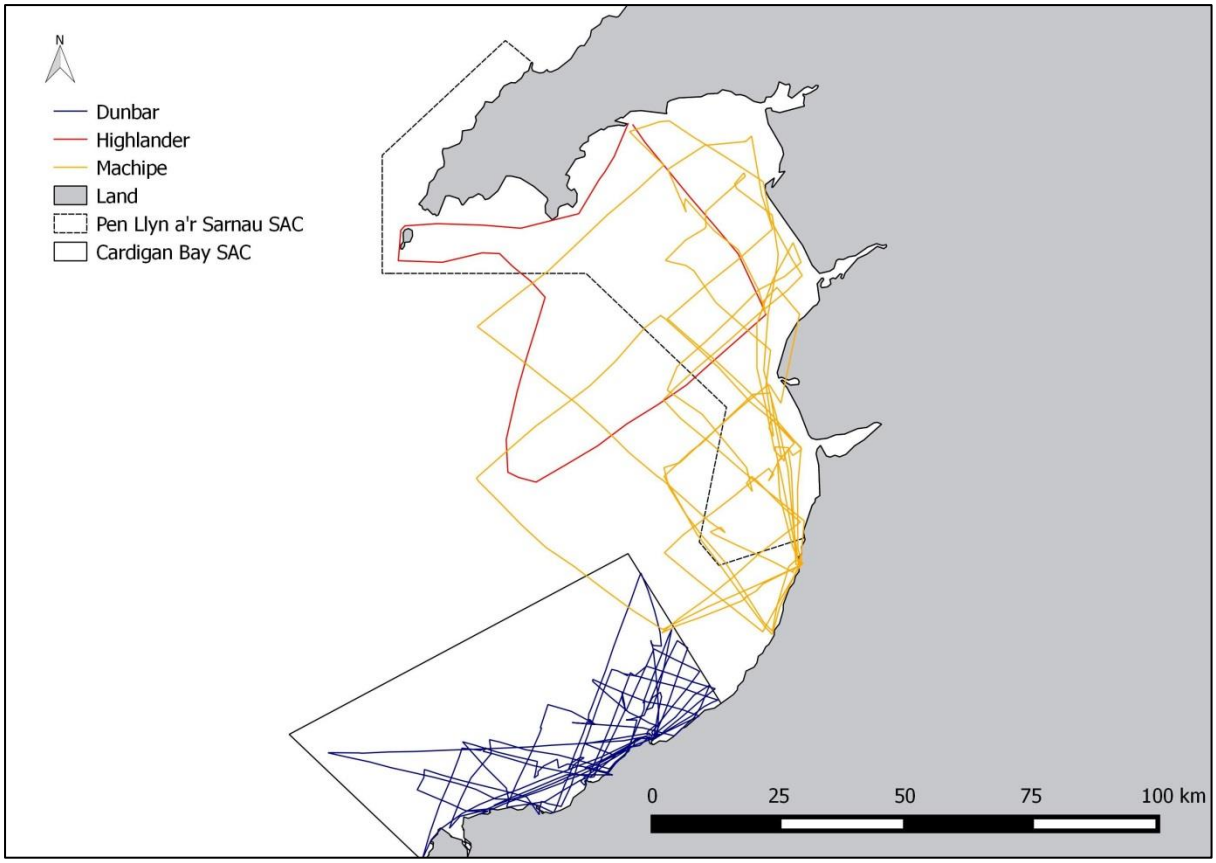


Figure 6: Line-transect (LT) survey effort conducted in Cardigan Bay 2011-2015 (BND- bottlenose dolphin, HP- harbour porpoise, GS – Atlantic grey seal)

Despite poor weather conditions, a fairly even coverage of Cardigan Bay was achieved using *Dunbar Castle II* for surveys of the southern SAC and *Ma Chipe Seabrin* for northern surveys. A third vessel, *Highlander*, was trialled for those outer transect surveys, which are usually covered by *Pedryn*.

Table 4: Marine mammal sightings detected on line transect (LT) surveys in 2011- 2015 (BND- bottlenose dolphin, HP- harbour porpoise, GS – Atlantic grey seal)

Vessel	Year	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	2011	55	24	30	21	56	31
	2012	84	31	47	39	76	39
	2013	91	29	87	74	128	62
	2014	40	25	12	7	22	12
	2015	42	21	25	17	30	13
Ma Chipe Seabrin	2011	7	5	6	4	2	2
	2012	13	13	32	29	33	32
	2013	18	12	29	26	23	21
	2014	12	3	7	6	14	7
	2015	23	16	9	5	19	15
Pedryn	2011	5	2	20	18	16	11
	2012	4	4	8	7	6	5
	2013	18	8	30	25	14	13
	2014	17	11	9	9	7	4
Highlander	2015	1	0	2	2	1	1
Total 2011-15		**430**	**204**	**353**	**289**	**447**	**268**

Most bottlenose dolphin sightings were concentrated inshore with particularly high encounter rates in several areas, including New Quay and Ynys Lochtyn in the southern SAC and Aberdovey in the Pen Llŷn a'r Sarnau SAC (compare Figure 7). The majority of bottlenose dolphin sightings were made within the SACs but two sightings fell outside both: a group of three adult individuals sighted in Aberystwyth harbour, and a large dispersed group including several calves (with at least one newborn) a few miles off Aberystwyth.

Harbour porpoise were most commonly sighted in the Cardigan Bay SAC and were fairly evenly distributed throughout. Notably, while most groups consisted of one or two animals, some larger groups with a maximum of seven animals were sighted in 2015, whereas the largest group size in 2014 was three. The mean group size was overall higher in 2015 at 1.9 compared to 1.5 in 2014, although this difference was not statistically significant. Roughly fifty percent of harbour porpoise sightings made on northern surveys were outside of the Pen Llŷn a'r Sarnau SAC.

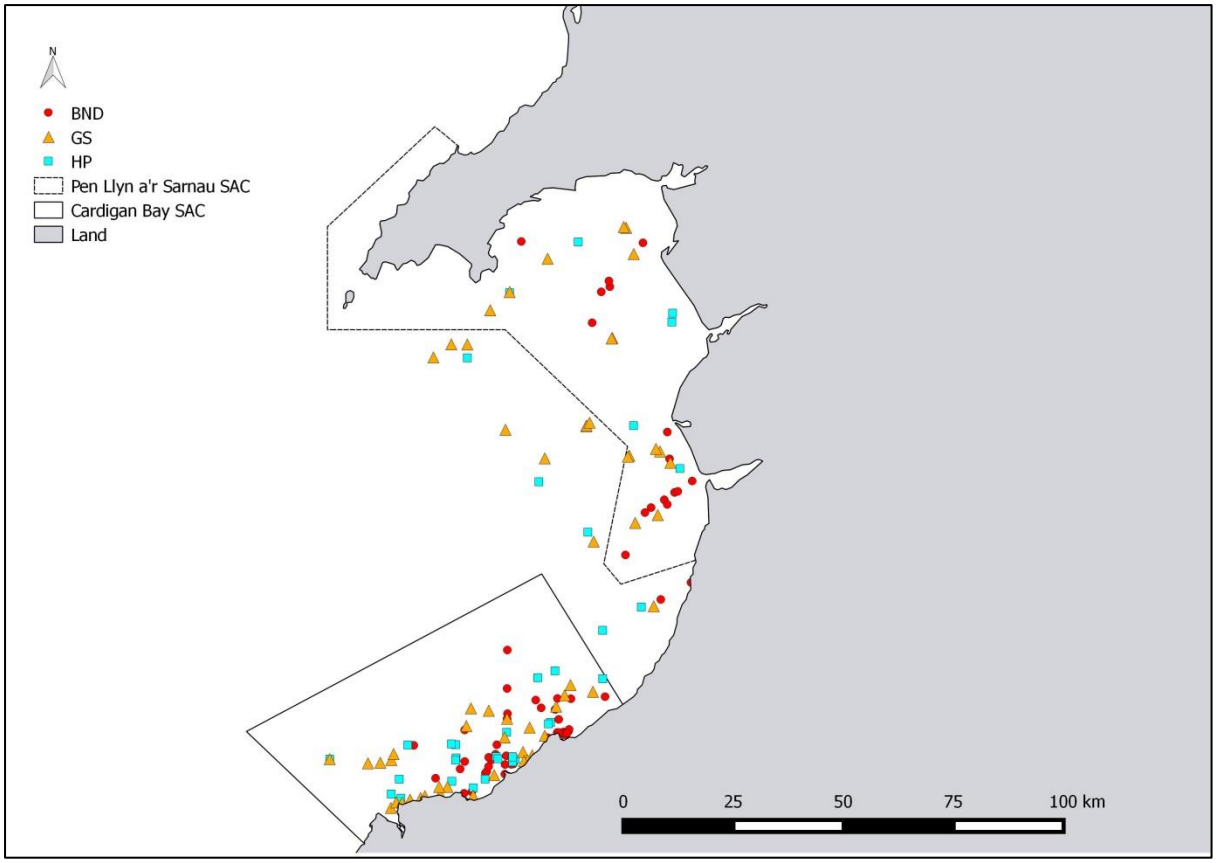


Figure 7: Sightings recorded during line-transect (LT) surveys in Cardigan Bay in 2015 (BND=bottlenose dolphin, HP= harbour porpoise, GS=Atlantic grey seal). See Appendix 1 for detailed view of CB SAC

Grey seals were spotted frequently throughout the Bay. The highest concentrations were found in the coastal sector with particularly high encounter rates around New Quay, Cwmtydu, and Cardigan Island. However, they were also regularly spotted offshore, and outside both SACs.

The wildlife tour operator *Dolphin Spotting Boat Trips* (DSBT) covers a proportion of the inshore area of the Cardigan Bay SAC, following set routes along the coast. The *Ermol V* runs from New Quay to Ynys Lochtyn while the *Ermol VI* runs from New Quay to Cwmtydu. In addition to regularly allowing a SWF intern on board to record effort, sightings and photo-identification data, this year, DSBT also took on two dolphin guides in cooperation with SWF. Their main purpose was to interact with guests and raise awareness of SWF and the 'Adopt a Dolphin' program, but they were also trained in SWF recording protocols, and recorded effort and sightings data. SWF interns were only placed on boats when dolphin guides were not working, to avoid duplication. This additional effort resulted in a total of 3417.91 km survey effort with 382 bottlenose dolphin sightings, exceeding all previous years. The sightings rate for Ermol trips in 2015 is also overall higher at 0.111 per km,

compared to 0.08 per km in 2014 (Norrman et al., 2015), but slightly lower than in previous years.

Table 5: Total effort and bottlenose dolphin sightings recorded during ad libitum dedicated surveys in Cardigan Bay 2011-15

Vessel	Year	No. surveys	Km of effort	BND sight.	BND sight/km
Dunbar Castle II	2011	7	282.51	22	0.078
	2012	0	-	-	-
	2013	3	83.89	5	0.060
	2014	4	116.94	28	0.239
	2015	5	209.99	20	0.095
Ma Chipe Seabrin	2015	1	151.57	4	0.026
Boat Gallois	2011	6	148.69	14	0.094
	2012	12	280.24	22	0.079
	2013	0	-	-	-
	2014	0	-	-	-
Pedryn	2011	0	-	-	-
	2012	2	99.56	1	0.010
	2013	1	42.23	2	0.047
	2014	1	219.32	0	0
Bay Explorer	2011	3	41.63	4	0.096
	2012	0	-	-	-
	2013	0	-	-	-
	2014	0	-	-	-
	2015	7	176.29	15	0.085
All Vessels	2011	16	472.83	40	0.085
	2012	14	379.78	23	0.061
	2013	4	126.12	7	0.056
	2014	5	336.26	28	0.083
	2015	13	537.85	39	0.073

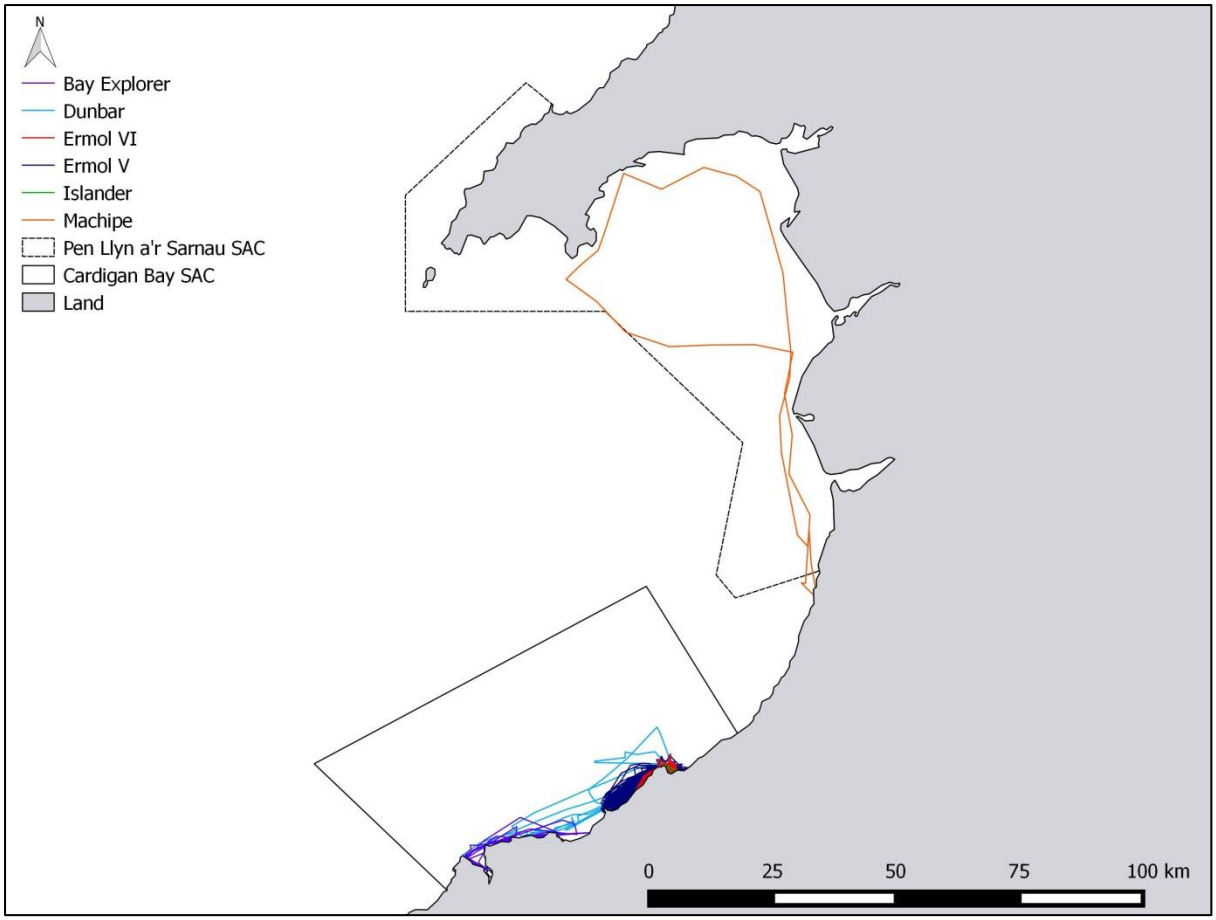


Figure 8: Tracks of non line transect (NLT) and opportunistic surveys conducted in Cardigan Bay in 2015. See Appendix 1 for detailed view of CB SAC

Most opportunistic and NLT surveys were conducted within the coastal area of the Cardigan SAC. While these data could not be used in abundance estimates, they were useful for the collection of additional photo-identification data. Opportunistic observations aboard *Bay Explorer*, departing from Gwbert near Cardigan, were particularly valuable as this area often receives less systematic coverage than the rest of the SAC due to time limitations while on line transect surveys. A number of well-marked individuals that were not photographed at any other point during the season were picked up on these surveys this year.

Table 6: Total effort and sightings recorded during surveys on board platforms of opportunity in Cardigan Bay SAC in 2011-15

Vessel	Year	No. surveys	Km of effort	BND sight.	BND sight/km
Ermol V	2011	30	515.07	41	0.080
	2012	33	633.51	51	0.081
	2013	34	597.24	67	0.112
	2014	109	1949.82	152	0.078
	2015	165	2736.79	275	0.100
Ermol VI	2011	46	379.11	47	0.124
	2012	34	288.94	41	0.142
	2013	83	795.00	103	0.130
	2014	19	111.26	23	0.207
	2015	88	681.12	107	0.157
Islander	2011	14	109.23	7	0.064
	2012	20	138.39	38	0.275
	2013	4	66.45	8	0.120
	2014	0	-	-	-
	2015	1	13.37	0	0.000
All Vessels	2011	90	1003.41	95	0.095
	2012	87	1060.84	130	0.123
	2013	121	1458.69	178	0.122
	2014	128	2061.08	175	0.085
	2015	254	3431.28	382	0.111

Bottlenose sightings from opportunistic platforms mirrored those observed during line transect surveys, with concentrations of sightings around New Quay, Ynys Lochtyn, and Mwnt (Figure 9). Harbour porpoises were spotted close to the coast from opportunistic platforms on several occasions, in contrast to 2014 when they were only spotted on dedicated surveys and primarily further offshore. Opportunistic surveys along the coast also recorded a high number of Atlantic grey seals with particular high concentrations of encounters around New Quay, Cwmtydu, Cardigan Island and the Alltycoed headland near Cardigan, where there is a large haul-out site.

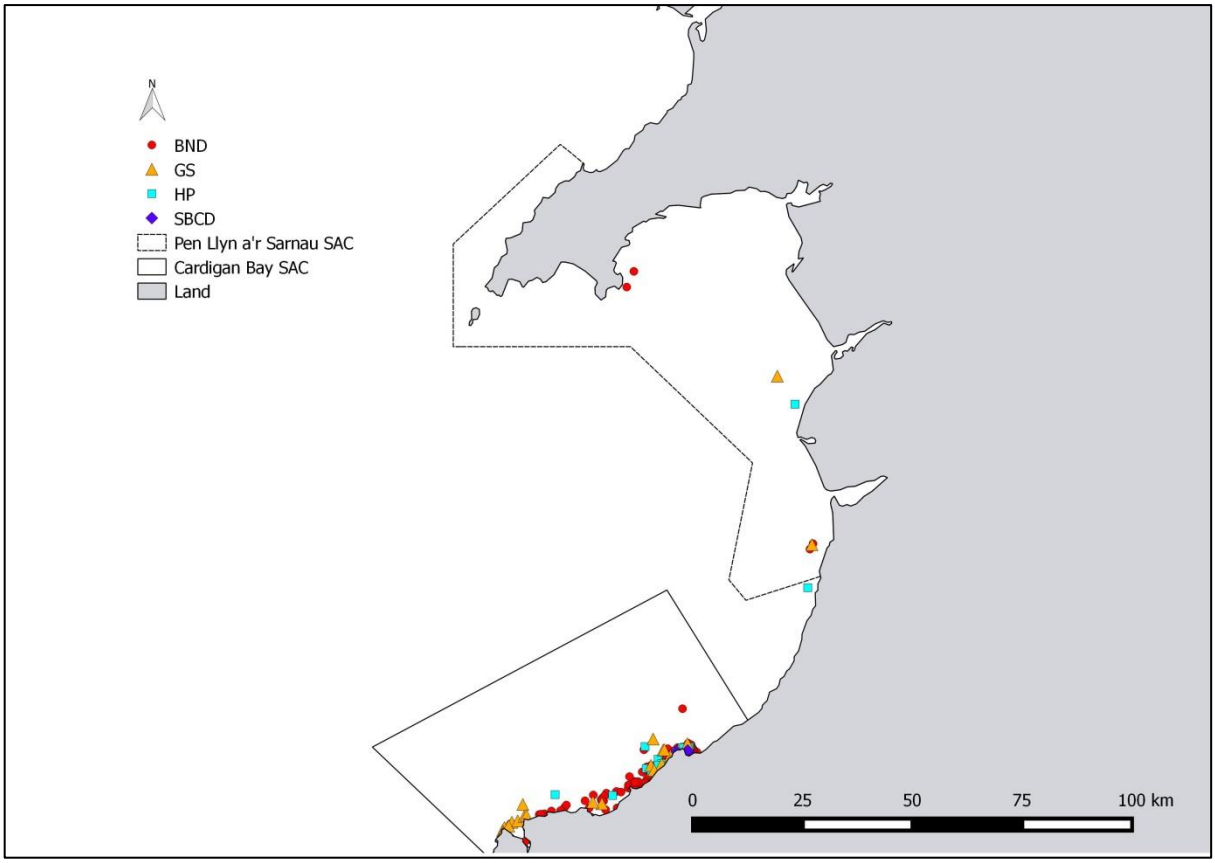


Figure 9: Sightings recorded during non-line-transect (NLT) surveys in Cardigan Bay in 2015 (BND= bottlenose dolphins, HP= harbour porpoise, GS= Atlantic grey seal), see Appendix 1 for detailed view of CB SAC

In addition to bottlenose dolphins, harbour porpoises and grey seals, a solitary short-beaked common dolphin was observed in New Quay harbour, primarily from land but also from opportunistic platforms, continuously from the end of December 2014 until mid-April 2015. The animal was spotted on 97 different occasions, always in a similar location within the harbour close to a large buoy. The animal had no visible injuries and was not in any obvious poor body condition. The last sighting of the animal in New Quay was made on the 15th April 2014. No direct interactions with bottlenose dolphins were observed. However, no common dolphin sightings were made in New Quay harbour while bottlenose dolphins were present. A common dolphin was observed in Aberystwyth harbour on the 19th April where it was spotted for several consecutive days. No further sightings of common dolphins were made for the remainder the season. A dead male common dolphin was reported in Aberdesach at the end of May; however, neither the animal observed in New Quay nor the stranded animal had distinguishing features to ascertain whether it was the same individual.

Abundance estimates

Bottlenose dolphin abundance estimates and detection curves were calculated both for Cardigan Bay and Cardigan Bay SAC (Tables 7 & 8, Figure 10) for 2015. Previous years surveys indicate a rise in abundance within the SAC from 2001 to 2006 (no line transect

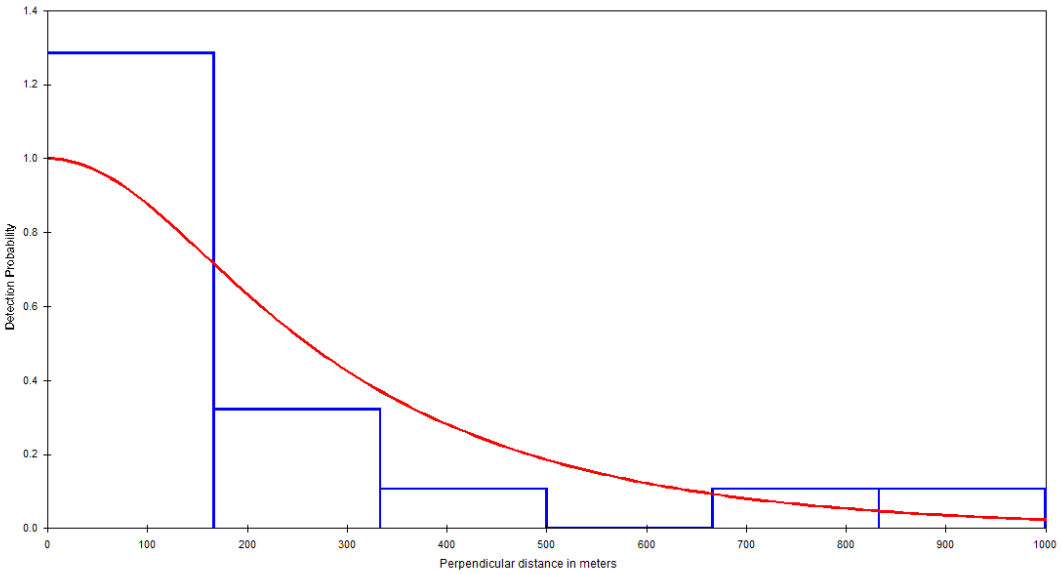
surveys were undertaken 2008-10), before declining. Estimates in 2012, 2013 and 2015 estimates are much lower, up to 50% less compared to previous estimates. While effort in 2015 was low compared to previous years due to poor weather conditions, the estimate is in line with the observed more recent decline. Estimates for the wider Cardigan Bay are more variable with no obvious trends, although overall estimates seem to have declined slightly since 2012.

Table 7: Abundance estimates of bottlenose dolphin (BND) from line transect surveys in wider Cardigan Bay 2011, 2012, 2013 and 2015

Definition	BND 2011	BND 2012	BND 2013	BND 2014	BND 2015
Abundance	309	330	254	-	277
95% CI	179-353	203-534	151-427	-	138-555
CV	28.34	24.87	26.83	-	35.87
Observations	27	32	33	-	19

Table 8: Comparison of abundance estimates of bottlenose dolphin (BND) from line transect surveys in Cardigan Bay SAC for 2001- 2015

Year	Abundance	95% CI	CV	Observations
2001	135	85-214	23.7	93
2003	140	69-284	36.6	19
2005	139	88-218	23.2	49
2006	214	108-422	35.6	30
2007	109	49-239	41.7	24
2011	133	75-235	29.5	22
2012	70	37-131	33.0	19
2013	90	45-179	35.6	22
2015	64	19-220	64.6	12



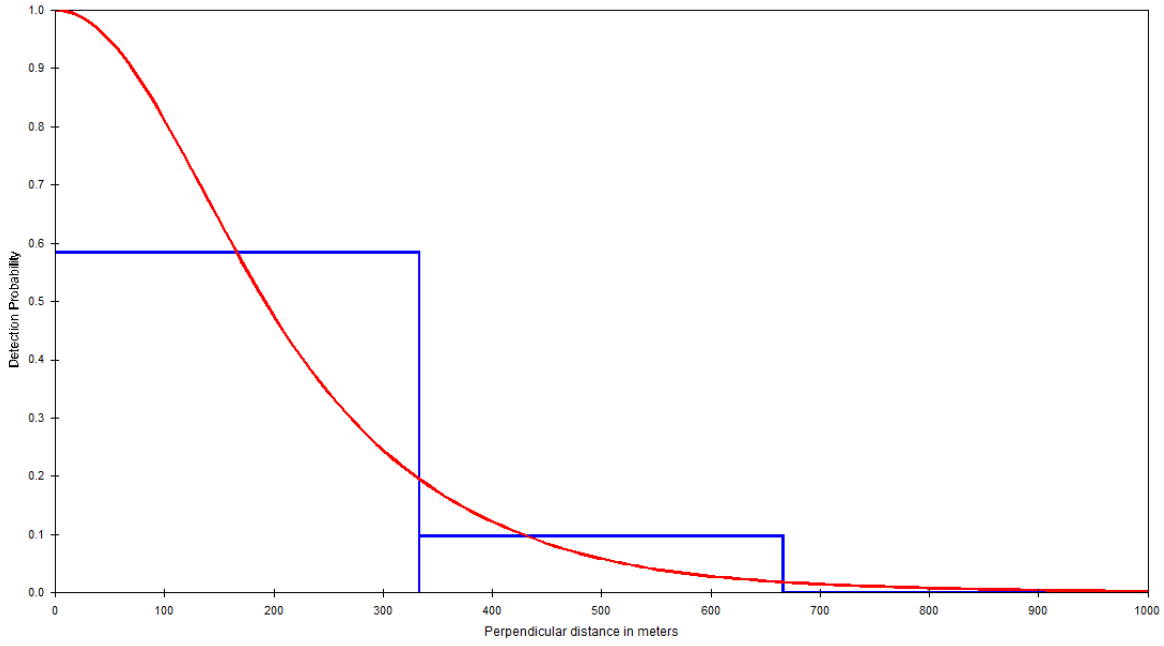


Figure 10: Detection functions of bottlenose dolphins in wider Cardigan Bay (top) and Cardigan Bay SAC (bottom)

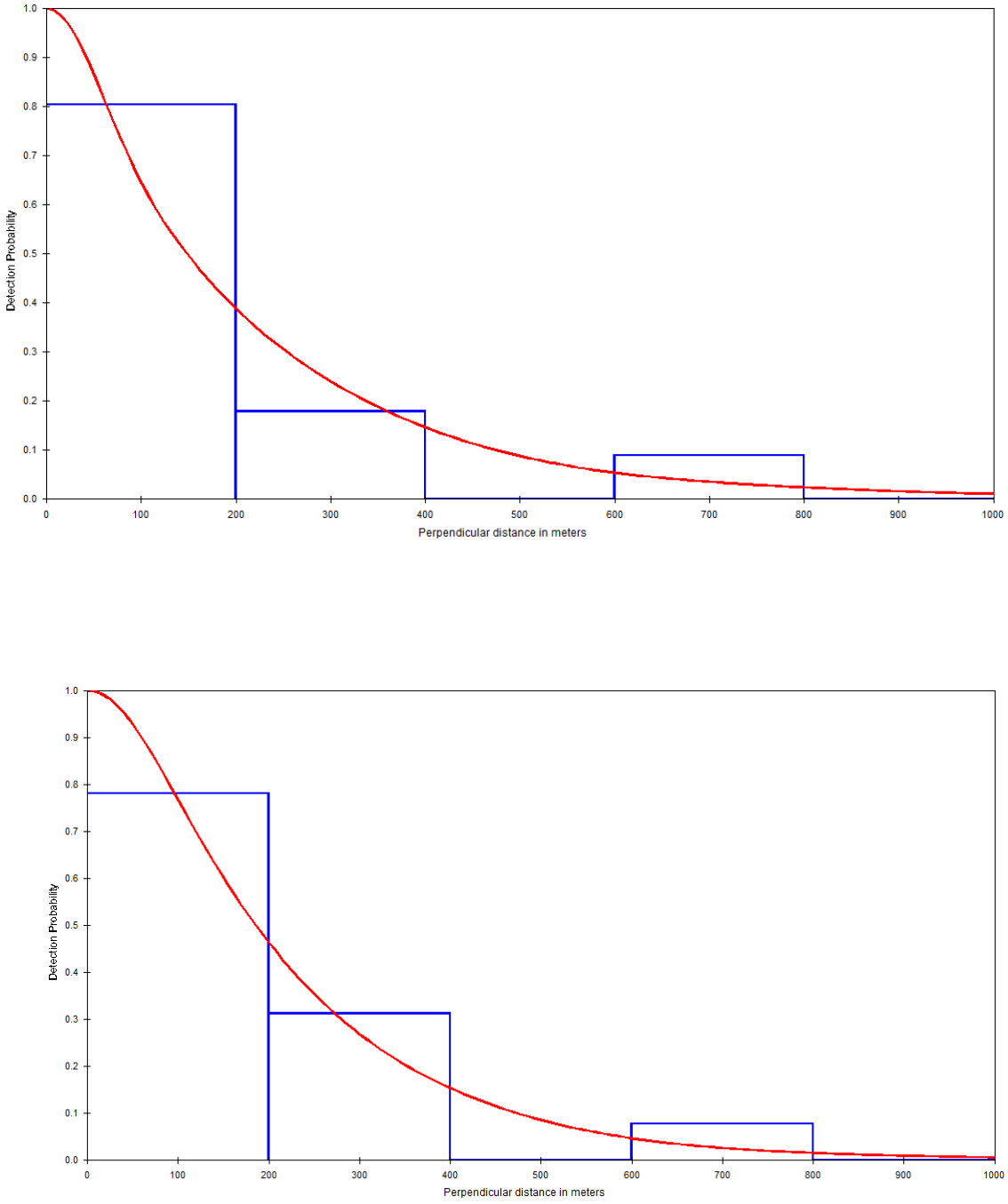


Figure 11: Detection function of harbour porpoise in wider Cardigan Bay (top) and the Cardigan Bay SAC (bottom)

Harbour porpoise abundance estimates and detection curves were also calculated both for the wider Cardigan Bay area and Cardigan Bay SAC (Tables 9 & 10, Figure 11). Harbour porpoise numbers have significantly decreased in recent years, more than halving since 2011. While the amount of effort data collected this year may have impacted the accuracy

of the estimate for the wider Cardigan Bay area, particularly as only a limited number of outer line transects took place, the decrease is in accordance with trends observed in recent years.

Table 9: Abundance estimates of harbour porpoise (HP) from line-transect surveys in Cardigan Bay, 2011-13 and 2015

Definition	HP 2011	HP 2012	HP 2013	HP 2014	HP 2015
Abundance	1074	565	410	-	291
95% CI	634-1821	379-840	298-564	-	128-661
CV	28.73	20.42	20.42	-	42.40
Observations	42	57	88	-	15

Table 10: Comparison of abundance estimates between years of harbour porpoise in Cardigan Bay SAC, 2011-13 and 2015

Year	Abundance	95% CI	CV	Observations
2001	108	81-146	15.1	144
2003	236	148-337	24.0	50
2004	215	136-339	23.1	46
2005	170	121-240	17.5	81
2006	161	109-238	20.1	57
2007	182	123-269	20.2	49
2011	340	140-828	46.4	20
2012	169	96-296	29.1	32
2013	147	97-222	29.1	32
2014	-	-	-	-
2015	183	56-606	64.6	12

Group sizes

Average group size of bottlenose dolphins calculated for the whole of Cardigan Bay was 4.75 (range 1-18, SD=4.02) based on encounters made while on line transect mode. This is broadly similar to previous years and slightly increased on 2014, where it was estimated at 4.33. Maximum group sizes were larger in the latter part of the season with several groups of over ten individuals. However, average group size did not vary significantly through the season. When calculated for all years from 2001-15, large group sizes (over 10 individuals) are most common early and late in the season, from April to May and September to

October. The majority of groups encountered number between one and five individuals (Figure 14)

Similar to previous years, whereas bottlenose dolphin encounters were fewer (see Figure 5), group sizes were significantly larger in Pen Llŷn a'r Sarnau SAC than in the Cardigan Bay SAC, 3.86 and 6.07 respectively (X^2 =28.09, df =1, p 0.032) (see Figure 13).

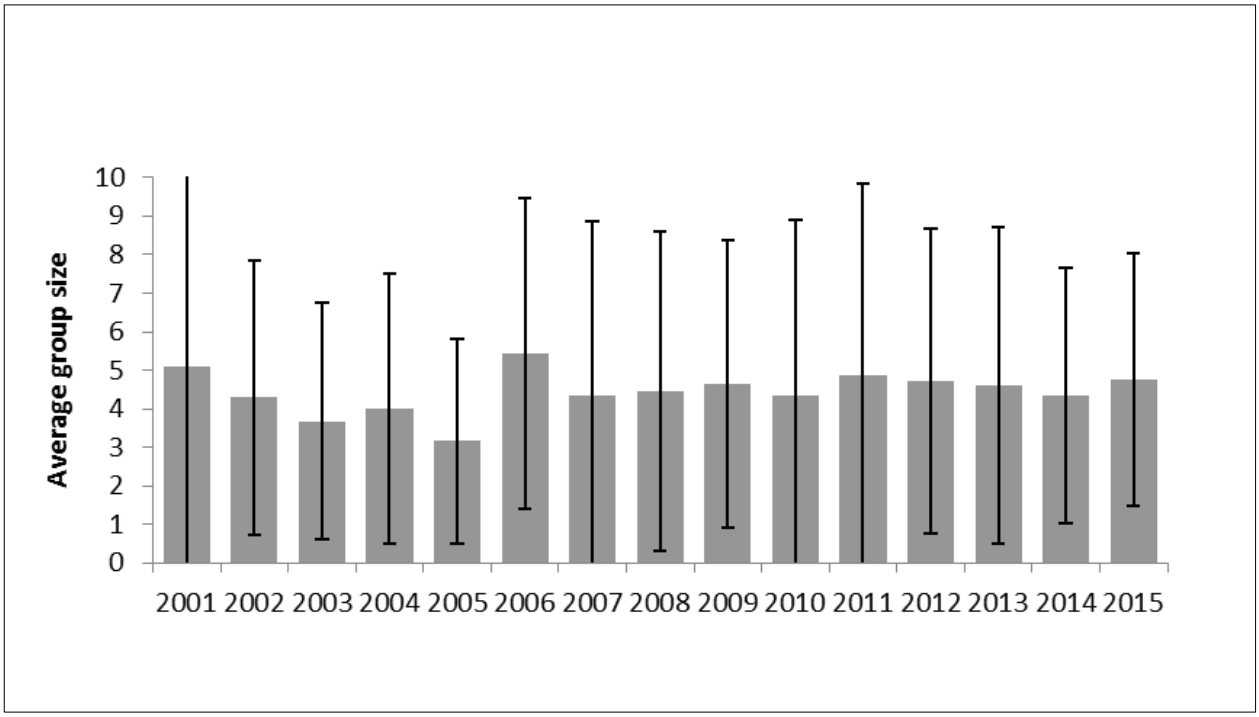


Figure 12: Average (±SD) group size of bottlenose dolphins by year, recorded from line-transect surveys in Cardigan Bay, 2001-15

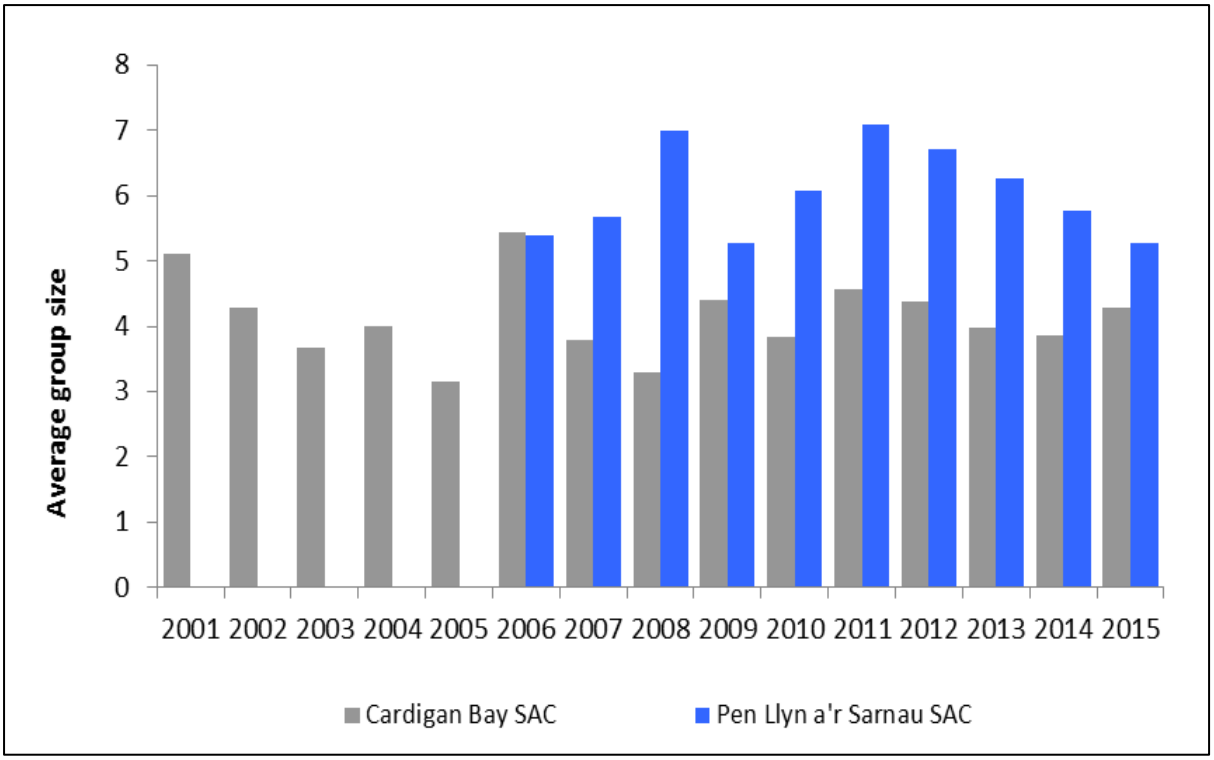


Figure 13: Comparison of average group sizes of bottlenose dolphins recorded from line transect surveys in Cardigan Bay SAC and Pen Llŷn a'r Sarnau SAC, 2001-15

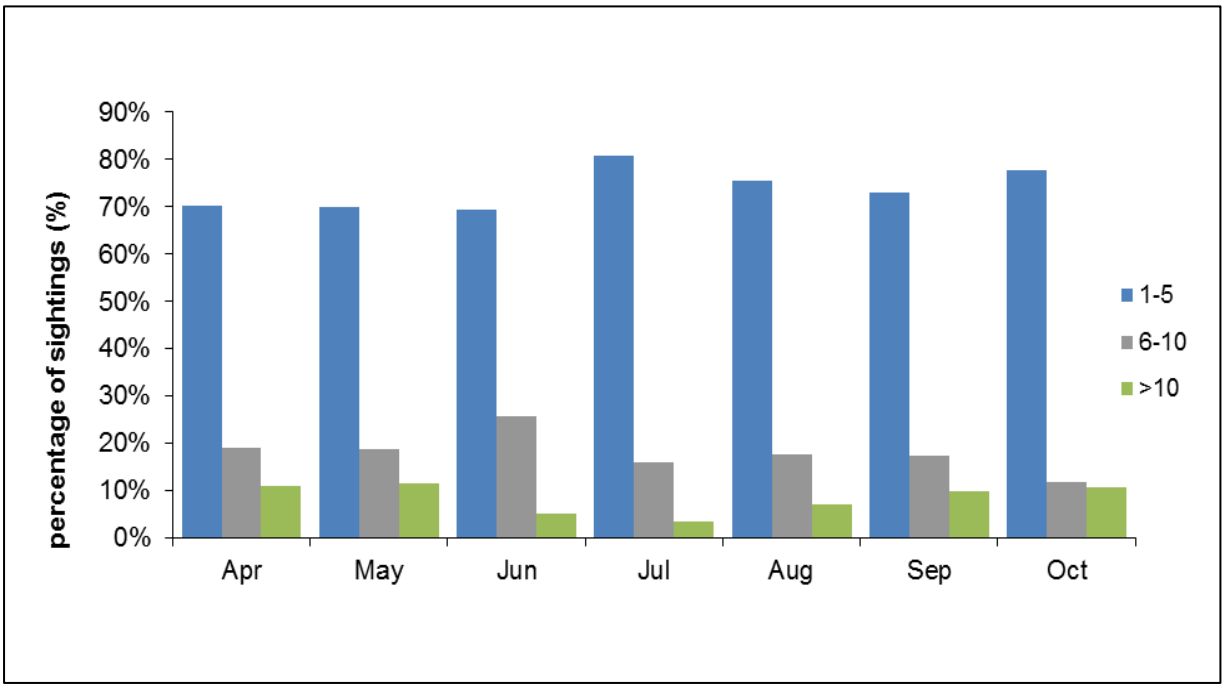


Figure 14: Bottlenose dolphin group sizes (expressed as a percentage of sightings) by month recorded from line-transect surveys in Cardigan Bay, 2001-2015

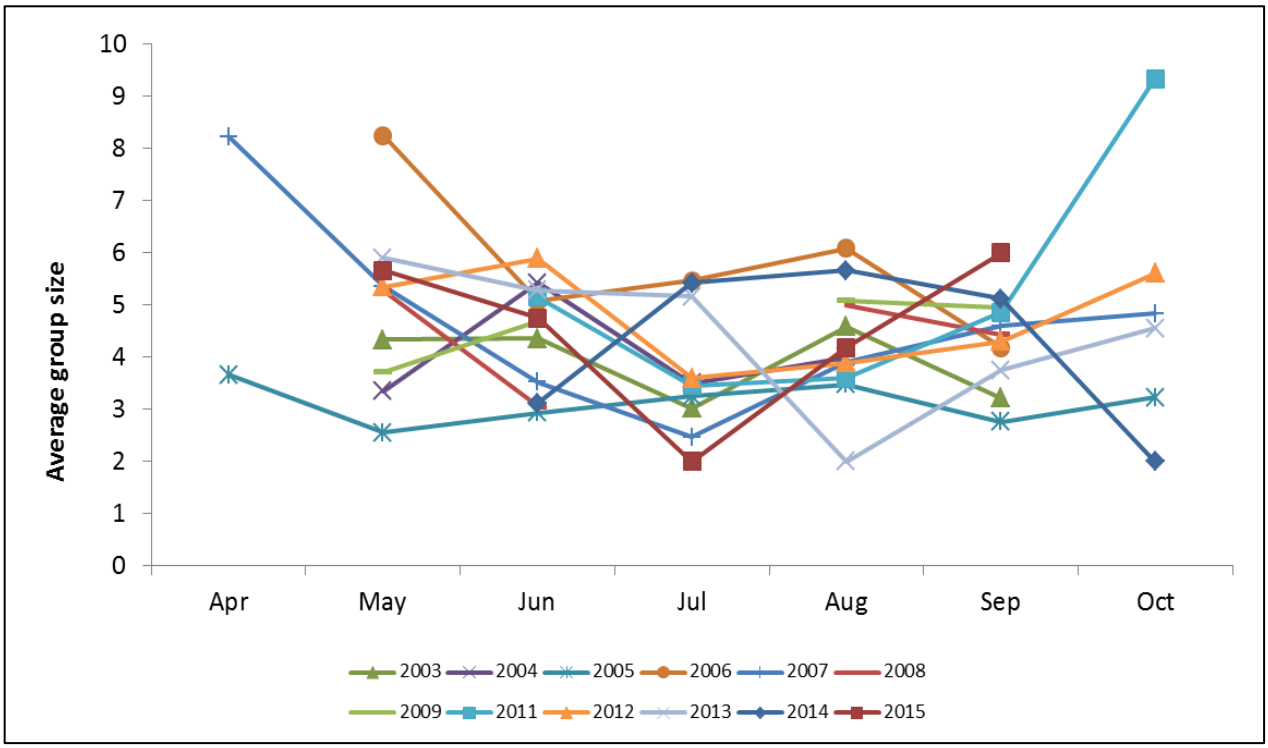


Figure 15: Bottlenose dolphin average group sizes by month and year, recorded from line transect survey in Cardigan Bay, 2001-2015.
Months with less than 5 sightings have been omitted

Activity budgets

Bottlenose dolphin behaviours were collected during both line-transect and *ad libitum* surveys throughout Cardigan Bay. Initially, *ad libitum* surveys were excluded as previous years had shown a pronounced difference between activity budgets from line transect and non line transect surveys, owing perhaps to the way the animals use the inshore and offshore area (Veneruso & Evans, 2011). This was not the case this year and therefore they are presented together.

When looking at Cardigan Bay as a whole, the predominant behaviour observed was travel (67%) followed by foraging or feeding (30%). The lowest proportions of time were recorded socialising and resting (both c. 1.5%).

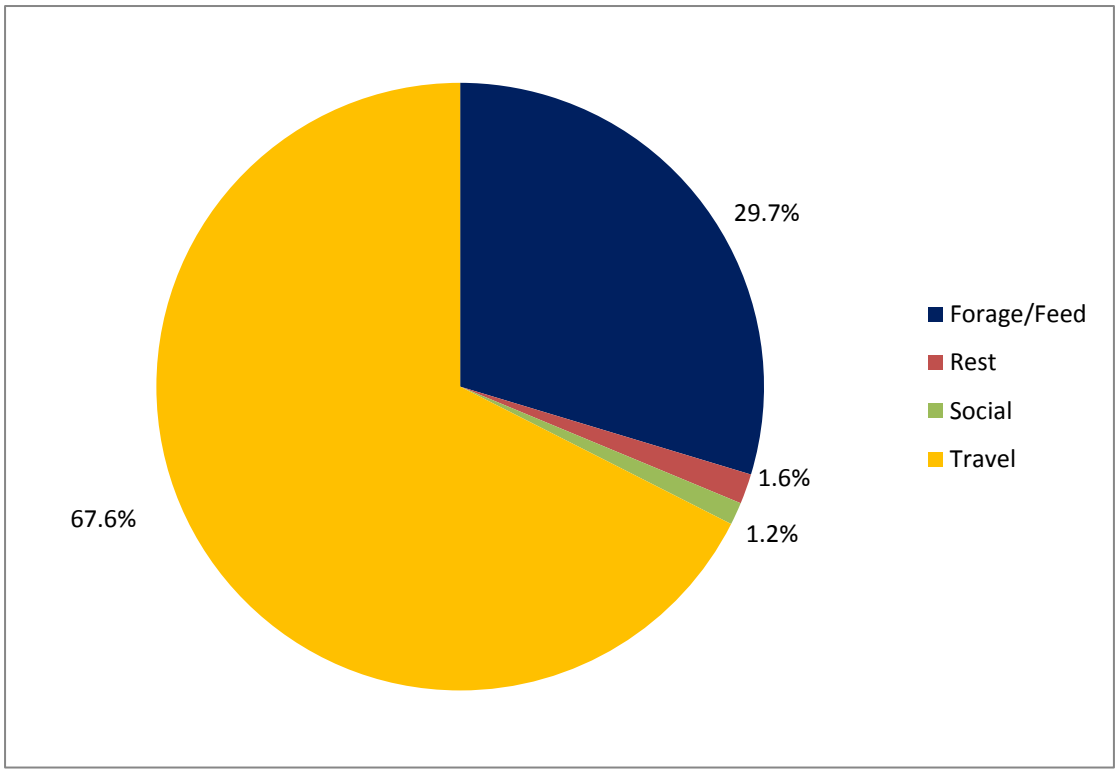


Figure 16: Behavioural budget of bottlenose dolphins recorded from all dedicated boat surveys in Cardigan Bay (n=62)

The activity budget for Cardigan Bay SAC closely mirrors the overall activity budget for Cardigan Bay, which is unsurprising considering that most *ad-libitum* surveys that were included in the analysis were conducted in Cardigan Bay SAC. Travel remains the predominant behaviour (67.6%) observed, followed by feeding and foraging (29.7%), rest (1.6%), and socialising (1.2%). Behavioural budgets for Cardigan Bay SAC in 2014 and 2015 closely resemble one another and are notably different to 2012 and 2013, when the proportion of time spent feeding and socialising was reduced while the amount of time spent travelling considerably increased.

There was some variation through the season. April to June closely resembled the overall summer activity budgets for Cardigan Bay SAC whereas August and October deviated from these proportions (Figure 16). In August, travel was at an all-time high (90%) whereas feeding and foraging activities were their lowest (combined value of 6%). October, on the other hand, saw the lowest proportion of travel (52%) and the highest proportions of confirmed feeding activity (40%) and resting (8%).

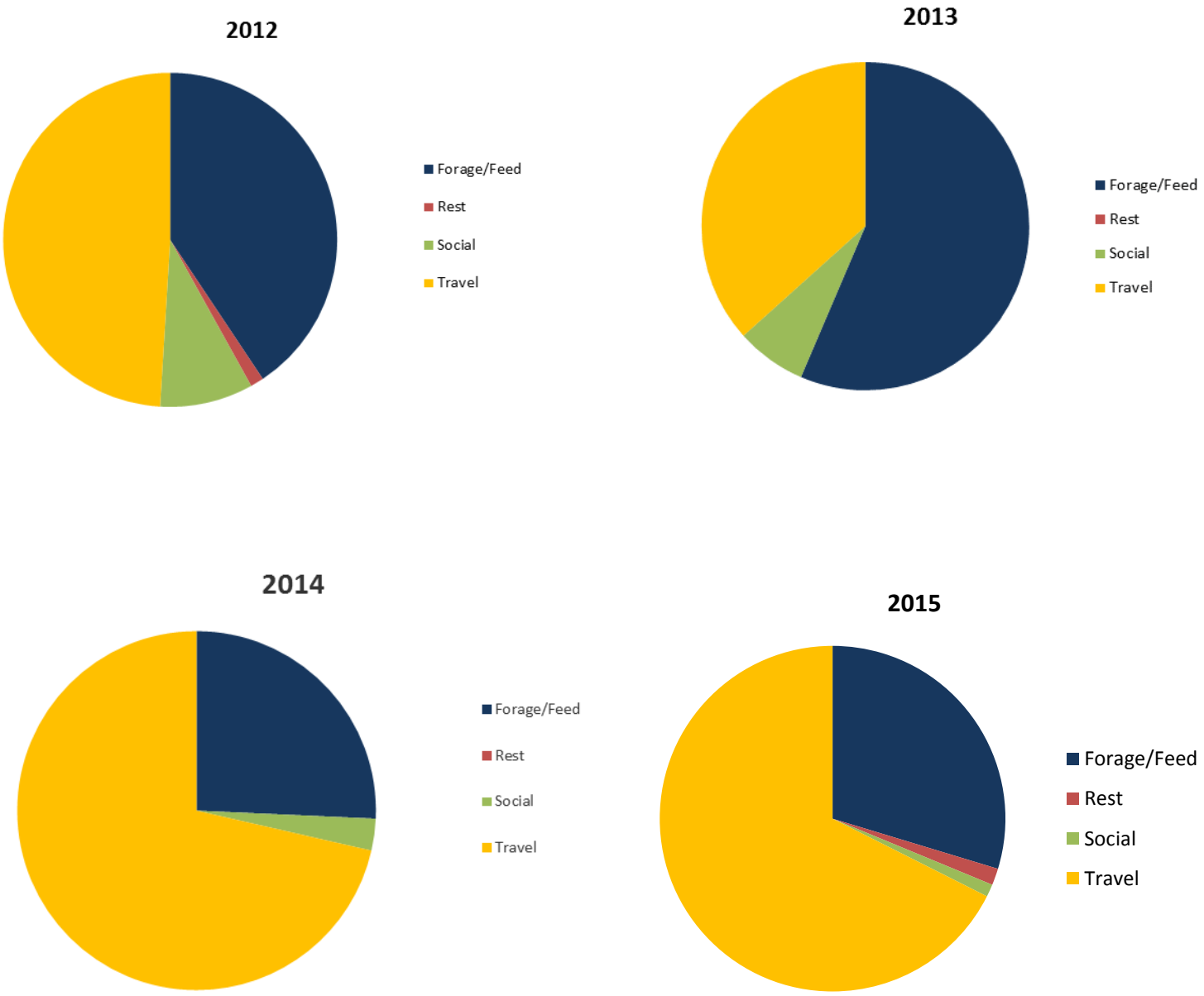


Figure 17: Behavioural budget of bottlenose dolphins recorded from line-transect and *ad libitum* in Cardigan Bay SAC in 2012, 2013, 2014 and 2015 respectively (n=99, 101, 70 and 42)

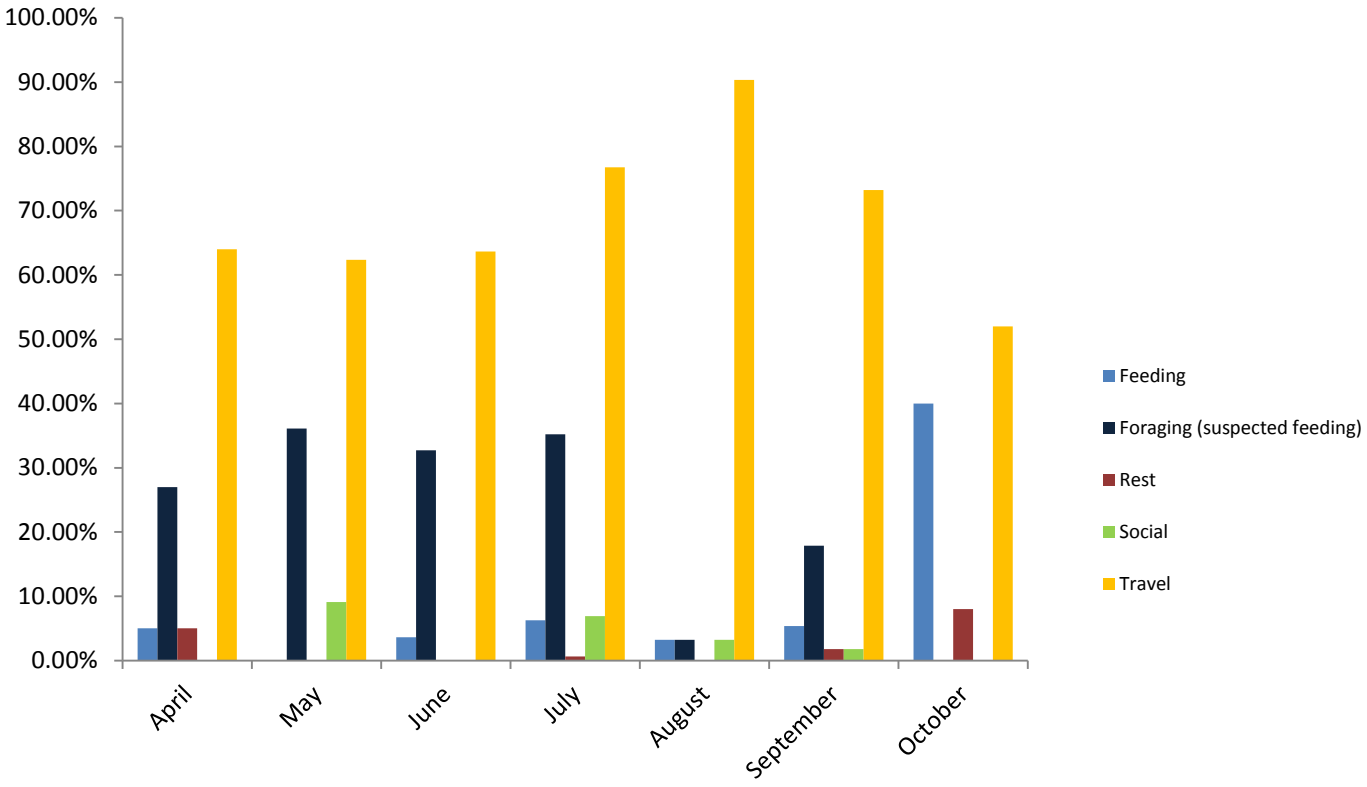


Figure 18: Behavioural budgets of bottlenose dolphins recorded from line-transect and ad libitum surveys (including opportunistic platforms) in Cardigan Bay SAC in 2015 (n=22, 36, 55, 25, 31, 56 and 25 respectively)

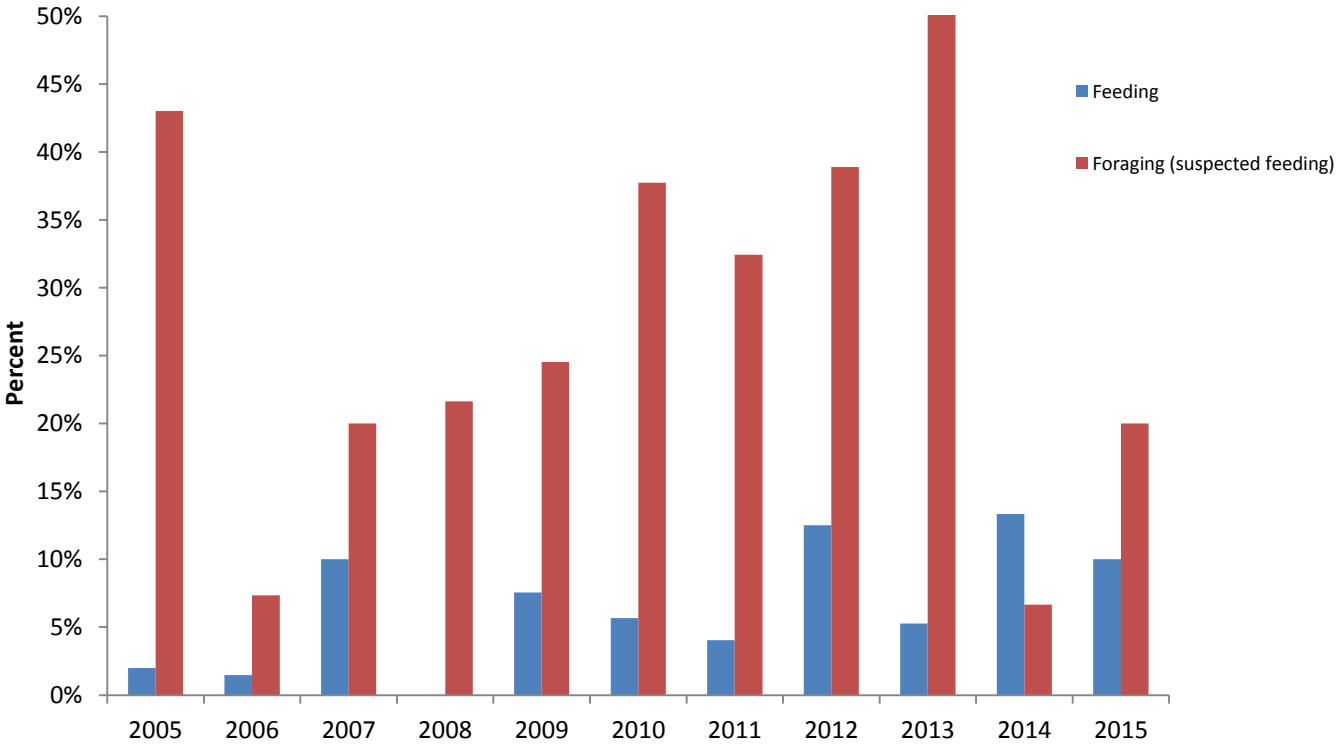


Figure 19: Yearly comparison of behavioural budgets of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC 2011- 2015 (feeding and suspected feeding only) (n= 87, 77, 88, 39, 59, 56, 83, 99, 101, 70 and 42 respectively**)**

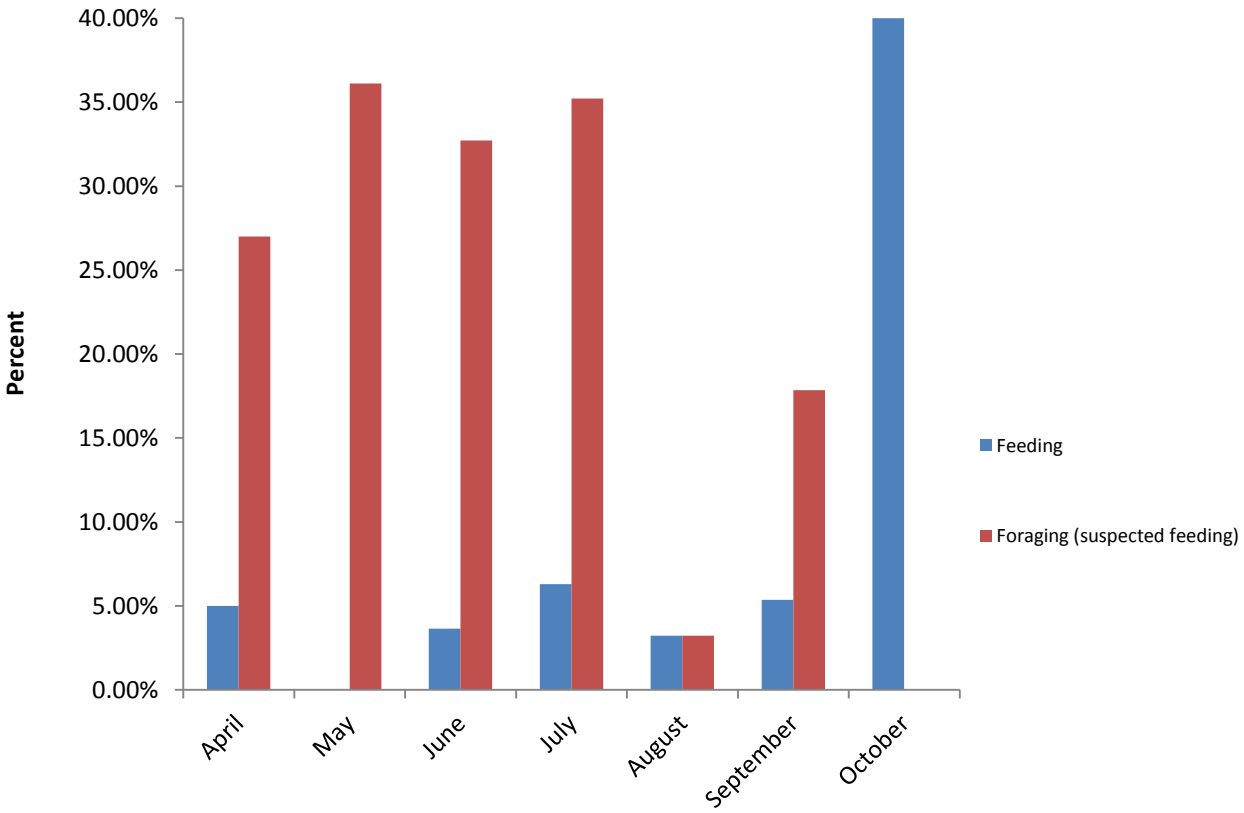


Figure 20: Seasonal comparison of behavioural budgets of bottlenose dolphins recorded from line-transect and ad-libitum surveys (including opportunistic platforms) in Cardigan Bay SAC in 2015 (n=7, 13, 20, 6, 2, 13 and 10 respectively)

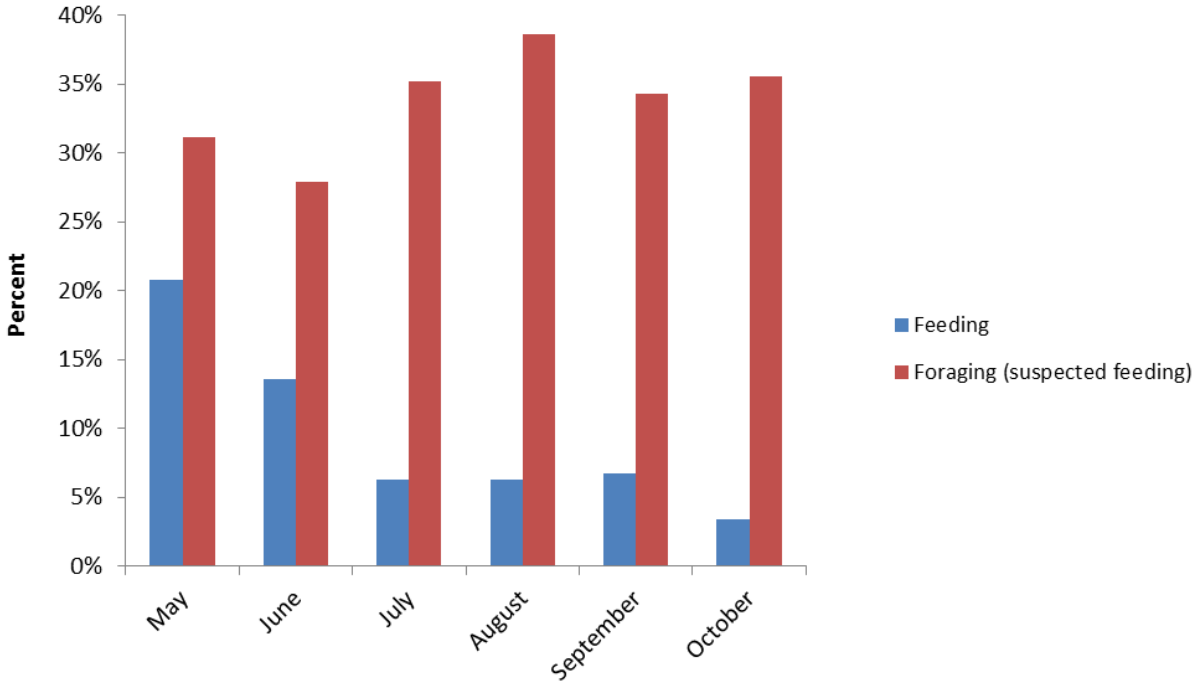


Figure 21: Seasonal comparison of behavioural budgets of bottlenose dolphins recorded from line transect and ad libitum surveys in Cardigan Bay SAC 2011-2014 (n=77, 115, 128, 124, 162, 55; April was omitted from analyses due to low sample size, n=9)

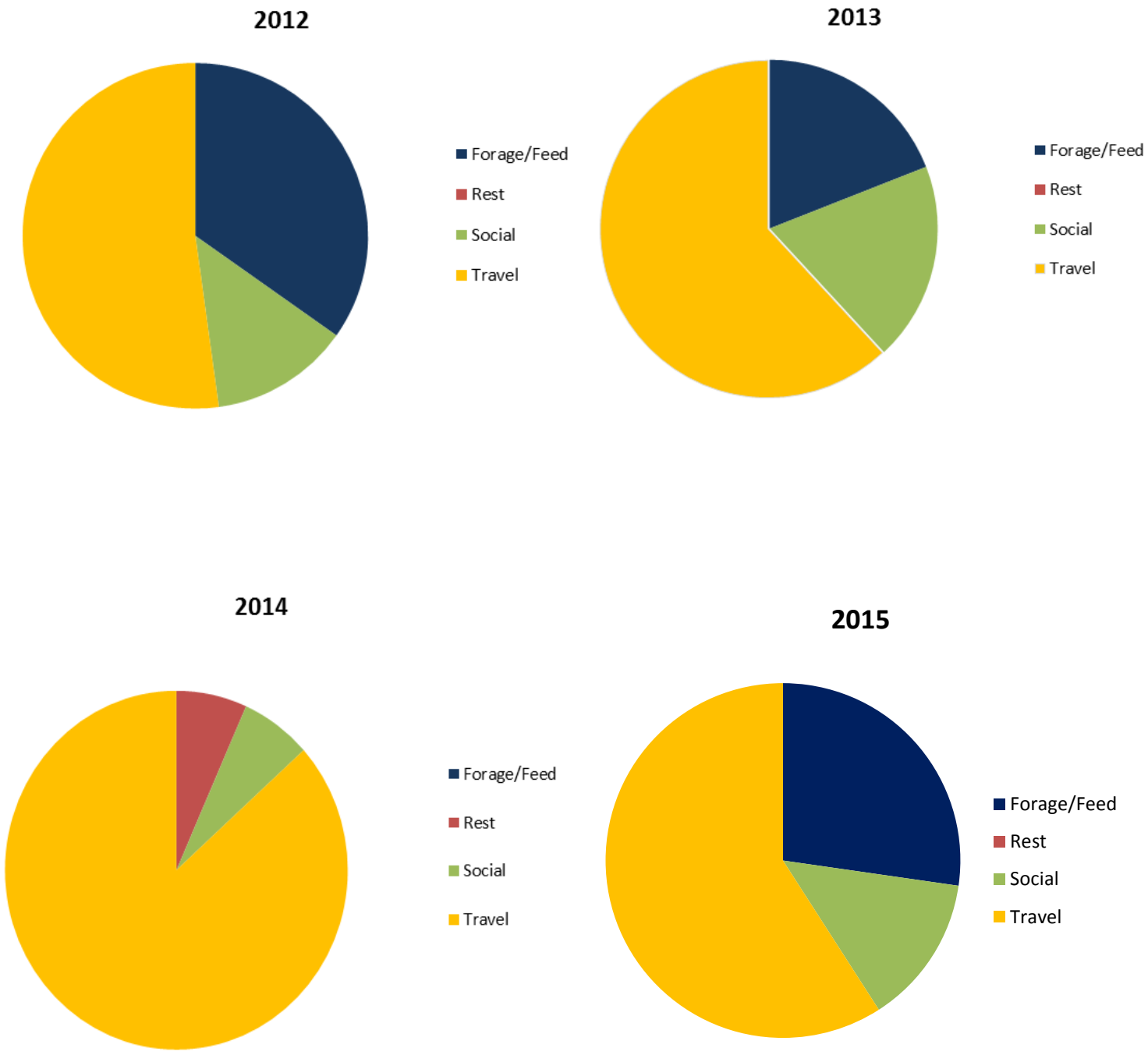


Figure 22: Behavioural budget of bottlenose dolphins recorded from line-transect and dedicated surveys in Pen Llŷn a'r Sarnau SAC in 2012, 2013, 2014, and 2015 respectively (n=23, 42, 15, and 22)

There was no apparent trend in feeding activities throughout the years, although there seems to have been a steady increase in foraging behaviour up to 2013, before a sharp drop off in 2014 to the lowest level recorded since 2006. When combining data from past years (2011 to 2015), there is a general decline through the season in confirmed feeding activity, with a concurrent rise in food searching (foraging) behaviour (Figure 20). While this is still true when looking at data from 2011 to 2015 combined, it is in stark contrast to what was observed in 2015 alone where the highest levels of foraging were observed at the start of the season and the highest levels of confirmed feeding were recorded later in the season, particularly in October (Figure 21).

Behavioural budgets for the Pen Llŷn a'r Sarnau SAC showed minor differences to those of Cardigan Bay SAC. Travel (59%) and foraging (27%) remained the behaviours predominantly observed but social behaviour was more frequently observed (13%). This seems to be fairly typical of the area, with 2012 and 2013 showing very similar values. The outlier is 2014, which recorded no confirmed feeding behaviour and the largest proportion of travel seen in any year.

Reproductive and mortality rates

Cardigan Bay SAC has long been reported as an important nursery ground for bottlenose dolphins (Ugarte & Evans, 2006, Pesante, 2008b, Veneruso & Evans, 2012a, Baylis, 2013, Feingold & Evans, 2013a, b). Between 2011 and 2013, around 50% of groups encountered in Cardigan Bay SAC had one or more calves present (47%, 51% and 53% respectively). This year, 12 newborns were encountered throughout Cardigan Bay, ten of which were recorded within Cardigan Bay SAC. An average of nearly ten newborn calves per year was recorded in the SAC between 2011 and 2015. 2013 and 2014 fell short of this average, with only six and five calves recorded respectively. 2008 and 2009 showed a similar dip in births (Figure 23). While these years were comparatively low in survey effort, some of the higher birth rates, such as 2011 and 2015 were also recorded in low effort years.

Birth rates were calculated in Cardigan Bay SAC at 6.8% per annum using mark-recapture population estimates with a closed model and 10.75% for an open population model (Table 12). These are slightly higher compared to the long term-average of 5.3% per annum, with a closed population estimate, and 7.7% for an open population model (Table 12).

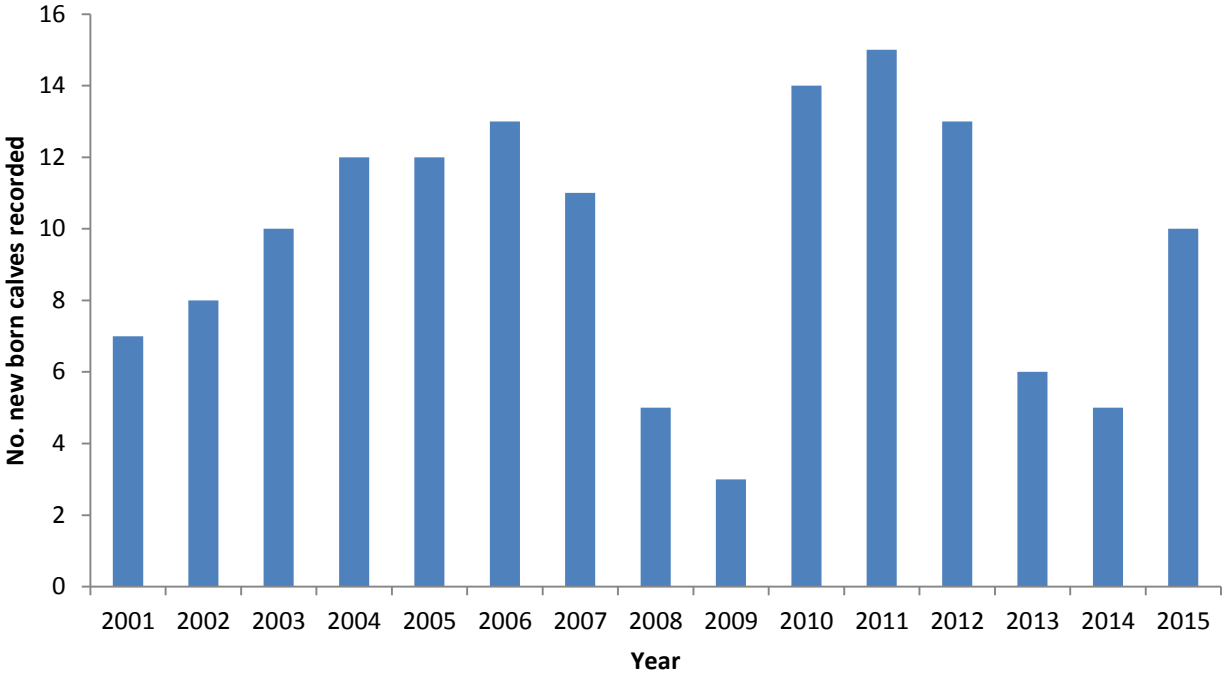
The closed population model shows a steady increase in birth rates between 2001 and 2004, peaking at 7.8% before declining, the lowest birth rate being recorded in 2009 at 1.4%. The birth rate increased following this marked decline, peaking in 2011 at 8.2%. It fell back into decline the following year until 2015 which shows a slight increase on previous years (Figure 21).

Table 11: 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	140	99	5.00	7.07
2002	8	135	77	5.93	10.39
2003	10	167	141	5.99	7.09
2004	12	153	154	7.84	7.79
2005	12	223	106	5.38	11.32
2006	13	223	139	5.83	9.35
2007	11	206	165	5.34	6.67
2008	5	260	118	1.92	4.24
2009	3	221	117	1.36	2.56
2010	14	234	153	5.98	9.15
2011	15	182	147	8.24	10.20
2012	13	229	168	5.68	7.74
2013	6	153	101	3.92	5.94
2014	5	116	103	4.31	4.85
2015	10	147	93	6.80	10.75
Average	9.6			5.30	7.67

Table 12: Number of newborns recorded in wider 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	2013	2014	2015
No. newborns	15	18	17	14	12	21	25	20	6	6	12
Population estimate (closed)	210	230	243	310	342	259	243	240	205	152	206
Population estimate (open)	128	182	222	181	167	192	193	232	167	126	135
Birth rate (closed)%	7.14	7.89	7.00	4.52	3.51	8.11	10.29	8.33	2.93	3.95	5.83
Birth rate (open)%	11.72	9.89	7.66	7.73	7.19	10.94	12.95	8.62	3.59	4.76	8.89



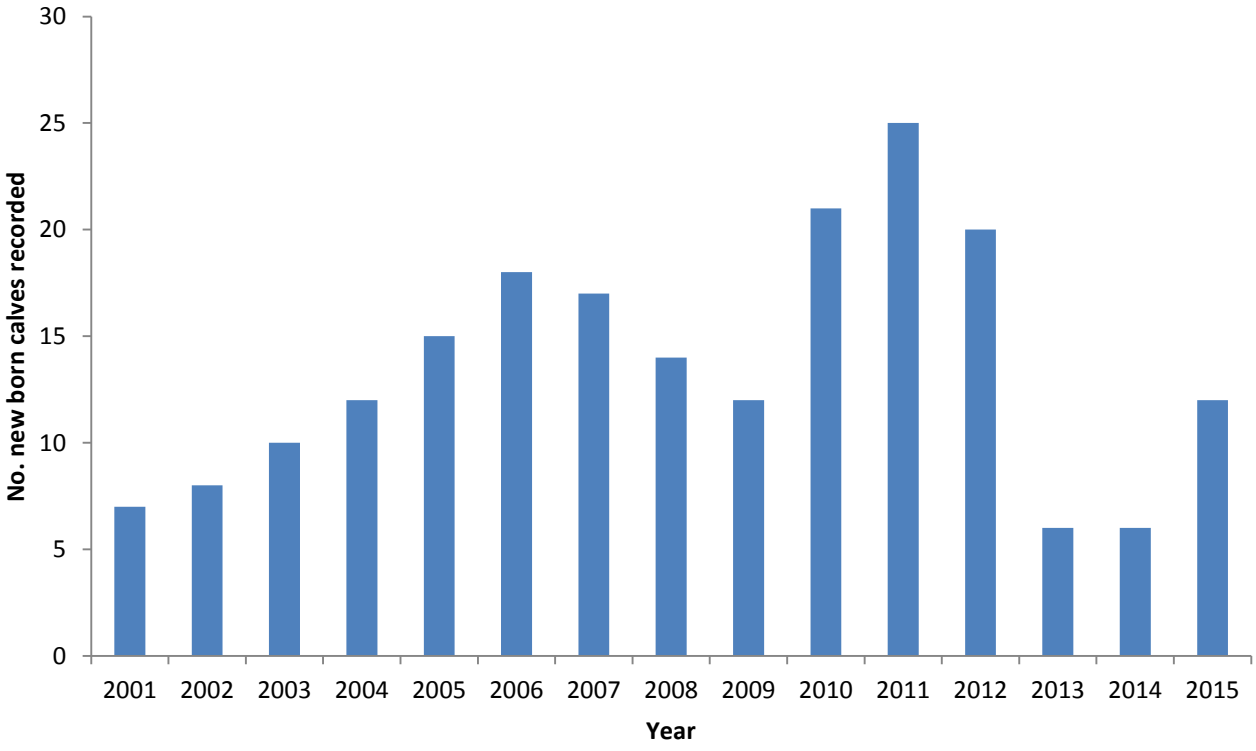


Figure 23: Number of bottlenose dolphin newborns in Cardigan Bay SAC and wider Cardigan Bay, 2001-15

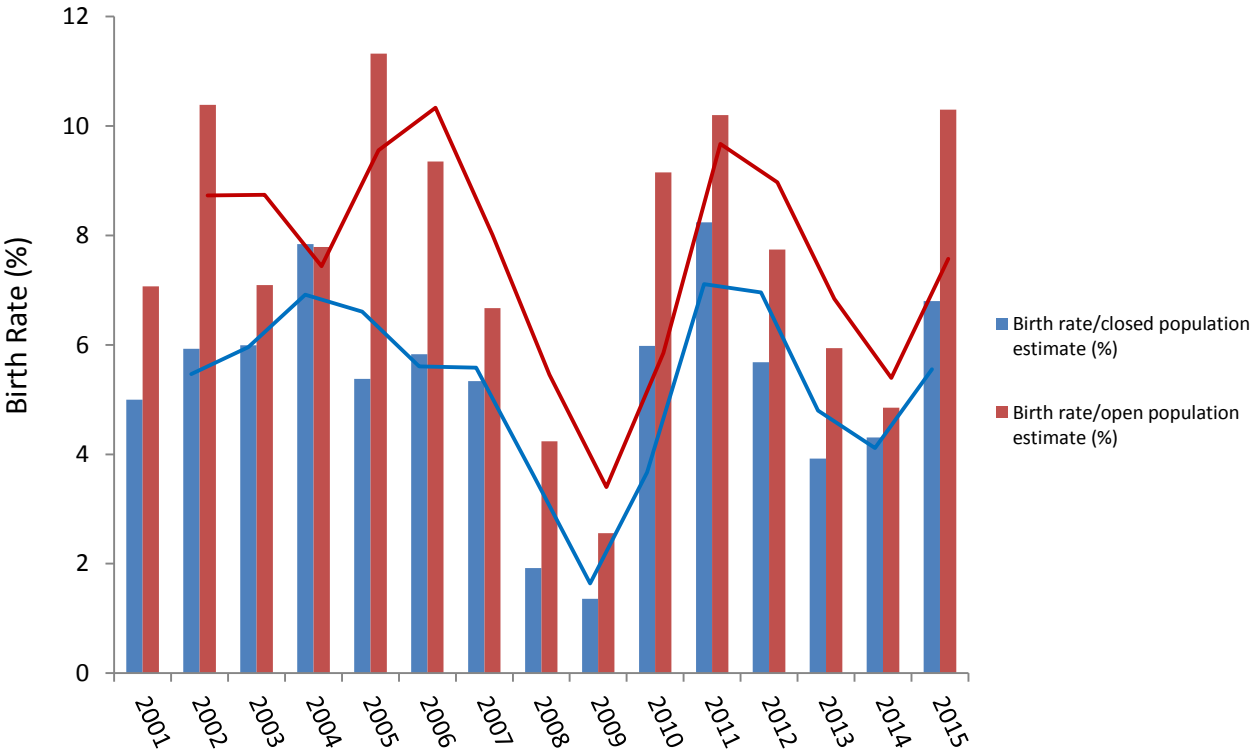


Figure 24: Birth rates of bottlenose dolphins in the Cardigan Bay SAC calculated using closed and open population estimates

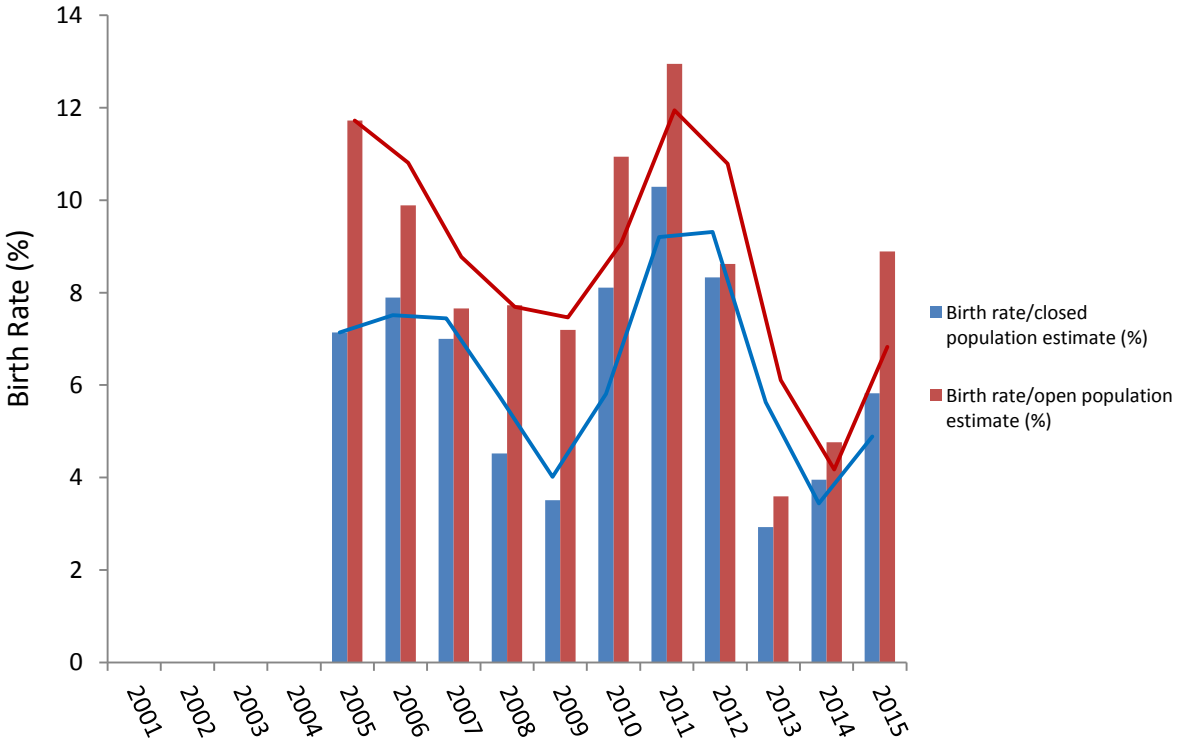


Figure 25: Birth rates of bottlenose dolphins in the wider Cardigan Bay area calculated using closed and open population estimates

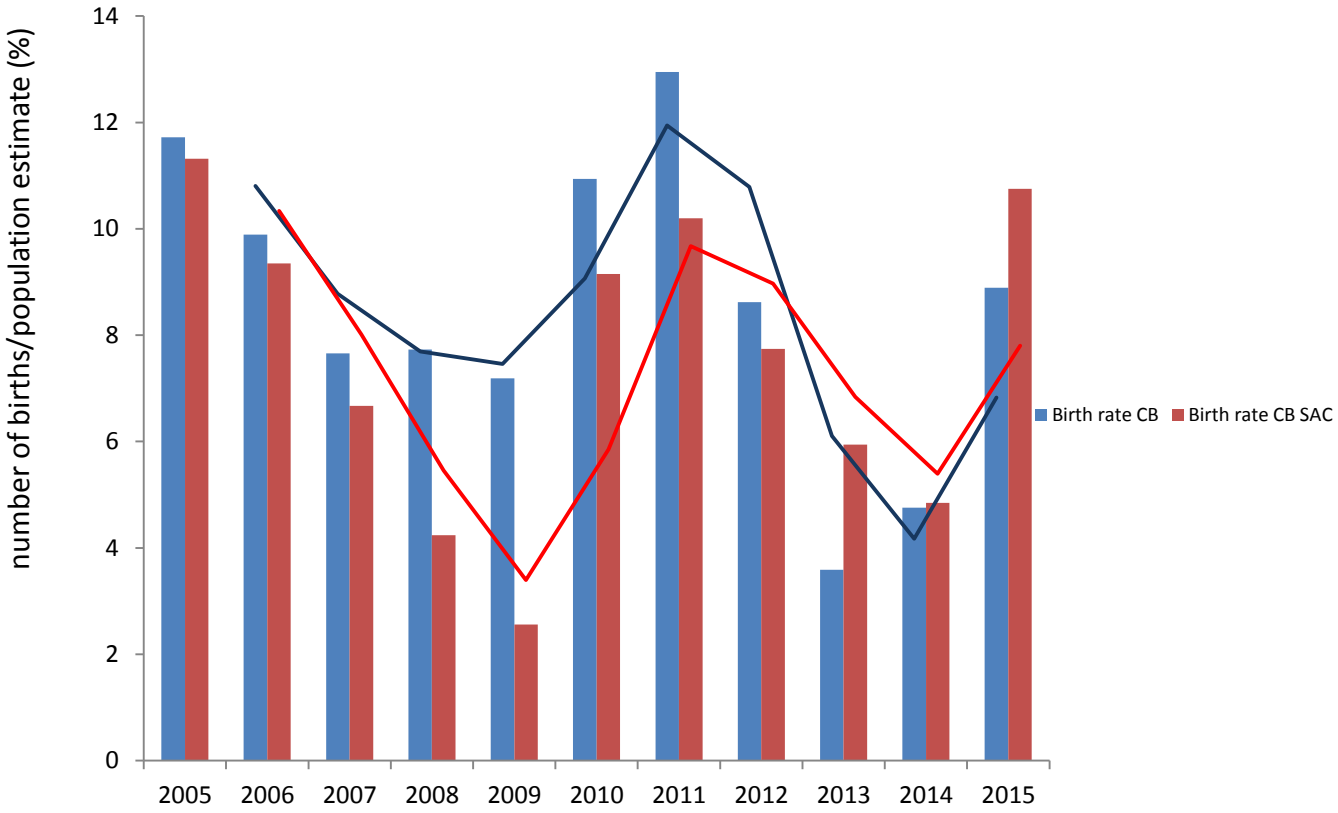


Figure 26: Birth rates of bottlenose dolphins in Cardigan Bay vs Cardigan Bay SAC calculated using open population estimates

The open population model shows broadly similar trends although slightly more variable, the lowest birth rate on record being in 2009 at 2.6% with peaks in 2002 (10.4%), 2005 (11.3%), 2011 (10.2%), and 2015 (10.75%).

Figure 22 shows crude birth rates for Cardigan Bay calculated annually from 2005, when coverage increased to include the Pen Llŷn a'r Sarnau SAC. When considered over all 11 years, the crude birth rates were calculated at 6.3% based on a closed population estimate and 8.5% based on an open population estimate. Birth rates calculated for 2015 fall very close to this average, at 5.8% based on a closed population estimate and 8.9% based on an open population estimate. Similar to within Cardigan Bay SAC, the birth rates fluctuate over the years. The lowest birth rate based on closed population estimates was recorded in 2009 at 3.5%, followed by a clear peak in 2011 (10.3%) The last three years (2013, 2014 and 2015) have been the only years since 2005 when birth rates have been lower in wider Cardigan Bay compared to Cardigan Bay SAC (Figure 26).

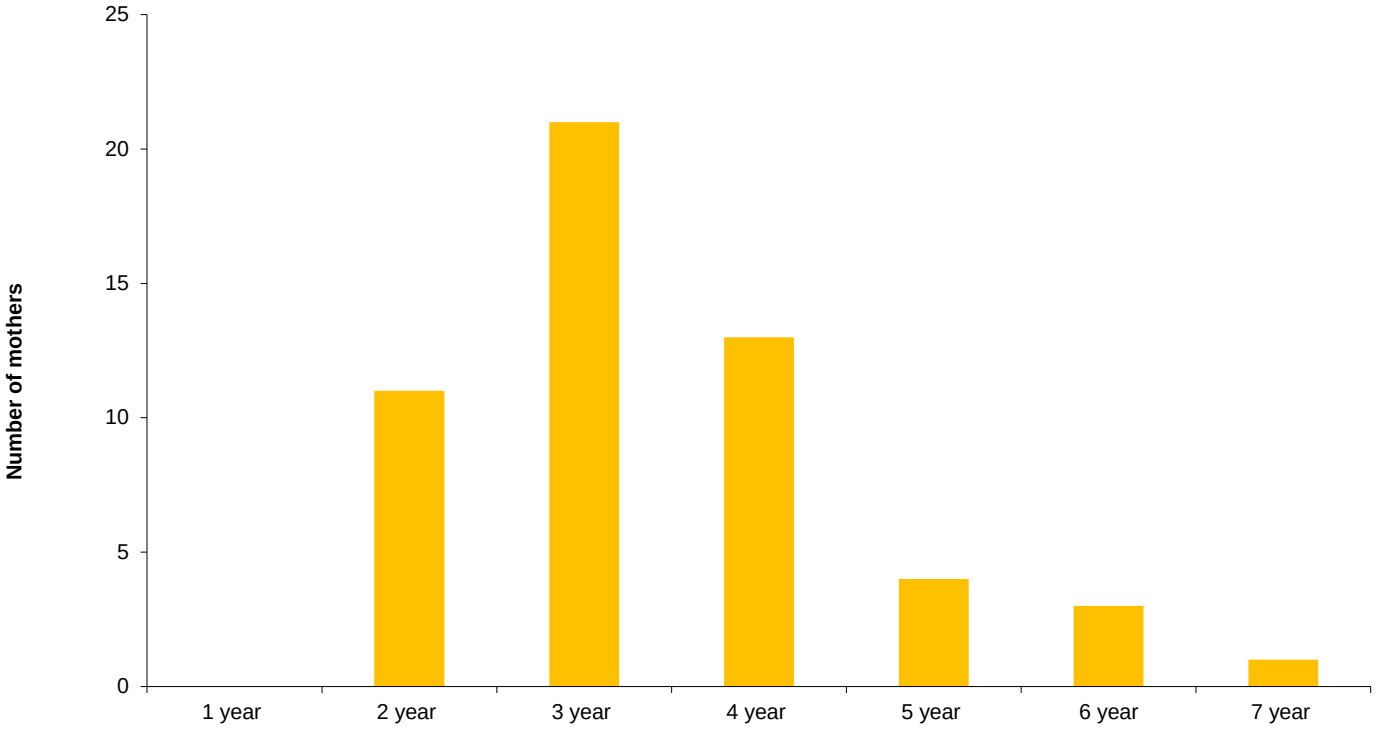


Figure 27: Inter-birth intervals of 43 known mothers in Cardigan Bay between 2001 and 2015

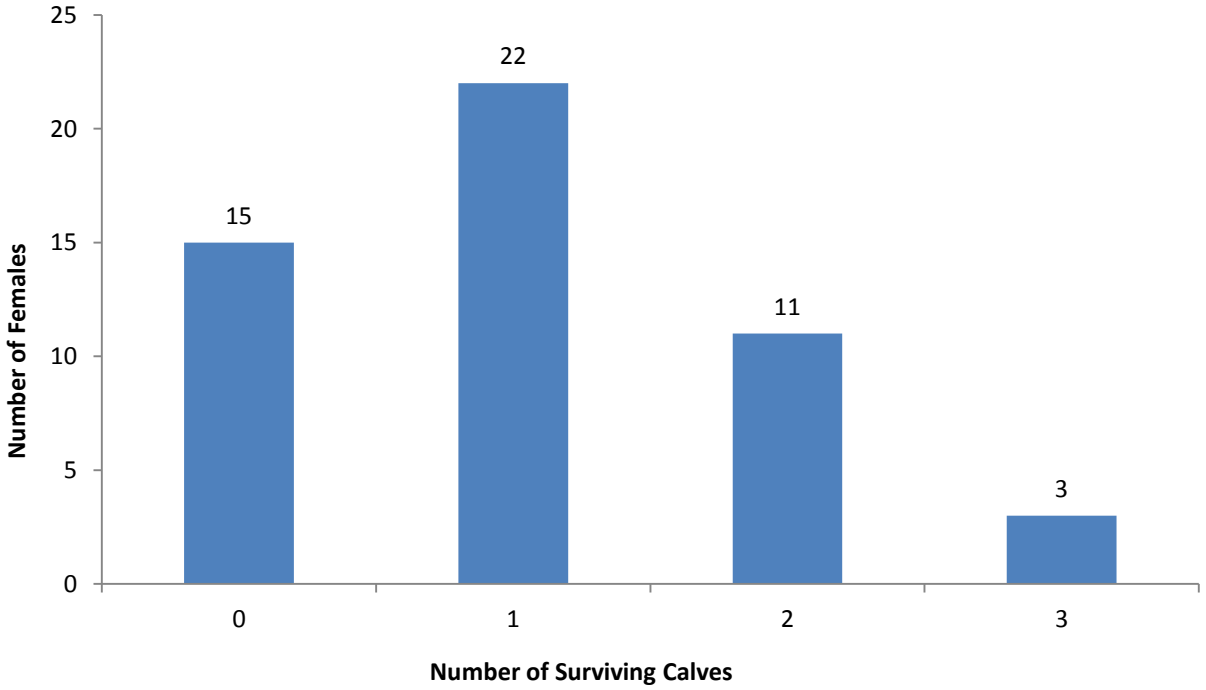


Figure 28: Female reproductive success: number of calves surviving to the age of three within Cardigan Bay, 2001-15

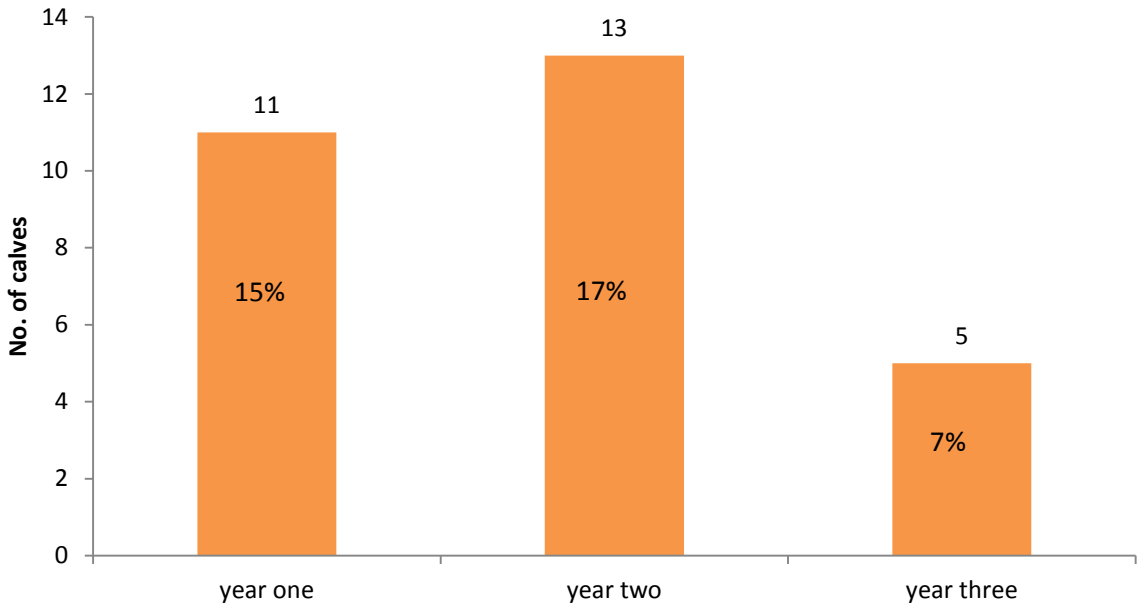


Figure 29: Number and percentages of calves that have died between the age of 1 and 3 years between 2001 and 2014

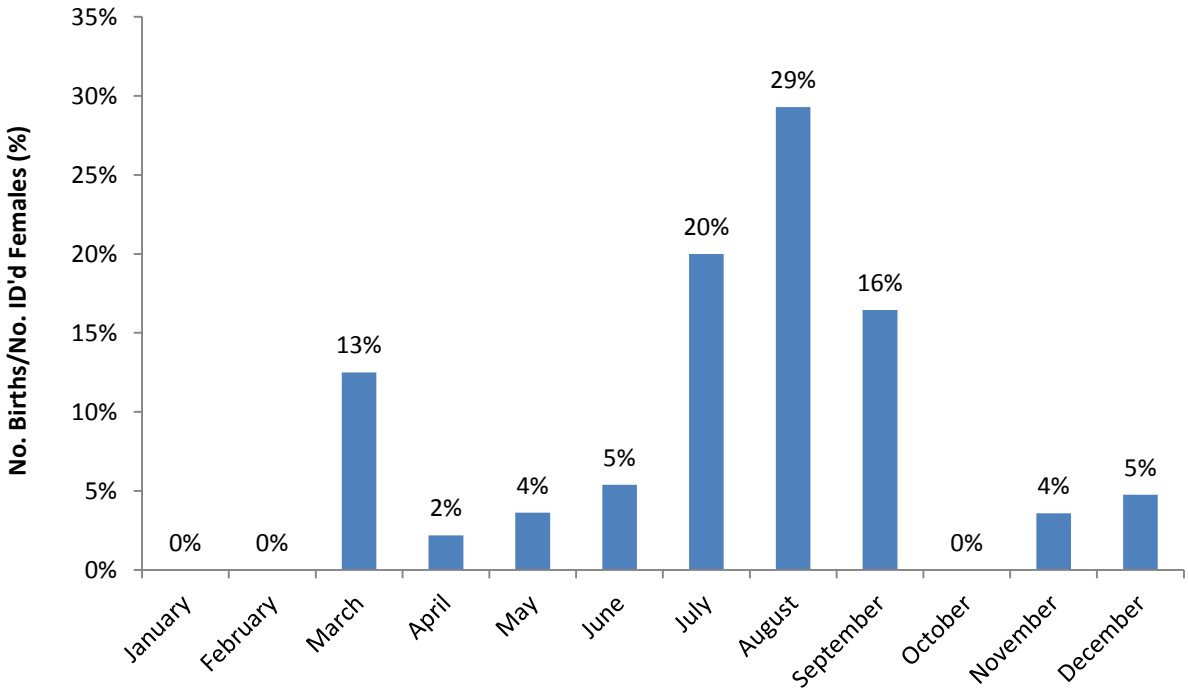


Figure 30: Number of births recorded by number of identified females each month in Cardigan Bay between 2001 and 2015

Interbirth intervals were calculated for 43 known females, each having given birth to at least two calves in the period of 2001 to 2015 (Figure 27). Females not seen in consecutive years were excluded from the analysis. Interbirth intervals ranged from two to seven years, with most females giving birth every 3 years, which is unchanged from previous estimates (Evans, 2014; Feingold & Evans, 2014a; Norrman et al., 2015).

Female reproductive success was analysed for 51 confirmed females giving birth to at least one calf between 2001 and 2015. Most females (72.5%) had one or no surviving calves. Eleven females (21.6%) had two surviving calves and only three females (5.8%) are known to have three surviving calves. However, this is likely to be a conservative estimate as some calves may not be recognisable once they leave their mother, resulting in a negative bias in the data.

Calf mortality was calculated from a sample of 76 mother-calf pairs born between 2001 and 2013. Calf mortality was particularly high in the first two years, 14.5% and 17.1% respectively, dropping off to 6.6% in year 3. However, it should be noted that this calculation may be missing calves that survive but split from their mothers before the age of three but do not have distinguishing features by which to positively identify them.

Calving season

Calving season in Cardigan Bay was analysed by estimating birth dates of newborn calves in Cardigan Bay between 2001 and 2014 based on the last sighting of a female without a calf and the first sighting of a female with a newborn calf (n=66). In 2015, none of the mothers with newborns were sighted without calves earlier in the season, and therefore these data could not be included in the analysis. Based on data from previous years, births occur throughout the season (with the exception of October) with peak calving season between July and September, 65% of births being recorded in these months. Some newborns have been spotted during the winter months around Anglesey (Figure 30).

Population dynamics and residency patterns

A total of 1223 bottlenose dolphin encounters were made between 2011-15 throughout Cardigan Bay and off North Wales. Of these, 197 dolphins were identified in 2011, 200 in 2012, 161 in 2013, 101 in 2014 and 186 in 2015 (Table 14). The Welsh photo-Id catalogue now holds a minimum of 388 individuals (Table 15).

A discovery curve of marked individuals plotted between 2001 and 2015 (Figure 31) shows an initial steep rise at the start of the study (when all dolphins encountered would have been considered ‘new’). Further significant rises can be seen in 2005 and 2007 when systematic surveys of Pen Llŷn a’r Sarnau SAC and North Wales began respectively. The curve has plateaued in recent years, particularly within the Cardigan Bay SAC, suggesting that most dolphins in this area have been photographed. New dolphins continue to be

added on an annual basis and are likely to be a mixture of juvenile dolphins that acquire identifiable markings and transient dolphins entering the study area.

Table 13: Bottlenose dolphin encounters in 2011-2015

	2011	**2012**	**2013**	**2014**	**2015**
Total no. encounters	233	272	261	271	186
Total maximum no. dolphins identified	197	200	161	101	111
No. marked dolphins identified	160	164	130	99	83
No. unmarked dolphins (left) identified	30	35	29	0	13
No. unmarked dolphins (right) identified	37	36	31	2	15

Table 14: SWF catalogue content in 2014

Well marked (WM)	110
Slightly marked (SM)	145
Left (L)	122
Right (R)	133
WM+SM+L	377
WM+SM+R	388

Overall frequencies of re-sightings range from 1 to 180 (mean=21.06, SD=23.46; Figure 32). Multiple sightings per day for any individual were excluded from this analysis. Comparing re-sightings results from the wider Cardigan Bay area to Cardigan Bay SAC show some subtle differences, while a large proportion of the animals is still considered resident (38-45%), a larger proportion is consistent transient, 34% compared to 16-17% in wider Cardigan Bay.

Previous studies suggest that the Cardigan Bay bottlenose dolphin population comprises a combination of transients, occasional visitors, and resident animals (Feingold & Evans, 2014a). Between 16% and 17% of the population are considered to be transient, having been sighted less than four times and in only one or two years; a further 19% and 29% are occasional visitors, with 4-11 sightings in 3-6 years of the study. The majority of the wider Cardigan Bay population, however, can be considered residents, 54% and 64% of individuals having been sighted for over 6 years and more than 12 times during the study period (Figures 33 & 34). About 60% of residents have been sighted in excess of 20 times and two individuals have been sighted 180 times (074-03W and 004-90W); five individuals have been seen for 14 years, and a further two for 15 years.

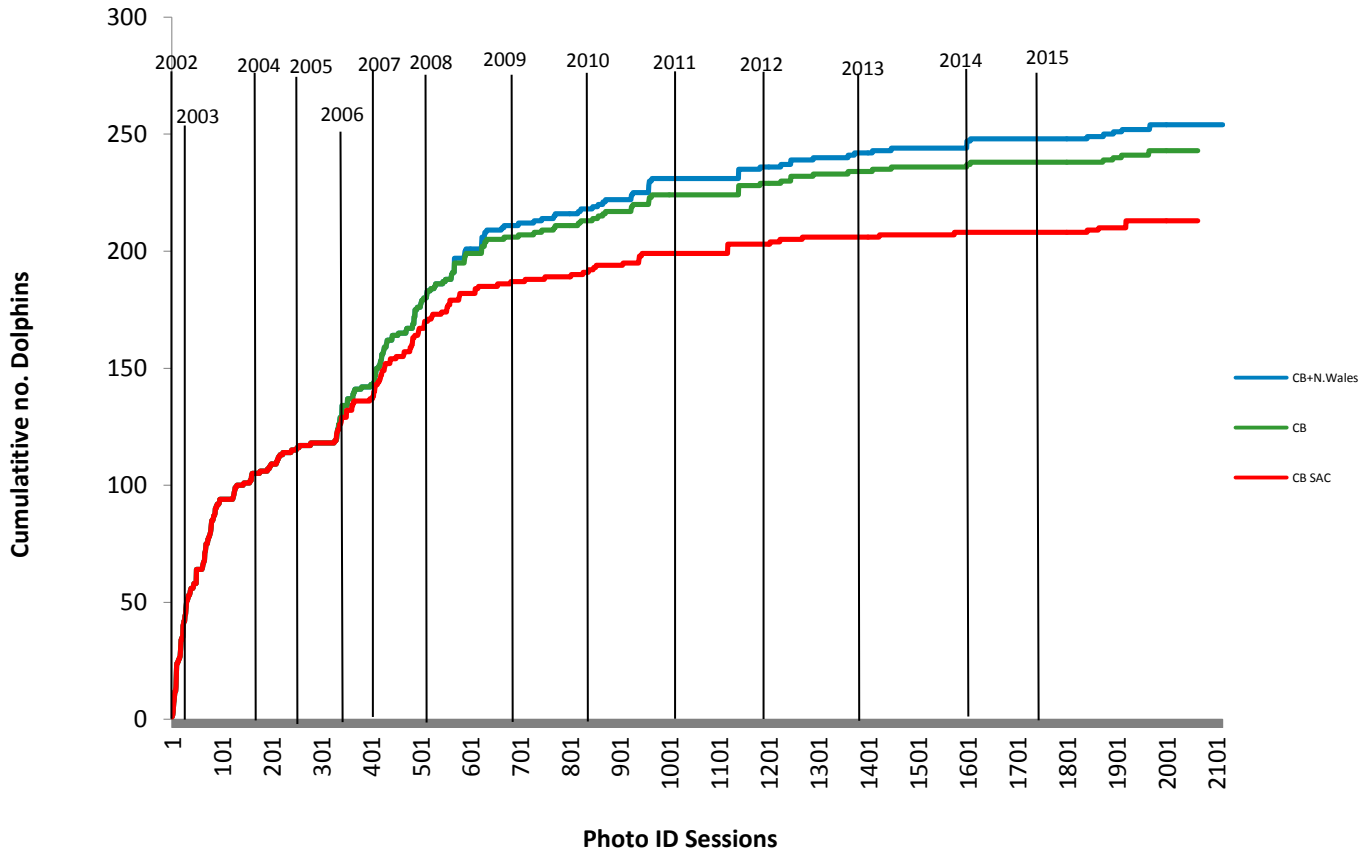


Figure 31: Discovery curve for marked bottlenose dolphins from 2001-15

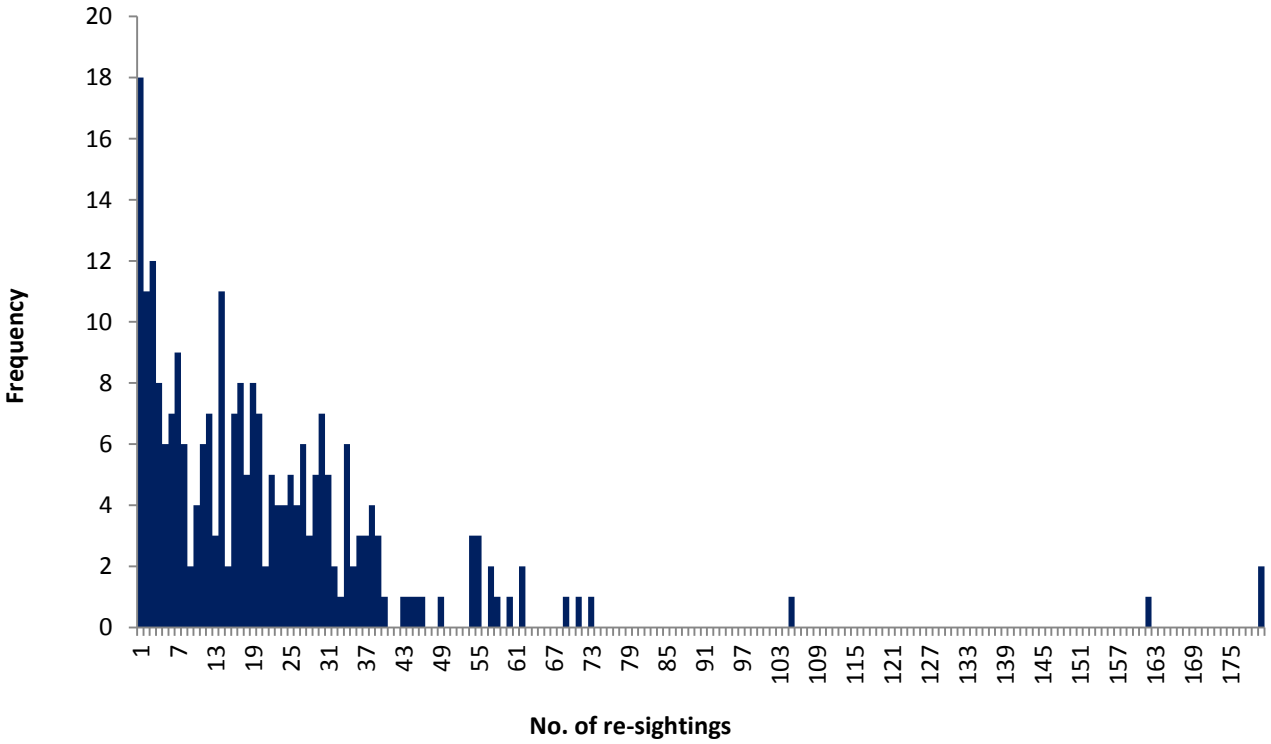
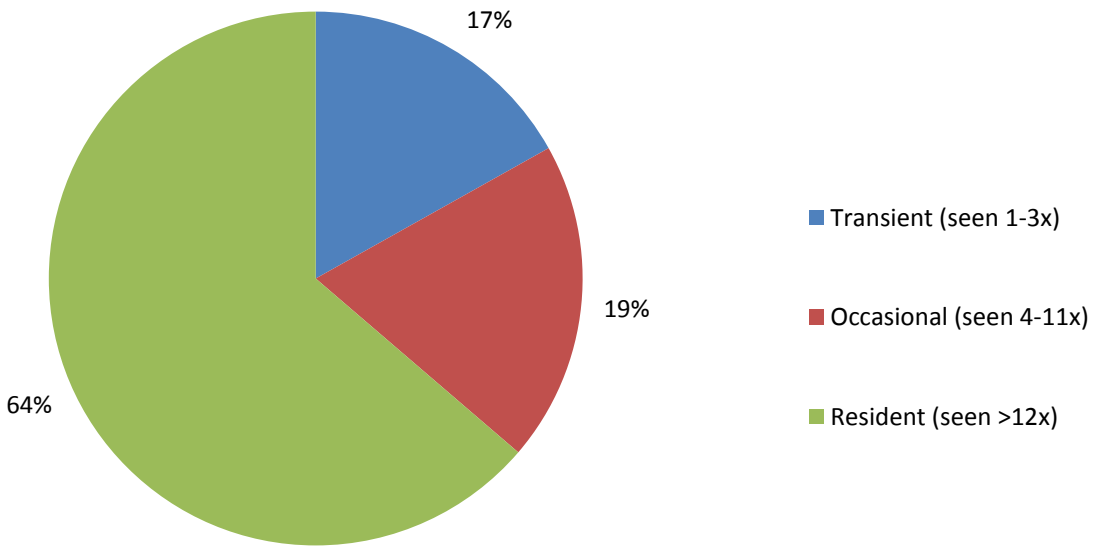


Figure 32: Frequency of re-sighted individuals in Cardigan Bay, 2001-2015



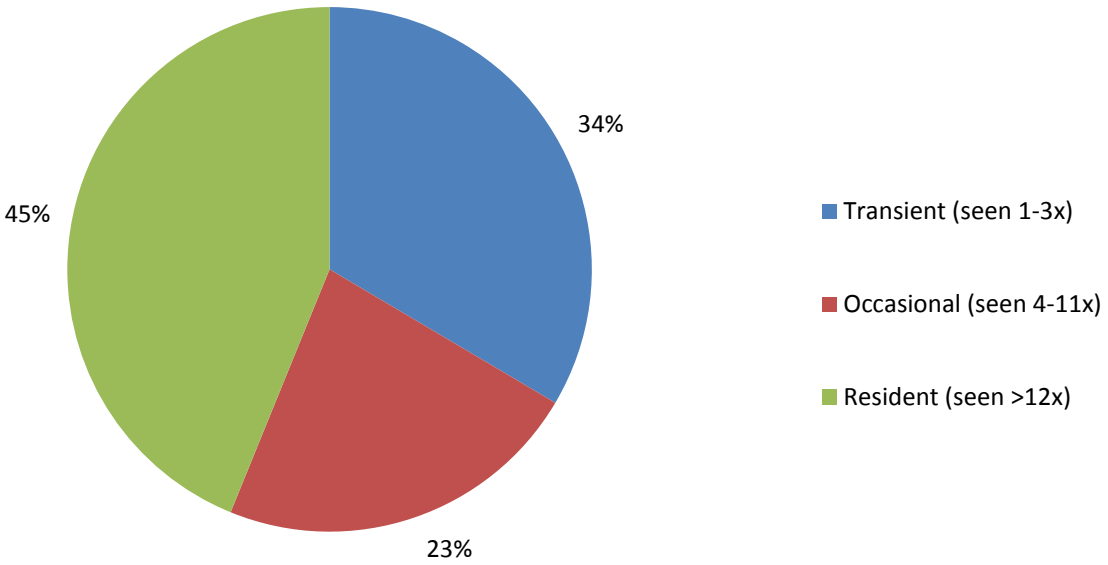


Figure 32: Percentage of individual re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom) from 2001-2015

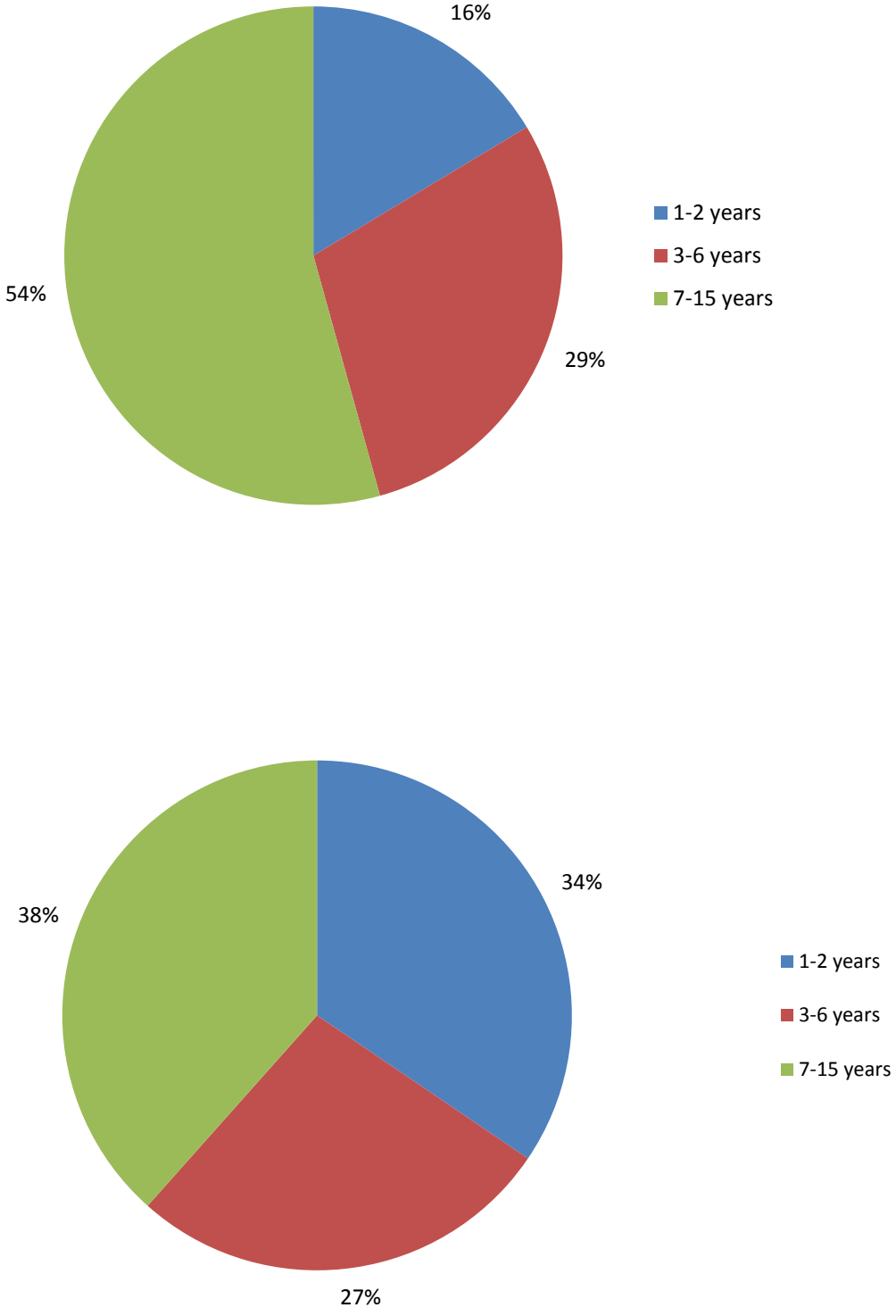


Figure 33: Percentage of yearly re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom) from 2001-2015

Mark-recapture population estimates

Mark recapture population estimates were calculated for both open and closed population models for both Cardigan Bay and Cardigan Bay SAC. Cardigan Bay SAC in particular has been subject to regular systematic coverage over the last 15 years and therefore mark-recapture calculations should provide reasonably robust population estimates for the area. Estimates based on an open population model vary greatly over the years, showing no strong trends; estimates reached a peak in 2007 and 2012 at 165 and 168 respectively, whereas particularly low estimates were recorded in 2001-02, 2005, and 2013-14 (Table 15). A polynomial trend line shows a steady increase in population size up to 2008 before dropping off in recent years (Figure 35, Table 15). The open population model also considers individuals, emigration, immigration, birth and death rates. A general increase in the probability of permanent emigration from Cardigan Bay SAC can be seen from 2001 to 2014, although it has fallen again in the past year (Figure 36).

Table 15: Population estimates for bottlenose dolphins in the Cardigan Bay SAC for 2011-2015 using an open population model and considering the marked proportion of emigration from Cardigan

Year	Population estimate	Standard Error	Proportion of marked
2001	**99**	0	0.64
2002	**77**	1.28E-04	0.48
2003	**141**	0	0.62
2004	**154**	7.0233961	0.59
2005	**106**	1.33E-05	0.63
2006	**139**	3.36E-06	0.61
2007	**165**	2.62E-07	0.55
2008	**118**	7.189E-06	0.63
2009	**117**	2.68E-05	0.65
2010	**153**	0.00E+00	0.61
2011	**147**	3.26E-17	0.57
2012	**168**	0	0.52
2013	**101**	0	0.60
2014	**74**	0	0.55
2015	**97**	2.67E-005	0.64

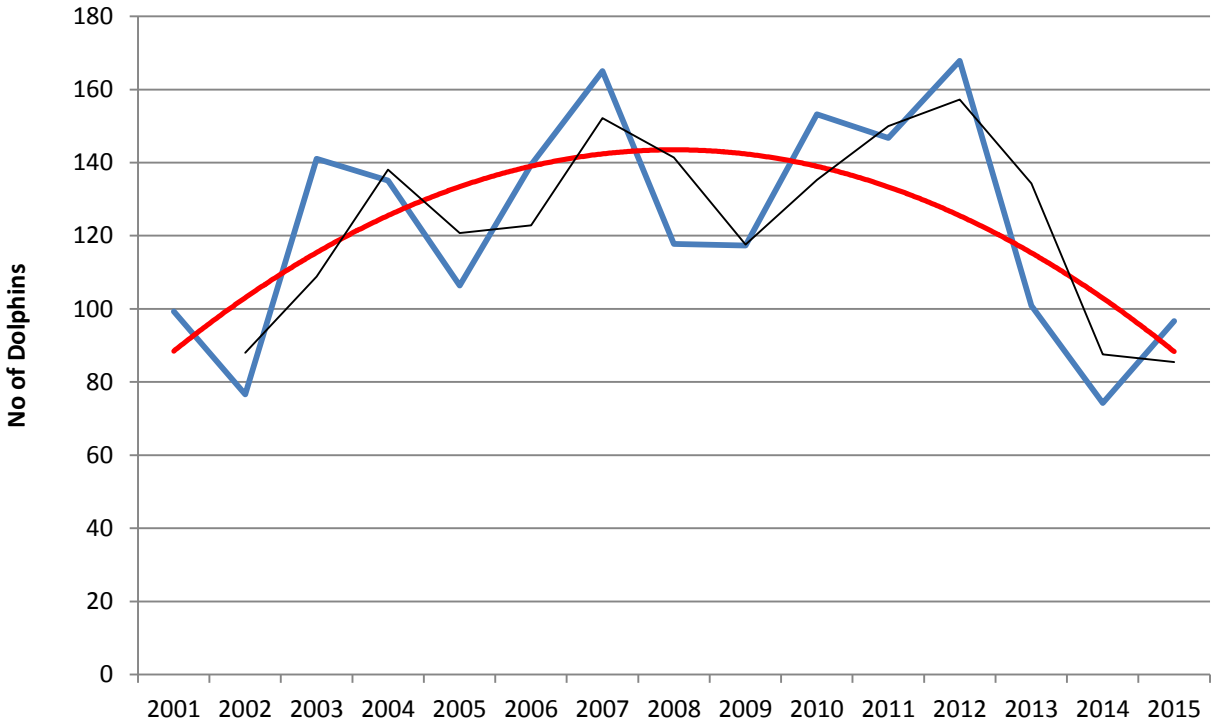


Figure 34: Population trend for bottlenose dolphins in Cardigan Bay SAC for the years 2011-2015, obtained using an open population model
(blue line= whole population estimate; red line-polynomial trend; black line- moving average trend)

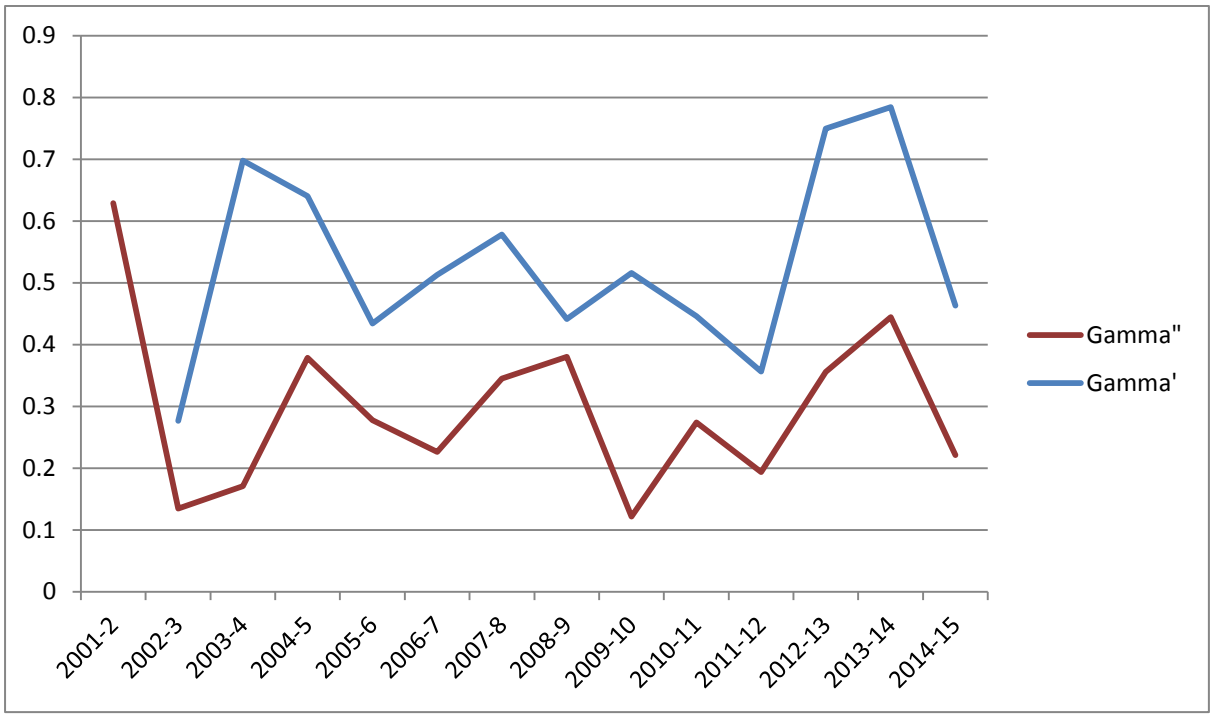


Figure 35: Bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model;
Gamma”-probability of animal emigrating out of study area;
Gamma’- probability of an animal staying out of the study area

Table 16: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model

Period	Gamma''	Standard Error	Gamma'	Standard Error
2001-2	0.62	0.06		
2002-3	0.13	0.06	0.28	0.08
2003-4	0.17	0.04	0.70	0.13
2004-5	0.38	0.06	0.64	0.10
2005-6	0.28	0.06	0.43	0.08
2006-7	0.23	0.05	0.51	0.09
2007-8	0.34	0.05	0.58	0.09
2008-9	0.38	0.06	0.44	0.08
2009-10	0.12	0.04	0.52	0.08
2010-11	0.27	0.05	0.45	0.10
2011-12	0.19	0.05	0.36	0.10
2012-13	0.36	0.06	0.75	0.07
2013-14	0.44	0.07	0.78	0.07
2014-15	0.22	0.07	0.46	0.09

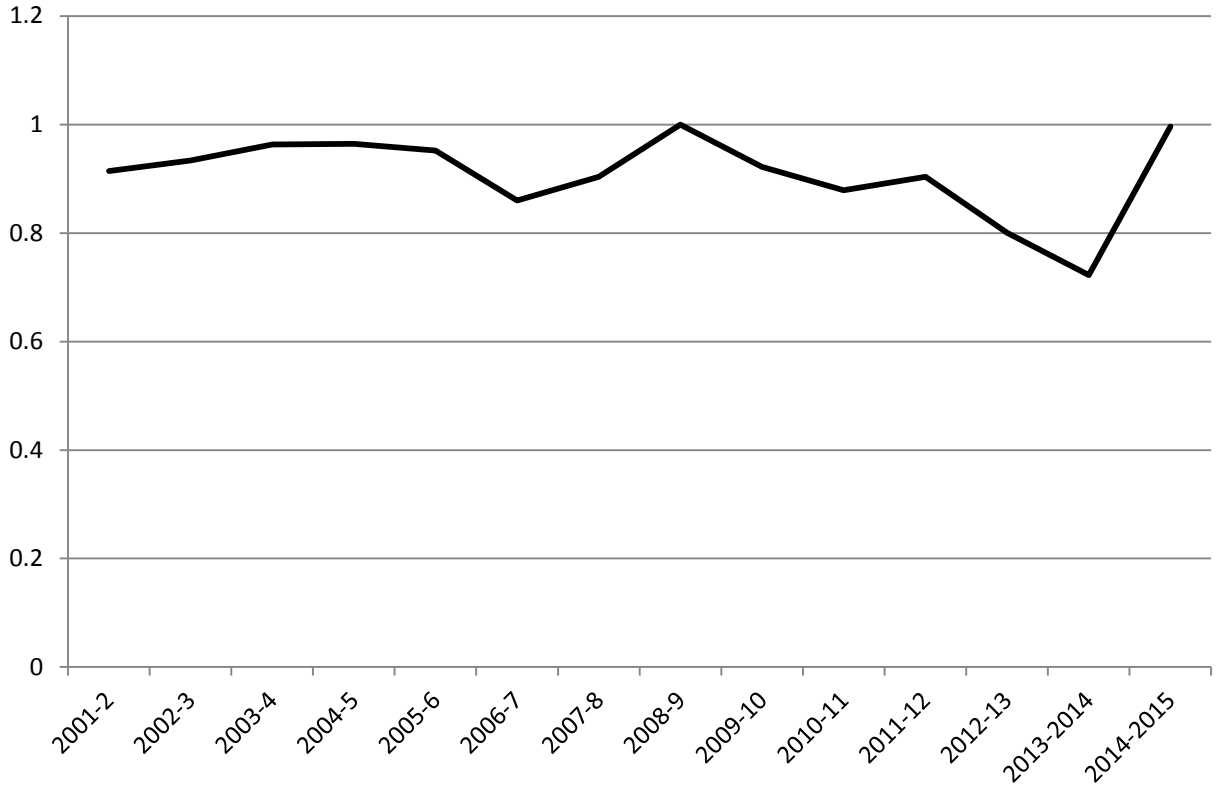


Figure 36: Bottlenose dolphin survival rates in Cardigan Bay SAC, using an open population model, between 2001 and 2015

The steep rise in permanent emigration in 2013 also coincides with a sharp decrease in survival rates (Figures 36 & 37) and the lowest number of dolphins identified since 2003.

Population estimates based on a closed population model show similar trends for Cardigan Bay SAC, peaking in 2008 with an estimate of 260 individuals. It shows smaller peaks in 2010 and 2012 but has generally declined since 2008, with the exception of a small increase in 2015. 2014 shows the lowest value since the study started in 2001, with an estimate of 116 individuals (Figure 38, Table 17).

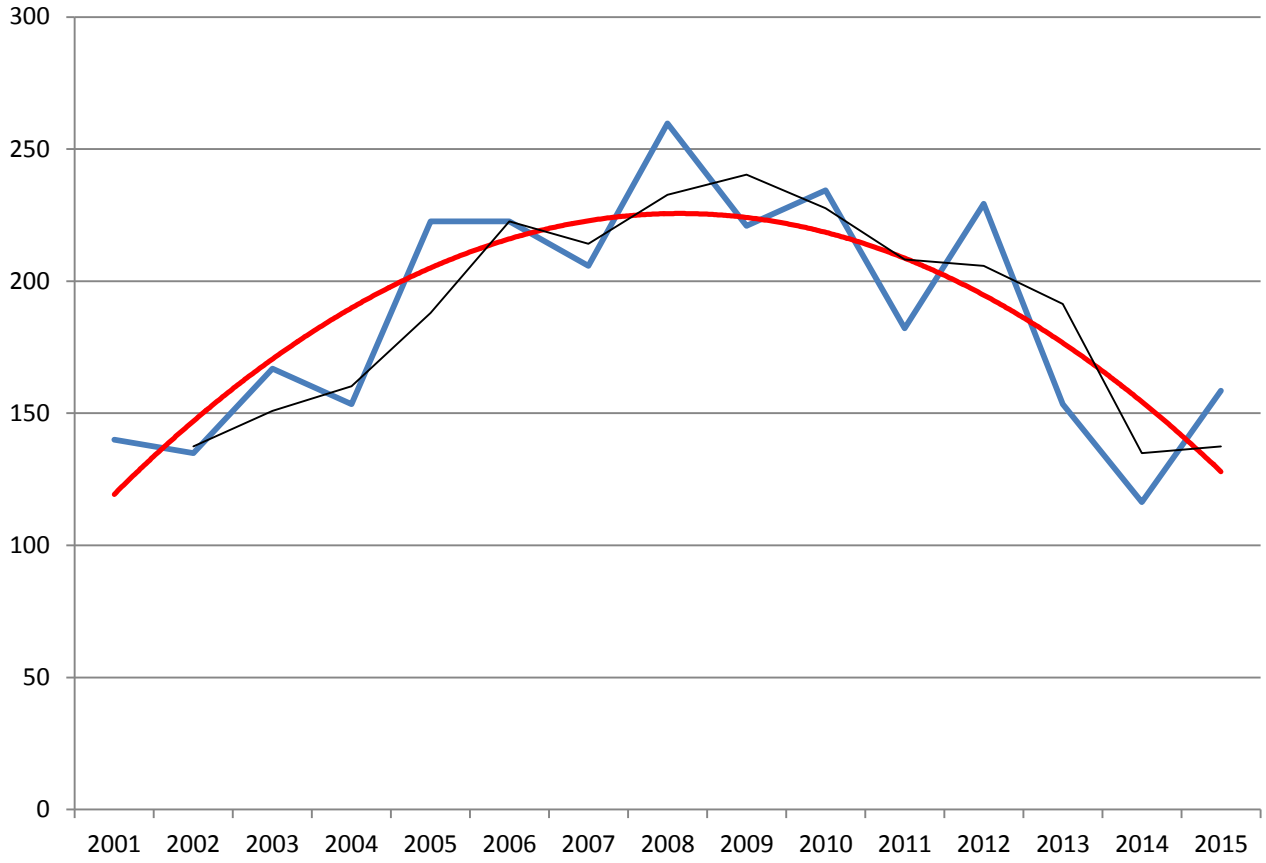


Figure 37: Population trend for bottlenose dolphins in Cardigan Bay SAC for the years 2001-2015 using a closed population model (blue line= whole population estimate; red line-polynomial trend; black line- moving average trend)

Table 17: Population estimates for bottlenose dolphins in Cardigan Bay SAC for the years 2001-2015 obtained using a closed population model and considering the marked proportion of individuals

Year	Capture events	Animals captured	Population estimate	Lower 95% CI	Upper 95% CI	Standard error
2001	117	64	**140**	121	192	10.09
2002	46	37	**135**	88	275	25.64
2003	234	87	**167**	155	194	5.51
2004	200	80	**153**	143	180	5.46
2005	97	67	**223**	164	349	26.59
2006	136	85	**223**	184	307	17.96
2007	162	91	**206**	179	266	12.73
2008	122	74	**260**	192	401	30.35
2009	142	76	**221**	175	315	20.54
2010	214	94	**234**	199	302	15.02
2011	197	83	**182**	160	228	9.86
2012	186	88	**229**	191	305	16.76
2013	140	61	**153**	126	211	12.17
2014	113	41	**116**	91	175	12.30
2015	116	62	**159**	130	228	14.20

Population estimates for wider Cardigan Bay were calculated for the period of 2005-13, since 2005 marked the beginning of systematic Pen Llŷn a'r Sarnau surveys, using both closed and open population models

The open population model shows peaks in the population estimates in 2007 at 222, and in 2012 at 232 (Table 18). Since then, the estimates have declined, reaching the lowest

estimate since the beginning of the study, in 2014, with an estimate of 126, before rising slightly in the past year (2015). Some years of low estimates coincide with years of low effort intensity (2008-09), but this is probably not the sole reason for the low estimates in those years since other years (e.g. 2011, 2015) with relatively low survey effort do have high estimates.

Emigration rates fluctuate widely between 2005 and 2015. The years 2012-13 show particularly low values of less than 1% (Table 20, Figure 40). Although the likelihood of emigration has risen in the past year, the likelihood of staying out of the bay has risen sharply in the last two years.

Table 18: Population estimates for bottlenose dolphin in wider Cardigan Bay for 2005-14 obtained using an open population model, considering the marked proportion of individuals

Year	Population estimate	Standard Error	Proportion of marked
2005	**128**	1.99E-07	0.66
2006	**182**	7.963E-05	0.65
2007	**222**	5.13E-05	0.59
2008	**181**	6.01E-05	0.68
2009	**167**	1.04E+01	0.67
2010	**192**	3.96E-05	0.63
2011	**193**	2.19E-05	0.59
2012	**232**	1.96E-06	0.53
2013	**167**	1.96E-06	0.64
2014	**126**	0	0.56
2015	**153**	0.48E-08	0.66

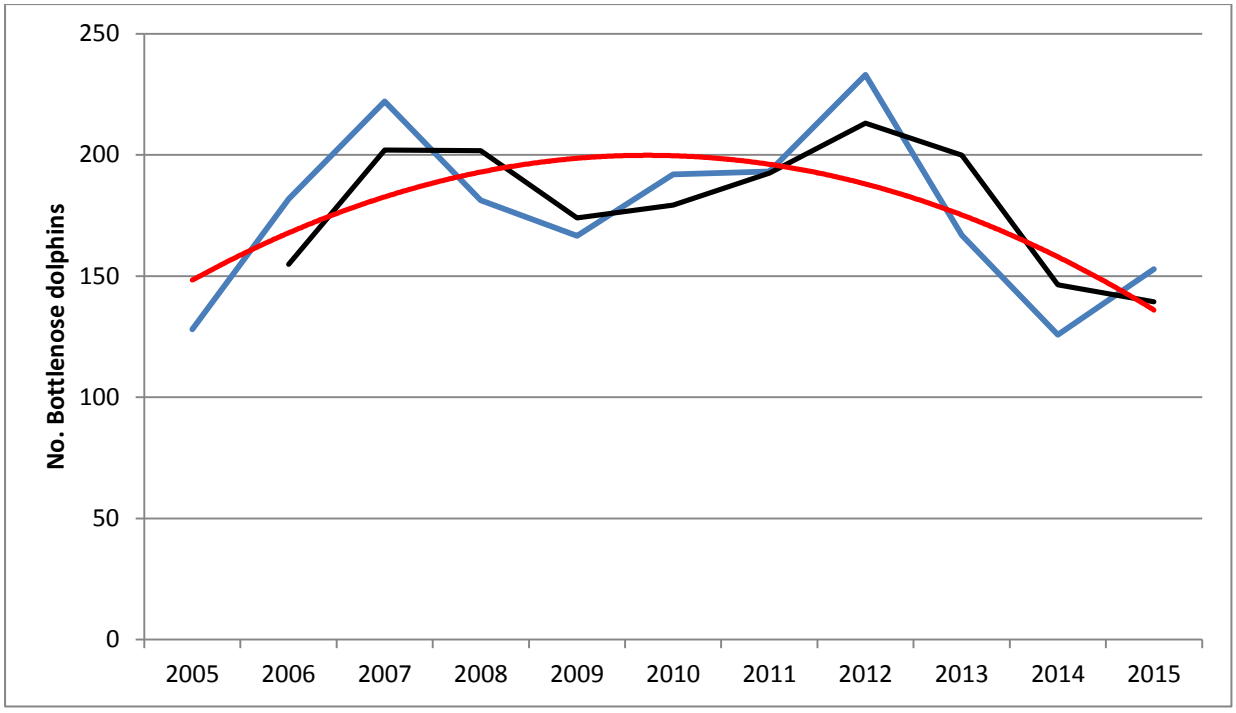


Figure 38: Population trend for bottlenose dolphins in wider Cardigan Bay for the years 2005-15 obtained using an open population model

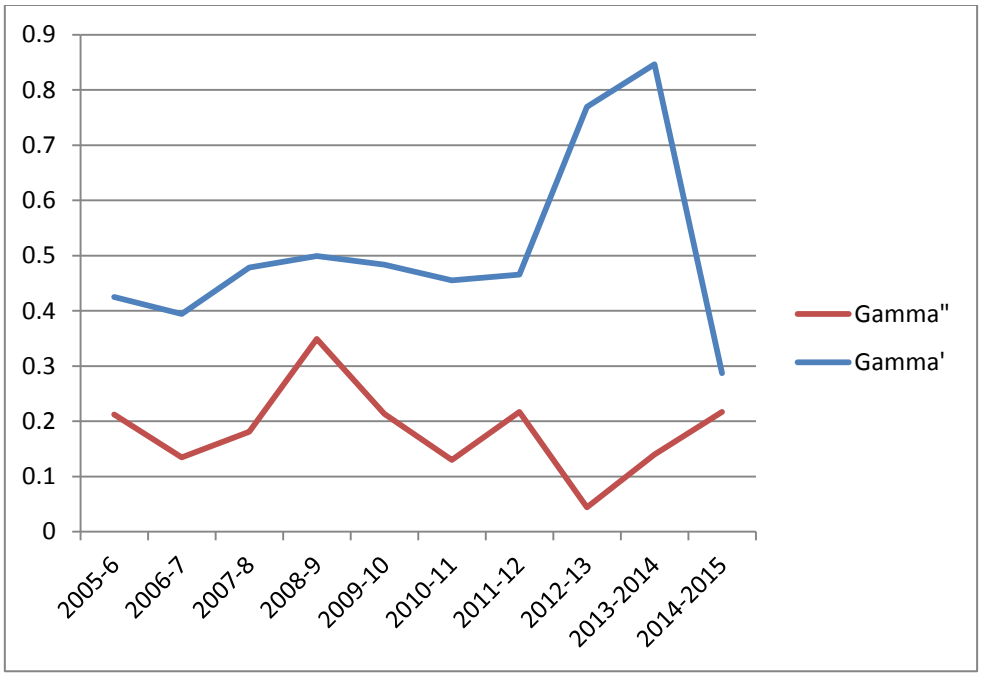


Figure 39: Bottlenose dolphin residency patterns in wider Cardigan Bay using an open population model

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 19: Standard Errors for bottlenose dolphin residency patterns in wider Cardigan Bay using an open population model

Period	Gamma''	Standard Error	Gamma'	Standard Error
2005-6	0.212	0.046		
2006-7	0.135	0.034	0.394	0.117
2007-8	0.181	0.038	0.479	0.089
2008-9	0.349	0.042	0.499	0.079
2009-10	0.213	0.037	0.483	0.059
2010-11	0.130	0.041	0.455	0.078
2011-12	0.217	0.033	0.466	0.051
2012-13	0.044	0.038	0.769	0.033
2013-14	0.140	0.051	0.847	0.067
2014-15	0.217	0.053	0.287	0.122

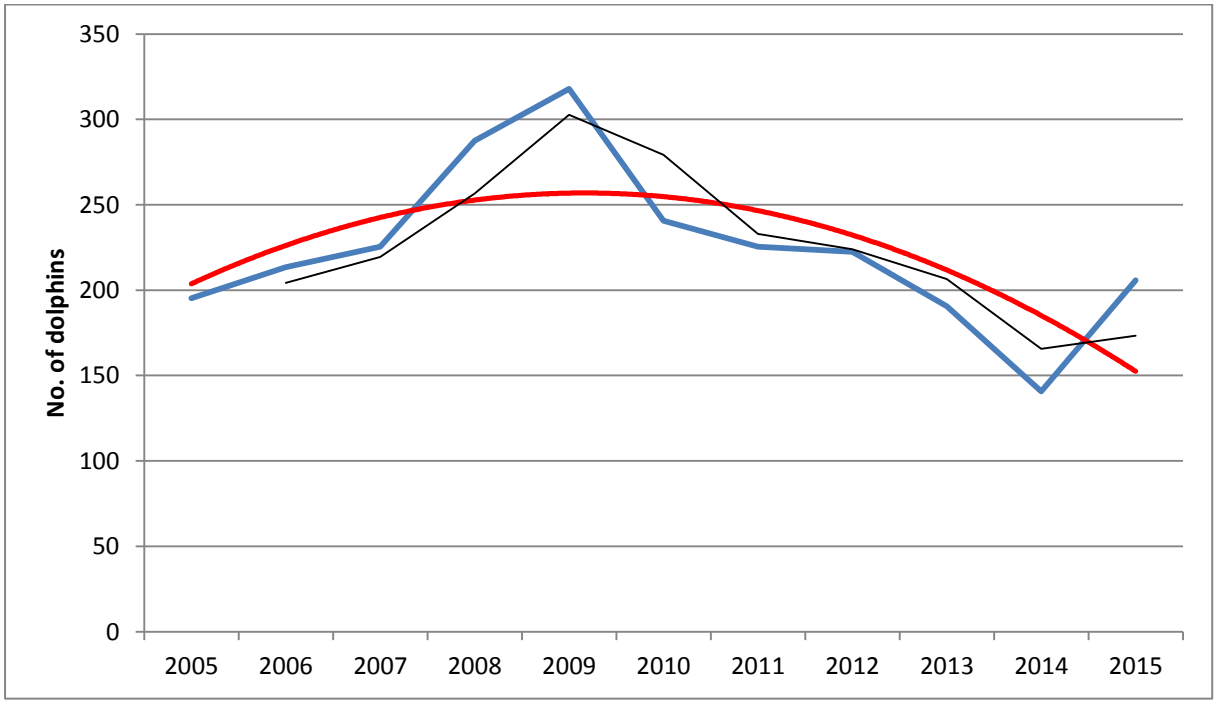


Figure 40: Population trend for bottlenose dolphins in the wider Cardigan Bay area from 2005-15

Table 20: Population estimates of bottlenose dolphins occupying Cardigan Bay, calculated using the mark-recapture and a closed population model, taking into account the marked proportion of individuals

Year	Capture events	Animals captured	Population estimate	Lower 95% CI	Upper 95% CI	Standard error
2005	142	85	**210**	174	284	16.55
2006	221	118	**230**	210	275	9.83
2007	291	132	**243**	228	279	7.50
2008	248	124	**310**	264	391	19.46
2009	191	111	**342**	271	474	30.95
2010	283	120	**259**	231	311	12.47
2011	265	114	**243**	217	292	11.57
2012	293	122	**240**	220	280	9.36
2013	262	107	**205**	189	241	7.80
2014	127	73	**152**	126	282	19.9
2015	162	90	**222**	184	300	14.20

Population estimates based on the closed population model shows a steady increase in the population peaking at 310 in 2008, before steadily declining. Unlike the open model, there are fewer peaks (see Figure 41), although the estimate does show a (small) spike in 2012 with an estimate of 240 (see Table 20), mirroring the increase in the open population model. Much like the open model, the lowest estimate occurs in 2014 with 152 individuals, and shows a slight increase again in the succeeding year.

Although all estimates across both Cardigan Bay SAC and wider Cardigan Bay show a slight increase on estimates of the previous year (which has some of the lowest estimates for Cardigan Bay and Cardigan Bay SAC since the start of the study), overall, the population seems to have declined since 2008.

Home ranges

Since 2007, extended effort has taken place in North Wales, particularly around the Isle of Anglesey, and it is now well known that identifiable individuals from the Cardigan Bay

population are regularly sighted off North Wales and as far as the Isle of Man (Pesante et al., 2008a, b; Veneruso & Evans, 2012b; Feingold & Evans, 2013, 2014b). A large proportion (40%) of marked individuals photographed between 2007 and 2013 were sighted in both the Cardigan Bay and Pen Llŷn a'r Sarnau SAC, as well as in North Wales and the Isle of Man. Nearly 26% were seen in Cardigan Bay SAC and North Wales but not in Pen Llŷn a'r Sarnau SAC, potentially due to the lower level of survey effort in this area. Some individuals exhibited strongly localised home ranges, with 7% of individuals sighted only within Cardigan Bay SAC, 3% only seen in the Pen Llŷn a'r Sarnau SAC, and 8% only in North Wales and Anglesey. While observations of bottlenose dolphins around Anglesey and in North Wales were previously thought to be mainly seasonal occurrences, with animals moving north in the winter months (Pesante et al., 2008b), there are now increasing observations of dolphins remaining there during the summer as well.

During a first dedicated survey in Liverpool Bay, in July 2013, nine (50%) of the individuals photographed in the encounter were matched to the SWF catalogue. Of the nine identified individuals, three were spotted throughout Cardigan Bay, North Wales and the Isle of Man, four had only been spotted off Anglesey, and the remaining two had only been recorded in the Pen Llŷn a'r Sarnau SAC and Anglesey but not the Cardigan Bay SAC or the Isle of Man (Lohrengel, et al., 2012).

During a more recent survey off North-east Wales, in May 2014, twelve (32%) of individuals photographed were also definitely matched to the Sea Watch catalogue, including a well-known individual, 051-89W who had previously been sighted frequently in Cardigan Bay SAC but had been 'missing' for over a year prior to this sighting (unpublished data, Sea Watch Foundation, 2014).

Some well-known individuals that were formerly commonly observed in Cardigan Bay SAC were not observed so often – or at all - this year. 074-04W who was the most frequently sighted individual in Cardigan Bay SAC at over 180 sightings in total, was not sighted once in 2015. While it is entirely possible that this animal is deceased, the sighting of former Cardigan Bay SAC residents in North Wales does suggest that some animals may be changing home ranges, or ranging further than previously recorded. Another frequently sighted individual, 048-90W, who was commonly observed around New Quay Head in recent years, was sighted only in the southernmost part of the Cardigan Bay SAC, early in the year, but was then photographed on numerous occasions around Fishguard, south of the Cardigan Bay SAC throughout the season.

A large proportion of Cardigan Bay dolphins seem to have large home ranges, encompassing all of Cardigan Bay and increasingly North Wales also, although some animals show strong site fidelity to specific areas within Cardigan Bay or North Wales.

Body condition

On occasion, underweight and injured dolphins have been recorded in Cardigan Bay, either observed during surveys or from images sent in by the general public.

In 2015, no obviously underweight animals were observed but a number of animals with injuries were recorded. One of these individuals is a well-known female, 035-03W, or "Dodo", who was first recorded in 2003 and has been regularly sighted in Cardigan Bay, Anglesey, and the Isle of Man over the past few years. The injury was first recorded in 2007 and has remained unchanged since then.

Figure 41: Individual bottlenose dolphin 035-03W, "Dodo", with long-lasting peduncle injury observed first in 2007 (left) in the Cardigan Bay SAC and sighted again in 2015 (right) in Anglesey

The second animal was a large juvenile with a distinctive nick in the leading edge of the dorsal fin, recorded off the Llŷn Peninsula in October 2015. The injury is very similar to that recorded in a very young calf (under a month in age) in 2012, and both the location and shape of the injury as well as the animal's age would suggest that this is the same individual. The calf's mother is a known individual, 225-09S or "Arya", and this was the first calf she was recorded with.

Figure 42: Newborn calf of 225-09S with dorsal in injury photographed in 2012 (left). Juvenile with similar injury recorded in 2015 (right). Both photographed in the Pen Llŷn a'r Sarnau SAC

Finally, a calf with a deformity around the dorsal area was observed on several occasions in 2015, both within the Pen Llŷn a'r Sarnau SAC and the Cardigan Bay SAC. The mother was unmarked and could not be identified An animal with similar deformities was observed in 2013; however, it is unlikely that this is the same animal as the individuals in question were of similar size.

Figure 43: Calf with deformity in dorsal area, photographed in Cardigan Bay SAC in 2015 (left). Animal with similar injury, photographed in Cardigan Bay SAC in 2013 (right)

A sub-adult male bottlenose dolphin was found dead near Aberystwyth in September. Cause of death is as yet unknown (awaiting necropsy results). Few external injuries were apparent besides abrasions and one small injury in the abdominal area. The animal was unmarked and could not be matched to the Sea Watch catalogue.

An adult female was also found floating dead in the water offshore Aberystwyth in September during a Sea Watch line transect survey. Due to the advanced state of decomposition, it was not possible to recover the body.

Figure 44: Unmarked dorsal fin of dead sub-adult male dolphin that washed up at Aberystwyth (left). Abdominal injury (right)

Discussion

Sightings rates, group size and abundance estimates

Nineteen dedicated surveys (13 line transect and six *ad libitum* surveys) were undertaken in Cardigan Bay in 2015, covering 2,028km of survey effort. This is a decrease from previous years and is largely related to poor weather conditions. Sightings rates for all three commonly sighted marine mammal species during line transect surveys showed an increase from 2014 to 2015, increasing from 0.028 to 0.030/km for bottlenose dolphins, from 0.011 to 0.028/km for harbour porpoise and from 0.018 to 0.024/km for grey seals. For bottlenose dolphins, this apparent increase could have been affected by the relative lack of offshore coverage in the Pen Llŷn a'r Sarnau SAC; where fewer encounters but larger groups tend to occur, reducing the average number of sightings per km surveyed. In line with this observation, bottlenose dolphin sighting rates in southern Cardigan Bay (0.060/km) were

double the rates observed in the Pen Llŷn a'r Sarnau SAC (0.030). Whereas sighting rates were lower, group sizes were significantly higher in northern Cardigan Bay, numbering on average six individuals compared to four in southern Cardigan Bay. This has been observed consistently in previous years as well and may reflect the fact that dolphins are using different parts of the Bay in different ways. This is also supported to an extent by differences in activity budgets.

Overall, average group size was similar to previous years, groups of 1-5 animals being the most frequently observed but with a slight increase in large groups (>10) encountered towards the end of the season; coinciding with the arrival of herring shoals in September and October which are thought to attract aggregations of dolphins (Veneruso & Evans, 2012; Feingold & Evans, 2014a).

Effort from opportunistic surveys increased significantly, rising from 128 trips with *Dolphins Spotting Boat Trips* covering 2,061 km to 253 trips covering 3,417 km. The increase in survey effort on opportunistic platforms can largely be attributed to additional observers, the Dolphin Guides. However, due to the poor weather conditions prohibiting more extensive dedicated survey coverage, a concerted effort was made to take advantage of opportunistic platforms whenever possible in order to at least collect additional photo-identification data. In addition to data collected on *Dolphin Spotting Boat Trips*, seven trips were carried out with *Bay to Remember*, covering an additional 176km. Unlike *Dolphin Spotting Boat Trips*, *Bay to Remember* do not follow set routes and therefore this platform was highly effective at collecting additional photo-identification data, particularly as they cover an area that is not routinely covered by other opportunistic platforms. Furthermore, it is not as frequently covered by systematic line transect surveys as areas close to New Quay due to time and tidal constraints not always allowing for this area to be visited.

Bottlenose dolphin abundance was calculated for both Cardigan Bay as a whole and Cardigan Bay SAC, resulting in estimates of 277 (CV 35.87) and 64 (CV 64.65) respectively. The high CV values are the result of a low number of dolphin encounters caused at least in part by the comparatively low survey effort. Extending survey efforts in coming years, as well as the inclusion of observations made in dedicated survey mode may help to reduce this problem in the future. The abundance estimates for the wider Cardigan Bay seem to show similar trends to estimates obtained using the open model of the mark-recapture analysis; both show a peak in abundance in 2012, declining until 2014 then slightly rising again in 2015. Overall, the 2015 abundance estimate falls short of both the peak value in 2012 and the first estimate in 2011, suggesting an overall decline in numbers within Cardigan Bay.

Abundance estimates for bottlenose dolphins within Cardigan Bay SAC were at an all-time low at 64 and while the CV value for this estimate was very high, it is in keeping with a trend

of general decline from 2011 onwards. As this contradicts the trend observed in wider Cardigan Bay, a slight increase in numbers in wider Cardigan Bay in 2016, this might suggest that animals are starting to use the area differently, moving out of Cardigan Bay SAC but remaining in the wider Cardigan Bay area.

Harbour porpoise abundance estimates differed in that the wider Cardigan Bay experienced an overall decrease to an all-time low of 291 (CV 42.40) while Cardigan Bay SAC showed an increase on previous years, with an estimate of 183 (CV 64.55). CV values are very high again, however, especially for the estimate for wider Cardigan Bay, the estimate fits the trend of general decline that has been observed since 2011, dropping from 1,074 in 2011, to 565 in 2012, 410 in 2013, and finally to 291 in 2015. The harbour porpoise is generally much more abundant and widespread than bottlenose dolphin in the Irish Sea (Baines & Evans, 2012; Hammond *et al*., 2013), reflected also in previous abundance estimates for Cardigan Bay. However, currently, the overall abundance estimate for wider Cardigan Bay is not dissimilar to that for bottlenose dolphin. Although there has certainly been a decline in harbour porpoise abundance within Cardigan Bay in recent years, this estimate could have been affected by relatively low sample size and the fact that there were few offshore surveys in northern Cardigan Bay, which often result in additional harbour porpoise sightings.

Similarly, the low sample size may have affected the estimate for harbour porpoise abundance within Cardigan Bay SAC; although the overall sample size was low, large groups of up to 7 porpoise were observed on several occasions which may have driven up the SAC abundance estimate. Surveys across the Bay in future years will help to establish any trends.

Activity budgets

Dolphin behaviour can be difficult to measure accurately as most of it takes place outside the view of the observer, below the surface. Different interpretations of behaviour by different observers can also introduce an element of error. Feeding and foraging behaviour in particular may be hard to discern as ‘definite feeding’ can only be recorded if prey is visible during the encounter, either jumping out of the water while being pursued or if the animal surfaces with the prey item in its mouth. There are, however, other indicators of feeding behaviour such as prolonged, deep dives, showing flukes on descent, or repeatedly rushing at the surface, which were recorded as foraging. In order to minimise inconsistencies, all behavioural data was checked and validated by the Monitoring Officer or another experienced researcher such as the Sightings Officer while on survey. For the purpose of activity budgets, both definite feeding and foraging were combined here.

The two predominant behaviours that were observed while on transect in the wider Cardigan Bay were travel (68%) and foraging/feeding (30%), which is consistent with previous years (Feingold & Evans, 2014a).

Values were nearly identical for Cardigan Bay SAC but slightly lower for both behaviours within the Pen Llŷn a'r Sarnau, at 60% travel and 27% foraging/feeding. Overall, there was a slight increase in feeding/foraging behaviour from 2014 within the Cardigan Bay SAC, increasing from 26% to 30%, but it was still notably lower than in previous years - 56% in 2013 and 64% in 2012. Previous behavioural budgets and acoustic monitoring have confirmed a high concentration of feeding behaviour in the coastal area of Cardigan Bay SAC, particularly around New Quay Head, Ynys Lochtyn, Aberporth Head and Mwnt (Lewis & Evans, 1993; Baines et al., 2000; Pesante et al., 2008b; Feingold & Evans, 2014a). Broadly speaking this seemed to be the case in 2015 as well; with abundant bottlenose dolphin encounters around New Quay Head, Ynys Lochtyn and Aberporth, although there were no encounters near Mwnt during line transect surveys.

It has been suggested that a significant portion of travel could be described as "forage-travel", representing animals travelling in search of food (Feingold & Evans, 2014a). This seems to be supported by the seasonal comparison of behavioural budgets in 2015, which shows August, the month with the highest percentage of travel, to be the month also with the lowest recorded feeding activity, and October, the month with lowest travel activity, being the one with the highest definite feeding activity. This would in turn suggest that prey availability may have been lower in recent years, resulting in animals spending more time searching for food and less time actually feeding. This could also be a contributing factor to the decreasing abundance estimates in Cardigan Bay SAC and some of the observed shifts in home ranges by long-term residents. If prey is less abundant, animals may need to travel more - and further - to feed and may venture outside of the SAC more frequently. There has in fact been an increase in sightings of known Cardigan Bay individuals spending the summer in North Wales and Liverpool Bay (Lohrengel et al., 2014; Sea Watch Foundation, unpublished data), which could also be a result of animals increasingly foraging outside of Cardigan Bay.

In 2015 also, there seemed to be a temporal shift in feeding/foraging behaviour. An examination of data from previous years that differentiate between suspected feeding and definite feeding, indicated a clear trend, with a high proportion of definite feeding recorded at the start of the season and a high proportion of foraging but low proportion of definite feeding recorded towards the end of the season. Although sample sizes were limited, this year showed the complete opposite with a high proportion of foraging and low levels of definite feeding observed at the start of the season, and a high proportion of definite feeding and low proportion of foraging observed towards the end of the season. Although

the data are somewhat limited due to the low sample size, the results are in keeping with the hypothesis that there may have been a shift in prey availability.

As in previous years, there was some variation in activity budgets between northern and southern Cardigan Bay. Travel and foraging/feeding remained the two dominant behaviours recorded in northern Cardigan Bay, but the values were slightly lower than recorded in the south whereas the amount of time spent socialising was notably higher - 1% in Cardigan Bay SAC compared with 13% in the Pen Llŷn a'r Sarnau SAC. Previous observations have suggested that the animals may be using the two areas in different ways: the Cardigan Bay SAC serving as a nursery and feeding ground, whereas the Pen Llŷn a'r Sarnau SAC is used primarily for mating and socialising. However, more recent research suggests that the Northern SAC is equally important and observed differences may be down to seasonal variation as additional surveys in the Northern part of the bay are often undertaken in the autumn months (Feingold & Evans, 2014a).

Reproductive and mortality rates

Cardigan Bay SAC has long been considered an important nursery area for bottlenose dolphins with a large proportion of groups encountered including at least one calf. However, some females with calves have only been sighted in the northern part of the Bay, suggesting that the entire Bay is important to mother-calf pairs (Feingold & Evans 2014a).

Fifteen newborn calves were recorded across Cardigan Bay in 2015, more than twice the number (six) recorded in both 2013 and 2014. Of these, ten were first recorded within Cardigan Bay SAC, four in Pen Llŷn a'r Sarnau SAC, and one near Aberystwyth in the area between the two SACs. Three mothers with newborns were recorded exclusively in northern Cardigan Bay.

Table 21: 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 (2001-15)**
Sado Estuary, Portugal	5.4	Gaspar, 2003
Sarasota Bay, Florida	5.5	Wells & Scott, 1990
Moray Firth, Scotland	6.0	Wilson *et al*., 1999
Cardigan Bay, Wales (closed)	**6.3**	**This study (2001-15)**
Port River Estuary, Australia	6.4	Steiner & Bossley, 2008
Doubtful Sound, New Zealand	6.6	Haase & Schneider, 2001
Southern California	7.2	Hansen, 1990
Cardigan Bay SAC (open)	**7.6**	**This study (2001-15)**
Northern Gulf of Mexico	7.7	Leatherwood, 1977
Florida	8.2	Irvine *et al*., 1981
Cardigan Bay, Wales (open)	**8.5**	**This study (2001-15)**
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 mark-recapture estimates and both closed and open population models, resulting in estimates of 5.3% and 7.6% respectively. For the wider Cardigan Bay, values were slightly higher at 6.3% and 8.5% respectively for closed and open models. These are similar to the estimated mean birth rate (6.0%) of the semi-resident bottlenose dolphin population in the Moray Firth (Table 19; Wilson et al., 1999). The birth rates calculated for 2015 were also very similar: 5.3% and 6.7% for Cardigan Bay SAC, and 5.8% and 8.9% for the wider Cardigan Bay, using closed and open models respectively. Although similar to average birth rates, this represents a considerable increase on 2014 when birth rates in Cardigan Bay SAC were particularly low at 4.3% (closed model) and 4.85% (open model) and even lower for the wider Cardigan Bay at 3.9% (closed model) and 4.8% (open model).

Mean inter-birth interval was calculated at 3.3 years, ranging from a minimum of two years to a maximum of seven years, and is similar to other studies of this species (Table 20)

Table 22: Inter-birth intervals from bottlenose dolphins studies 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
Moray Firth, Scotland	3.2	3-6	Mitcheson, 2008
Cardigan Bay, Wales	**3.3**	**2-7**	**This study**
Port River Estuary, Australia	3.8	3-6	Steiner & Bossley, 2008
Shark Bay, Australia	4.1	3-6	Connor *et al*., 2000
Sarasota Bay, Florida	5.4	2-11	Wells & Scott, 1999

Limited additional information was obtained on juvenile mortality rates, and these remained unchanged from 2014, with 15% mortality in year one, 17% in year two, and 7% in year three, values broadly comparable to studies elsewhere (although first year mortality appears to be relatively low) (Table 21).

While calves are born throughout the year, the majority of newborns (65%) are first observed between July and September, which is similar to the calving season of the Moray Firth bottlenose dolphin population (Grellier, 2000).

Table 23: 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
Cardigan Bay, Wales	**15%**	**17%**	**7%**	**This study**
Sarasota Bay, Florida	19%	-	-	Wells & Scott, 1990
Natal, South Africa	22%	-	-	Cockcroft *et al*., 1989
Shark Bay, Australia	29%	18%	3%	Mann *et al*., 2000
Port River Estuary, Australia	30%	-	-	Steiner & Bossley, 2008
Doubtful Sound, Australia	31%	14%	-	Brough *et al*., 2016

Photo-ID and Population Estimates using Mark Recapture

The Welsh photo-Id catalogue now holds a minimum of 388 individuals. A discovery curve of marked individuals shows an initial steep increase (when all animals were considered 'new'), gradually flattening out around 2008 and only rising slightly since then. This suggests that a large proportion of marked dolphins were photographed and identified by 2008. Most new dolphins that are added to the catalogue tend to be juveniles that acquire marks as they age. However, with additional survey effort in North Wales, some recent additions to the catalogue have been well-marked individuals that had not previously been encountered in Cardigan Bay.

The bottlenose dolphin population in Cardigan Bay can be described as a mixture of residents, occasional visitors, and transients. Residency patterns were calculated both based on re-sightings of individual animals and number of years an animal was re-sighted, resulting in an estimate of 54-64% of animals being considered resident, 19-29% occasional visitors, and 16-17% transient in the wider Cardigan Bay. Values are similar for Cardigan Bay SAC but with a higher percentage of transients and a lower percentage of residents: 38-45% residents, 23-27% occasional visitors, and 34% transients. This suggests that a large proportion of bottlenose dolphins is resident in the wider Cardigan Bay but does not necessarily utilise the southern Cardigan Bay SAC. This is similar to estimates from 2014, which put the proportion of resident dolphins in Cardigan Bay SAC at 35%. However, it is considerably lower than the 2001-07 estimate of 58%. This suggests that in recent years a greater proportion of animals are leaving the southern SAC (Feingold & Evans, 2014a).

Population estimates based on mark-recapture have been calculated for Cardigan Bay SAC since 2001, whereas estimates for the wider Cardigan Bay only extend back to 2005, when survey coverage started to include Pen Llŷn a'r Sarnau SAC. Population estimates were calculated both for Cardigan Bay SAC and the wider Cardigan Bay, using both open and closed population models. Population estimates of Cardigan Bay SAC using a robust open population model suggests a general increase to a peak of 165 individuals recorded in 2007, fluctuating between 2008 and 2011 and peaking again at 168 individuals in 2012, before falling into general decline in recent years, reaching its lowest value in 2014 at an estimate of 74. 2015 sees a slight increase to 97, just short of the first estimate in 2001 of 99 individuals. The closed population model shows similar trends with higher overall estimates, although with less pronounced fluctuations between years. An overall increase is seen from 2001, peaking in 2008 at 260 individuals, before steadily declining to the lowest estimate since 2001 in 2014 at 116 individuals and again, increasing somewhat in 2015 to an estimate of 159 individuals. The low estimates of 2014 coincide with a peak in both temporary and permanent emigration.

Estimates for the wider Cardigan Bay appear to follow similar trends to Cardigan Bay SAC for both open and closed population models, with an increase in early years of the study and a decline in more recent years. Similar to Cardigan Bay SAC, the estimate based on the open population model shows a gradual increase from 2005 to 2008, peaking at 222 in 2007, fluctuating between 2008 and 2011, with another peak of 232 in 2012 followed by a sharp decline to 126 in 2014, the lowest value in the last ten years. Once again, there was a slight increase in the estimate for 2015, to 153 individuals, but overall, there has been a decline in numbers since 2008. The closed population model varies slightly from the open model, with less distinct peaks in estimates. An increase was observed from 210 in 2005 to 310 in 2008, after which a steady decline takes hold (lacking the distinct peak in 2012 observed in nearly every other model), reaching a low of 152 in 2014, followed by an increase to 222 in 2015. Overall, there has been an increase in permanent emigration in recent years, peaking in 2014, which coincides with some of the lowest abundance estimates calculated for both Cardigan Bay SAC and the wider Cardigan Bay. Whereas the models vary in their overall estimates of numbers, all show a similar trend of initial increase until 2007/2008 before a steady decline in recent years. Broadly similar trends have also been observed in abundance estimates obtained through line transect surveys, although a direct comparison is not possible as several years are lacking from that analysis.

It is difficult to pinpoint the cause of this decline in recent years but it seems clear both from abundance estimates and changes in emigration patterns that Cardigan Bay, specifically Cardigan Bay SAC, is less favourable to bottlenose dolphins than it was in 2007-08. The decline also coincides with increased observations of bottlenose dolphins outside of Cardigan Bay, in North Wales across to Liverpool Bay, during the summer months. This includes sightings of well-known individuals which previously showed strong site fidelity to Cardigan Bay SAC and were only sighted in the North in winter months, such as 051-089W,

052-93W, 005-92W and 093-01W suggesting an increasing number of animals are choosing to spend more time outside of Cardigan Bay in the summer.

Changes in behavioural budgets, as mentioned earlier, indicate that animals are spending more time travelling and searching for food which could be indicate that prey availability has decreased in Cardigan Bay, However, anthropogenic impacts such as vessel disturbance or commercial fisheries may also be contributory factors (Feingold & Evans, 2014a; Norrman *et al*., 2015). Disturbance through boat traffic has been known to affect behaviour of bottlenose dolphins, and areas of high vessel activity have in the past been linked to lower sightings rates (Lohrengel et al., 2012; Richardson et al., 2013). Continued monitoring and an increased focus on studies of prey availability and anthropogenic activities are essential to further our understanding of the underlying factors that may be driving this apparent recent decline.

Body condition

At least eight underweight dolphins were observed in Cardigan Bay between 2011 and 2013, but no obviously underweight animals were observed in either 2014 or 2015. Many of the underweight animals observed prior to 2014 were thought to be females and were seen in late autumn 2011, coinciding with a peak in birth rates in that year. Lactation puts high energetic demands on females, often necessitating a significant increase in food intake (Kastelein et al., 2002). In previous years, the highest proportion of definite feeding activity, particularly in the Cardigan Bay SAC, was observed during the early part of the season, which might indicate dolphins spent more time searching for food in the latter part of the season as prey became less available. The combination of these two factors could explain the high prevalence of underweight individuals in 2011.

Overall, three injured individuals were observed in 2015. The first was a known female, 035-03W, who was first observed with a deep indentation in the tailstock in 2007 but has been known to Sea Watch since 2003. The injury, probably the result of a boat strike, has not significantly changed over the years and does not seem to affect the animal's mobility or reproductive success as she has been observed with at least two calves since then, including with a newborn in 2015.

The second, a large juvenile, was thought to be the 2013 calf of a known individual, 225-09S, who was first observed with an injury to its dorsal fin at under a month of age. It is unusual for calves to sustain injuries within the first month of their life, which may suggest that this was a birth defect. However, both mother and calf were observed frequently bow-riding vessels during a Sea Watch survey in 2012 which is unusual for mothers with such young calves, and may suggest that the calf could have become injured during a boating accident due to the inexperience of its mother. 225-09S was recorded with a newborn calf this year, but was not present in the encounter with this individual in 2015.

The third injured individual was a young calf with a deformity in the dorsal area - a pronounced indentation at the base of the dorsal fin next to a large lump. The mother was unmarked and could not be identified. No obvious mobility problems were observed. The animal was swimming normally, keeping pace with the rest of the group and was seen leaping out of the water. It is unclear what the cause of this injury was. It could be the result of a boat strike or a birth defect. It is not dissimilar to injuries thought to have been inflicted through blunt trauma from boat strikes, but no other injuries that may have been expected as a result of a boat strike, such as sharp angular cuts as caused by propellers, were obvious.

Acknowledgements

We would like to thank Natural Resources Wales for funding this study, and in particular to Charles Lindenbaum, Dr Thomas Stringell, and Ceri Morris for their invaluable input.

We would particularly like to acknowledge the contribution of all our long term interns and local volunteers who have worked with Sea Watch staff, donating countless hours to the project. It would have been impossible to carry out this research without them. A special mention goes to our Research Assistant and Intern Coordinator, Katrina Gillet, who worked tirelessly and provided invaluable support throughout the season and beyond. Thank you also to the students who worked on their theses alongside Sea Watch in New Quay during 2016, covering a range of topics including habitat use, effects of vessel disturbance, social behaviour, and more.

A special thanks goes to Daphna Feingold, our former Monitoring Officer, Kathy James, our Sightings Officer, and Mathew Clough, our Wales Development Officer, all of whom were a great help throughout the season and in the production of this report. Thanks to all the boat crews and skippers who spent long hours in the field with us - Winston Evans, Dafydd Lewis, Gary Hartley and crew, Mike Harris, Tony Barber and crew. *New Quay Boat Trips* and *Bay to Remember* kindly allowed SWF staff and volunteers to accompany their trips free of charge. Very warm thanks also go to Mick Baines for his valuable assistance with the Mark-Recapture models, and to Janet Baxter, Alan Gray, and Tom Felce of Manx Whale and Dolphin Watch, for kindly providing additional images used for Photo ID.

References

Anon (2007) *Cardigan Bay SAC Management Plan*. Ceredigion County Council, Aberystwyth.

Baines, M.E. and Evans, P.G.H. (2012) *Atlas of the Marine Mammals of Wales*. CCW Monitoring Report No. 68. 143pp.

Baines, M.E., Evans, P.G.H. and Shepherd, B. (2000) *Bottlenose dolphins in Cardigan Bay, West Wales*. Report to EU INTERREG and Countryside Council for Wales. Sea Watch Foundation, Oxford. 35pp.

Baines, M.E., Reichelt, M., Evans, P.G.H. and Shepherd, B. (2002) *Bottlenose dolphin studies in Cardigan Bay, West Wales*. INTERREG final report. Sea Watch Foundation, Oxford.

Bearzi, G., Notarbartolo-Di-Sciara, G. and Politi, E. (1997) Social ecology of bottlenose dolphins in the Kvarneric (Northern Adriatic Sea). *Marine Mammal Science*, 13(4): 660-668.

Brough, T.E., Henderson, S., Guerra, M., Dawson, S.M., 2016, Factors influencing heterogeneity in female reproductive success in Critically Endangered population of bottlenose dolphins, Endangered Species Research Journal 29: 255-270

CCW (2007) *Cardigan Bay European Marine Site. Advice provided by the Countryside Council for Wales in fulfilment of Regulations 33 of the Conservation (Natural Habitats, &c.) Regulations 1994*. Countryside Council for Wales, Bangor.

Chao, A., Lee, S.M., and Jeng, S.L. (1992) Estimating population size for capture-recapture data when capture probabilities vary by time and individual animal. *Biometrics*, 48: 201-216.

Cockcroft, V.G. and Ross, G.J.B. (1990) Age, growth and reproduction of bottlenose dolphins *Tursiops truncatus* from the east coast of southern Africa. *Fishery Bulletin*, 88: 289-302.

Cockcroft, V.G., Cliff, G. and Ross, G.J.B. (1989) Shark predation on Indian Ocean bottlenose dolphins *Tursiops truncatus* off Natal, South Africa. *South African Journal of Zoology*, 24: 305-309.

Connor, R.C., Wells R.S., Mann J. and Read A.J. (2000) The bottlenose dolphin: social relationships in a fission-fusion society. Pp. 91-126. In: *Cetacean Societies, Field Studies of Dolphins and Whales* (Editors J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead). The University of Chicago Press, London.

Daehne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Kruegel, K., Sundermeyer, J., Siebert, U., Effects of pile-driving on harbor porpoise (Phocoena phocoena) at the first offshore windfarm in Germany, *Environmental Research Letters*, 8 (2) : 025002

Deaville, R. and Jepson, P.D. (compilers) (2011) *UK Cetacean Strandings Investigation Programme*. Final Report to Defra for the period 1st January 2005 – 31st December 2010. (Contract numbers CR0346 and CR0364). Institute of Zoology, London. 98pp.

Evans, C.D.R. (1995) *Wind and Water*. In: *Coasts and Seas of the United Kingdom*. *Region 12 Wales: Margam to Little Orme.* (Eds J.H. Barne, C.F. Robson, S.S. Kaznowska, and J.P. Doody). Joint Nature Conservation Committee, Peterborough. 239pp.

Evans, P.G.H. and Hintner, K. (2010) *A Review of the Direct and Indirect Impacts of Fishing Activities on Marine Mammals in Welsh Waters*. CCW Policy Research Report No. 104. 160pp.

Evans, P.G.H. and Pesante, G. (2008) Research for management: the Cardigan Bay experience. Pp. 61-69. In: *Selection criteria for marine protected areas for cetaceans* (Editor P.G.H. Evans). Proceedings of the ECS/ASCOBANS/ACCOBAMS Workshop held in San Sebastían, Spain, 22 April 2007, European Cetacean Society Special Publication Series, 48, 1-104.

Evans, P.G.H., Anderwald, P. and Baines, M.E. (2003) *UK Cetacean Status Review*. Report to English Nature and Countryside Council for Wales. 160pp.

Feingold, D. and Evans, P.G.H. (2013a) *A comparative analysis of mother-calf bottlenose dolphin home-ranges in Welsh Waters.* Poster at the 27th Annual Conference of the European Cetacean Society, Setubal, Portugal, 8-10 April 2013.

Feingold, D. and Evans, P.G.H. (2013b) *Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation*. CCW Interim Monitoring Report.

Feingold, D. and Evans, P.G.H. (2013c) *A Summary of Photo-Identification of Bottlenose Dolphins in Cardigan Bay, Wales conducted by the Sea Watch Foundation in 2012*. CCW Photo ID Report. 86pp.

Feingold, D. and Evans, P.G.H. (2014a) *Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2011-2013*. Natural Resources Wales Evidence Report Series No. 4. 124pp.

Feingold, D. and Evans, P.G.H. (2014b) *Connectivity of Bottlenose Dolphins in Welsh Waters: North Wales Photo-Monitoring Report*. Natural Resources Wales Research Report. 15pp.

Feingold, D., Vestey, C., Pesante, G., Evans, P.G.H. (2010) *Relationship between the bottlenose dolphin (Tursiops truncatus) population and ecological factors in Cardigan Bay, Wales*. Poster at the 24th Annual Conference of the European Cetacean Society, Stralsund, Germany, 22-24th March 2010.

Gaspar, R. (2003) *Status of the resident bottlenose dolphin population in the Sado estuary: past, present and future*. PhD thesis, University of St Andrews, St Andrews.

Grellier, K. (2000) *Reproductive biology of female bottlenose dolphins (Tursiops truncatus) using the Moray Firth, Scotlan*d. MSc thesis, University of Aberdeen. 74pp.

Grellier, K., Hammond, P.S., Wilson, B., Sanders-Reed, C.A. and Thompson, P.M. (2003) Use of photo-identification data to quantify mother-calf association patterns in bottlenose dolphins. *Canadian Journal of Zoology*, 81: 1421-1427.

Haase, P.A. and Schneider, K. (2001) Birth demographics of bottlenose dolphins, *Tursiops truncatus*, in Doubtful Sound, Fiordland, New Zealand - preliminary findings. *New Zealand Journal of Marine and Freshwater Research*, 35: 675-680.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, M.L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Øien, N., Paxton, C.G.M., Ridoux, V., Rogan, E., Samarra, F., Scheidat, M., Sequeira, M., Siebert, U., Skov, H., Swift, R., Tasker, M.L., Teilmann, J., Van Canneyt, O. and Vázquez, J.A. (2013) Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation,* 164**:** 107-122.

Hansen, L.J. (1990) California's coastal bottlenose dolphins. Pp. 403-420. In: *The bottlenose dolphin* (Editors S. Leatherwood and R.R. Reeves). Academic Press, Inc., San Diego.

Hersh, S.L., Odell, D.K. and Asper, H.D. (1990) Bottlenose dolphin mortality patterns in the Indian/Banana River system of Florida. Pp. 155-164. In: *The bottlenose dolphin* (Editors S. Leatherwood and R.R. Reeves). Academic Press, Inc., San Diego.

Ingram, S.N. and Rogan, E. (2002). Identifying critical areas and habitat preferences of bottlenose dolphins. *Marine Ecology Progress Series*, 244: 247-255.

Ingram, S.N. and Rogan, E. (2003). *Estimating abundance, site fidelity and ranging patterns of bottlenose dolphins (Tursiops truncatus) in the Shannon Estuary and selected areas of the west-coast of Ireland.* Report to the National Parks and Wildlife Service. 28pp.

Irvine, A.B., Scott, M.D., Wells, R.S. and Kaufmann, J.H. (1981) Movements and activity of the Atlantic bottlenose dolphin, *Tursiops*, near Sarasota, Florida. *Fishery Bulletin*, 79: 671-688.

Jepson P.D. and Baker J.R. (1998) Bottlenosed dolphins (*Tursiops truncatus*) as a possible cause of acute traumatic injuries in porpoises (*Phocoena phocoena*). *Veterinary Record*, 143, 614-615.

Kastelein, R.A., Vaughan, N., Walton, S., Wipkema, P.R., 2002, Food intake and body measurements of Atlantic bottlenose dolphins (*Tursiops truncatus*) in captivity, Marine Environmental Research 53 (2): 199-218

Kendall, W.L., and Nichols, J.D. (1995) On the use of secondary capture recapture samples to estimate temporary emigration and breeding proportions. *Journal of Applied Statistics*, 22: 751-762.

Kendall, W.L., Pollock, K.H., and Brownie, C. (1995) A likelihood-based approach to capture-recapture estimation of demographic parameters under the robust design. *Biometrics*, 51: 293-308.

Lear, R.J. and Bryden, M.M. (1980) *A study of the bottlenose dolphin Tursiops truncatus in eastern Australian waters*. Australian National Parks and Wildlife Service Occasional Paper. No. 4: 25pp.

Leatherwood, S. (1977) Mother-infant interactions of bottlenose dolphins in captivity and at sea. Pp. 143-167. In: *Breeding dolphins: present status and suggestions for the future* (Editors S.H. Ridgway and K. Benirchke). Report to the Marine Mammal Commission. Contract MM6AAC009 (NTIS PB-273-673). 308pp.

Lewis, E.J. and Evans, P.G.H. (1993) Comparative ecology of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay and the Moray Firth. *European Research on Cetaceans*, 7: 57-62.

Lohrengel, K., Veneruso, G., Evans, P.G.H., 2012, Boat traffic trends and effects on bottlenose dolphin sighting rates in Cardigan Bay, Wales, Poster at 27th Annual Conference of European Cetacean Society, Setubal, Portugal

Lohrengel, K., Evans, P.G.H., Clough, M., Bryan, S., 2014, First record of resident bottlenose dolphins in Liverpool Bay may provide answers to heightened levels of PCBs previously observed in Welsh dolphins, Poster at 29th Annual Conference of European Cetacean Society, Liege, Belgium

Mann, J., Connor, R.C., Barre, L.M., and Heithaus, M.R. (2000) Female reproductive success in wild bottlenose dolphins (*Tursiops* sp.): life history, habitat, provisioning, and group size effects. *Behavioural Ecology*, 11: 210-219.

Mirimin, L., Miller, R., Dillane, E., Berrow, S.D., Ingram, S., Cross, T.F., and Rogan, E. (2011) Fine-scale population genetic structuring of bottlenose dolphins in Irish coastal waters. *Animal Conservation*, 14(4): 342-353.

Mitcheson, H. (2008) *Inter-Birth Interval Estimation for a population of Bottlenose Dolphins (Tursiops truncatus): accounting for the effects of individual variation and changes over time*. MRes thesis, University of St Andrews, St Andrews. 66pp.

Norrman, E.B., Dussan-Duque, S., Evans, P.G.H, 2015, Bottlenose dolphins in Wales: Systematic Mark-Recapture Surveys in Welsh waters, Natural Resources Wales Research Report.

Peel Ports (2016), Fast Facts Liverpool2 Development. Accessed 7 March 2016 from http://peelports.com/liverpool2/about/fast-facts

Penrose, R.S. (2014) *Marine Mammal & Marine Turtle Strandings (Welsh Coast) Annual Report 2013.* Marine Environmental Monitoring, Llechryd, Cardigan. 32pp.

Pesante, G. and Evans, P.G.H. (2008) *Sea Watch Foundation Welsh Bottlenose Dolphin Photo Identification Catalogue*. CCW Marine Monitoring Report No. 66: i-xii, 1-204.

Pesante, G., Evans, P.G.H., Anderwald, P., Powell, D. and McMath, M. (2008a) *Connectivity of bottlenose dolphins in Wales: North Wales photo-monitoring*. CCW Marine Monitoring Report No. 62: 1-42.

Pesante, G., Evans, P.G.H., Baines, M.E. and McMath, M. (2008b) *Abundance and Life History Parameters of Bottlenose Dolphin in Cardigan Bay: Monitoring 2005-2007*. CCW Marine Monitoring Report No. 61: 1-75.

Reid J.B., Evans, P.G.H., and Northridge, S. (2003) *Atlas of Cetacean Distribution in North-west European Waters*. Joint Nature Conservation Committee (JNCC), Peterborough.

Richardson, H., Lohrengel, K., Feingold, D., Evans, P.G.H, 2013, Boat traffic effects on the social behaviour of bottlenose dolphins in Cardigan Bay, Poster at 27th annual Conference of European Cetacean Society Conference, Setubal, Portugal

Reynolds, J.E. III, Wells, R.S., and Eide. S.D. (2000) *The Bottlenose dolphin: Biology and conservation*. University Press of Florida, Gainesville, Florida, U.S. 288pp.

dos Santos, M.E. and Lacerda, M. (1987) Preliminary observations of the bottlenose dolphin (*Tursiops truncatus*) in the Sado Estuary (Portugal). *Aquatic Mammals*, 13: 65-80.

Scott, M.D., Wells, R.S. and Irvine, A.B. (1990) A long-term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244. In: *The bottlenose dolphin* (Editors S. Leatherwood and R.R. Reeves). Academic Press, Inc., San Diego.

Shane, S.H (1990) Behavior and ecology of the bottlenose dolphin at Sanibel Island, Florida. Pp. 245-265. In: *The bottlenose dolphin* (Editors S. Leatherwood and R.R. Reeves). Academic Press Inc., San Diego.

Spitz, J., Rosseau, Y. and Ridoux, V. (2006) Diet overlap between harbour porpoise and bottlenose dolphin: An argument in favour of interference competition for food? *Estuarine Coastal and Shelf Science*, 70: 259-270.

Steiner, A., Bossley, M., 2008, Some reproductive parametres of an Estuarine Population of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*), Aquatic Mammals 34(1): 84-92

Thayer, V.G. (2008) *Life history parameters and social associations of bottlenose dolphins (Tursiops truncatus) off North Carolina, USA*. PhD thesis, Duke University. 180pp.

Thompson, P.M, Lusseau, D, Corkrey, R., and Hammond, P.S. (2004) *Moray Firth bottlenose dolphin monitoring strategy options.* Scottish Natural Heritage Commissioned Report No. 079 (ROAME No. F02AA409).

Ugarte, F. and Evans, P.G.H. (2006) *Monitoring of marine mammals in the Cardigan Bay SAC: surveys from May 2003 to April 2005*. Marine Monitoring Report No. 23. Species Challenge Report No. 05/01/04. Countryside Council for Wales, Bangor. 38pp.

Veneruso, G. and Evans, P.G.H. (2012a) *Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Cons*ervation. CCW Monitoring Report No. 95. 66pp.

Veneruso G. and Evans P.G.H. (2012b) *Connectivity of Bottlenose Dolphins in Welsh Waters: North Wales Photo-Monitoring Interim Report*. Report to Countryside Council for Wales. Sea Watch Foundation. 17pp.

Wells, R.S. and Scott, M.D. (1990) Estimating bottlenose dolphin population parameters from individual identification and capture-recapture techniques. *Reports of the International Whaling Commission* (Special Issue 12): 407-415.

Wells, R.S. and Scott, M.D. (1999) Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821). Pp. 137-182. In: *Handbook of Marine Mammals*. Volume 6: The Second Book of Dolphins and the Porpoises (Editors S.H. Ridgway and R. Harrison). Academic Press, London.

Wilson, B., Thompson, P.M., and Hammond, P.S. (1997) Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology*, 34: 1365-1374.

Wilson, B., Hammond, P.S. and Thompson, P.M. (1999) Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecological Applications*, 9(1): 288-300.

Würsig, B. (1978) Occurrence and group organization of Atlantic bottlenose porpoises (*Tursiops truncatus*) in an Argentine Bay. *Biological Bulletin*, 154: 348-349.

Appendices

Appendix 1: Survey effort, sightings rates and spatial analysis: additional figures

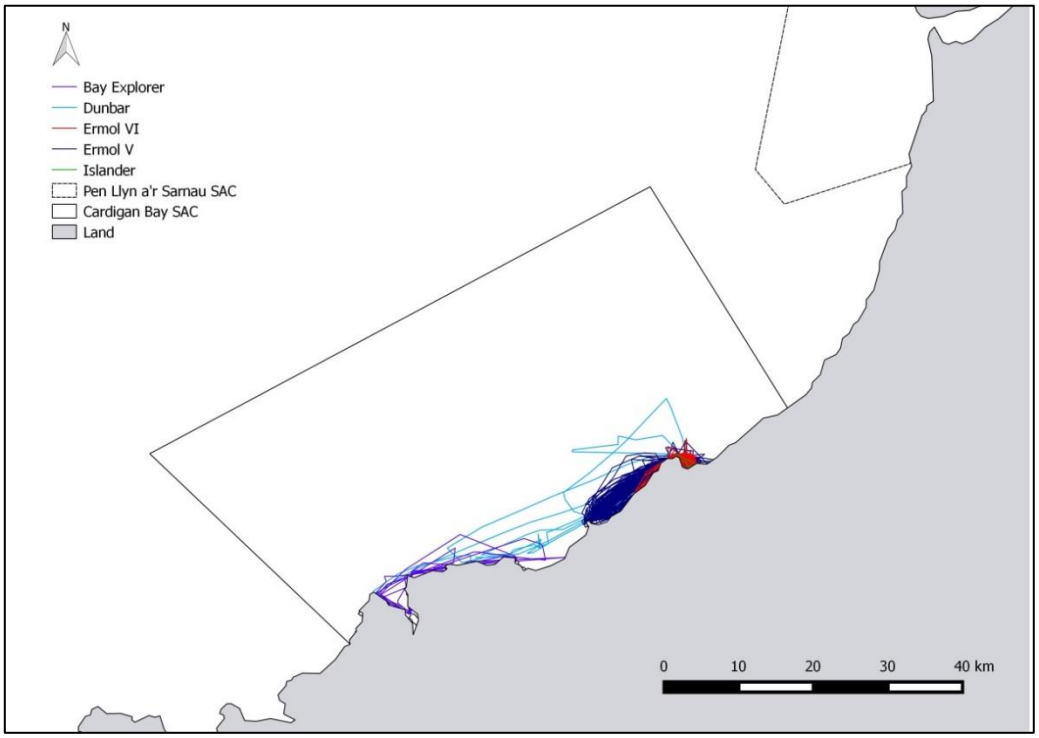


Figure 45: Non line transect survey effort focusing on Cardigan Bay SAC

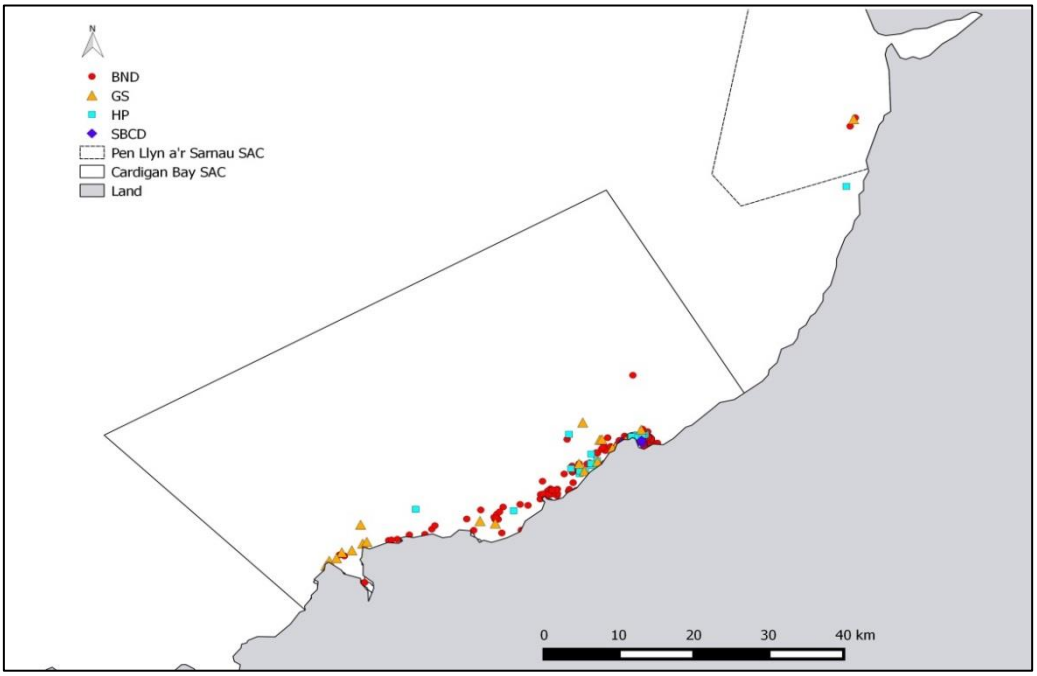


Figure 46: Marine mammal sightings from *ad-libitum* surveys focusing on Cardigan Bay SAC

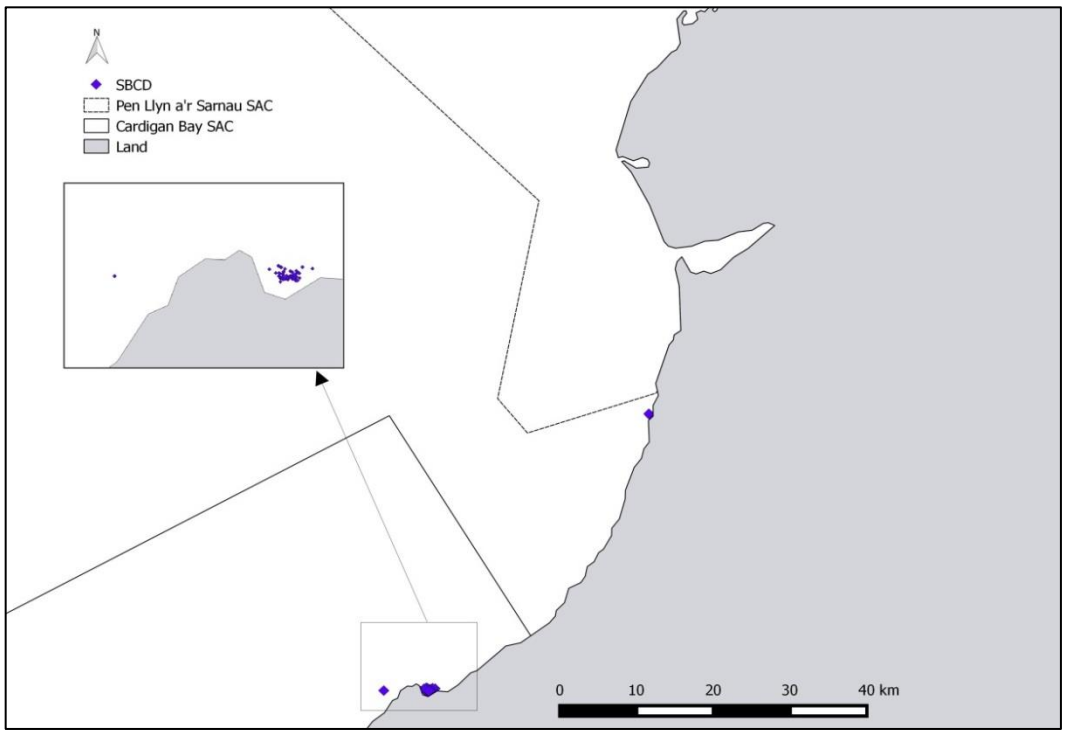


Figure 47: Opportunistic sightings of solitary short beaked common dolphin (including landbased observations and submissions from public)

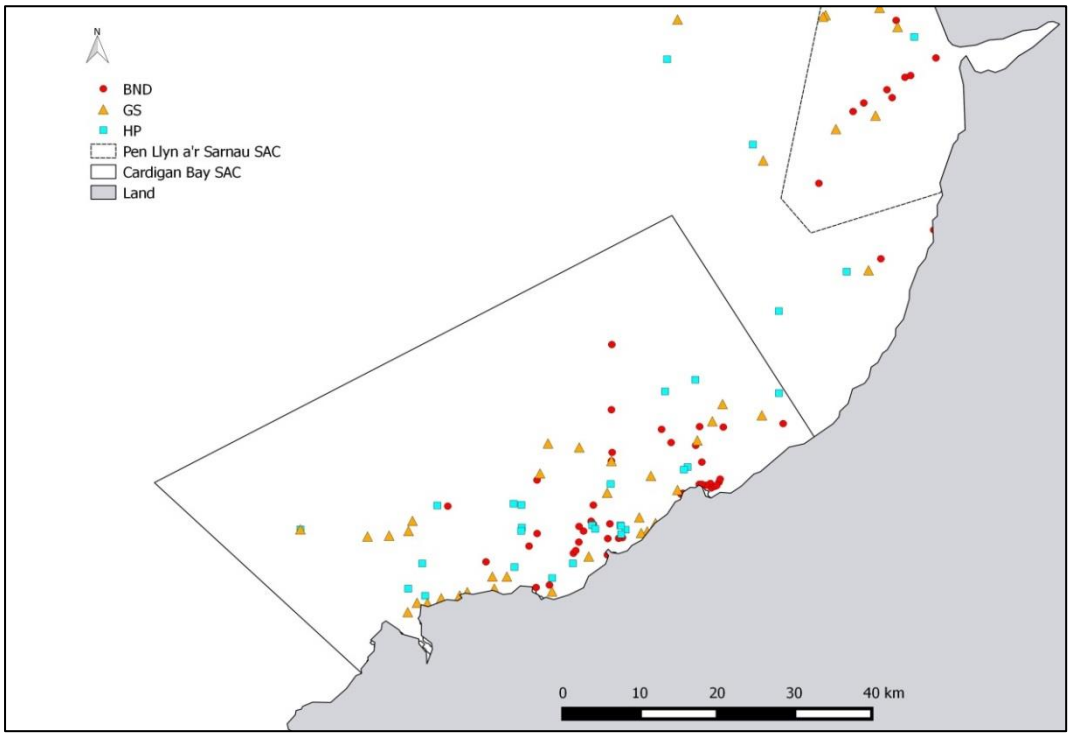


Figure 48: Marine mammal sightings from line transect surveys focusing on Cardigan Bay SAC

Appendix 2: Home ranges: individual maps

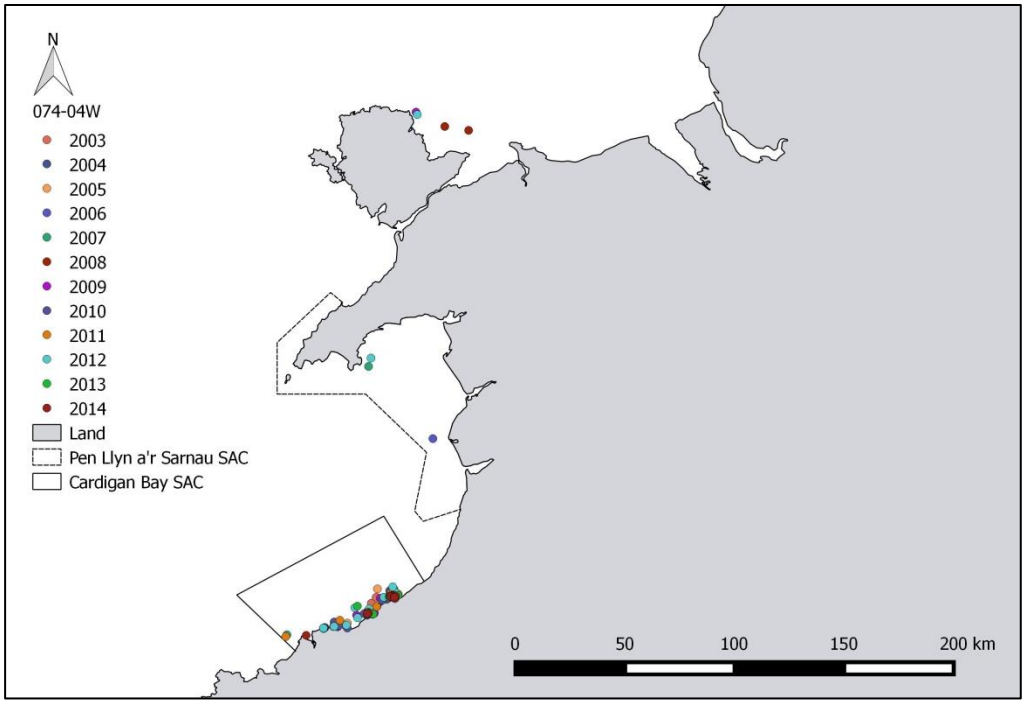


Figure 49: Home range of individual 074-04W from 2003 to 2014

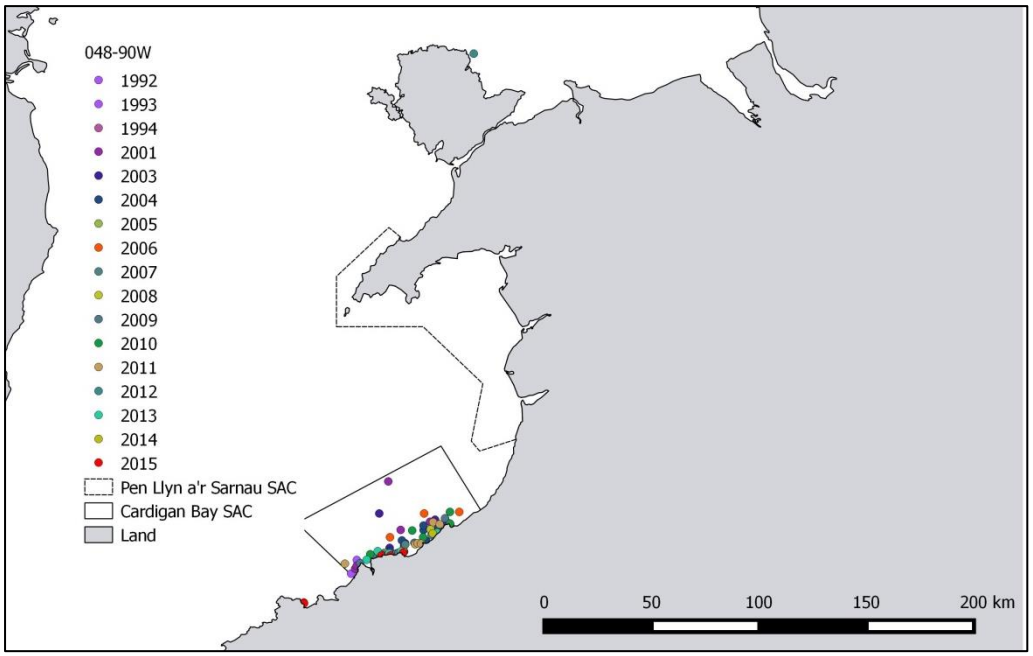


Figure 50: Home range of individual 048-90W from 1992 to 2015

Appendix 3: Student projects - Thesis Abstracts

Boys, R. (2015) Fatal Interactions between Bottlenose Dolphins (*Tursiops truncatus*) and Harbour Porpoises (*Phocoena phocoena*) in Welsh Waters. BSc thesis, University of Bangor. 133pp.

Competition between sympatric species is a well-known phenomenon throughout the animal kingdom and can be direct or indirect. Competition over a shared resource often leads to aggressive interactions, which can be fatal to the inferior species (Polis *et al.*, 1989). Bottlenose dolphins (*Tursiops truncatus*) and harbour porpoises (*Phocoena phocoena*) are two of the most commonly recorded cetaceans in UK waters. Aggressive interactions between these were first recorded in the early 1990s and since have been reported with increasing frequency worldwide Using strandings' data for Wales from 1991 to 2013, a total of 142 porpoises stranded-attacked by bottlenose dolphins were examined.

Sightings data were used to examine geographical overlap and fish stock data were used to examine changes in fish abundance with ICES (International Council for the Exploration of the Sea) VIIa. Literature was reviewed to examine dietary overlap. These variables were input to a GLMM using R, to examine which variables had an effect of the occurrence of a stranding due to attack by bottlenose dolphins. The study suggests that the cetaceans do compete for resources, and that dietary and geographical overlap significantly ($p<0.05$) affect stranding occurrence. Infanticide, play and hormone levels, suggested in the literature were reviewed and examined for their occurrence where possible, in Welsh waters.

Bottlenose dolphins were found to be the main agonists in many aggressive interactions between odontocetes. In Wales, high co-occurrence and interference feeding appear to explain many of the attacks, but other factors such as object-oriented play and testosterone levels are likely to further influence the seasonality and extent of these attacks.

Frinault, B.A.V. (2015) Maritime traffic effects on the semi-resident population of bottlenose dolphins, *Tursiops truncatus*, inhabiting Cardigan Bay, West Wales. BSc thesis, University of Bangor. 72pp.

Anthropogenic activities can widely impact wildlife populations and ecosystems. Cetaceans, when sharing coastal waters with burgeoning vessel activity, can be particularly vulnerable to disturbances. Bottlenose dolphins *Tursiops truncatus*, inhabiting the coastal zones of Cardigan Bay, west Wales are a key natural resource and currently provide a tangible, important tourist attraction supporting the Welsh economy. However recent years have shown a decline in species count. The presence of vessel activity is known to initiate various short- and long-term responses in cetaceans, some with detrimental effects.

To determine if vessel activity has an effect on dolphin sightings, statistical analyses were performed on refined, sea-based, amalgamated data for the years 2006-2014. Six individual vessel type densities, plus their corresponding cumulative vessel density, were compared to dolphin density. In several cases, results of linear regression indicated a significant and negative relationship between dolphin and vessel density and in some cases no significance.

Of vessels studied, motorboats, including wildlife watching vessels, elicited the strongest negative impact on dolphin density ($p = 0.000190$). Total cumulative vessel density showed a strong negative impact on dolphin density ($p = 0.000808$). Overall results indicate that a threshold or cap on vessel activity, or further coastal management considerations, could be envisaged to mitigate potential future decline of bottlenose dolphins in the area.

Sim, T.M.C. (2015) Associations or alliances? Comparisons of social relationships between male bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay and the Moray Firth. MSc thesis, University of Bangor. 102pp.

Mating strategies are important aspects of animal social structure, and variation in environmental conditions may drive the formation of conditional tactics which are based on an individual's social rank, age, size or fitness. The social patterns between male bottlenose dolphins (*Tursiops truncatus)* in the Moray Firth, northeast Scotland, and Cardigan Bay, west Wales, were investigated and compared using long-term observational data compiled by the Cetacean Research & Rescue Unit, and the Sea Watch Foundation respectively. The present study aimed to ascertain whether males in these regions formed alliance-type relationships as a mating strategy to improve reproductive success, and whether association patterns were similar between the two discrete populations. A total of 66 males from the Moray Firth, and 50 males from Cardigan Bay were identified over the study periods of 18 and 14-years, respectively.

Associations were examined using only males sighted more than twice during the study period, amounting to 62 individuals from the Moray Firth, and 47 from Cardigan Bay. Whereas non-random preferential alliances were found between certain males in both regions, they were stronger in the Moray Firth. The mean HWI was also higher between males in the Moray Firth, at 0.09± 0.05 (±SD), than Cardigan Bay at 0.03± 0.02 (±SD). Patterns of temporal stability between associations were similar, and were described as 'casual acquaintances' which is typical of bottlenose dolphins in a fission-fusion society. Demographic factors such as mortality, emigration and re-immigration were further shown to affect association patterns between males in both populations.

Results from the present study suggest that male bottlenose dolphins in the Moray Firth and Cardigan Bay use both alliances and solitary strategies to locate receptive females and compete for mating opportunities. The present examination ultimately allows further insight into the long-term social dynamics between male bottlenose dolphins in two semi-resident UK communities, and broadens current understanding of male mating strategies utilised in these regions, which has received limited study to date.

Taylor, V.C. (2015) Spatio-Temporal Variation in the Social Network of the Welsh Bottlenose Dolphin (*Tursiops truncatus*) Population, MSc thesis, University of Bangor. 102pp.

Quantitative techniques, initially developed for the assessment of human sociality, are increasingly being used to assess animal social networks. Bottlenose dolphins (*Tursiops truncatus*) are a socially intelligent species displaying complex fission-fusion societies, which are well suited to detailed social network analysis. In this study, the social network of bottlenose dolphins occurring in Welsh waters were investigated over a 14-year period, over an area ranging from southern Cardigan Bay, as far north as Anglesey, the Isle of Man and Liverpool Bay. The overall network had a low density although individuals were relatively well connected, primarily by indirect associations. Solitary individuals were identified and certain individuals had disproportionately high centrality, occupying key roles within the network. Centrality was not linked to gender. No long-term stable associations lasting the whole 14-year study period were observed. The majority of the population were clustered into two large sub- groups, but there was no evidence of assortative mixing by gender or home range size. Some individuals did have much larger home ranges than others and many undertook seasonal movements resulting in variation in home range usage in different seasons. The true range of some individuals may be much greater than is covered in this study. There were seasonal differences in network structure on a spatial and seasonal scale. The network was better connected in summer in southern Cardigan Bay than in winter, and was better connected in winter to the north of the study area than in summer, when the networks were highly clustered with defined sub-groups. Seasonal movements and differences in home range usage were concluded as being, at least in part, responsible for changes in the social network on a spatio-temporal scale. Variation in target prey, and area usage for behaviours such as calving, were suggested as major reasons for seasonal changes in area usage.