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Natural Resources Wales

Bottlenose Dolphins in Wales: Systematic Mark-Recapture Surveys in Welsh Waters

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Report No

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We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

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Contents

List of Figures

List of Tables

1. Crynodeb Gweithredol

2. Executive Summary

In this report, we summarise the field research conducted by the Sea Watch Foundation in 2014 on behalf of Natural Resources Wales. Our research goal was to monitor the bottlenose dolphin populations of Cardigan Bay including the Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation (SACs) as well as offshore areas, using Photo ID techniques to evaluate dolphin movements, distribution and abundance; to assess population structure and life history; and to gather evidence to determine whether bottlenose dolphins are at Favourable Conservation Status. A series of boat-based surveys were conducted in Cardigan Bay in order to collect data that would achieve these objectives, building upon earlier surveys that started in 2001. Survey effort has varied across years, and so some analyses focused upon the years 2011-14 when attempts were made to cover the entire Bay.

A total of 18 line-transect and 5 *ad-libitum* surveys in Cardigan Bay took place during summer 2014, amounting to nearly 3,000 km of effort travelled in favourable conditions (sea states <3 Beaufort, low swell, and no rain). In addition, regular surveys aboard platforms of opportunity were undertaken within Cardigan Bay SAC, adding a further 2,000 km of effort. Together, these yielded a total of 203 sightings of bottlenose dolphin. The only other marine mammal species sighted within Cardigan Bay were harbour porpoise and Atlantic grey seal.

Line-transect and *ad-libitum* surveys in Cardigan Bay resulted in sighting rates for bottlenose dolphin of 0.028/km and for harbour porpoise of 0.011/km. The average sighting rate for bottlenose dolphin in 2013-14 (0.0315/km) represents a 16% reduction compared with 2011-12 (0.038/km), and a 30% reduction compared with 2005-07 (0.045/km).

For consistency with previous years, Cardigan Bay SAC received the greatest amount of survey effort. During summer 2014, bottlenose dolphins were concentrated in the coastal area from New Quay to Cardigan, with most sightings around New Quay headland, Ynys Lochtyn and between Pen Peles and Mwnt. Unlike in previous years, there were few sightings in the vicinity of Aberporth, whereas there were several sightings offshore north of New Quay.

Throughout Cardigan Bay, the predominant bottlenose dolphin behaviour observed in any year has been either travel or feeding/foraging. In Pen Llŷn a'r Sarnau SAC, consistently higher percentages of 'socialising' events were observed suggesting the northern part of the Bay may be used as a mating and socialising ground for the population whereas the southern areas are used more for feeding and as a nursery area. In 2014, socialising was the predominant behaviour in 7% of encounters in the north, and 3% in the south, with no foraging/feeding observed during any of the encounters in this SAC. Within Cardigan Bay SAC, feeding/foraging during 2014 was the predominant behaviour in 26% of encounters, the lowest since 2006, suggesting that food may have been particularly scarce throughout the Bay this year.

Dedicated photo ID surveys of bottlenose dolphins were conducted throughout the season, mainly in Cardigan Bay SAC, whilst opportunistic photo-identification sessions occurred whenever possible during line-transect surveys. Our photo ID catalogue currently holds images of a minimum of 382 individuals (252 marked, 120 left side and 130 right side individuals). Analyses were completed using capture-mark-recapture methods, and for 2014, took into consideration an overall average of 55% of marked individuals in the SAC, and 56% in the whole of Cardigan Bay.

Annual estimates of the number of bottlenose dolphins using Cardigan Bay SAC between 2001 and 2014 using a robust open population model have ranged from 77 (in 2002) to 168 (in 2012). Fitting a polynomial function to the estimates indicated a rise up to 2007, the curve flattening off and then declining. Values for the last four years were 147 (2011), 168 (2012), 101 (2013), and 103 (2014). The last estimate coincided with high emigration rates and a high probability of animals staying outside the SAC.

Estimates for the number of bottlenose dolphins using the entire Cardigan Bay can only be calculated since 2005, when survey coverage was extended to include Pen Llŷn a'r Sarnau SAC and adjacent areas in northern Cardigan Bay. Population estimates over the ten-year period using a robust open population model have ranged from a peak of 232 (2012) to a low of 126 (2014). As was the case with Cardigan Bay SAC, fitting a polynomial function to the estimates indicated an initial rise, the curve flattening off around 2009 and then declining to 167 in 2013 and 126 in 2014. Closed population models for both Cardigan Bay SAC and all of Cardigan Bay gave broadly similar results but with consistently higher values.

Photo-identification surveys off the coast of Anglesey commenced in 2007, and along with data provided from the Isle of Man and Liverpool Bay, have provided evidence that bottlenose dolphin individuals from Cardigan Bay extend their home ranges, particularly in winter, to the northern Irish Sea at least as far as the Isle of Man.

Part of the population appears to be relatively site faithful with small home ranges: 7% of individuals have been sighted only in Cardigan Bay SAC, 3% solely in the Pen Llŷn a'r Sarnau SAC, and 8% only in North Wales (north of the Llŷn Peninsula).

On the other hand, an analysis of home ranges of 221 bottlenose dolphins sighted since 2007 found that 64% had been recorded in Cardigan Bay SAC as well as in areas around North Wales and the Isle of Man east into Liverpool Bay, whilst 78% recorded in one of the two SACs within Cardigan Bay had also occurred around and beyond North Wales. The majority of the Cardigan Bay population appears to have large home ranges that extend to North Wales, and possibly also all of the northern Irish Sea. On the other hand, there is no photographic evidence that matches individuals within the Cardigan Bay population to Scotland, the Republic of Ireland or Southern England.

Residency within Cardigan Bay SAC for 2001-07 was calculated as between 47-58%, but in recent years has declined to 38-44%, suggesting that some individuals are moving out of the area. Residency between 2005-14 within the wider Bay is calculated between 53-63%.

Calves may be born at any time of year, but peak calving occurs between July and September, when 76% of all births are recorded. Females give birth on average every three years (range 2-7 years). Using an open population model, birth rates in 2014 were 4.85% in Cardigan Bay SAC and 4.8% in the entire Cardigan Bay. These compare with long-term averages of 7.5% in Cardigan Bay SAC and 8.5% in the entire Cardigan Bay. No new information was available on calf mortality rates since last year when they were calculated from a sample of 71 mother-calf pairs born between 2001 and 2013. Higher mortality rates were found in the first two years (15% in year one and 17% in year two) with lower rates in the third year (7%), and a total of 60% of calves surviving into their fourth year.

Several lines of evidence (lower population sizes, disappearance of marked individuals out of the Bay with re-sightings off North Wales, low birth rates, etc) suggest that Cardigan Bay is less favourable for bottlenose dolphins than it was in 2007-08. Prey availability may be a cause for this but it is also possible that local anthropogenic activities are contributory factors. There is clearly a need for consistent monitoring to be undertaken throughout the Bay, and a more in depth study of food availability and possible effects of anthropogenic activities in the region.

3. Introduction

Cardigan Bay is one of the two main areas of UK territorial waters where there are semi-resident groups of bottlenose dolphins, the other being the Moray Firth, Scotland (Wilson *et al.*, 1997, Thompson *et al.*, 2004). This population is the largest of semi-resident bottlenose dolphins in the UK (Evans and Pesante, 2008). There is also a resident population in the Shannon Estuary, Ireland (Ingram and Rogan, 2002, 2003; Mirimin *et al.*, 2011). Bottlenose dolphins are also recorded off other coasts of the UK including Cornwall, Devon, and the Hebrides, as well as in offshore waters along the Northwest European shelf edge (Evans *et al.*, 2003; Reid *et al.*, 2003; Hammond *et al*, 2014).

Two marine Special Areas of Conservation (SACs) were established in Cardigan Bay to conserve bottlenose dolphins as the species requires spatial protective measures within Annex II of the EU Habitats and Species Directive (Council Directive 92/43/EEC). These are Cardigan Bay SAC where bottlenose dolphins are the primary reason for designation and Pen Llŷn a'r Sarnau where they are a qualifying feature. The species are also listed under Annex IV of the Directive, which requires strict protection.

The scope of this work included systematic photo-ID surveys of bottlenose dolphins following previously described line transects. Incidental species sightings (e.g. other cetaceans, seals, etc) were to be recorded if encountered.

The primary focus was of Cardigan Bay and Pen Llŷn a'r Sarnau SACs, but did not preclude the wider area when time and conditions allowed. These were largely undertaken aboard "Pedryn" In order to sample areas offshore and between the two SACs.

Since 2001, a catalogue of images of the dorsal fins of individual bottlenose dolphins has been maintained for Cardigan Bay, on an annual basis by Sea Watch Foundation (Pesante & Evans, 2008; Feingold & Evans, 2013c). The current project covered analysis and reporting of images captured during the photo monitoring from chartered boats in 2014.

3.1 General Aims

- Conduct fieldwork in 2014 to photograph, record, and document bottlenose dolphins sighted within and outside the key study areas of Cardigan Bay and Pen Llŷn a'r Sarnau SACs, using standard photo-ID protocols (Pesante *et al.*, 2008a, b).
- Link to an existing electronic catalogue to check for any matches between dorsal fin images of dolphins in Welsh waters (Pesante & Evans, 2008; Feingold & Evans, 2012).
- Analyse the photographic data to evaluate dolphin movements, distribution and abundance estimates (using appropriate mark: recapture statistics) of Welsh dolphins.

- In a concise report, using these data, available metadata, previous data, knowledge and literature, report on the annual abundance estimate in relation to previous years (and update/provide maps of range, distribution of photo-data locality, and connectivity).

3.2 Requirements

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 this 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 when 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.

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

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.

4. Methodology

4.1 The Study Area

Cardigan Bay is the largest bay in the UK, measuring over 100 km (60 miles) across its westernmost extent and encompassing a total area of 4986.86 km^2 from the western tip of the 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).

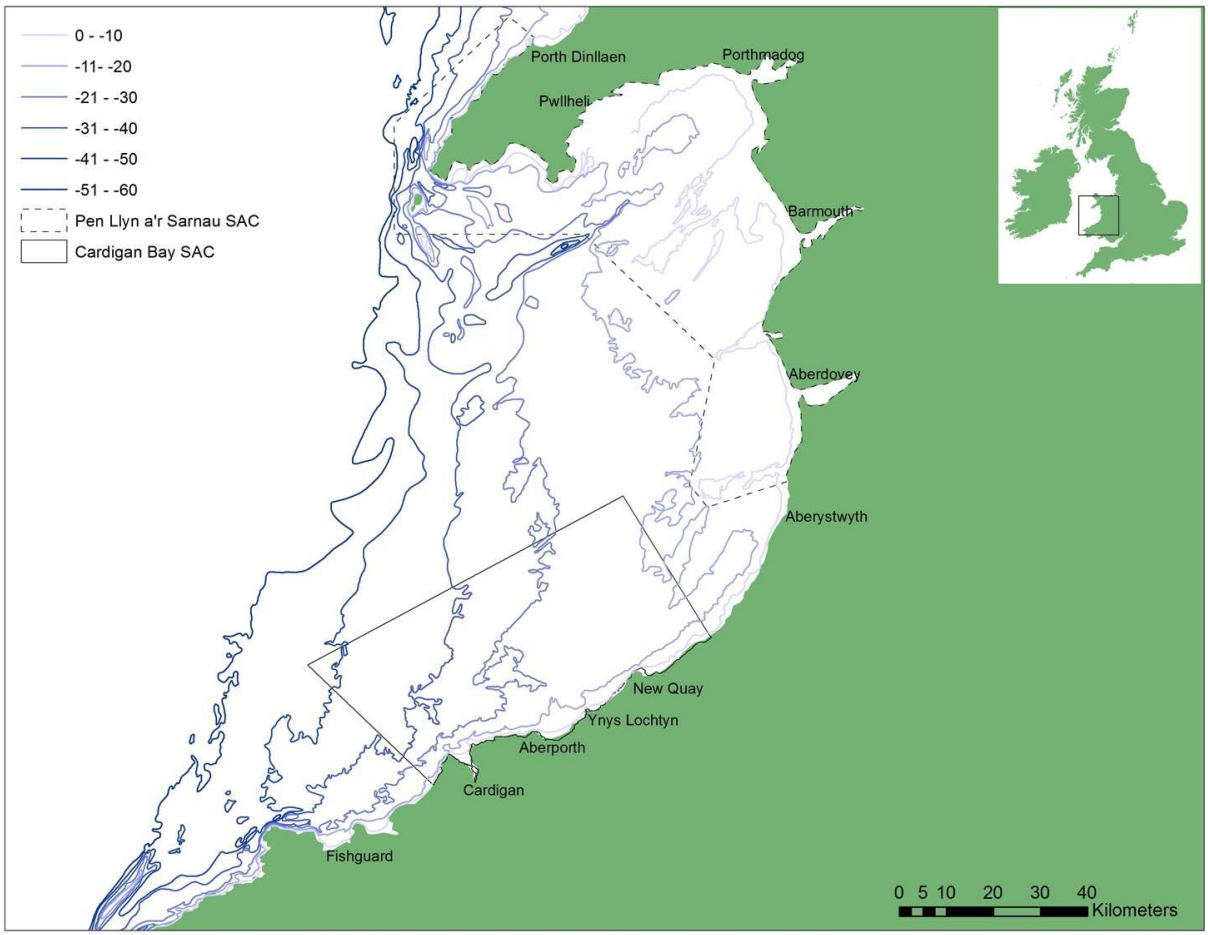


Figure 1: The Study Area: Cardigan Bay in West Wales
The boundaries to Cardigan Bay SAC are indicated by continuous lines,
and for Pen **Llŷn** a’r Sarnau SAC by hatched lines

A population of bottlenose dolphins forms a primary interest of the Bay and it was for this that the Bay was first selected as a Special Area of Conservation. Cardigan Bay SAC is located in the south of the bay and encompasses 958.65 km^2 (Figure 1). Besides being recognised as important for bottlenose dolphins, it is also thought to be a key area for Atlantic grey seals (*Halichoerus grypus*) as well as important for some fish and invertebrate species

(Anon, 2007; CCW, 2009). The SAC has also been designated for various features that qualify under Annex I and Annex II of the Habitats Directive such as reefs, submerged or partially submerged sea caves, sandbanks which are slightly covered by seawater all the time, grey seals, river lampreys (*Lampetra fluviatilis*), and sea lampreys (*Petromyzon marinus*) (Anon, 2007; CCW, 2009).

The Pen Llŷn a'r Sarnau SAC encompasses areas of sea, coast and estuary that support a wide range of different marine habitats and wildlife. It is situated in the north of Cardigan Bay and covers an area of 1460.35 km^2. The latitudinal range of the SAC is 52.43˚N to 52.97˚N. Some additional qualifying features in this SAC include coastal lagoons, estuaries, mudflats and the otter (*Lutra lutra*) (Anon, 2007; CCW, 2009).

4.2 Surveys

The CMR specific methodology sections outlined in Pesante *et al*. (2008) and Feingold & Evans (2014a) were used and the line transect routes in these publications (Figures 2 & 3) were followed to standardise data collection.

Although the primary CMR work did not cover line transect distance sampling due to budget limitations, photo-ID being the focus of the research, when following line transects, the field protocols adopted did follow standard distance sampling procedures.

The same survey design that was used in previous years in Cardigan Bay SAC was adopted. Transect lines previously used by Ugarte *et al*. (2006) and Pesante *et al.* (2008b) were used (Figure 2). Transects were divided into two strata - inner and outer transects (split at 52.15°N, 4.89°W and 52.33°N, 4.31°W), since bottlenose dolphin density within Cardigan Bay SAC has been shown to be highest in inshore waters (Baines *et al.*, 2002; Ugarte *et al*., 2006; Pesante *et al*., 2008b; Feingold *et al*., 2010). Continuing the efforts of 2011-13, line-transect tracks were followed in Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay during 2014 (Figure 3).

Transect numbers were chosen at random, and these were followed for the duration of the survey. In some cases, when weather deteriorated or when a transect could not be completed for some other reason, a different one was chosen while in the field.

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

Dedicated surveys were conducted by SWF staff and a team of trained volunteers. These were all started in favourable conditions: Beaufort sea state <3, visibility >1.5 km, and no precipitation. Occasionally, conditions deteriorated during the survey in which case those would be recorded so they could be treated separately during analysis. The surveys were conducted in Cardigan Bay SAC, Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay. As in

previous years, dedicated surveys were conducted from three vessels: Dunbar Castle III, Ma Chipe Seabrin, and the NRW vessel, Pedryn. Details of these are given in Table 1.

Table 1: Vessels used for line-transect surveys in Cardigan Bay in 2014
(* 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**
Pedryn	11	3.0	10	350 hp diesel	PL SAC** & offshore

In addition, *ad libitum* surveys were conducted using two platforms of opportunity: Ermol V and Ermol VI. This survey effort was increased substantially compared with previous years, following agreement with the local boat operator. Details of these vessels are given in Table 2.

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

During the majority of the dedicated surveys, a double platform of observers was used, consisting of two pairs of observers. Observers were paired so that at least one was experienced with a minimum of 20 hours of survey time achieved. An exception to this was on during Pedryn surveys in which only one independent observer operated at the bow.

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

Both POs and IOs estimated the distance to the animals when first detected. The survey team was given regular distance training sessions by testing them with objects at known ranges. For the majority of sightings, distances were checked by SWF staff.

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

One person was dedicated to recording effort using the 'effort form', which logged the vessel journey and environmental variables throughout the survey. One line was completed on the form each time any of the variables collected changed (sea state, visibility, swell height, boat course, end of transect leg, etc). Otherwise, if none of these variables had changed, a line of effort was recorded every 15 minutes by default. The track of the vessel was recorded continuously using a handheld GPS.

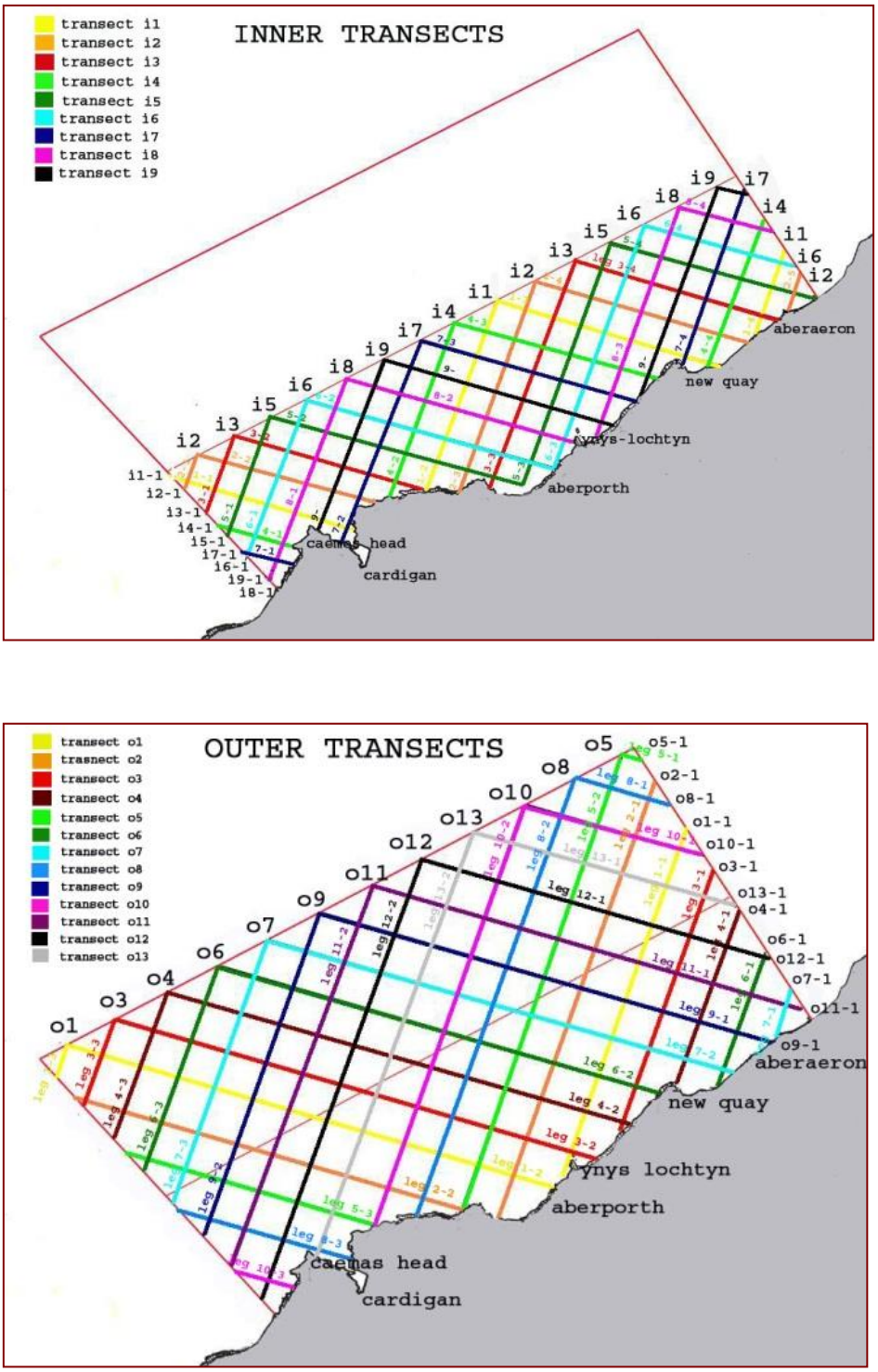


Figure 2: Transect lines used for line-transect surveys in Cardigan Bay SAC (inner – top and outer – bottom)

The number and type of boats in view was recorded during every line of effort (every 15 minutes) in order to provide a record of boat traffic in the vicinity. Four types of effort were considered during the survey: a) line-transect, where the vessel travelled along the pre-defined transect line with dedicated observers scanning for sightings; b) dedicated search, where POs were on duty but the boat was not following a transect line. This occurred when

leaving the transect line to conduct Photo ID, or once the transects for the day had been completed and the vessel 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); 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.

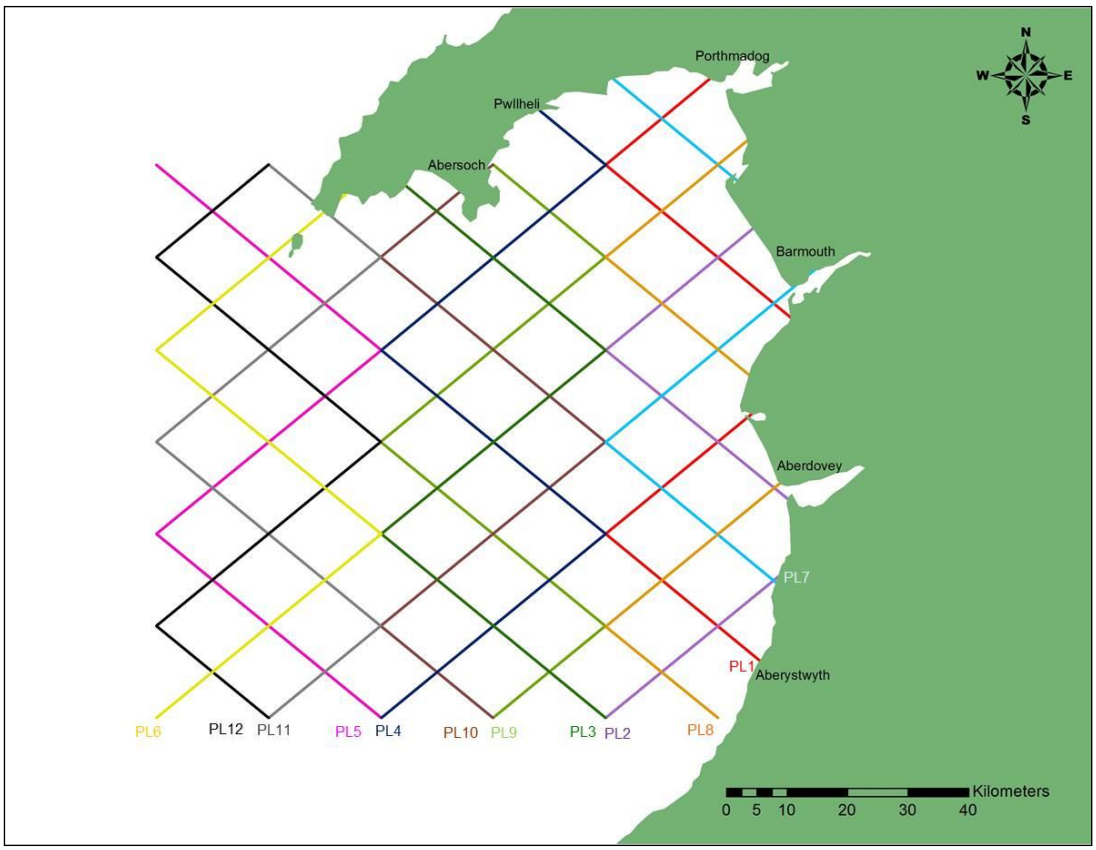


Figure 3: Transect lines designed for Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay
(Transect numbers: PL1- red; PL2- purple; PL3- green; PL4- blue; PL5- pink; PL6- yellow; PL7-light blue; PL8-orange; PL9-light green; PL10-brown PL11-grey; PL12-black)

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.

On encountering bottlenose dolphins, photographs were taken using either a Canon EOS 40D or a Canon 7D camera body with 18-200 mm, 18-300 mm or 75-300 mm telephoto zoom lens. During dedicated surveys, dolphins were approached to 20-50 metres. Photographs were obtained under NRW licence, following their protocols.

Information on behaviour of bottlenose dolphins was collected during sightings onboard every survey, both line-transect and *ad-libitum.* A dolphin group was defined as any group of dolphins observed in apparent association, moving in the same direction and often, but not

always, engaged in the same activity (Shane, 1990). Behaviours were recorded on the standardised 'sighting form'. Four main behaviours were collected:

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

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

An additional category of 'suspected feeding' was noted in the field when dolphins were seen performing deep dives often preceded by fluke up or peduncle arches although no visible prey was seen. 'Suspected feeding' may indicate that feeding activities are taking place below the surface or that dolphins are engaging in behaviours related to searching for food though not necessarily being successful, otherwise termed 'foraging'. In most cases, 'suspected feeding' is a combination of foraging and successful feeding.

4.3 Data Analysis

Effort and sightings data were entered into Microsoft Excel, and plotted using ArcGIS v. 10.1. These were examined to investigate temporal variation in sightings and group composition, and to assess activity budgets.

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 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.

On all dedicated surveys during the 2014 summer season there was always one person in charge of recording bottlenose dolphin behaviours at regular intervals. This person recorded the GPS position, group formation, group composition, behaviours, etc. every three minutes from the beginning of the encounter to the very end of the encounter. These data were archived for a potential future student project analysing behavioural budgets in more detail. In the meantime, for analysis of the behavioural budgets in this report, the first behaviour written down was the behaviour that the majority of the dolphin group was expressing when the group was first seen. These were used to derive the percentage of encounters with different behaviours. Values for previous years were calculated in the same way. A separate analysis was conducted using all behaviours recorded in an encounter.

5. Results

5.1 Survey sighting rates

In 2014, a total of 18 surveys following line-transects and a further five *ad-libitum* surveys were undertaken, totaling 2,431 km and 336 km respectively (see Tables 3 & 5). The tracks of the line-transects are shown in Figure 4, and for the *ad-libitum* surveys in Figure 5. These surveys yielded 69 bottlenose dolphin sightings from systematic surveys (Table 4) and 28 bottlenose dolphin sightings from *ad-libitum* surveys (Table 5). Figures 6 and 7 provide plots of the locations of sightings of cetaceans and seals for the respective types of survey. The resultant sighting rates were 0.028 per km and 0.083 per km respectively, or when combined, an overall sighting rate of 0.035 per km. For comparison, the equivalent sighting rate for bottlenose dolphin in 2013 was 0.028 per km (Feingold & Evans, 2014a), i.e. similar to the current season. In 2005-07, the equivalent average sighting rate was 0.045 per km (Pesante *et al*, 2008b).

The two commercial dolphin watching vessels, Ermol V and Ermol VI, although operating as platforms of opportunity, cover the same inner sector of Cardigan Bay SAC on a very regular basis. This year we reached agreement with the operator to routinely place observers on board, resulting in a significant increase in coverage – a total of 2,090 km survey effort (Table 6). Although not appropriate for line-transect absolute abundance estimation, it proved very useful for photo-ID, yielding a total of 175 bottlenose dolphin sightings (Table 6). The resultant overall sighting rate of 0.08 per km is rather lower than the sighting rate from Ermol trips in 2013, which was 0.13 per km (Feingold & Evans, 2014a).

Table 3: Line-transect (LT) survey effort conducted in Cardigan Bay in 2011-2014

	Vessel	2011	2012	2013	2014	Total	Total 2011-14
No. of Surveys	Dunbar Castle II	10	18	26	10	64	101
	Ma Chipe Seabrin	2	7	8	3	20	
	Pedryn	3	2	7	5	17	
Km travelled	Dunbar Castle II	897.42	1364.05	1843.54	709.57	4814.58	12438.77
	Ma Chipe Seabrin	382.82	1222.75	1201.90	380.12	3187.59	
	Pedryn	939.55	522.75	1632.80	1341.50	4436.60	
Km travelled in LT mode	Dunbar Castle II	450.85	686.06	1019.26	412.17	2568.34	7656.92
	Ma Chipe Seabrin	258.71	852.37	896.57	175.36	2183.01	
	Pedryn	554.81	326.37	1115.00	909.39	2905.57	
Km in inner transects	Dunbar Castle II	289.92	565.53	706.65	387.99	1950.09	4458.89
	Ma Chipe Seabrin	258.71	699.69	838.12	-	1796.53	
	Pedryn	111.76	172.22	156.81	271.48	712.27	
Km in outer transects	Dunbar Castle II	160.93	120.53	312.61	24.17	618.24	3038.27
	Ma Chipe Seabrin	-	152.68	58.45	79.17	290.30	
	Pedryn	443.06	154.15	880.58	651.94	2129.73	
Total Km travelled	All three vessels	2219.79	3109.55	4678.24	2431.19	12438.77	
BND sight/km	All three vessels	0.030	0.032	0.027	0.028	0.029	
HP sight/km	All three vessels	0.025	0.028	0.031	0.011	0.025	
GS sight/km	All three vessels	0.033	0.037	0.035	0.018	0.032	

Table 4: Marine mammal sightings yielded from line-transect (LT) surveys conducted in Cardigan Bay in 2011-2014 (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
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
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
Total 2011-14		**364**	**167**	**317**	**265**	**397**	**239**

Table 5: Total effort and sightings recorded during *ad-libitum* dedicated surveys in Cardigan Bay in 2011-14

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
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	-	-	-
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

Table 6: Total effort and sightings recorded during surveys on board platforms of opportunity in Cardigan Bay SAC in 2011-14

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
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
Islander	2011	14	109.23	7	0.064
	2012	20	138.39	38	0.275
	2013	4	66.45	8	0.120
	2014	0	-	-	-
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

Annual bottlenose dolphin sighting rates (sightings per km effort per year) were calculated for Cardigan Bay SAC between 2001 and 2014. These showed variation across the years with peaks in 2001-03 and 2009-11, and lows in 2004, 2006-07, and 2012-14 (Figure 8).

Table 7: Effort and sightings by month, recorded from line-transect surveys in Cardigan Bay in 2011-14

Month	Year	No. Sightings	No. Animals	No km travelled	Sightings/km
April	2011	-	-	-	-
	2012	3	13	93.18	0.032
	2013	2	3	29.19	0.069
	2014	-	-	-	-
May	2011	-	-	-	-
	2012	21	98	671.45	0.031
	2013	20	118	650.67	0.031
	2014	-	-	-	-
June	2011	-	-	-	-
	2012	17	104	336.70	0.050
	2013	17	89	1128.79	0.015
	2014	25	78	293.52	0.085
July	2011	20	63	221.07	0.090
	2012	10	37	120.29	0.083
	2013	43	222	1761.04	0.022
	2014	21	114	1459.95	0.014
August	2011	19	66	605.58	0.031
	2012	22	92	1070.27	0.021
	2013	11	22	355.22	0.031
	2014	3	17	81.06	0.037
September	2011	13	63	248.30	0.052
	2012	10	45	393.25	0.025
	2013	26	97	570.27	0.046
	2014	16	82	506.07	0.032
October	2011	15	140	653.75	0.023
	2012	18	100	424.40	0.042
	2013	9	41	147.34	0.061
	2014	4	8	129.02	0.031

Systematic surveys yielded 28 harbour porpoise sightings (Table 4), or a sighting rate of 0.013 per km. For comparison, the equivalent sighting rate for harbour porpoise in 2013 was 0.031 per km, i.e. much higher than the current season; in 2012, it was 0.028 sightings/km (Feingold & Evans, 2014a). In 2005-07, the equivalent average sighting rate was 0.045 per km (Pesante *et al*, 2008b).

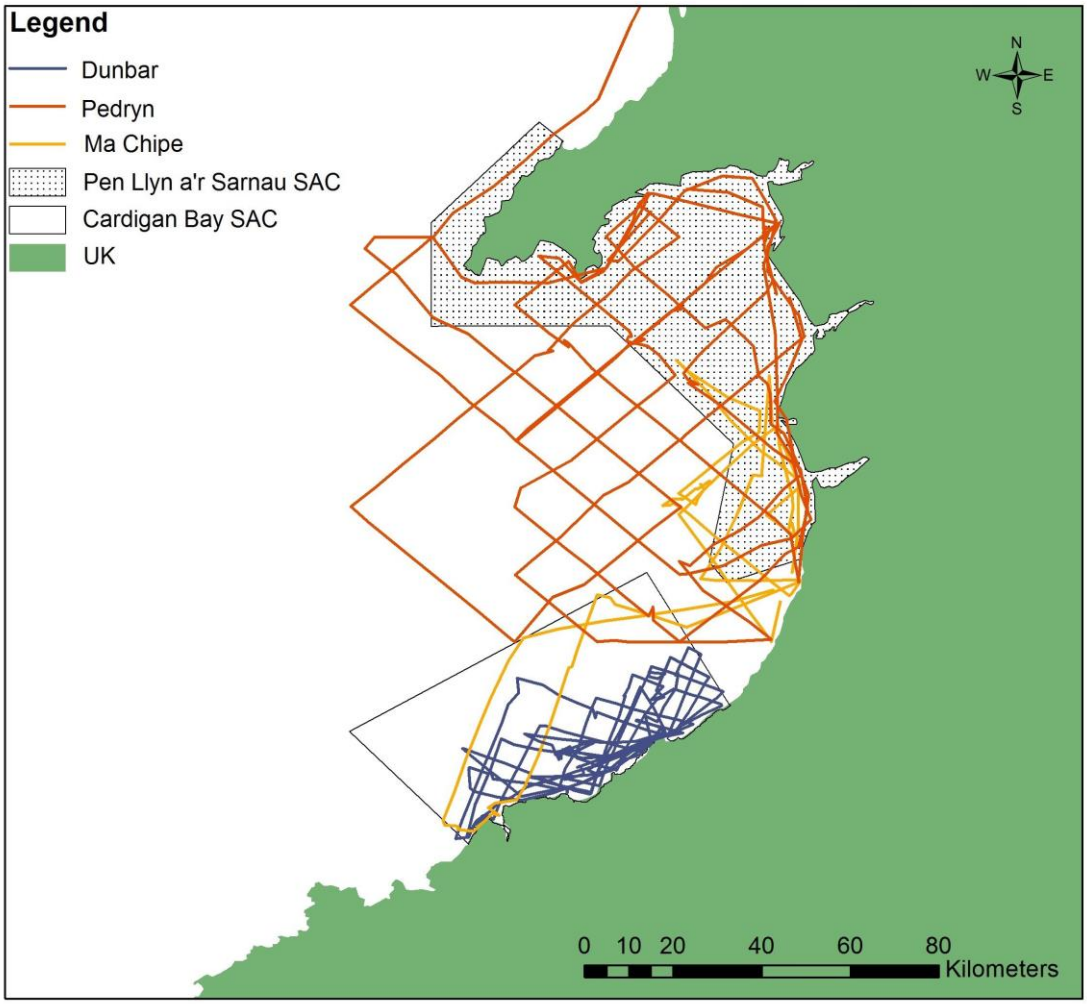


Figure 4: Tracks of line-transect (LT) surveys conducted in Cardigan Bay in 2014. Coloured lines represent tracks from different vessels

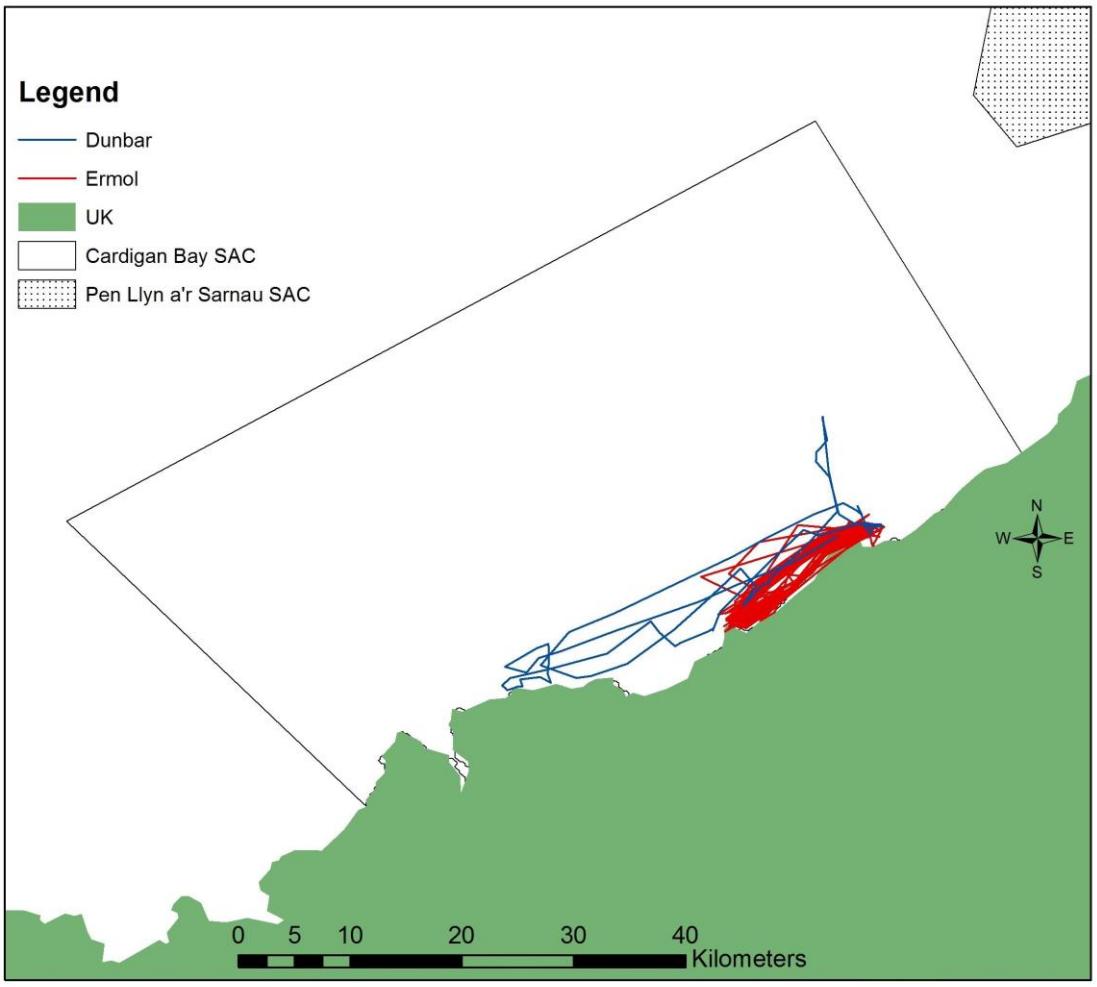


Figure 5: Tracks of *ad-libitum* and platform of opportunity surveys conducted in Cardigan Bay in 2014. Coloured lines represent tracks from different vessels

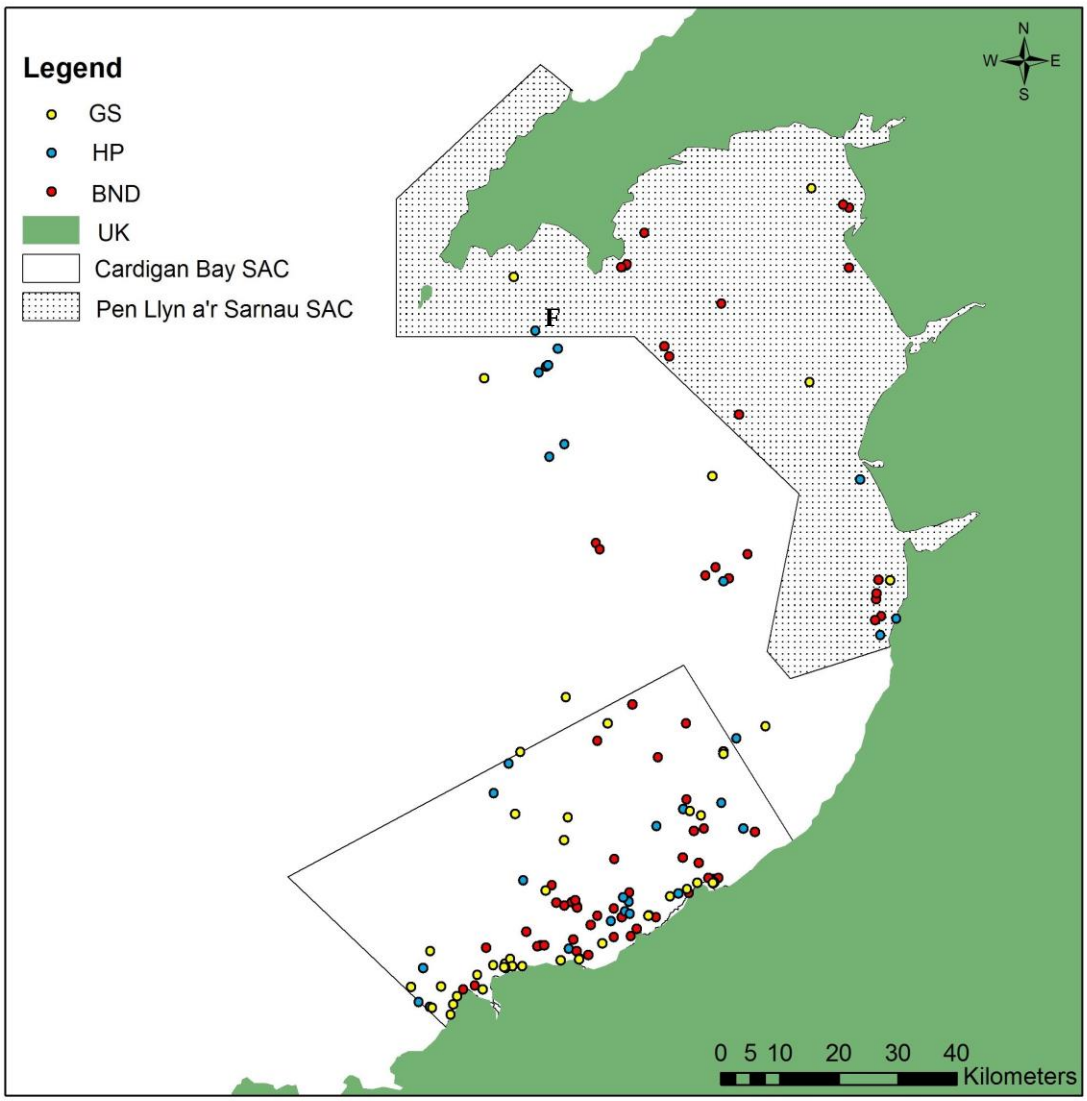


Figure 6: Sightings recorded during line-transect surveys in Cardigan Bay in 2014.
(BND = bottlenose dolphin - red; HP = harbour porpoise - blue; GS =Atlantic grey seal - yellow)

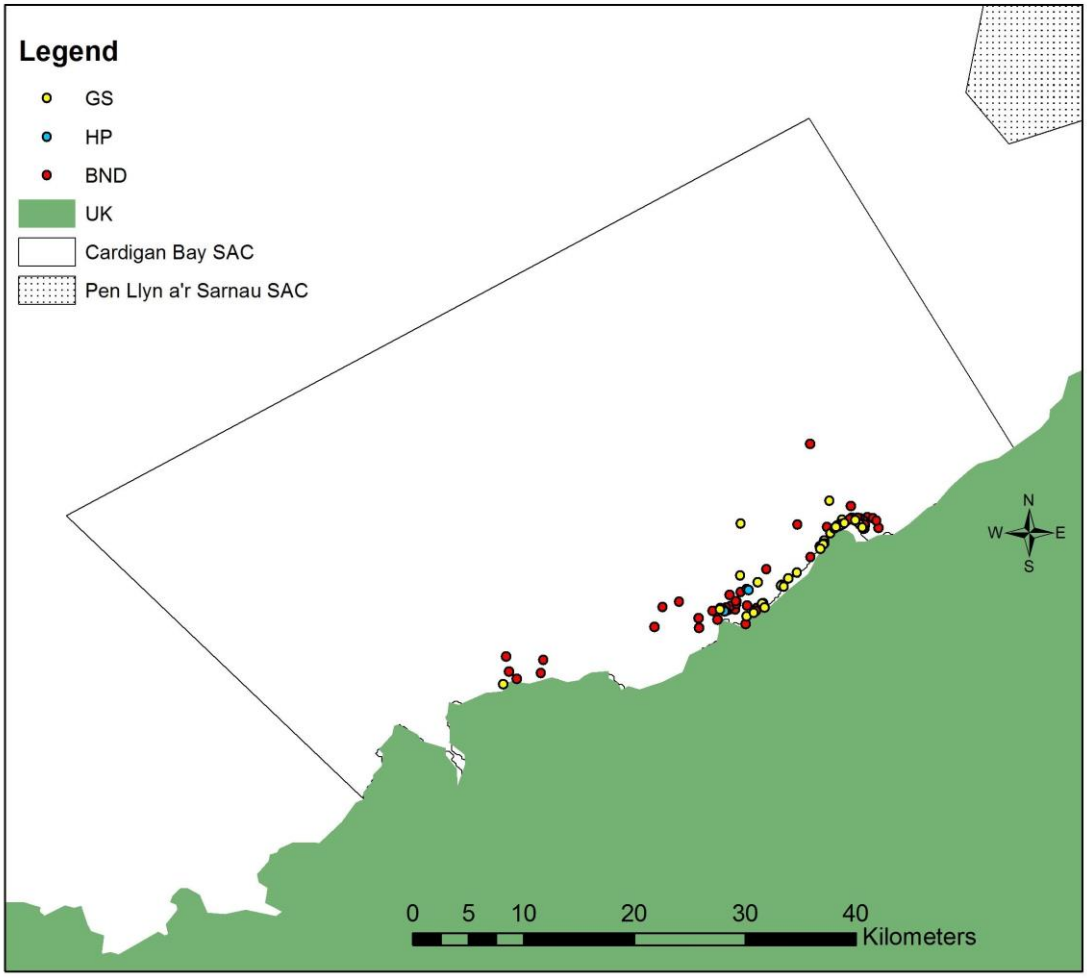


Figure 7: Sightings recorded during *ad-libitum* and platform of opportunity surveys in Cardigan Bay in 2014. (BND = bottlenose dolphin - red; HP = harbour porpoise - blue; GS =Atlantic grey seal - yellow)

Seasonal patterns of sighting occurrence (sightings per km effort travelled per month) were collected during line-transect surveys in Cardigan Bay undertaken between April and October 2011-14 (Table 7). These showed a peak in sightings in April in 2013, June in 2014, and July in 2011 and 2012; sighting rates decreased after June in 2014 and July in the other years (Figure 9).

5.2 Group Sizes

Average group size of bottlenose dolphins, calculated for the whole of Cardigan Bay, was 4.33 (Range 1-15, SD = 3.31, n=69) in 2014, similar to previous years (Figure 10). Most group sizes varied between 1-5 individuals, with few groups numbering over ten individuals (Figure 11). The highest average group sizes occurred either in spring (April & May) or autumn (October), and were generally lower between June and August (Figure 12).

Regular surveys (*ad-libitum* and, later, line-transects) have taken place off the Llŷn Peninsula since 2005. A comparison between the two SAC's indicated significantly higher average group sizes within the Pen Llŷn a'r Sarnau SAC (mean = 6.19) than in Cardigan Bay SAC (mean = 4.15) (X^2 =28.09, df =1, p <0.001). Higher average group sizes between the two areas have remained largely consistent throughout the years (Figure 13).

5.3 Distribution Patterns

Bottlenose dolphins were distributed throughout Cardigan Bay, although within Cardigan Bay SAC, they were concentrated in the coastal sector from New Quay south but largely offshore north of New Quay (Figure 6). The offshore southwest sector of Cardigan Bay SAC had no sightings, consistent with other years although effort here was low. *Ad-libitum* surveys and surveys aboard platforms of opportunity (Ermol V & VI) were concentrated in the coastal sector, with most sightings in three clusters: off New Quay headland, around Ynys Lochtyn, and between Pen Peles and Mwnt (Figure 7). Harbour porpoises and grey seals were also widely distributed within the Bay, although harbour porpoises were observed mainly offshore and grey seals close inshore (Figures 6 & 7).

5.4 Activity Budgets

There are two ways one can compare the frequencies of different behaviours between 2001 and 2014: 1) the predominant behaviour noted at the beginning of an encounter; and 2) adding up all the behaviours observed throughout the encounter. Both approaches were used to see how they compare, and these are plotted in Figure 15. Table 8 gives the sample sizes of encounters upon which the behavioural budgets are based, by month and by year for 2001-14. Bottlenose dolphin behaviours collected during line-transect and *ad-libitum* surveys in Cardigan Bay SAC in 2011-14, are presented in Figure 14. Travel and feeding/foraging were the predominant behaviours recorded, the highest proportion of travel (71%) and lowest of foraging/feeding (26%) and social activity (3%) occurring in 2014.

Table 8: Number of encounters where different bottlenose dolphin predominant behaviours were observed, in Cardigan Bay between 2001 and 2014

Month	Behaviour	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
April	Forage/Feed	0	0	0	0	0	0	1	0	0	0	0	2	1	0
	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Travel	0	0	0	0	0	0	3	0	0	0	0	0	0	0
May	Forage/Feed	0	0	2	1	2	0	1	1	2	5	1	6	3	0
	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	0	0	0	2	1	0
	Travel	5	0	3	3	1	2	9	11	2	6	0	4	4	0
June	Forage/Feed	0	2	30	0	3	0	5	3	5	2	6	7	6	2
	Rest	0	0	0	0	0	1	0	1	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	1	0	0	0	1	1	0
	Travel	23	0	25	3	7	11	2	4	13	4	10	4	3	18
July	Forage/Feed	0	47	48	2	7	0	3	0	1	4	6	9	11	7
	Rest	0	0	8	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	1	0	0	0	0	3	0	0	0
	Travel	24	0	70	2	10	16	8	0	3	2	14	7	7	17
August	Forage/Feed	2	85	23	3	11	3	4	0	2	5	8	5	8	2
	Rest	0	2	1	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	0	1	1	0	1	0
	Travel	31	22	55	7	10	6	16	1	6	7	7	12	1	1
September	Forage/Feed	0	42	5	0	12	3	8	4	5	7	4	6	10	0
	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	0	1	2	0	0	0
	Travel	21	7	51	0	11	22	18	10	9	9	2	0	11	9
October	Forage/Feed	0	0	0	0	4	0	2	0	2	0	2	3	4	1
	Rest	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social	0	0	0	0	0	0	0	0	1	0	2	0	0	0
	Travel	0	0	0	0	8	3	0	0	2	0	6	5	4	3

Feeding activities within Cardigan Bay SAC varied between 2001 and 2014, showing no clear trend, with peaks in 2002 and 2012, and lows in 2006 and 2014 (Figure 16). There is also a decline through the season in actual feeding with a corresponding rise in foraging (Figure 17), suggesting that dolphins may be spending more time searching for prey but not necessarily being successful in the latter part of the season.

Behaviours collected during line-transect and *ad-libitum* surveys in Pen Llŷn a'r Sarnau SAC in 2011-14 are presented in Figure 18, and show that the highest proportion (52-87%) of activity in all years was spent travelling, the highest value being in 2014 when no foraging/feeding was observed during any of the encounters.

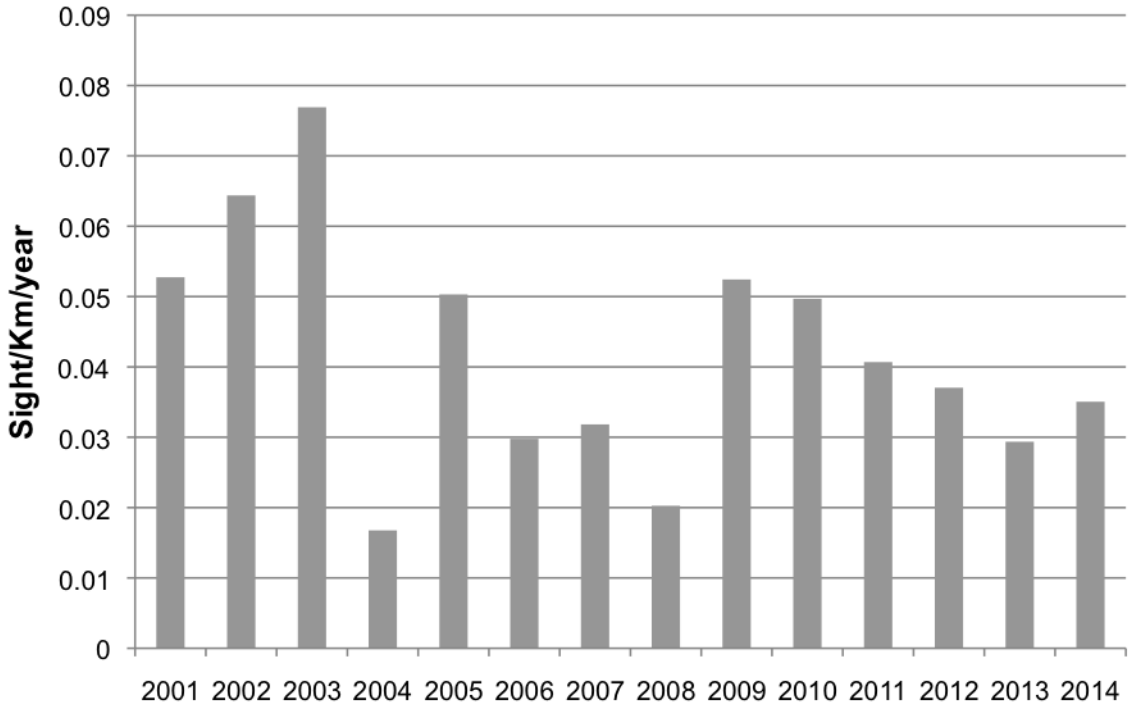


Figure 8: Mean number of bottlenose dolphin sightings per kilometre per year travelled, recorded from line-transect and *ad-libitum* surveys each year in Cardigan Bay, 2001-14

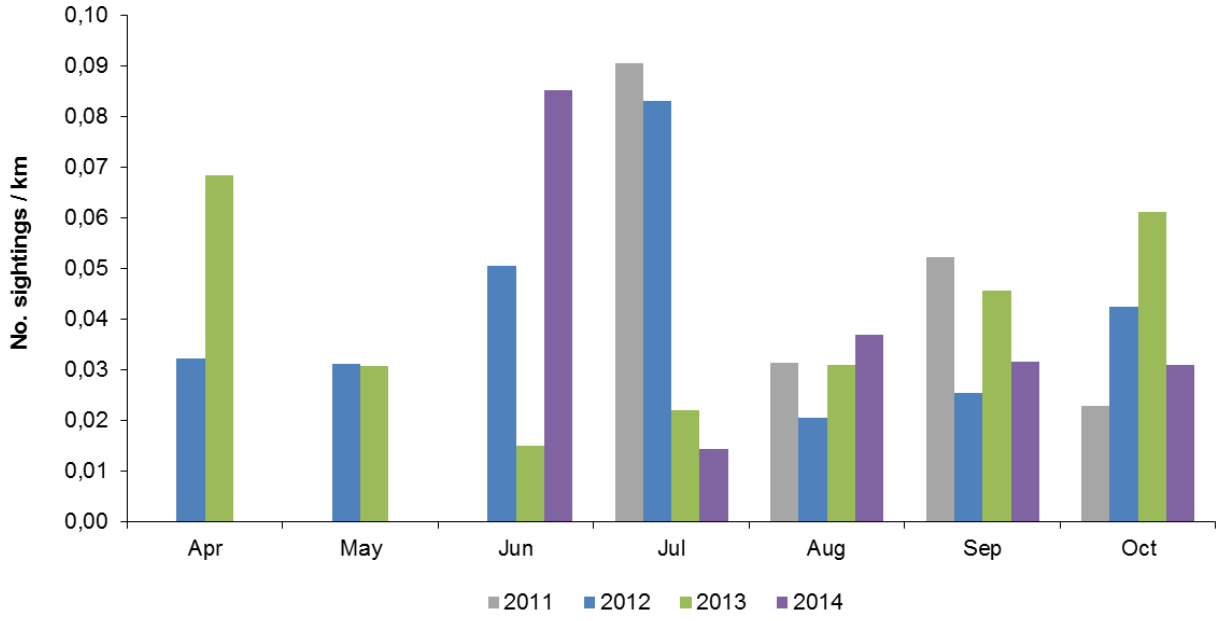


Figure 9: Number of bottlenose dolphin sightings per kilometre travelled by month, recorded from line-transect surveys in Cardigan Bay, 2011-14

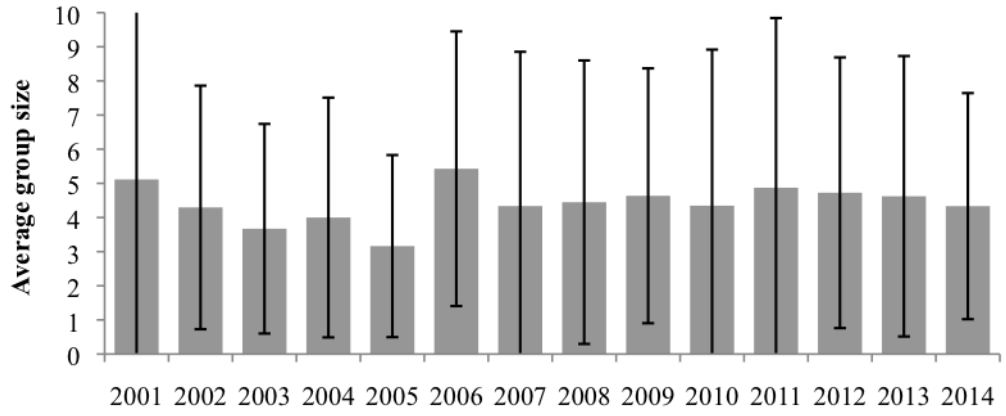


Figure 10: Average (±SD) group size of bottlenose dolphins by year recorded from line-transect surveys in Cardigan Bay, 2001-14 (number of encounters: 87, 315, 429, 62, 172, 84, 143, 58, 99, 52, 102, 124, 135 and 69 respectively)

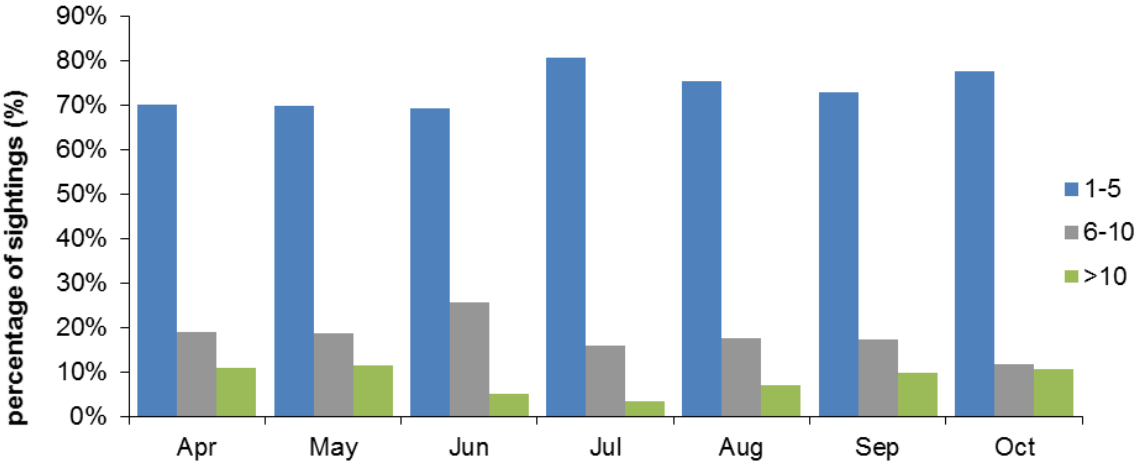


Figure 11: Bottlenose dolphin group sizes (expressed as a percentage of sightings) by month, recorded from line-transect surveys in Cardigan Bay, 2001-14 (no. of encounters for group size 1-5: 26, 105, 203, 388, 380, 285, 59 respectively; no. of encounters for group size 6-10: 7, 28, 75, 76, 89, 68, 9 respectively; no. of encounters for group size >10: 4, 17, 15, 16, 35, 38, 8 respectively)

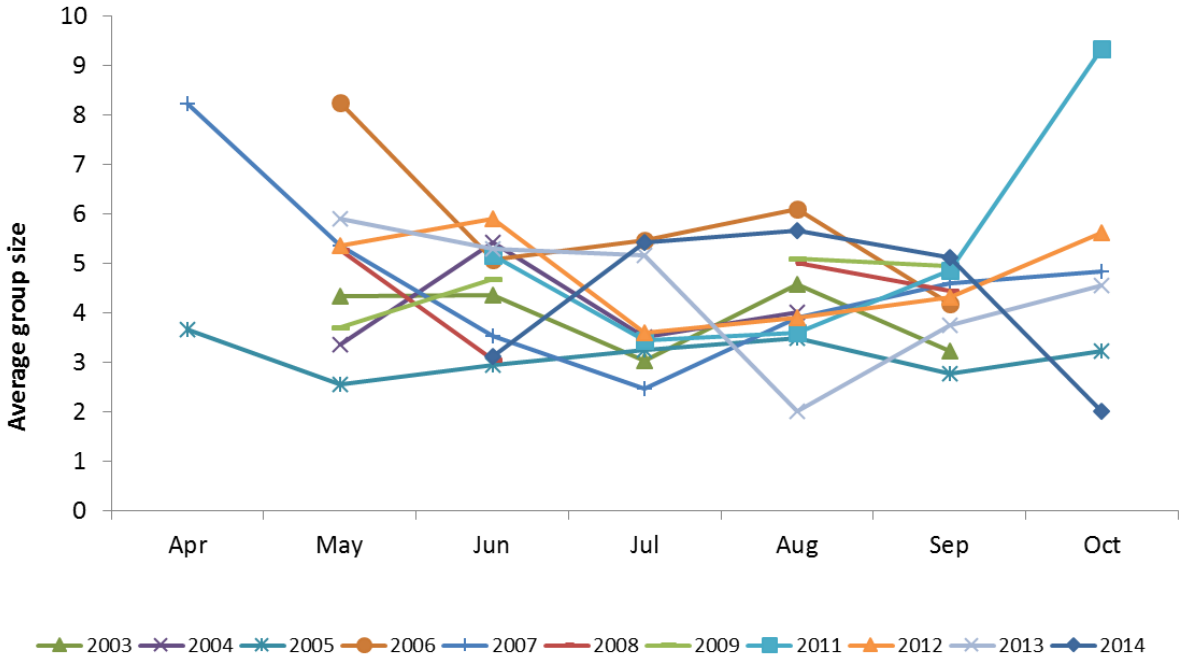


Figure 12: Bottlenose dolphin average group sizes by month and by year, recorded from line-transect surveys in Cardigan Bay, 2001-14

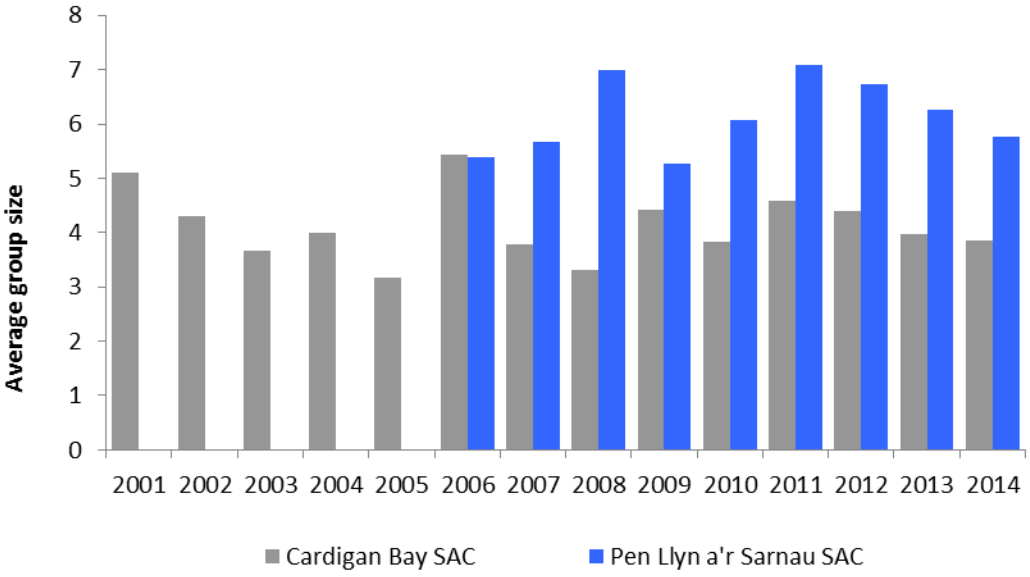
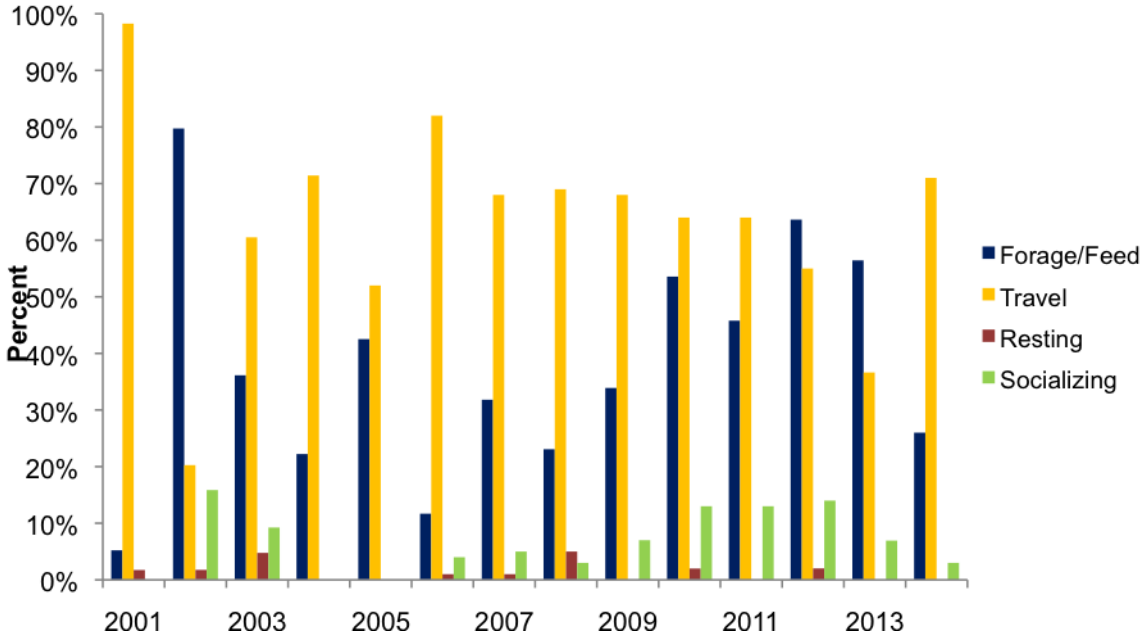


Figure 13: Comparison of average group sizes of bottlenose dolphins recorded from line-transect surveys **i**n Cardigan Bay and Pen **Llŷn** a'r Sarnau SAC's, 2001-14 (no of encounters CB SAC: 87, 315, 429, 62, 172, 56, 101, 40, 73, 40, 90, 106, 97, 52 respectively; no. of encounters PL SAC: 28, 42, 18, 26, 12, 12, 18, 38, 17 respectively)

Figure 14: Behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC in 2011-14 (n = 83, 99, 101, and 70 respectively)

a) *Behavioural budgets based upon all behaviours recorded during an encounter*



b) *Behavioural budgets based upon the predominant behaviour recorded on first encounter*

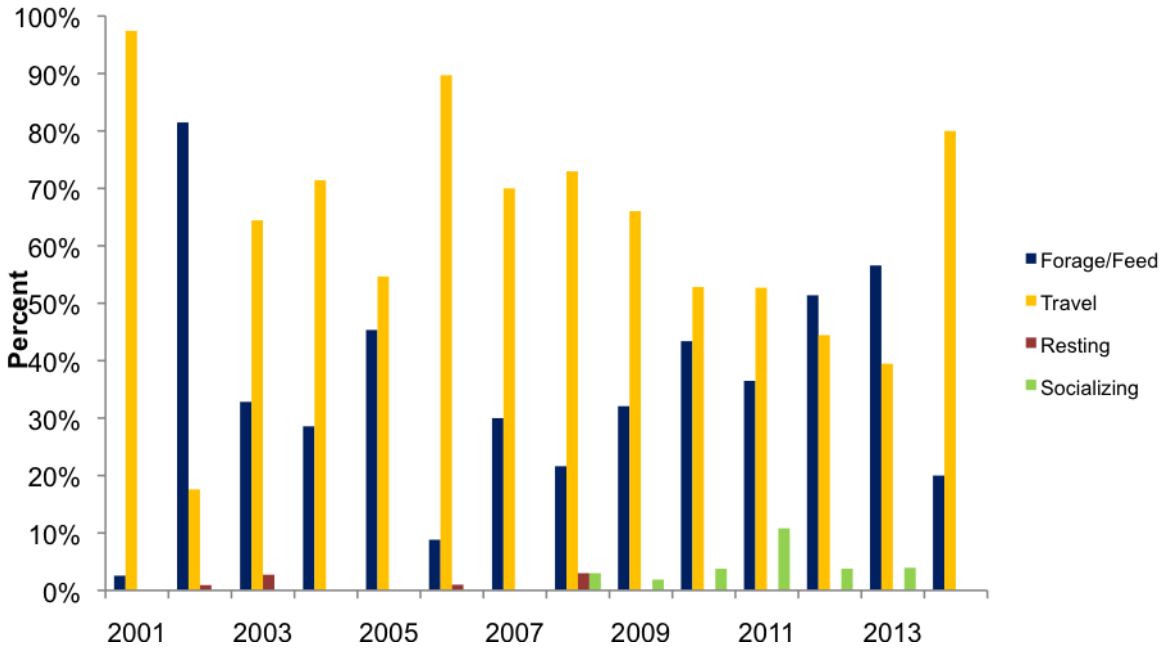


Figure 15: Behavioural budgets of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2001-14. Sample sizes for a) = 115, 227, 357, 21, 87, 77, 88, 39, 59, 56, 83, 99, 101 and 70; and for b) = 117, 216, 329, 21, 86, 68, 80, 37, 53, 53, 74, 72, 76 and 60 respectively, for each year

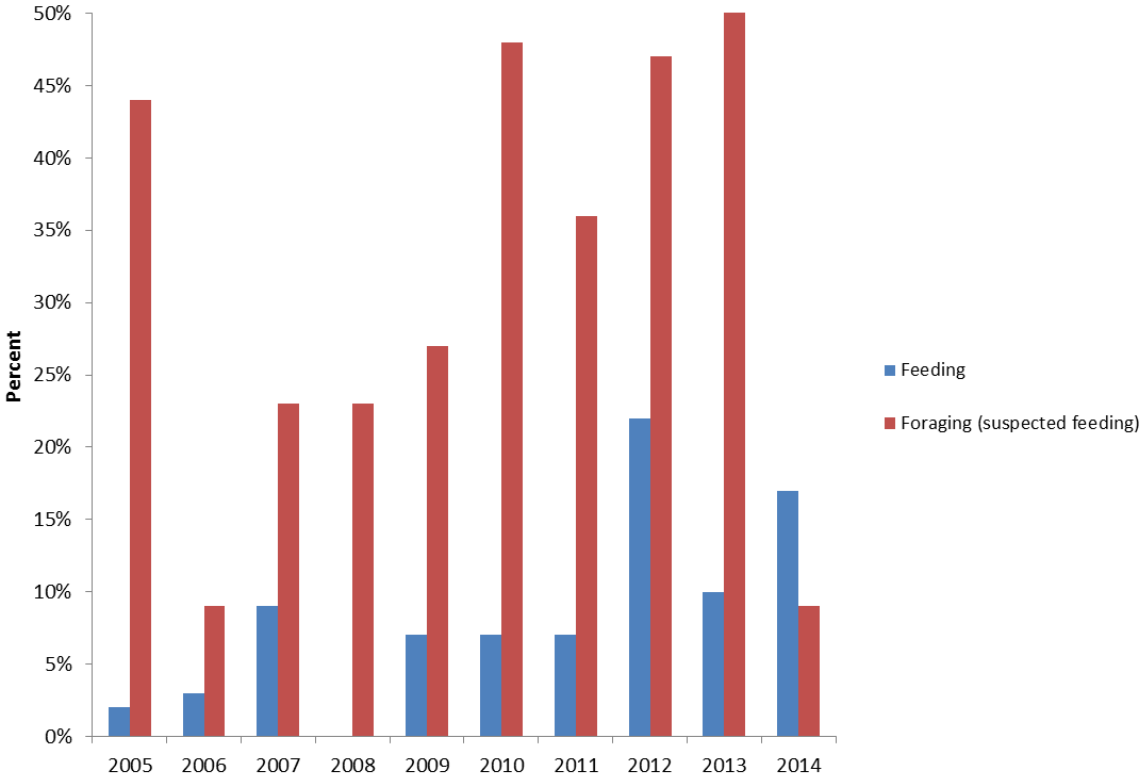


Figure 16: Yearly comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-14 (feeding and suspected feeding only) (n = 87, 77, 88, 39, 59, 56, 83, 99, 101 and 70 respectively, for each year)

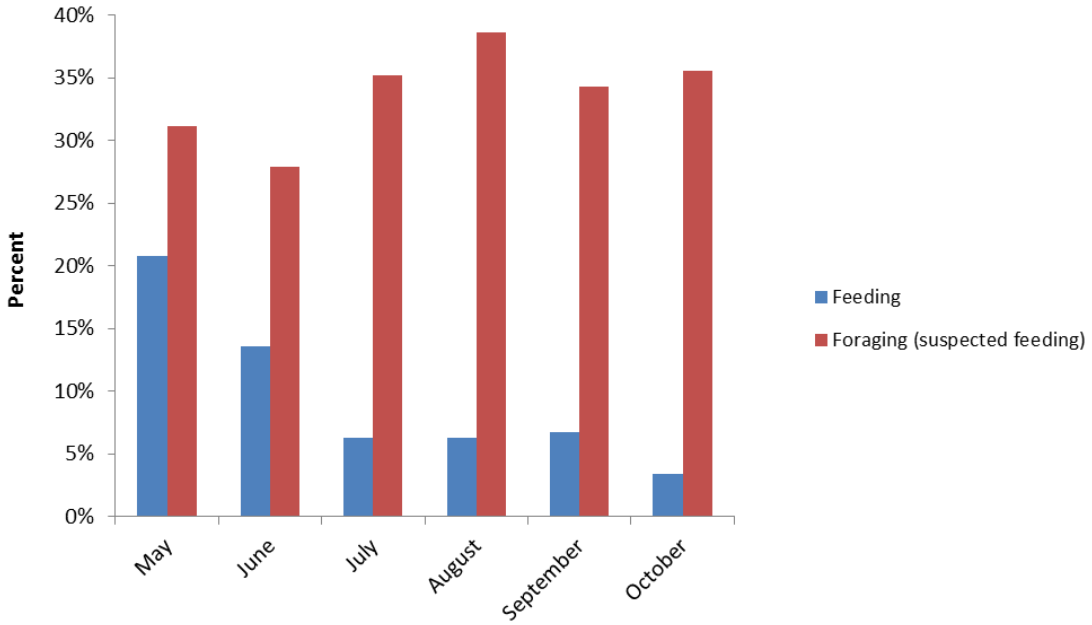


Figure 17: Seasonal comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-14 (feeding and suspected feeding only) (n = 77, 115, 128, 124, 162, 55; April was omitted from analyses due to low sample size, n = 9)

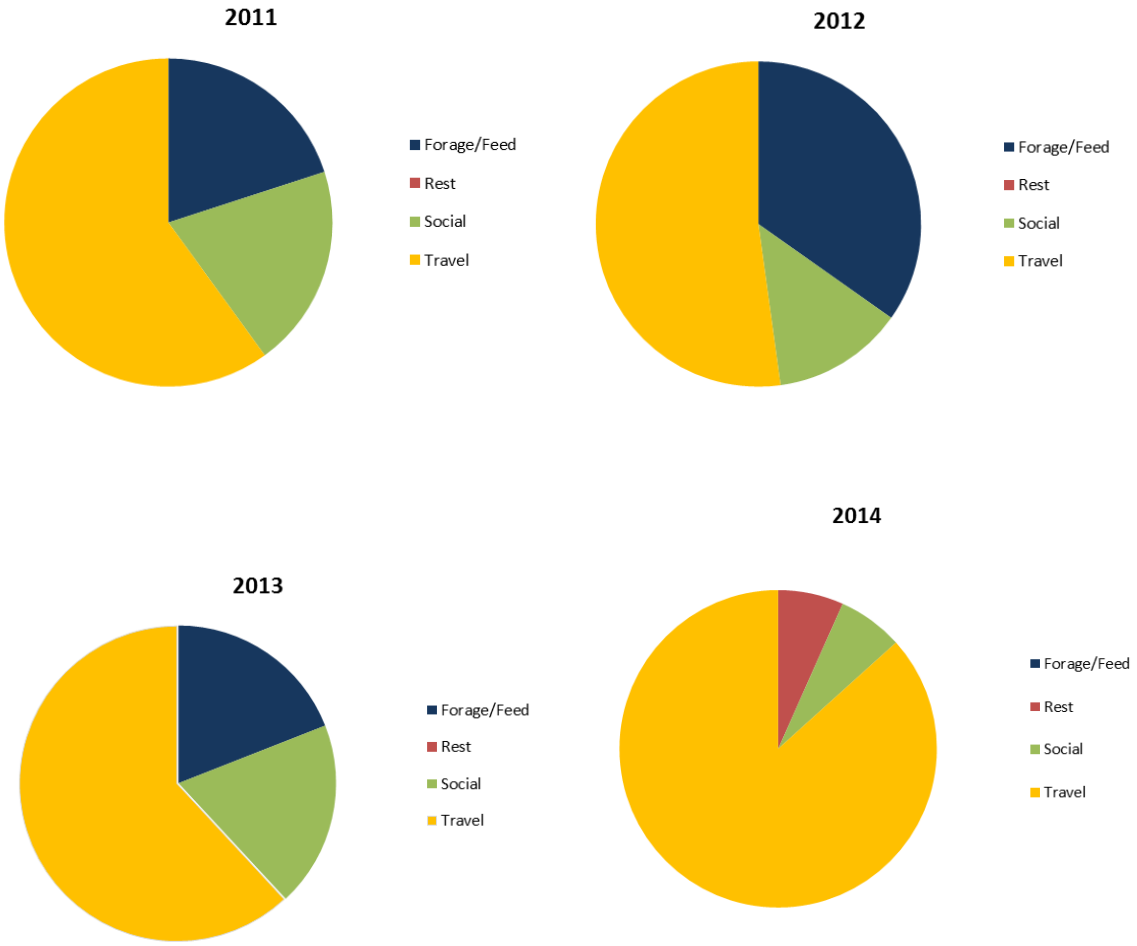


Figure 18: Behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Pen Llŷn a'r Sarnau SAC in 2011-14 (n=10, 23, 42, and 15 respectively)

5.5 Reproductive & Mortality Rates

Cardigan Bay SAC has long been known as a nursery ground for bottlenose dolphins and thus an important area for mothers and calves (Ugarte & Evans, 2006; Pesante & Evans, 2008b; Veneruso & Evans, 2012a; Baylis, 2013; Feingold & Evans, 2013a,b). Around 50% of groups encountered within Cardigan Bay SAC had one or more calves present between 2011 and 2013 (47%, 51% and 53% respectively) (Feingold & Evans, 2014a), with 43% of groups in 2014. Fifteen and thirteen newborns were recorded in 2011 and 2012 respectively (Feingold & Evans, 2014a). However, in 2013, only six newborns were recorded throughout Cardigan Bay, with the same number in 2014 (Figure 19). These represent the lowest values for the whole Bay since 2005 when surveys started covering the wider region.

Crude birth rates in 2014 for Cardigan Bay SAC were calculated to be 4.3% using mark-recapture population estimates with a closed model, and 4.85% using an open population model (Table 9). These compare with a long-term average of 5.2% per annum with a closed model, and 7.5% per annum using an open population model (Table 19). Birth rates have varied between years in the period 2001-14, with open population model peaks of c. 10% in 2002, 2005 and 2011, and a general decline since then (Figure 20).

Crude birth rates for all of Cardigan Bay were calculated from 2005 when effort was extended to the entire Bay including Pen Llŷn a'r Sarnau SAC. The long-term average is 6.4% per annum with a closed model, and 8.5% per annum using an open population model (Table 19). The equivalent values for 2014 were 3.95% per annum with a closed model, and 4.8% using an open population model (Table 10). Birth rates have also varied between years over the period 2005-14, with open population model peaks of c. 12% in 2005 and 2011, a similar general decline since then with the lowest values in 2013 and 2014 (Figure 21). The last two years (2013 and 2014) are the only years since 2005 when birth rates have been lower in the wider Cardigan Bay compared with the Cardigan Bay SAC (Figure 22).

Inter-birth intervals in Cardigan Bay were calculated using data from 33 definite females, all of which produced at least two calves between 2001 and 2014. Females, which were not seen in successive years, were excluded from the analysis. Inter-birth intervals varied between two and seven years, with most mothers giving birth to a new calf every three years (Figure 23).

Female reproductive success was analysed for 47 confirmed females giving birth to at least one calf between 2001 and 2014. Analyses included calculation of the number of offspring surviving to the age of three within a three-year time period. Most females (78%) had one or no calves surviving (18 and 17 respectively). Ten females (22%) had two, and only two females (4%) had three calves surviving to the age of three within a three-year period (Figure 24).

No new information exists on calf mortality rates since last year when they were calculated from a sample of 71 mother-calf pairs born between 2001 and 2013. Higher mortality rates were found in the first two years (15% in year one and 17% in year two) with lower rates in the third year (7%) and a total of 60% of calves surviving into their fourth year Figure 25).

5.6 Calving Season

The calving season in Cardigan Bay between 2001 and 2014 was analysed by estimating birth dates based on the last sighting of a female without a calf and the first sighting of a female with a newborn (n=66). Birth dates were estimated for females who were seen with and without a calf within a three-four month period. These were corrected for the number of identified females each month. Calves are born in all months of the main field season (March-October), with the exception of October. Some newborns have also been observed during the winter months off north Anglesey. Peak calving season in Cardigan Bay occurs between July and September, when 76% of all births are recorded (Figure 26).

5.7 Photo ID, and Population Estimates using Mark-Recapture

A total of 1,037 bottlenose dolphin encounters were made between 2011-14 throughout Cardigan Bay and off North Wales. From these, 197 dolphins were identified in 2011, 200 in 2012, 161 in 2013 and 101 in 2014 (Table 9). The Welsh Photo ID catalogue now holds a minimum of 382 individuals (Table 10).

Table 9: Bottlenose dolphin encounters in 2011-14

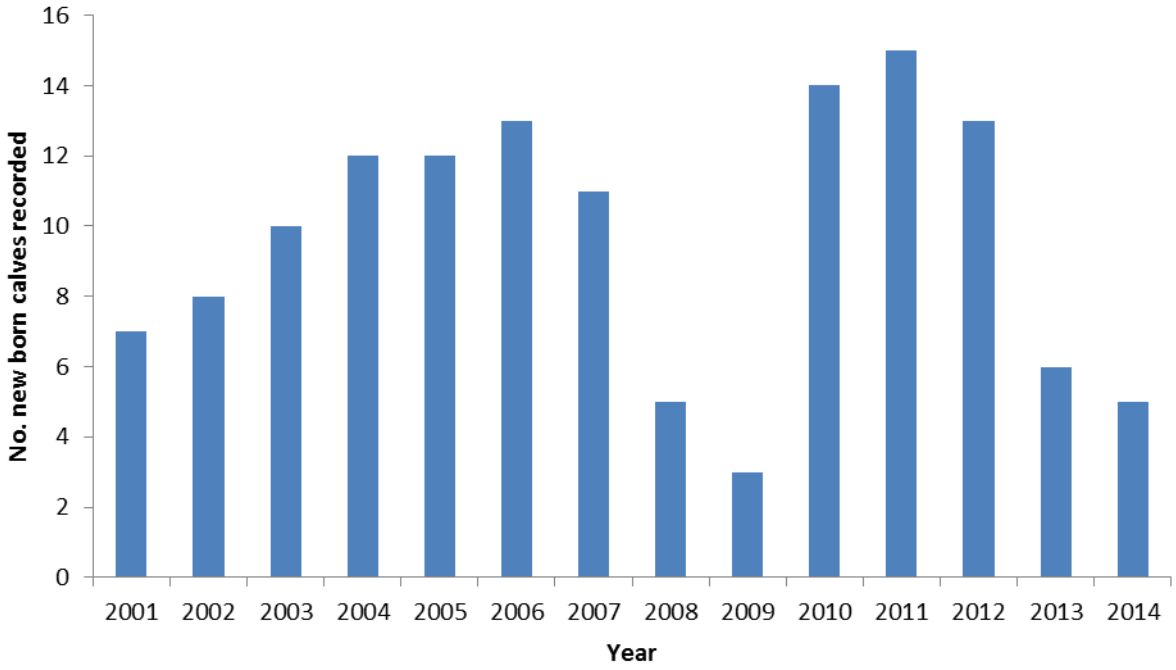
	2011	**2012**	**2013**	**2014**
Total no. encounters	233	272	261	271
Total maximum no. dolphins identified	197	200	161	101
No. marked dolphins identified	160	164	130	99
No. unmarked dolphins (left) identified	30	35	29	0
No. unmarked dolphins (right) identified	37	36	31	2

Table 10: SWF catalogue content in 2014

Well marked (WM)	108
Slightly marked (SM)	144
Left (L)	120
Right (R)	130
WM+SM+L	372
WM+SM+R	382

A discovery curve of marked individuals plotted from encounters between 2001 and 2014 indicates that since around 2008, the majority of marked dolphins in the region have been photographed and identified (Figure 27). Increases in the detection curve were seen in 2005 when surveys expanded to Pen Llŷn a'r Sarnau SAC, and in 2007 when extended effort into North Wales commenced. The detection curve is expected to continue to rise slightly, due to transient dolphins entering the study area, and juveniles and calves gaining their first dorsal fin marks, and thus being added to the marked category.

Cardigan Bay SAC



Entire Cardigan Bay

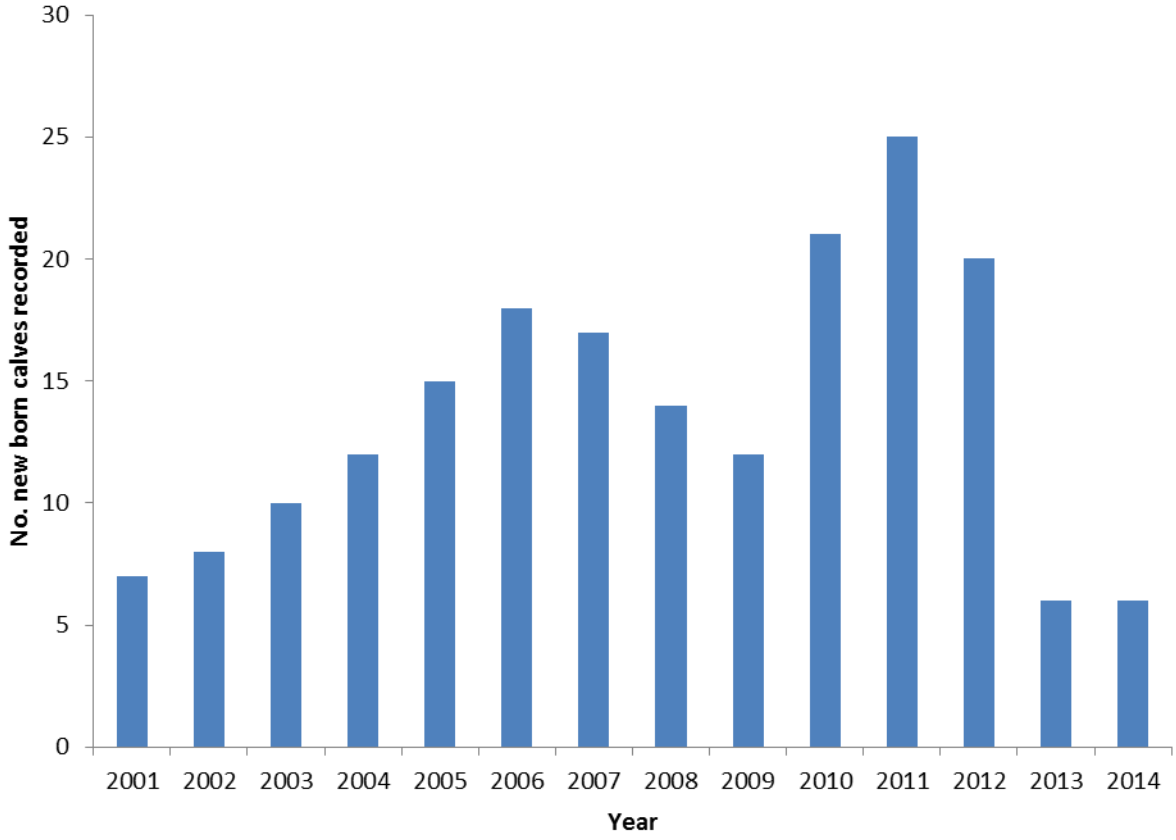


Figure 19: Number of bottlenose dolphin newborns in Cardigan Bay SAC and the wider Cardigan Bay, 2001-14

Table 11: Number of newborns recorded in 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

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

Figure 20: Birth rates of bottlenose dolphin calves in Cardigan Bay SAC calculated using closed and open population estimates

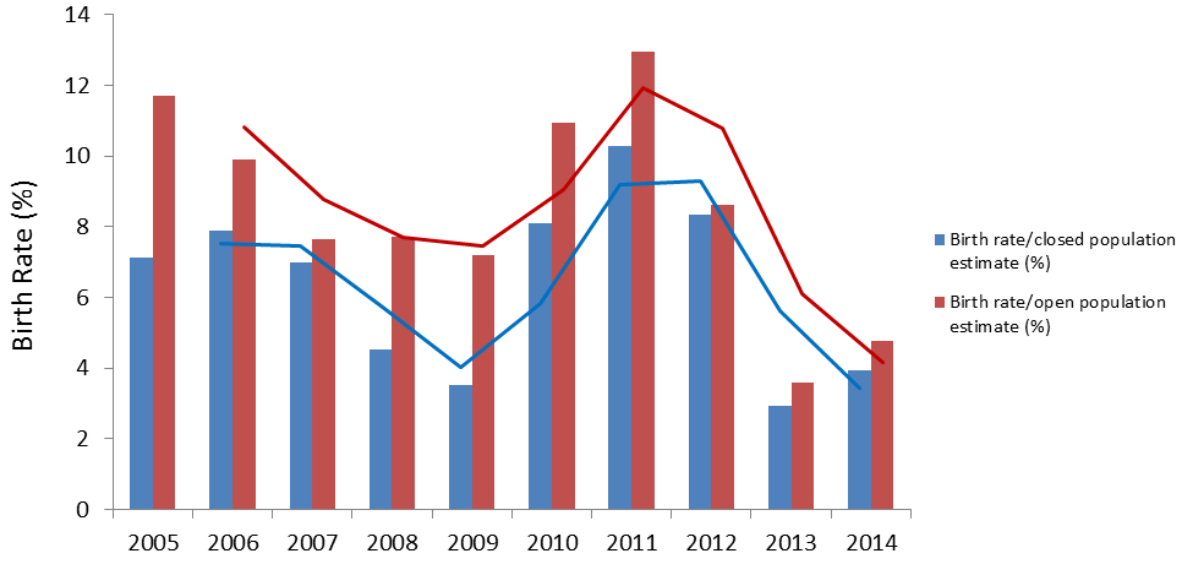


Figure 21: Birth rates of bottlenose dolphin calves in the wider Cardigan Bay calculated using closed and open population estimates

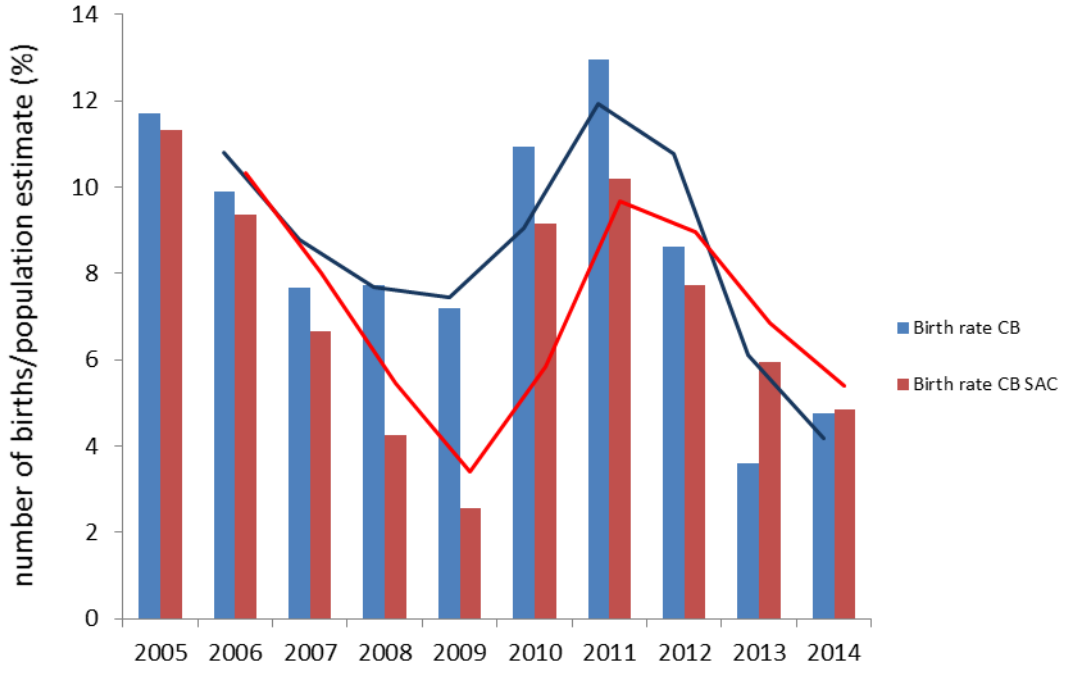


Figure 22: Birth rates of bottlenose dolphin calves in Cardigan Bay vs. Cardigan Bay SAC, calculated using open population estimates

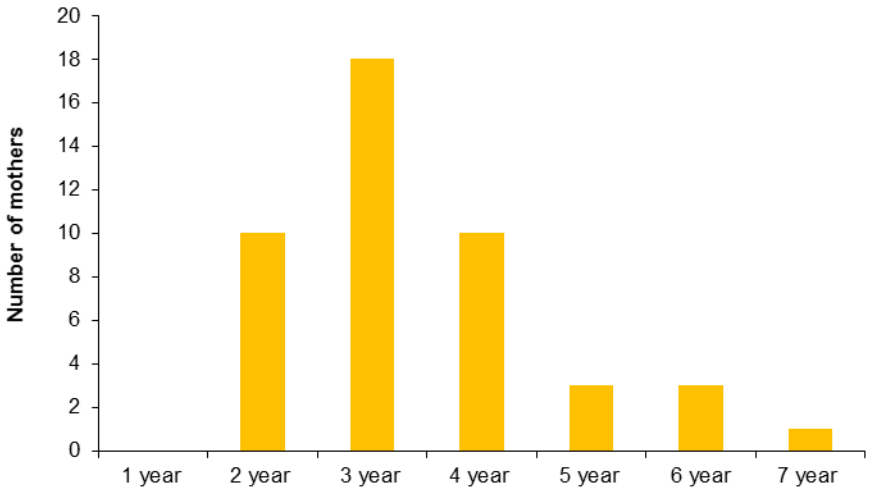


Figure 23: Inter-birth intervals of 33 known mothers in Cardigan Bay between 2001 and 2014

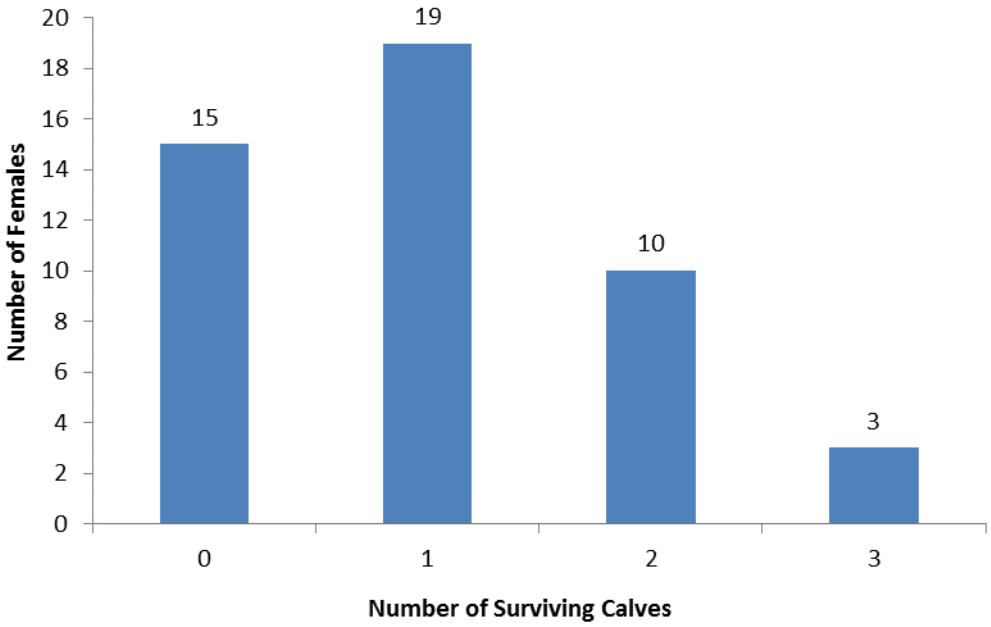


Figure 24: Female reproductive success: number of calves surviving to the age of three within a three-year time period, in Cardigan Bay between 2001 and 2014

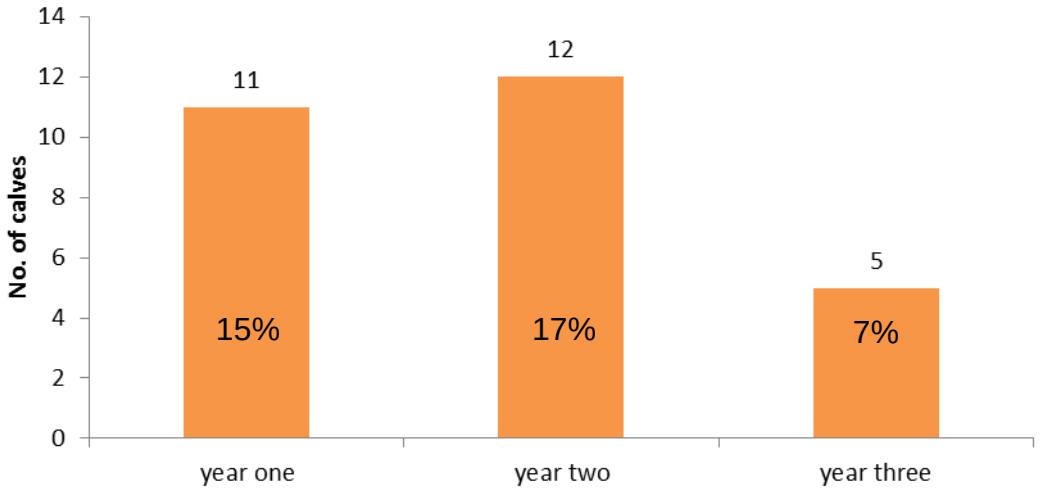


Figure 25: Number and percentages of calves that have died between age 1 and 3 years, between 2001 and 2014

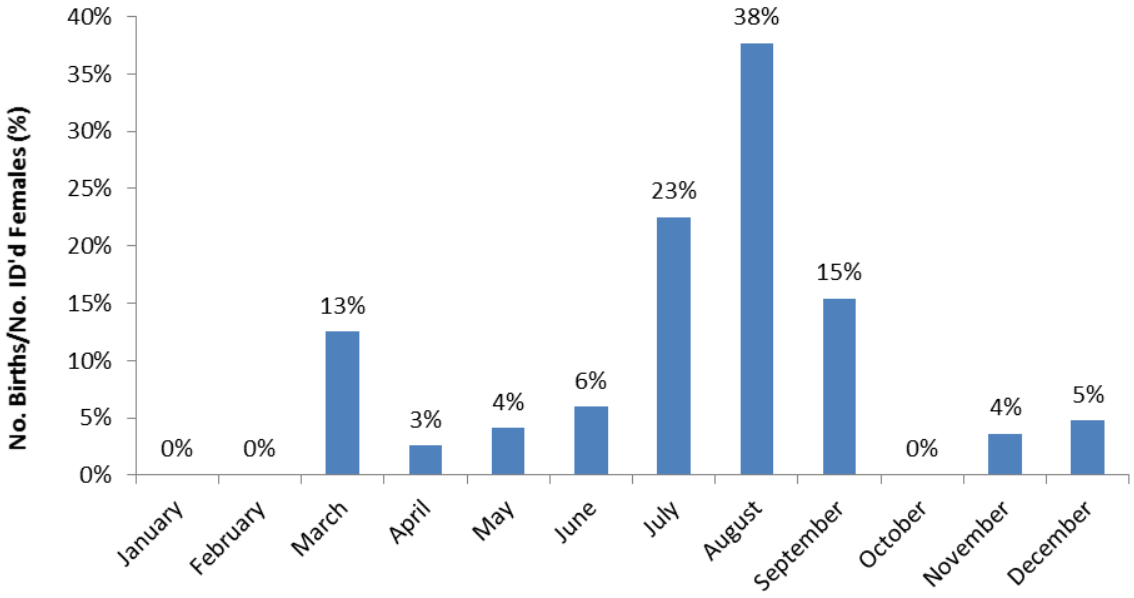


Figure 26: Number of births recorded by number of identified females each month in Cardigan Bay, between 2001 and 2014 (expressed as percentages)

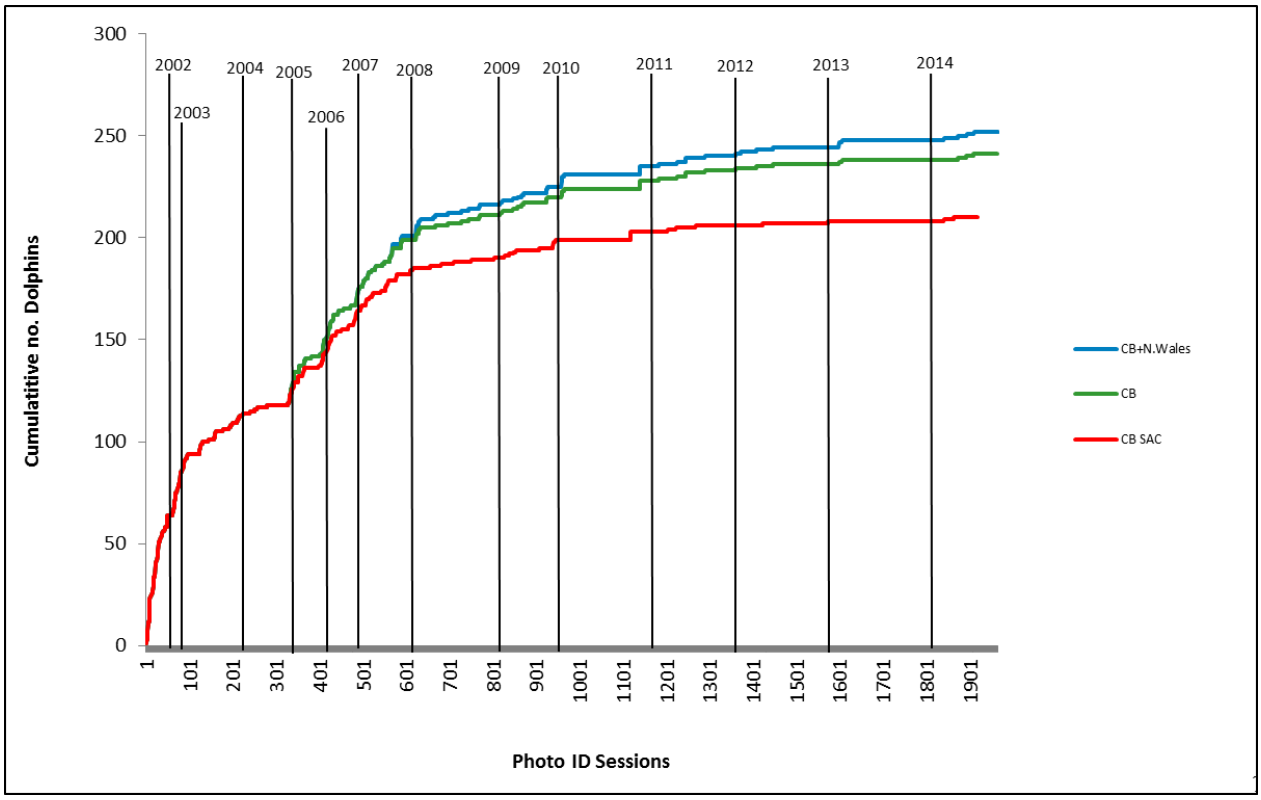


Figure 27: Discovery curve for marked bottlenose dolphins from 2001-14
(CB SAC - Cardigan Bay SAC, CB - all Cardigan Bay; CB + N Wales - Cardigan Bay and North Wales)

The bottlenose dolphin population in Cardigan Bay SAC has been described as a combination of transients, occasional visitors, and resident animals (Pesante, 2008b, Feingold & Evans, 2013b, c). With surveys extended across Pen Llŷn a'r Sarnau SAC and adjacent areas since 2005, it is possible to apply the same criteria to the entire Cardigan Bay. Between 17 and 19% of the population are considered transient, being seen less than four times and in only one or two years; between 20 and 29% are considered occasional, spotted between 4-11 times and in 3-6 years; and between 53 and 63% are considered resident inhabitants of the Bay, having been seen in more than six years and on more than 12 occasions throughout the study period (Figures 28, 29), with four individuals seen in all fourteen years of the study period (Figure 30).

Frequencies of re-sightings have ranged from 1 to 180 (mean = 20.21, SD = 22.6; Figure 30). Multiple sightings per day for any individual were omitted from this analysis. Within Cardigan Bay SAC, a higher percentage of 35% are considered transient and a lower percentage of between 38 and 44% are considered resident inhabitants, suggesting that some animals using the wider area of Cardigan Bay may not be entering the southern SAC.

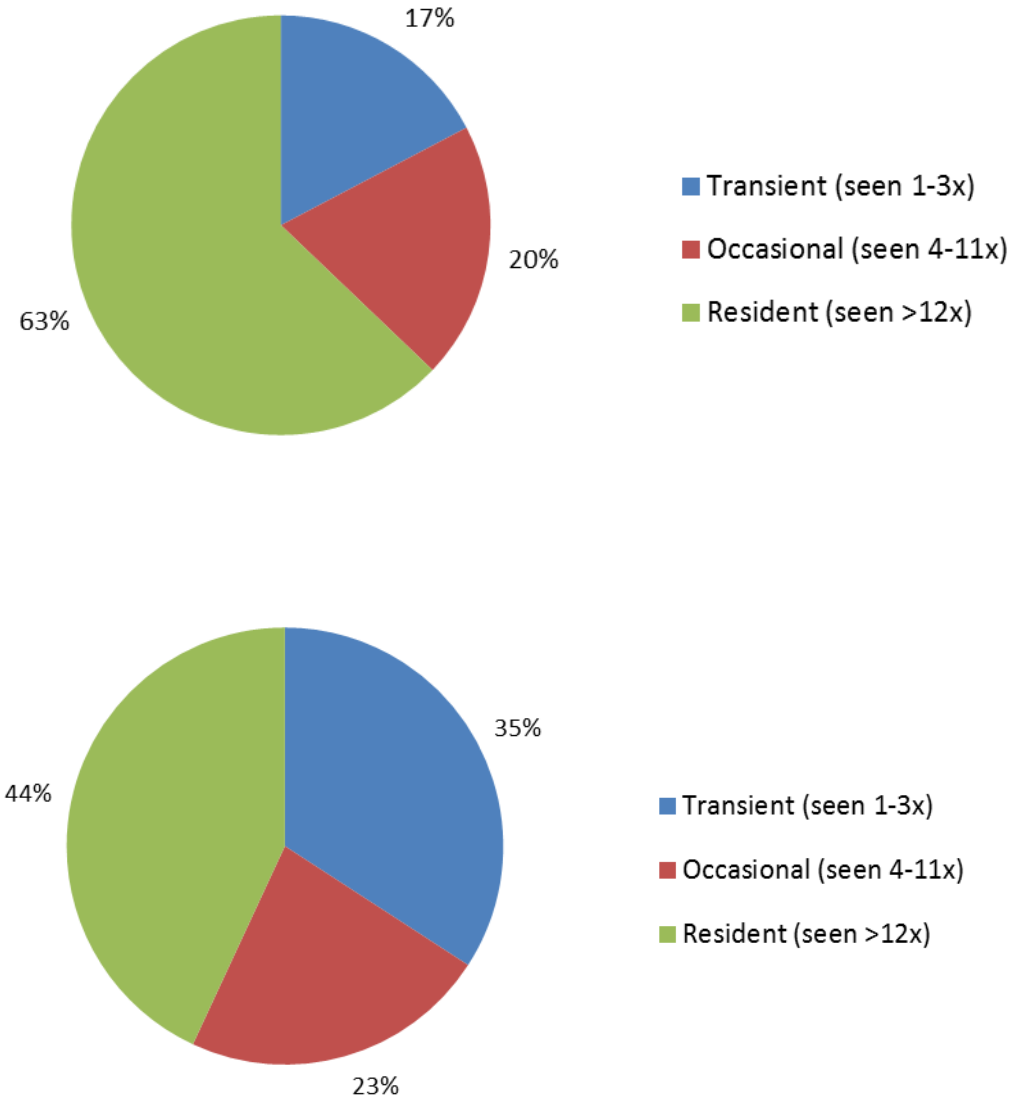


Figure 28: Percentage of individual re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)

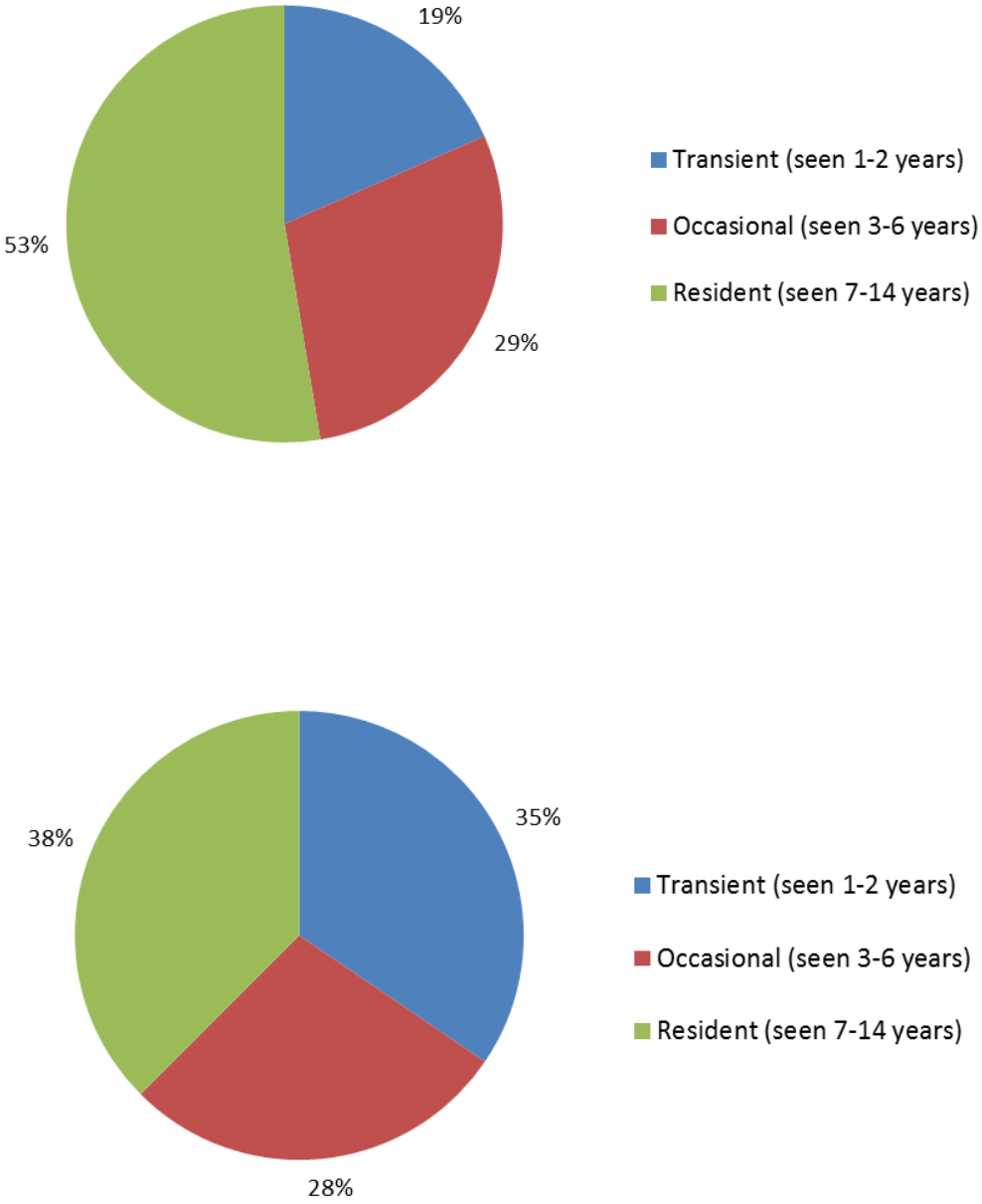


Figure 29: Percentage of yearly re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)

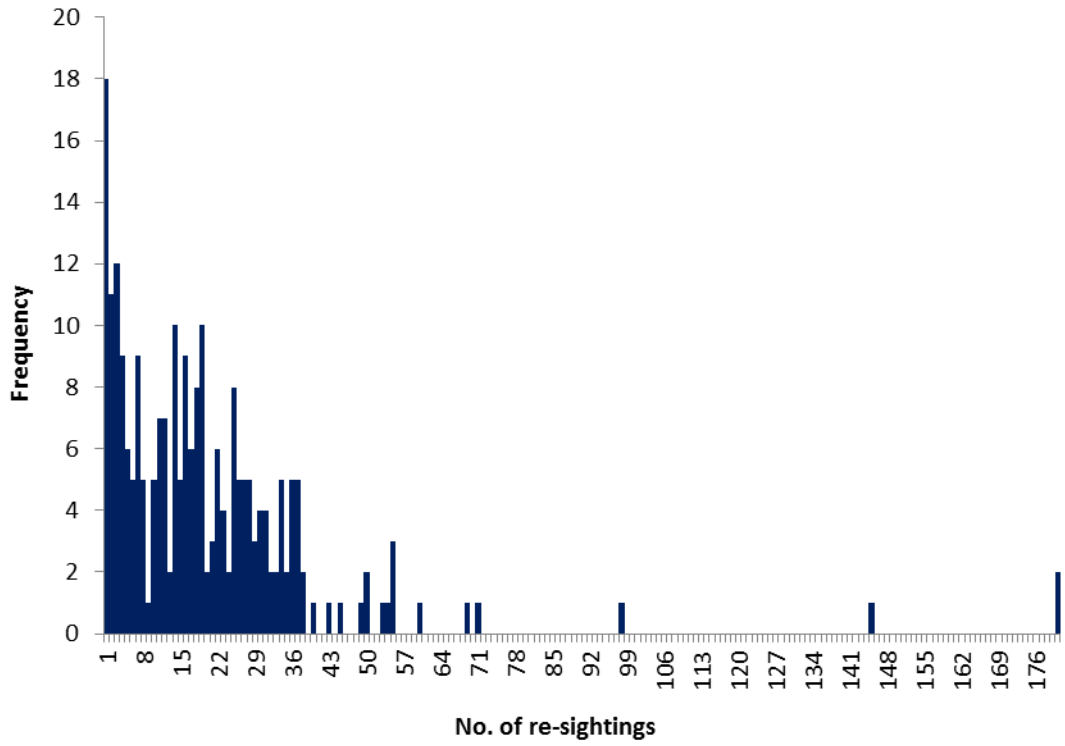


Figure 30: Frequency of re-sighted individuals in Cardigan Bay, 2001-14

Monitoring using Photo ID between 2001 and 2014 has been most consistent within Cardigan Bay SAC. Population estimates using a robust open population model over this time period reveal no apparent long-term trend, reaching a peak of 165 and 168 individuals in 2007 and 2012 respectively, with low numbers in 2001-02, 2005, and 2013-14 (Table 13). A polynomial trend line and moving average trend indicate an increase in population size between 2001 and 2007 and a decrease in recent years (Figure 31). The open population model also considers emigration, immigration, and birth & death rates. A general increase in the probability of permanent emigration from Cardigan Bay SAC can be seen over the fourteen years of the study (Figure 32, Table 14). Although there was a sharp decrease in survival rates (S) between 2012 and 2013, this increased again between 2013 and 2014 (Figure 33). This latest value has greater uncertainty associated with it because there are no future data from which to estimate probabilities. In future years, this value may return to a general trend (as has occurred with previous years' estimates). This is to be expected since 2014 also had the lowest number of dolphins identified that year (101) compared to 161 in 2013, 200 in 2012, and 197 dolphins identified in 2011.

Population estimates within Cardigan Bay SAC using a closed population model between 2001 and 2014 reveal a similar general trend with an increase, peaking at 260 individuals in 2008, and then steadily declining to only 116 individuals in 2014, the lowest value since the study started in 2001 (Table 15, Figure 34).

Table 13: Population estimates for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-14, obtained using an open population model and considering the marked proportion of individuals

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	**103**	7.50E+00	0.55

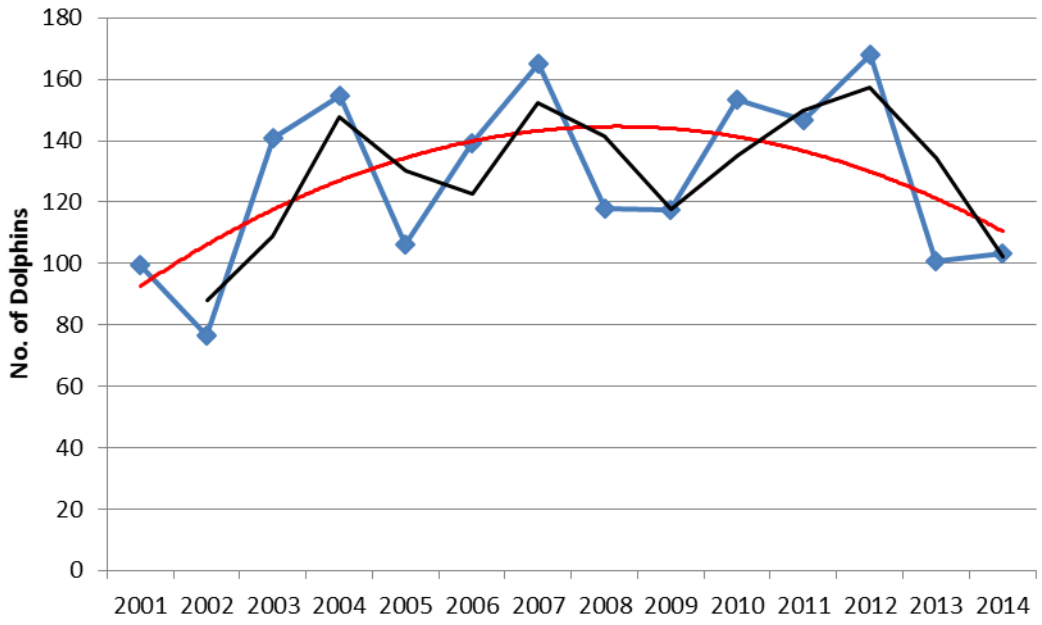


Figure 31: Population trend for bottlenose dolphins in Cardigan Bay SAC for the years 2001-14, obtained using an open population model and an average survival rate of S=0.89
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

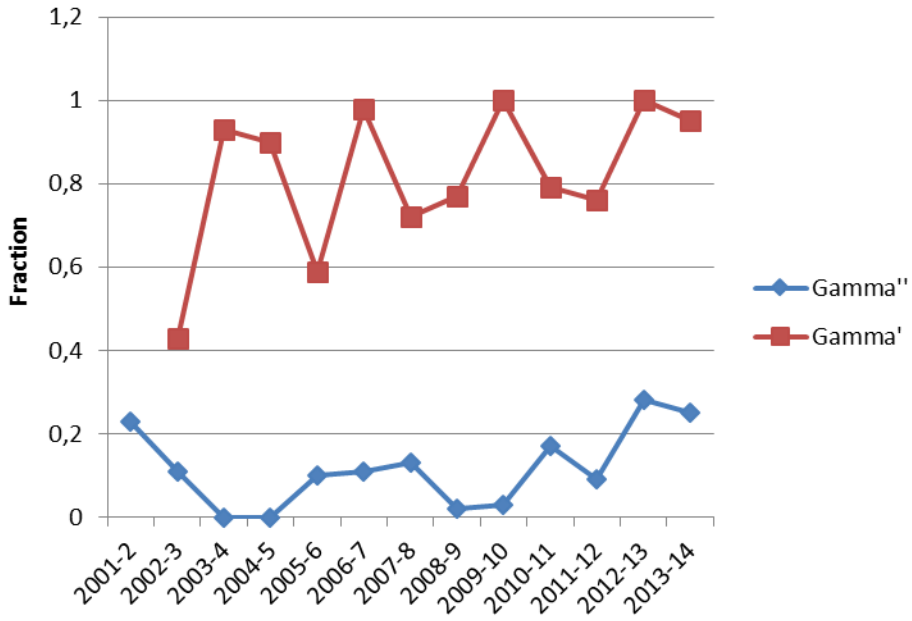


Figure 32: Bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model; (gamma"- probability of an animal emigrating out of the study area; gamma'- probability of an animal staying out of the study area)

Table 14: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay SAC, using an open population model; (gamma"-probability of an animal emigrating out of the study area; gamma'- probability of an animal staying out of the study area)

Period	Gamma''	Standard Error	Gamma'	Standard Error
2001-2	0.23	0.22		
2002-3	0.11	0.06	0.43	0.41
2003-4	0	0	0.93	0.26
2004-5	0	0	0.9	0.16
2005-6	0.1	0.06	0.59	0.26
2006-7	0,11	0.07	0.98	0.24
2007-8	0.13	0.06	0.72	0.2
2008-9	0.02	0.08	0.77	0.17
2009-10	0.03	0.06	1	0
2010-11	0.17	0.08	0.79	0.19
2011-12	0.09	0.05	0.76	0.17
2012-13	0.28	0.07	1	0
2013-14	0.25	0.12	0.95	0.06

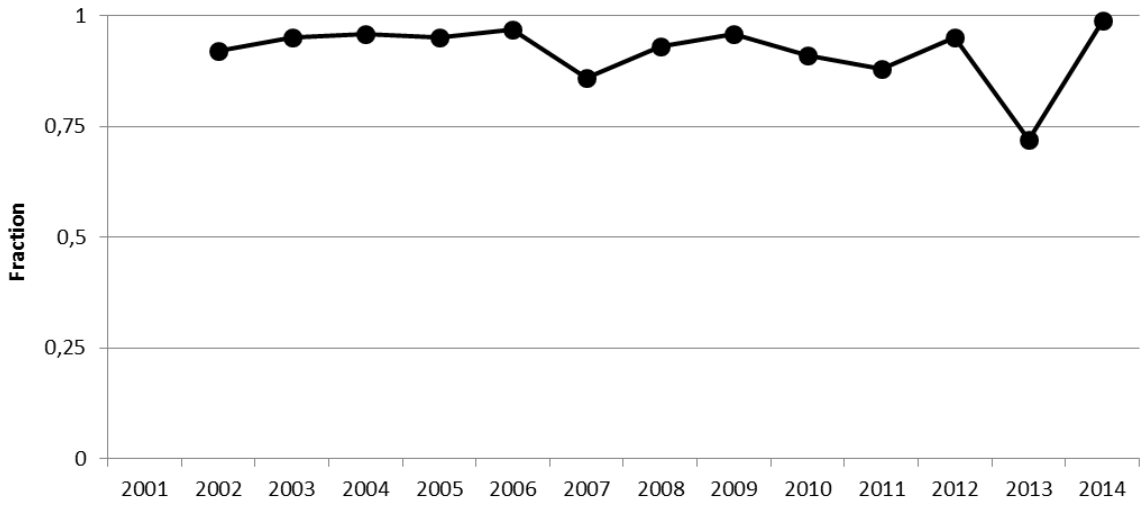


Figure 33: Bottlenose dolphin juvenile survival rates in Cardigan Bay SAC, using an open population model, between 2001 and 2014

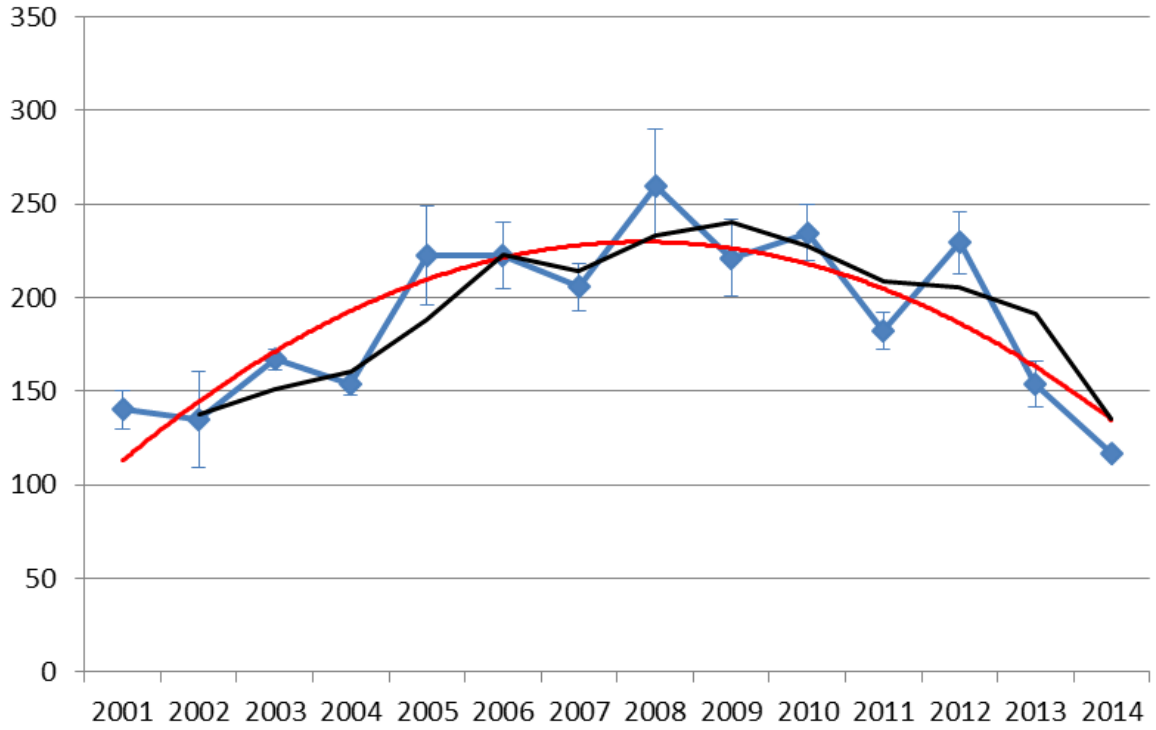


Figure 34: Population trend for bottlenose dolphins in Cardigan Bay SAC for the years 2001-14, obtained using a closed population model and an average survival rate of S=0.593.
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

Table 15: Population estimates for bottlenose dolphins in Cardigan Bay SAC for the years 2001-14, 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

Population estimates for the wider Cardigan Bay were made using the robust open model. Only data from 2005-14 will be presented for this purpose since coverage in Pen Llŷn a'r Sarnau SAC was more regular during these years. A peak of 222 individuals was reached in 2007, and 232 in 2012 (Table 16). Since then, a general decline in the population size appears to have occurred, with 167 in 2013 and 126 in 2014, the lowest value in the last ten years (Figure 35). The smooth polynomial function and the moving average trend line both indicate a recent decrease after an earlier increase in population estimate (Figure 35).

Table 16: Population estimates for bottlenose dolphins in the wider Cardigan Bay for the years 2005-14, obtained using an open population model, and 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

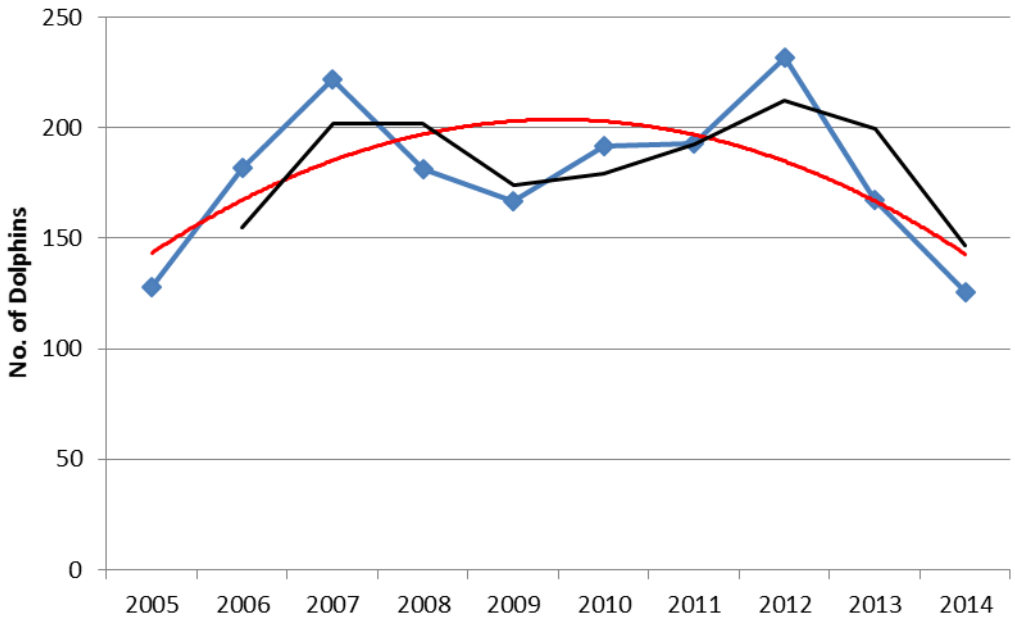


Figure 35: Population trend for bottlenose dolphins in the wider Cardigan Bay for the years 2005-14, obtained using an open population model
blue line –whole population estimate; red line – polynomial trend; black line – moving average trend

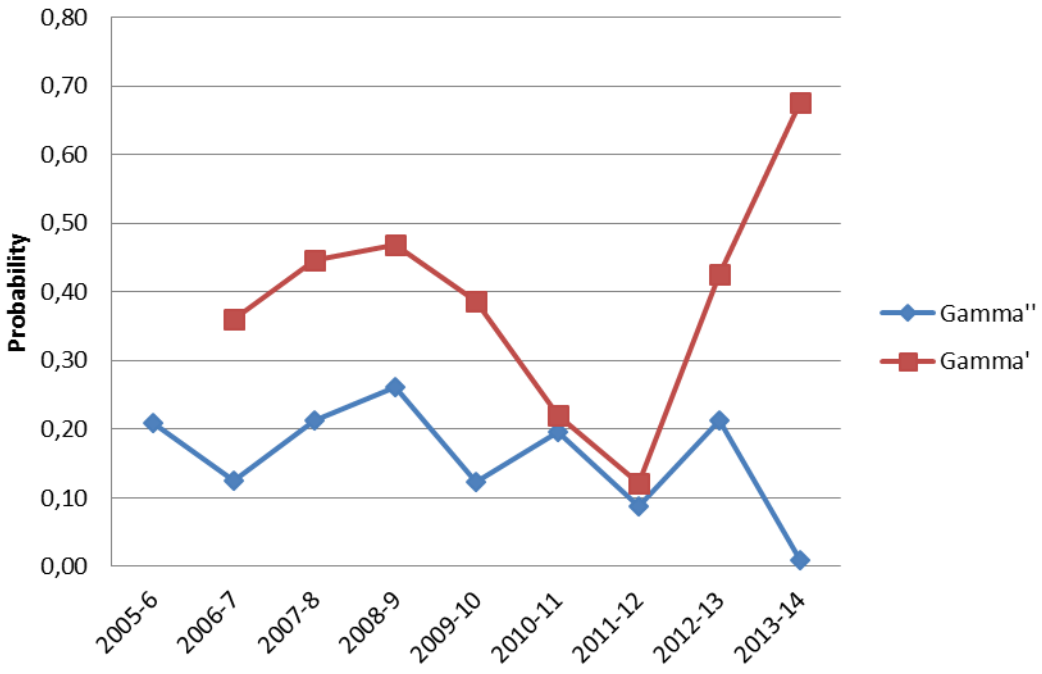


Figure 36: Bottlenose dolphin residency patterns in the wider Cardigan Bay, using an open population model (gamma" is the probability of an animal emigrating out of the study area;
gamma' is the probability of an animal staying out of the study area)

Bottlenose dolphin residency patterns in the wider Cardigan Bay show marked changes between 2005 and 2014 (Figure 36). Similarly to Cardigan Bay SAC, a general decrease in emigration rates can be seen in the whole of Cardigan Bay, with a very low rate of less than 1% in 2013-14 (Table 17). Interestingly, whereas the probability of remaining out of the Bay declined steadily between 2008-09 and 2011-12, it has risen sharply since then (Figure 36).

Table 17: Standard Errors for bottlenose dolphin residency patterns in the 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)

Period	Gamma''	Standard Error	Gamma'	Standard Error
2005-6	0.210	0.048		
2006-7	0.125	0.034	0.360	0.126
2007-8	0.213	0.039	0.446	0.122
2008-9	0.261	0.044	0.469	0.092
2009-10	0.123	0.035	0.386	0.080
2010-11	0.196	0.039	0.221	0.085
2011-12	0.087	0.000	0.122	0.000
2012-13	0.213	0.000	0.426	0.000
2013-14	0.009	7.297	0.676	1.488

Population estimates were also determined for all of Cardigan Bay using the mark-recapture closed population model, taking into account of the average marked proportion of individuals (61%) (Table 18, Figure 37). A steady increase was observed in the earlier years, from 210 in 2005 rising to 310 in 2008. However, since then there has been a steady decline reaching a low of 152 in 2014.

Together, these results suggest that over Cardigan Bay as a whole, the bottlenose dolphin population has been declining in recent years. At first, emigration was transient but since 2011, animals appear to be leaving the Bay increasingly on a more permanent basis. Within Cardigan Bay SAC, the population has also been declining recently. In this case, however, there has been a general trend (though with fluctuations between years) of more permanent emigration from 2001 onwards.

5.8 Home Ranges

Since 2007, survey effort extended to North Wales, particularly around the Isle of Anglesey, and it is now well established that individually identifiable bottlenose dolphins from Cardigan Bay can be seen regularly at least on a seasonal basis there and around the Isle of Man (Pesante *et al.*, 2008a, b; Veneruso & Evans, 2012a, b, Feingold & Evans, 2013c, 2014a, b).

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

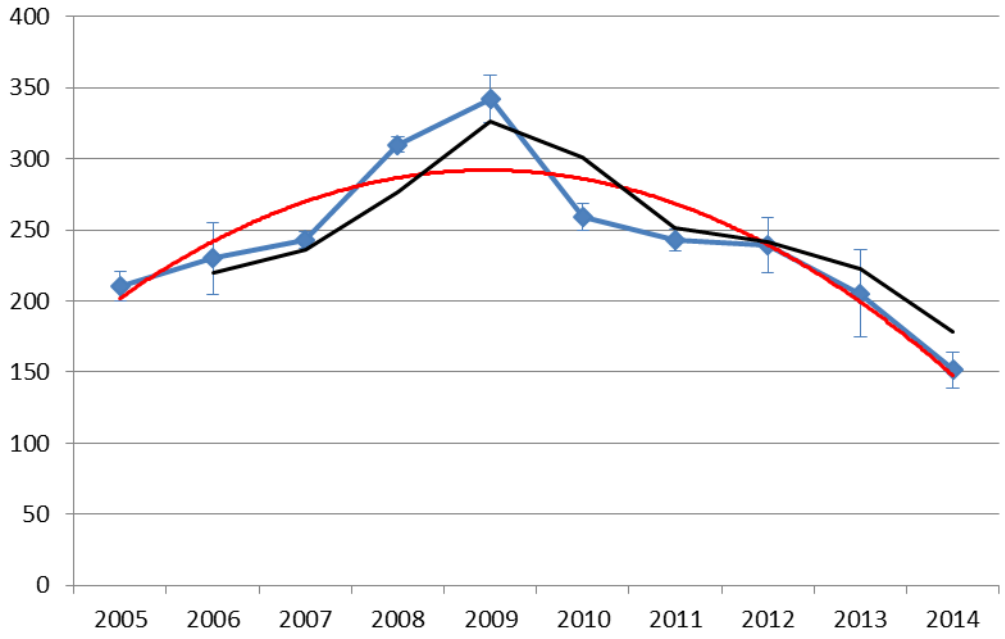


Figure 37: Population trend for bottlenose dolphins in the wider Cardigan Bay for the years 2005-14, obtained using a closed population model
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

An analysis of bottlenose dolphin home ranges using photo ID data from 221 dolphins sighted since 2007 showed that 64% (141/221) of individuals were recorded in both Cardigan Bay SAC and areas in North Wales and beyond (including the Isle of Man) and 78% (172/221) of individuals recorded in one of the two SACs within Cardigan Bay also occurred in North Wales (Feingold & Evans, 2014b; Figure 38). Around 40% have been identified in both SACs and in North Wales and beyond. Nearly 26% were seen in Cardigan Bay SAC and North Wales, but not in Pen Llŷn a'r Sarnau SAC, most probably due to lower coverage in

this SAC, particularly in the offshore area. Some individuals exhibited localised home ranges, with 7% of individuals sighted only in Cardigan Bay SAC, 3% seen only in the Pen Llŷn a'r Sarnau SAC, and 8%only in North Wales (north of the Llŷn Peninsula). Forty-five individuals from the SWF catalogue have been recorded off the Isle of Man. During a first dedicated survey in Liverpool Bay, in July 2013, nine (50%) of the individuals in the encounter were matched to the SWF catalogue, strengthening the hypothesis of further migration outside of Welsh waters. It is clear from these results that the majority of the bottlenose dolphin population have large home ranges encompassing all of Cardigan Bay and North Wales, and possibly also all of the northern Irish Sea, although a proportion of the population appears to be relatively site faithful with small home ranges. These more sedentary animals may occur in any part of the study area, and not solely within Cardigan Bay SAC.

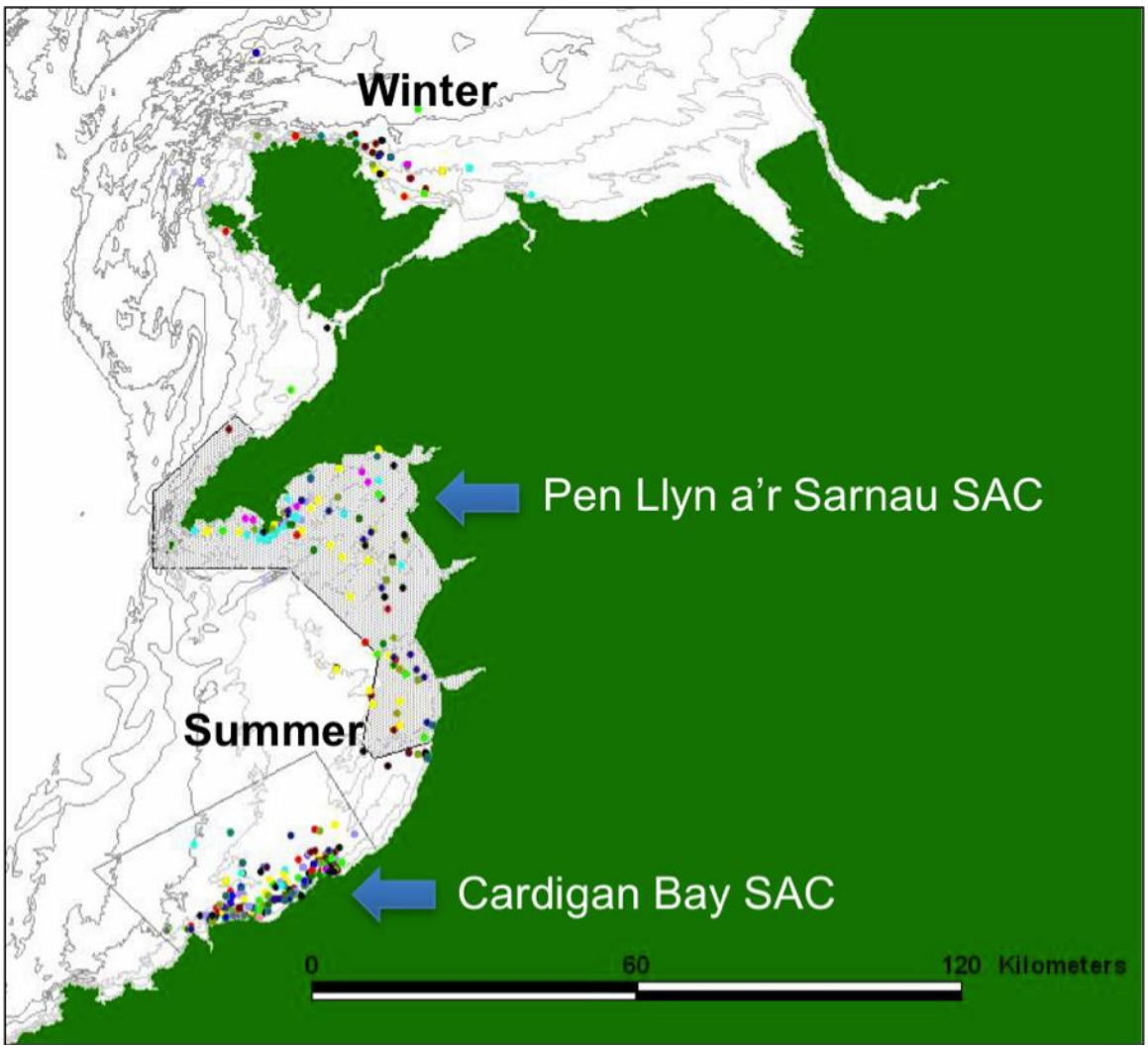


Figure 38: Home Range Patterns of Bottlenose Dolphins in Welsh Waters

Figure 39: Attack sequence by bottlenose dolphin upon harbour porpoise, Cardigan Bay SAC, 13th June 2014

5.9 Bottlenose Dolphin Attacks on Harbour Porpoise

Attacks by bottlenose dolphins upon harbour porpoise in Wales were first recorded in 1991, and since then, have become the most common known cause of mortality for porpoises, at 22% (Jepson & Baker, 1998; Evans & Hintner, 2010; Deaville & Jepson, 2011). Numbers of deaths caused by dolphin attacks rose sharply, reaching a peak in 2004, but since then has declined steadily (Penrose, 2014). Some of this decline, however, may be due to reduced funding for conducting post mortems (R. Penrose, *pers. comm.*). Only two cases were recorded during 2013, both in Cardigan Bay (Penrose, 2014).

In 2014, a porpoise was observed by Sea Watch staff and volunteers, being attacked by a bottlenose dolphin just south of New Quay on 13 June (see Figure 39). Its fate was not confirmed although a moderately decomposed porpoise with evidence of a dolphin attack was recovered at sea off New Quay on 18 June, presumed to be the same individual. The attacker of the porpoise on 13 June could not be identified. However, other attacks were observed by personnel from the Cardigan Bay Marine Wildlife Centre, and associated individuals were identified. On 22 May, a porpoise was chased by two dolphins onto Dolau beach at New Quay (successfully refloated). A third dolphin was seen in the vicinity and identified as Chris (004-90W), a mature female with a 3-year old calf. It is not clear whether it was actually involved in the attack, however.

On 7 July, three dolphins were observed attacking a porpoise off Ynys Lochtyn, one of which was believed to be Effy (223-09S) of unknown sex. And then on 30 July, a further attack was observed on a porpoise by two dolphins, identified as Bond (074-03W) and Voldemort (023-03), the first a known male and the second a possible (but unconfirmed) male.

5.10 Body Condition

Underweight and injured dolphins have occasionally been observed during Sea Watch Foundation research surveys and from images sent to us by others (Feingold & Evans, 2014a).

During 2014, no underweight individuals were observed, but an unidentified bottlenose dolphin with an assumed propeller cut on its peduncle was photographed off North Wales on 21 May (Figure 40). An unidentified individual with a nick in exactly the same location on the peduncle was photographed off Anglesey on 13 Jan 2013.

Figure 40: Top: An injured dolphin photographed off North Wales on 21st May 2014. Bottom: Possibly the same individual seen in the same region in 2013

Strandings of bottlenose dolphins are rare, with only 48 recorded in Wales since 1990 (an average of just two a year, mainly in July and August) (Penrose, 2014). On 3 May 2014, an adult male bottlenose dolphin (3 m length) was found dead at Hell's Mouth, Llŷn Peninsula. Cause of death was asphyxiation, a probable brill (*Scopthalmus rhombus*) of >30cm length found blocking its gullet. The stomach was full of fish, and species identified from photographs included common sole (*Solea solea*), red gurnard (*Aspitrigla cuculus*), and a salmonid thought to be Atlantic salmon (*Salmo salar*). Within the SWF Photo ID catalogue, we identified the animal as 128-02S (Figure 41), first identified in 2002 and recorded every year since then. It has been photographed mainly within Cardigan Bay SAC, but has also been photographed in Pen Llŷn a'r Sarnau SAC, off Anglesey, and the Isle of Man. It acquired the second upper nick in 2009.

Figure 41: Left: A dolphin that choked on a fish, found at Hell's Mouth, Llŷn Peninsula on 3rd May 2014. Right: The same individual photographed in Cardigan Bay on 26th Sept 2011

A bottlenose dolphin neonate (female, 1.46m length) was found dead near Barmouth on 20 August (cause of death unknown as it was in an advanced state of decomposition), and a second neonate was found dead near Pwllheli on 14 September.

6. Discussion & Conclusions

6.1 Survey sighting rates

Twenty-three (18 line-transect & 5 *ad-libitum*) dedicated surveys were undertaken in Cardigan Bay during summer 2014, covering 2,767 km of effort. These resulted in sighting rates for bottlenose dolphin of 0.028/km and for harbour porpoise of 0.011/km. The average

sighting rate for bottlenose dolphin in 2013-14 (0.0315/km) represents a 16% reduction compared with 2011-12 (0.038/km), and a 30% reduction compared with 2005-07 (0.045/km) (Pesante *et al.*, 2008b; Feingold & Evans, 2014a). The average sighting rate for harbour porpoise in 2013-14 (0.021/km) represents an 11% reduction compared with 2011-12 (0.0265/km), and a 56% reduction compared with 2005-07 (0.0475/km).

Although absolute abundance estimates for bottlenose dolphin from Distance sampling were not obtained in 2014, in previous years they had also yielded a sustained declining trend from a high in 2006 to the lowest estimate in 2013 (Feingold & Evans, 2014a). Harbour porpoise numbers were highest in 2011 and lowest also in 2013 (Feingold & Evans, 2014a).

Seasonal patterns of sighting occurrence have varied greatly between years, although peaks in any single year between 2011-14 have been in the first half of the season, between April and July. In 2014, sighting rates were much lower after June. This suggests a movement out of the Bay in the latter half of the season, possibly due to a deterioration in feeding conditions.

6.2 Group Sizes

Average group size of bottlenose dolphins in Cardigan Bay was 4.3 in 2014, showing little variation across the years 2001-14 (long term average = 4.2), with most groups consistently numbering 1-5 individuals, and few numbering over ten individuals. This contrasts with the average group size in winter (Nov-Mar) of 26.4 individuals around North Wales (mainly Anglesey), where group sizes range up to c. 100 individuals (Feingold & Evans, 2014b). The highest average group sizes in Cardigan Bay occurred either in spring (April & May) or autumn (October), and were generally lower between June and August. Calving occurs particularly between July and September (see section 5.7), and smaller group sizes around mid- to late summer may be related to this, as has been found elsewhere (Reynolds *et al.*, 2000). Average group sizes have been consistently higher in northern Cardigan Bay than in Cardigan Bay SAC, suggesting that the two areas may be used slightly differently (see also Feingold & Evans, 2014a).

6.3 Distribution Patterns

During summer 2014, bottlenose dolphins were distributed throughout Cardigan Bay, with a number of offshore sightings outside the two Special Areas of Conservation. The use of the offshore area in central and northern Cardigan Bay appeared to be greater in 2014, with a general increasing trend since 2011 (Feingold & Evans 2014a). Within Cardigan Bay SAC they were concentrated in the coastal sector between New Quay and Cemaes Head, but largely offshore north of New Quay. This follows the same pattern as in previous years (Baines *et al.*, 2002; Ugarte & Evans, 2006; Pesante *et al.*, 2008b; Feingold & Evans, 2014a).

Ad-libitum and platform of opportunity surveys took place in the coastal sector of Cardigan Bay SAC between New Quay and Cardigan on a regular basis, most sightings occurring off New Quay headland, Ynys Lochtyn, and between Pen Peles and Mwnt. These same areas were identified as hot spots in previous years (Feingold & Evans, 2014a).

Harbour porpoises and grey seals were also widely distributed within Cardigan Bay, although harbour porpoises were observed mainly offshore and grey seals close inshore. However, as noted above, relatively low numbers of sightings of these two latter species occurred in 2014 compared with previous years.

Previously, other centres of activity have been found in the north of Cardigan Bay, and included Tremadog Bay and around the reefs and sandbanks of Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy (Feingold & Evans, 2014a). However, in 2014, there were relatively few sightings and no obvious area of high usage.

6.4 Activity budgets

Throughout Cardigan Bay, the predominant bottlenose dolphin behaviour observed in any year has been either travel or feeding/foraging (Pesante *et al*., 2008b; Feingold & Evans, 2014a).

Within Cardigan Bay SAC, previous behavioural budgets (along with T-POD acoustic monitoring) have confirmed that a high proportion of dolphins are feeding in the coastal strip, particularly at certain locations such as New Quay Head, Ynys Lochtyn, Aberporth Head, and Mwnt (Lewis & Evans, 1993; Baines *et al*., 2000; Pesante *et al*., 2008b; Feingold & Evans, 2014a). In 2014, feeding/foraging was the predominant behaviour in just 26% of encounters, the lowest since 2006, suggesting that food may have been particularly scarce this year.

In Pen Llŷn a'r Sarnau SAC, Feingold & Evans (2014a) noted consistently higher percentages of 'socialising' events (north *vs* south: 29% *vs* 20% in 2011; 21% *vs* 14% in 2012; and 25% *vs* 7% in 2013), suggesting the northern part of the Bay may be used as a mating and socialising ground for the population whereas the southern areas are used more for feeding and as a nursery area. In 2014, 'socialising' was the predominant behaviour in 7% of encounters in the north and 3% in the south. No foraging/feeding was actually observed during any of the encounters in this SAC during 2014.

6.5 Reproductive & Mortality Rates

As noted earlier, Cardigan Bay SAC is considered an important nursery area for bottlenose dolphins, with around 50% of groups. Feingold and Evans (2014a) noted, however, that the whole of Cardigan Bay is an important area for mothers and calves, with some females with calves being sighted only in the northern part of the Bay.

The number of newborns recorded across all of Cardigan Bay in both 2013 and 2014 was six, equalling the lowest values since 2005 when surveys extended across the wider region. In 2014, one of the newborns was seen only in northern Cardigan Bay.

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

Location	Crude birth rate	Source
Eastern Australia	1.2	Lear & Bryden, 1980
North Adriatic, Croatia	4.9	Bearzi *et al*., 1997
Cardigan Bay SAC (closed)	**5.2**	**This study (01-14)**
Sado Estuary, Portugal	5.4	Gaspar, 2003
Sarasota Bay, Florida	5.5	Wells & Scott, 1990
Moray Firth, Scotland	6.0	Wilson *et al*., 1999
Doubtful Sound, New Zealand	6.6	Haase & Schneider, 2001
Cardigan Bay, Wales (closed)	**6.4**	**This study (05-14)**
Southern California	7.2	Hansen, 1990
Cardigan Bay SAC, Wales (open)	**7.5**	**This study (01-14)**
Northern Gulf of Mexico	7.7	Leatherwood, 1977
Florida	8.2	Irvine *et al*., 1981
Cardigan Bay, Wales (open)	**8.5**	**This study (05-14)**
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 population estimates with both a closed and open model (5.2%, 7.5% respectively) and for the whole of Cardigan Bay (6.4%, 8.5% respectively). These are similar to the estimated mean birth rate (6.0%) of the semi-resident population in the Moray Firth (Table 19; Wilson *et al.*, 1999; Grellier, 2000; Thompson *et al*., 2004). The calculated birth rates for Cardigan Bay SAC in 2014, however, were just 4.3% (closed model), and 4.85% (open model), i.e. reductions of 18% and 35% respectively from the long-term average, continuing a declining trend observed since 2011.

Similarly, for the whole of Cardigan Bay the birth rates for 2014 were 3.95% (closed model), and 4.8% (open model), representing reductions of 38% and 44% respectively from the long-term average. The last two years (2013 and 2014) are the only years since 2005 when birth rates have been lower in the wider Cardigan Bay compared with the Cardigan Bay SAC.

The mean inter-birth interval in Cardigan Bay between 2001 and 2014 is around three years, similar to other studies of the species (Table 20).

No new information was obtained in 2014 on juvenile mortality rates, 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).

Sixty percent of calves survive into their fourth year. Bottlenose dolphin calves in Cardigan Bay tend to leave their mother by the fourth year and are no longer recognisable as individuals until they have acquired markings useful for Photo ID.

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

Location	Mean (years)	Range (years)	Source
North Carolina, USA	2.9	2-7	Thayer, 2008
Doubtful Sound, New Zealand	3.0	2-5	Haase & Schneider, 2001
Natal, South Africa	3.0	2-6	Cockcroft & Ross, 1990
Moray Firth, Scotland	3.2	3-6	Mitcheson, 2008
Cardigan Bay, Wales	**3.3**	**2-7**	**This study**
Shark Bay, Australia	4.1	3-6	Connor *et al*., 2000
Sarasota Bay, Florida	5.4	2-11	Wells & Scott, 1999

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

Location	First year	Second Year	Third Year	Source
North Carolina, USA	11%	-	-	Thayer, 2008
Indian & Banana rivers, Florida	11%	-	-	Hersh *et al*., 1990
Cardigan Bay, Wales	**15%**	**17%**	**7%**	**This study**
Sarasota Bay, Florida	19%	-	-	Wells & Scott, 1990
Doubtful Sound, New Zealand	20%	-	-	Haase & Schneider, 2001
Natal, South Africa	22%	-	-	Cockcroft *et al*., 1989
Shark Bay, Australia	29%	18%	3%	Mann *et al*., 2000

6.6 Calving Season

The calving season between 2001 and 2014 (corrected for the number of identified females per month) occurs mainly during the summer months, with the majority of newborns (76%) observed between July and September. A similar calving season is observed in the Moray Firth bottlenose dolphin population (Grellier, 2000).

6.7 Photo ID, and Population Estimates using Mark-Recapture

The Welsh Photo ID catalogue currently holds a minimum of 382 individuals (four more than in 2013). However, the number of bottlenose dolphins identified in Cardigan Bay has decreased by around 50% over the last four years, from 197 in 2011, 200 in 2012, 161 in 2013 and 101 in 2014.

A discovery curve of marked individuals indicates that, since 2008, the majority of marked dolphins in Cardigan Bay have been photographed and identified. New dolphins tend to be juveniles that were previously unmarked; however, some dolphins added to the catalogue in recent years (including in 2014) were those inhabiting North Welsh waters, specifically the Anglesey area.

From individual re-sightings of bottlenose dolphins in the wider Cardigan Bay, the population can be described as a combination of residents (53-63%), occasional visitors (20-29%), and transients (17-19%). Residency patterns were calculated also for Cardigan Bay SAC alone, and showed lower percentages of resident individuals (38-44%) and higher percentages of transient dolphins (35%), suggesting that a larger proportion of the population is resident to the whole of the Bay but does not necessarily frequent the southern SAC. Feingold & Evans (2014a) noted a much higher residency figure (58%) within Cardigan Bay SAC between 2001-07, suggesting that in recent years a greater proportion of animals are leaving the area.

Population estimates using mark-recapture have been obtained every year within Cardigan Bay SAC since 2001. Using a robust open population model, there is indication of an increase from 2001 to a peak of c. 165 individuals in 2007 and since 2012, a decline from a similar number down to c. 100 individuals in 2014. A general increase in the probability of permanent emigration from Cardigan Bay SAC was revealed over the fourteen years of the study. The analysis was repeated using a closed population model and gave a similar general trend with an increase, peaking at 260 individuals in 2008, and then steadily declining to only 116 individuals in 2014, the lowest value since the study started in 2001.

Population size estimates for bottlenose dolphins for Cardigan Bay as a whole have been made since 2005, when survey coverage was extended to Pen Llŷn a'r Sarnau SAC. Estimates derived from an open population model indicate a general increase from 128 individuals in 2005 to 222 in 2007 and 232 in 2012, declining to 126 in 2014, the lowest value in the last ten years. Applying a closed population model, a steady increase was observed from 210 in 2005 to 310 in 2008, since when there has been a steady decline reaching a low of 152 in 2014. Thus although the different modelling approaches produce different overall estimates, they follow the same trend, with an apparent increase in earlier years followed by a decline most recently. At first, emigration has been transient but since 2011, animals appear to be leaving the Bay increasingly on a more permanent basis.

Several lines of evidence (lower population sizes, disappearance of marked individuals out of the Bay with re-sightings off North Wales, low birth rates, etc) thus suggest that Cardigan Bay is less favourable for bottlenose dolphins than it was in 2007-08. Prey availability may be a cause for this but it is also possible that local anthropogenic activities (vessel disturbance or scallop dredging) are contributory factors (Feingold & Evans, 2014a). At present, it is not possible to say. There is clearly a need for consistent monitoring to be undertaken throughout the Bay, and a more in depth study of food availability and possible effects of anthropogenic activities in the region.

6.8 Home Ranges

Over the years, since monitoring started in 2001, survey effort has increased. Between 2001 and 2005, effort was concentrated within Cardigan Bay SAC. From 2005, it was extended to cover Pen Llŷn a'r Sarnau SAC south of the Llŷn Peninsula, and from 2011, offshore areas of Cardigan Bay were also surveyed. Effort in Cardigan Bay, however, has not been consistent across years, lack of resources between 2008 and 2010 leading to much reduced effort.

Since 2007, survey effort extended to North Wales, particularly around the Isle of Anglesey. This established that individually identifiable bottlenose dolphins from Cardigan Bay can be seen regularly there and around the Isle of Man particularly in winter (Pesante *et al.*, 2008a, b; Veneruso & Evans, 2012b, Feingold & Evans, 2013, 2014b).

Part of the population appears to be relatively site faithful with small home ranges: 7% of individuals have been sighted only in Cardigan Bay SAC, 3% only in the Pen Llŷn a'r Sarnau SAC, and 8% only in North Wales (north of the Llŷn Peninsula). Should survey effort be increased in North Wales and extended to other parts of the Irish Sea, it may well be that further groups of individuals with localised distributions also exist.

On the other hand, an analysis of home ranges of 221 bottlenose dolphins sighted since 2007 found that 64% had been recorded in Cardigan Bay SAC as well as in areas around North Wales and the Isle of Man east into Liverpool Bay, whilst 78% recorded in one of the two SACs within Cardigan Bay had also occurred around and beyond North Wales (Feingold & Evans, 2014b). With a number of animals from Cardigan Bay seen also around the Isle of Man and in Liverpool Bay, it is clear that migration occurs outside of Welsh waters. Indeed, the majority of the Cardigan Bay population appears to have large home ranges that extend to North Wales, and possibly also all of the northern Irish Sea (although not yet observed outside the Irish Sea – Pesante *et al.*, 2008a, b; Feingold & Evans, 2014a, b).

This emphasises the need to intensify photo-ID coverage beyond Cardigan Bay SAC (where currently it remains greatest) if one is to better understand bottlenose dolphin home ranges within the Irish Sea, and ensure this EU Habitats Directive Annex II species is maintained at Favourable Conservation Status.

Sightings around Anglesey initially were more or less confined to between October and April. However in the last few years, dolphins that were once recorded during summer in

Cardigan Bay are being seen in North Wales and the Isle of Man at that time, coinciding with the mark-recapture results that indicate recent permanent emigration from Cardigan Bay of part of the population.

6.9 Bottlenose Dolphins Attacks on Harbour Porpoise

Although attacks by bottlenose dolphins represent the most common known cause of mortality for porpoises in Wales (Jepson & Baker, 1998; Evans & Hintner, 2010; Deaville & Jepson, 2011; Penrose, 2014), since 2004 the frequency appears to have declined, and only two cases were recorded in 2013.

Despite a large amount of survey effort within Cardigan Bay since 2001, only one attack had actually been seen until 2014 when four attacks were observed between May and July, all within a small area between New Quay and Ynys Lochtyn. Known identified attackers have all been adult males (as was the case with an attack observed and photographed by the last author in Red Wharf Bay, East Anglesey on 28 Feb 2008; in that instance one of the attackers was identified as Dusky, 085-03W, which had been observed on 7 June 2006 in a group attacking a porpoise off Aberystwyth).

The reason why bottlenose dolphins attack porpoises is not known, but one possible explanation is that they encounter one another when foraging after the same prey, leading to interference competition (Spitz *et al*., 2006).

6.10 Body condition

Between 2011 and 2013, eight clearly underweight dolphins were observed in Cardigan Bay, four of which were identified as females with calves (Feingold & Evans, 2014a). Most of these were in 2011 when birth rates in the Bay peaked. No underweight dolphins were observed, however, in 2014.

One injured individual was observed off the North Wales coast in May 2014, the injury resembling a propeller cut on the peduncle, and matching an unidentified individual observed off Anglesey in Jan 2013. The only other individual with an injury observed in 2011-13 (Feingold & Evans, 2014a) and re-sighted in 2014 was 035-03W, which was first observed in 2007 with a deep indentation on the dorsal surface of the tailstock but since then has been seen regularly including with a calf so does not appear to have been seriously affected. It was seen off Anglesey in April 2014 although the tail was not photographed.

An average of two bottlenose dolphins have stranded on the coast of Wales between 1990 and 2013 (Penrose 2014). In 2014, there were three strandings, two of which were neonates and the third an adult male that had been recorded annually in Cardigan Bay since at least 2002, and which was found asphyxiated on a >30cm brill in May. This latter stranded at Hell's Mouth, Llŷn Peninsula, whilst the neonates stranded at Barmouth and Pwllheli respectively.

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9. Appendices

Appendix 1: Student Projects – Thesis Abstracts

Akritopoulou, E. (2014) Investigation of spatio-temporal trends in skin lesions of bottlenose dolphins in Wales. MSc thesis, University of Bangor. 83pp.

Over the last 20 years, skin lesions in different populations of bottlenose dolphins have been studied worldwide via photo-ID techniques. The classification of skin lesions on bottlenose dolphins have been categorised according to their colour and texture in several studies. Climate change and anthropogenic activities seem to contribute in the appearance and development of skin lesions and diseases. The prevalence of skin lesions on the species has been used among others as a health indicator. The Welsh population of bottlenose dolphins is larger than the populations from the Moray Firth and Shannon Estuary. Cardigan Bay is one out of two main UK coastal areas used by semi-resident bottlenose dolphin populations and with the highest abundance.

The aim of this study was to investigate the spatio-temporal trends of skin lesions on the Welsh dolphins for the period 2001-14 using photo-ID techniques, mainly in Cardigan Bay. The possible effect of age, gender, residency and Sea Surface Temperature (SST) on skin lesion prevalence and extent was explored.

Overall, 260 individuals were analysed for 15 skin lesion categories, out of which nine of them were mainly observed over time. Tooth rakes/scars (84%), white lesions (43.8%) and cloudy lesions (23.4%) were some of them. Additionally, 73% of the individuals were affected by at least one type of lesion and 56% of the population by more than two different types. The females were more prevalent to skin lesions during the period 2010-14 than males. In contrast to other studies, calves were more prevalent in skin lesions than adults. Also, no significant association was found in skin lesion prevalence between SST, different areas, and between resident, visitors and transient individuals.

The presence of DFS and WFS (lesions, out of which pox viruses and herpes viruses have been isolated in other studies) and the analysis of photographic data indicated possible presence of pox viruses and/or tattoo lesions in the Welsh dolphins. Therefore further systematic and quantitative study of the prevalence and extent of skin lesions is needed in order to assess better the patterns of skin lesions on this population. Accurate evaluation is essential for effective management towards the sustainability of this important population.

Hudson, T.A. (2014) Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc thesis, University of Bangor. 72pp.

The bottlenose dolphin (*Tursiops truncatus*) is a widely distributed social species. As a consequence of human population growth, anthropogenic activities are intensifying in coastal areas, leading to a higher probability of interactions with wildlife. Vessel activities in inshore waters are of particular concern, as these are often significant feeding and nursery grounds. Vessel intrusion may lead to both short and long-term consequences, which affect dolphins at an individual and population level. It is debated whether dolphins respond to vessel activities and what features i.e. vessel behaviour, type and distance, may cause this response to occur.

Vessel and dolphin activities were monitored throughout June and July in New Quay Bay, mid Wales when vessel traffic was approaching its annual peak. Land-based observations were conducted at two locations in the Bay, to assess differences in response behaviour. It was found that the majority (51.2%) of dolphins did not respond to vessel interactions. However, behavioural responses have significantly increased over the past five years, with more positive (18.9%) and negative responses (24.3%), including both vertical and horizontal evasion, recorded this year than previously (2010 to 2014). Comparisons of residency between individuals in the local population revealed that residents display a degree of habituation to specific vessels, thus resulting in fewer response behaviours. Surfacing interval decreased in the presence of vessels, with a greater effect on mother and calf pairs. In time of day and seasonal comparisons, as vessel activity increased, dolphin sightings decreased, showing that dolphins were engaging in short-term site avoidance. Short-term behavioural responses may develop into long-term consequences, such as reduced energy acquisition, lowered reproductive success, and site avoidance. This has the potential to result in an overall population decline, and this has been found in the population inhabiting Cardigan Bay SAC.

Massey, D. (2014) Whistle variations within the bottlenose dolphin population of Cardigan Bay, Wales. MSc thesis, University of Bangor. 57pp.

Bottlenose dolphins (*Tursiops truncatus*) live in fission-fusion societies and constantly use vocal cues to stay in contact with one another. Of all the sounds emitted by this species, whistles are the most studied and observed vocalisation due to their ease of analysing and categorising. Whistle variations have been studied in many different populations and have been observed to change depending on specific environmental and biological factors. Similarities have also been observed between groups of dolphins due to individuals mimicking whistle characteristics. A study was conducted looking at the whistle variations of the bottlenose dolphin population in Cardigan Bay by combining acoustic data that was taken for three consecutive summers. This data was collected from a combination of *ad libitum* and line-transect surveys and multivariate analysis was used to assess if differences did occur between groups of dolphins and if these differences were due to certain environmental or biological factors.

Whistles produced were similar between groups. However, non-parametric testing revealed that each whistle parameter was significantly different from one another between groups. Whistle characteristics such as beginning frequency and minimum frequency increased at greater depths while minimum frequency decreased and duration increased in larger groups. These differences could be due to the fact that high frequency whistles do not travel as far in deeper waters and that whistles have to travel a farther distance when dolphins are more dispersed. The presence of calves also revealed to effect whistle characteristics, especially whistle contour being more complex in lone mother-calf pairs. It can be concluded that whistle variation does occur in the Cardigan Bay bottlenose dolphin population. However, further studies are needed to get a better understanding of what is causing these variations and how other factors such as geographic location and season could effect whistle characteristics.

Stevens, A. (2014) A photo-ID study of the Risso's dolphin (*Grampus griseus*) in Welsh coastal waters and the use of Maxent modeling to examine the environmental determinants of spatial and temporal distribution in the Irish Sea. MSc thesis, University of Bangor. 97pp.

The Irish Sea is considered to be an area containing important habitat for the Risso's dolphin (*Grampus griseus*), and a number of distribution hotspots have been identified over the years.

The creation of a photo-ID catalogue and database enabled the identification of 144 individuals in Welsh waters, from which it was estimated that a minimum of 162 individuals were encountered from 2003 to 2014. The 32 mother-calf pairings observed suggest the importance of Welsh waters for mating and parturition. Site fidelity in terms of re-sighting rates was relatively low (12.5%), similar to that which has previously been observed around Bardsey Island.

An examination of home ranges by looking for matches between this catalogue and that of five other organisations from around the British Isles, showed individuals to occupy varying ranges. The most individuals (15) matched with the Whale and Dolphin Conservation (WDC) catalogue, indicating mostly localised home ranges, but evidence for large-scale migrations was also found with two matches with the Hebridean Whale and Dolphin Trust's (HWDT) catalogue. These results suggest that the Risso's dolphins seen in Welsh waters are part of an open population.

In order to gain a better understanding of the drivers of their distribution, sightings data were analysed with respect to environmental variables: habitat type, energy, bathymetry, slope, oceanic thermal fronts, salinity, sea surface temperature and chlorophyll α concentration. Using Maxent species distribution modelling, the most important environmental variables found to determine habitat suitability were bathymetry, chlorophyll α concentration and salinity. These factors affect primary production and prey abundance either directly or indirectly by influencing oceanographic features including upwellings, fronts and gyres. Chlorophyll α concentration and salinity are also particularly important in the fine scale

determination of prey aggregations. Slope was found to be the least important factor affecting distribution. In accordance with high sightings densities and predicted habitat suitability, the coastal waters around the Isle of Man, Anglesey, Bardsey Island and west Pembrokeshire are the areas identified to be the most important to Risso's dolphins. These areas should therefore be the focus of any future conservation and management strategies in the Irish Sea, to ensure the long-term protection and viability of the population.

Peña, A. Vergara (2014) Temporal changes in site usage by bottlenose dolphins (*Tursiops truncatus*) in New Quay Bay, Wales. MSc thesis, University of Bangor. 90pp.

The Welsh bottlenose dolphin *Tursiops truncatus* population is found in significant proportions in the southern zone of Cardigan Bay, which has been established as a Special Area of Conservation (SAC). Within the SAC, New Quay Bay is recognised as an important area for their population in the Welsh waters, with records dating back to the 1920s.

Despite the fact that New Quay Bay is part of the Cardigan Bay SAC, the increasing boat activities in the area and their possible effects on the presence and behaviour of bottlenose dolphins are presently a great concern. Therefore, this study aimed to investigate the changes in bottlenose dolphin presence in New Quay Bay over time, as well as to establish any temporal changes in site usage for recognisable individuals.

The population of bottlenose dolphin in New Quay Bay was largely found to be non-resident. This may be because the area chosen for analyses was not within the core area of an individual's home range zone. The change in occurrence of individuals can be related to the purpose of their visits to the bay, which is believed to be both a feeding and breeding area for bottlenose dolphin. Depending upon their reproductive status (reflected in particular characteristics such as gender, age, mother or presence of calves), some individuals will use some zones more than others or may use New Quay Bay either early or later in the summer.

Even though the present study observed a neutral reaction towards the presence of boats as a frequent behavioural pattern, studies of reactions towards boats are still quite subjective, since bottlenose dolphins are mostly underwater, which makes it very difficult to determine the behaviours and reactions under the water. Therefore, presence of boats and it's effects upon the dolphins should be analysed in more detail as it could be that an increase in boat activity is causing some individuals to spend less time in New Quay Bay, which encourages more individuals to be transient. If this is the case, further management actions should be taken in the area to fully protect the bottlenose dolphins.

Appendix 2: Primary Observer Sighting Form

Entered into PC □ Checked by ____________

Date:_________________ Type of trip: LT □ NLT □ Page:___of___ GMT or BST

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

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

Appendix 3: Independent Observer Sighting Form

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

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

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

Appendix 4: Effort Form

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

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

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

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

a. Data Archive Appendix

Data outputs associated with this project are archived at [NRW to insert relevant server pathway and / or reference numbers] on server–based storage at Natural Resources Wales.

The data archive contains: [Delete and / or add to A-E as appropriate. A full list of data layers can be documented if required]

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A full set of maps produced in JPEG format.

[E] A database named ‘Sea Watch Foundation photo ID database’ in Microsoft Access 2000 format.

[F] A full set of images produced in [jpg/tiff] format.

Metadata for this project is publicly accessible through Natural Resources Wales’ Library Catalogue http://194.83.155.90/olibcgi by searching ‘Dataset Titles’. The metadata is held as record no [NRW to insert this number]

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