Cyfoeth Naturiol Cymru
Natural Resources Wales

Bottlenose Dolphin Monitoring in Cardigan Bay, 2014 - 2016

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The authors declare that the work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The long-term monitoring programme was initiated and maintained by Sea Watch Foundation (SWF). The work presented here was largely funded by Natural Resources Wales (NRW), with project managers Charlie Lindenbaum (CL), Ceri Morris (CM) and Tom Stringell (TS); data were collected by Katrin Lohrengel (KL), Peter Evans (PE) and personnel from SWF listed in the acknowledgments. KL reviewed and collated data, and undertook the bulk of the analyses with input from PE, Graham Pierce and Camilo Saavedra. The report was written by KL and PE. CL, CM and TS edited and provided comment on draft and final versions. No animals were handled during this project. Photo-ID work was carried out under licence no. 71375:OTHSA2016.

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Mae'r adroddiad hwn yn crynhoi'r gwaith monitro ar ddolffiniaid trwynbwl a gynhaliwyd gan y Sefydliad Gwylio Môr rhwng 2014 a 2016 ar ran Cyfoeth Naturiol Cymru. Mae'r boblogaeth o ddolffiniaid trwynbwl sy'n byw o bryd i'w gilydd ym Mae Ceredigion yn un o ddwy brif boblogaeth arfordirol yn y DU. Y rhywogaeth yw prif nodwedd Ardal Cadwraeth Arbennig (ACA) Bae Ceredigion, ac mae hefyd yn nodwedd cymhwyso ar gyfer Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau yng ngogledd Bae Ceredigion, a ddynodwyd o dan Gyfarwyddeb Cynefinoedd y Gymuned Ewropeaidd. Mae angen monitro ac adrodd ynghylch cyflwr nodweddion Ardaloedd Cadwraeth Arbennig drwy roi gwybodaeth ynglŷn â dosbarthiad a helaethrwydd, deinameg y boblogaeth, paramedrau hanes bywyd, ac iechyd y rhywogaeth dan sylw.

Prif nod y contract hwn oedd monitro poblogaeth dolffiniaid trwynbwl Bae Ceredigion gan gynnwys Ardal Cadwraeth Arbennig Bae Ceredigion ac ardal ehangach Bae Ceredigion. Cynhaliwyd arolygon trawsluniau llinellol ac arolygon trawsluniau anlinellol pwrpasol ym Mae Ceredigion yn ystod 2014–16, er nad oedd cwmpas ardal yr arolwg yn 2014 wedi'i gwblhau ac nid oes amcangyfrif ar gael. Roedd hyn yn adeiladu ar arolygon systematig cynharach a oedd wedi cael eu cynnal gan y Sefydliad Gwylio Môr ers 2001 yn Ardal Cadwraeth Arbennig Bae Ceredigion, ac ers 2005 yng ngogledd Bae Ceredigion. Defnyddiwyd arsylwadau manteisgar gan gychod teithiau bywyd gwyllt er mwyn ychwanegu at wybodaeth hanes bywyd ac ymddygiadol.

Defnyddiwyd samplu pellter er mwyn casglu amcangyfrifon ynghylch helaethrwydd dolffiniaid trwynbwl yn Ardal Cadwraeth Arbennig Bae Ceredigion ac ardal ehangach Bae Ceredigion, yn seiliedig ar arolygon trawsluniau llinellol, yn ogystal â system adnabod drwy lun gan ddefnyddio dadansoddiad Dal-Marcio-Ailddal, yn seiliedig ar ddata a gasglwyd yn ystod yr arolygon trawsluniau llinellol a'r arolygon trawsluniau anlinellol pwrpasol. Ni chafwyd amcangyfrifon helaethrwydd yn benodol ar gyfer Ardal Gadwraeth Arbennig Pen Llŷn a'r Sarnau, gan fod cynllun yr arolwg wedi blaenoriaethu holl ardal Bae Ceredigion yn hytrach nag ardal lawn yr Ardal Cadwraeth Arbennig hon sy'n ymestyn i'r gogledd o Ben Llŷn ac i Fae Caernarfon.

Cynhyrchodd amcangyfrifon helaethrwydd yn seiliedig ar samplu pellter ar gyfer Ardal Cadwraeth Arbennig Bae Ceredigion amcangyfrif o 64 unigolyn (CI = 19-220; CV = 0.65) yn 2015 a 84 (CI = 44-160; CV = 0.33) yn 2016; ac ar gyfer ardal ehangach Bae Ceredigion, 277 (CI = 138-555; CV = 0.36) yn 2015, 289 (CI = 184-453; CV = 0.23) yn 2016. Dangosodd dadansoddiad o dueddiadau ddirywiad sylweddol mewn helaethrwydd ar gyfer y cyfnod 2001-16 yn Ardal Cadwraeth Arbennig Bae Ceredigion, ond ni chafwyd dirywiad sylweddol yn y blynyddoedd diwethaf (2007-2016). Dim ond ers 2011 y mae arolygon trawsluniau llinellol yn ardal ehangach Bae Ceredigion wedi cael eu cynnal, ac nid oeddent yn dangos unrhyw dueddiad arwyddocaol o ran helaethrwydd.

Mae'r catalog ffotograffau adnabod bellach yn cynnwys lluniau o isafswm o 379 unigolyn (248 wedi'u marcio, 120 unigolyn ochr chwith ac 131 unigolyn ochr dde). Cynhaliwyd dadansoddiadau gan ddefnyddio dulliau Dal-Marcio-Ailddal, a oedd yn ystyried cyfartaledd cyffredinol o 64% o unigolion wedi'u marcio yn Ardal Cadwraeth Arbennig Bae Ceredigion, a 66% yn ardal ehangach Bae Ceredigion.

Cynhyrchodd dadansoddiad Dal-Marcio-Ailddal o ddata ffotograffau adnabod ar gyfer Ardal Cadwraeth Arbennig Bae Ceredigion a oedd yn seiliedig ar fodel poblogaeth gaeedig amcangyfrifon o 107 (CI = 84–161; CV = 0.47) yn 2014, 146 (CI = 119–210; CV = 0.40) yn 2015, ac 147 (CI = 127–194; CV = 0.29) yn 2016. Cynhyrchodd amcangyfrifon poblogaeth gaeedig ar gyfer ardal ehangach Bae Ceredigion amcangyfrifon o 141 (CI = 117-262; CV = 0.57) yn 2014, 206 (CI = 171–278; CV = 0.28) yn 2015, ac 174 (CI = 150–246; CV = 0.30) yn 2016. Roedd yr amcangyfrifon a gofnodwyd yn 2014 ar gyfer Ardal Cadwraeth Arbennig Bae Ceredigion ac ardal ehangach Bae Ceredigion ar eu hisaf ers i arolygon systematig ddechrau yn 2001 yn Ardal Cadwraeth Arbennig Bae Ceredigion ac ers 2005 yn ardal ehangach y Bae. Ni nodwyd unrhyw duedd arwyddocaol mewn perthynas ag Ardal Cadwraeth Arbennig Bae Ceredigion rhwng 2001 a 2016, ond mae 90% o sicrwydd bod poblogaeth yr Ardal Cadwraeth Arbennig wedi dirywio dros y 10 mlynedd diwethaf (2007–2016)[1]. O ran

[1] Ar gyfer y cyfnod 2007 i 2016, arsylwyd tuedd negyddol sylweddol mewn addasiad model byd-eang ($F=10.17$, $p=0.013$), ond 89.8% yn unig o efelychiadau atchweliad llinol oedd yn negyddol (10.2% yn bositif) (h.y. mae 90% o sicrwydd o ddirywiad). Mae gwaith dadansoddi pellach o dueddiadau yn cael ei gynnal.

ardal ehangach Bae Ceredigion, cafwyd tuedd negyddol arwyddocaol dros y deng mlynedd ers 2007 pan gychwynnwyd yr arolygon a 80% o sicrwydd o ddirywiad ers 2011[2].

Mae'r cyfraddau geni crai sy'n seiliedig ar amcangyfrifon poblogaeth gaeedig Dal-Marcio-Ailddal wedi codi a gostwng dros y blynyddoedd, ond roeddent yn arbennig o isel yn 2016, ar lefel o 3.4% yn Ardal Cadwraeth Arbennig Bae Ceredigion a 2.9% ar gyfer ardal ehangach Bae Ceredigion. Roedd y cyfraddau geni yn 4.7% yn 2014 a 6.8% yn 2015 ar gyfer Ardal Cadwraeth Arbennig Bae Ceredigion, ac yn 4.3% (2014) a 5.8% (2015) ar gyfer ardal ehangach Bae Ceredigion.

Er mwyn asesu tueddiadau'r boblogaeth a newidiadau i gyrhaeddiad ei chynefin a'i helaethrwydd gyda digon o rym ystadegol, argymhellwn y dylid monitro holl ardal Bae Ceredigion gan ddefnyddio cyfuniad o ffotograffau adnabod a samplu pellter bob blwyddyn. Argymhellir hefyd fod y cwmpas yn cael ei estyn rywfaint, yn enwedig yn Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau, ac ardaloedd eraill yng Ngogledd Cymru y gwyddys bod dolffiniaid trwynbwl yn byw ynddynt

[2]Mae'r addasiad model byd-eang yn dirywio'n sylweddol ar y lefel 95%, ond dim ond tua 82% o'r 1000 o efelychiadau atchweliad llinol oedd yn negyddol (h.y. mae 82% o sicrwydd bod y boblogaeth wedi dirywio). Mae gwaith dadansoddi pellach o dueddiadau yn cael ei gynnal.

2. Executive Summary

This report summarises the bottlenose dolphin monitoring work conducted by the Sea Watch Foundation between 2014 and 2016 on behalf of Natural Resources Wales. The semi-resident population of bottlenose dolphins found in Cardigan Bay is one of two major coastal populations in the UK. The species is the primary feature of Cardigan Bay Special Area of Conservation (SAC), and also a qualifying feature of Pen Llŷn a'r Sarnau SAC in northern Cardigan Bay, designated under the EC Habitats Directive. There is a requirement to monitor and report on the condition of SAC features by providing information on distribution and abundance, population dynamics, life history parameters, and health of species in question.

The primary objective of this contract was to monitor the bottlenose dolphin population of Cardigan Bay including both Cardigan Bay SAC and the wider Cardigan Bay area. Line transect and dedicated non-line transect surveys were conducted in Cardigan Bay, 2014- 2016, although coverage of the survey area in 2014 was not complete and no estimate is available. This built upon earlier systematic surveys that had been undertaken by the Sea Watch Foundation since 2001 in Cardigan Bay SAC, and since 2005 in northern Cardigan Bay. Opportunistic observations from wildlife tour boats were used to supplement life history and behavioural information.

Bottlenose dolphin abundance estimates for Cardigan Bay SAC and the wider Cardigan Bay were obtained through distance sampling, based on line transect surveys, as well as through photo-identification using Capture-Mark-Recapture analysis (CMR), based on data obtained during both line transects and dedicated non-line transect surveys. Abundance estimates were not obtained specifically for the Pen Llŷn a'r Sarnau SAC as the survey design had prioritised coverage of the entire Cardigan Bay rather than the full area of this SAC which extends north of the Llŷn Peninsula into Caernarfon Bay .

Abundance estimates based on distance sampling for Cardigan Bay SAC produced an estimate of 64 individuals (CI = 19-220; CV = 0.65) in 2015 and 84 (CI = 44-160; CV = 0.33) in 2016; and for the wider Cardigan Bay, 277 (CI = 138-555; CV = 0.36) in 2015, 289 (CI = 184-453; CV = 0.23) in 2016. Trend analysis showed a significant decline in abundance for the period of 2001-2016 for Cardigan Bay SAC, but no significant

decline in recent years (2007-2016). Line transects surveys in the wider Cardigan Bay have only been conducted since 2011 and showed no significant trends in abundance.

The photo-ID catalogue currently holds images of a minimum of 379 individuals (248 marked, 120 left side and 131 right side individuals). Analyses were completed using CMR methods, and took into consideration an overall average of 64% of marked individuals in Cardigan Bay SAC, and 66% in the wider Cardigan Bay.

CMR analysis of photo-identification data for Cardigan Bay SAC based on a closed population model yielded estimates of 107 (CI = 84-161; CV = 0.47) in 2014, 146 (CI = 119-210; CV = 0.40) in 2015, and 147 (CI = 127-194; CV = 0.29) in 2016. Closed population estimates for the wider Cardigan Bay yielded estimates of 141 (CI = 117-262; CV = 0.57) in 2014, 206 (CI = 171-278; CV = 0.28) in 2015, and 174 (CI = 150-246; CV = 0.30) in 2016. Estimates recorded in 2014 for both Cardigan Bay SAC and wider Cardigan Bay were the lowest since systematic surveys began in 2001 in Cardigan Bay SAC and since 2005 in the wider Bay. There has been no significant trend for Cardigan Bay SAC between 2001 and 2016, but there is a 90% certainty that the population in the SAC has declined over the last 10 years (2007-2016)[3]. For the wider Cardigan Bay there has been a significant negative trend over the ten years since 2007 when surveys started and an 80% certainty of a decline since 2011[4].

Crude birth rates based on closed CMR population estimates have fluctuated over the years but were particularly low in 2016, at 3.4% in Cardigan Bay SAC and 2.9% for the wider Cardigan Bay. Birth rates were 4.7% in 2014 and 6.8% in 2015 for Cardigan Bay SAC, and 4.3% (2014) and 5.8% (2015) for the wider Cardigan Bay.

To assess population trends and changes in home range and abundance with sufficient statistical power, annual monitoring of the entire Cardigan Bay area using a combination of photo-identification and distance sampling is recommended. It is also advised that coverage is extended, particularly in the Pen Llyn a'r Sarnau SAC and other areas of North Wales that are known to be occupied by bottlenose dolphins.

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[3] For the period 2007 to 2016, a significant negative trend in global model fit (F=10.17, p=0.013) was observed, but only 89.8% of the linear regression simulations were negative (10.2% positive) (ie, 90% certainty of a decline). Further trend analysis is being carried out.

[4] The global model fit significantly declines at the 95% level, but only approximately 82% of the 1000 linear regression simulations were negative (ie, there is an 82% certainty that the population declined). Further trend analysis is being carried out.

3. Introduction

The UK is home to two semi-resident coastal populations of bottlenose dolphins, semi-resident being defined as a population where some seasonal and longer-term migration occurs but a core group returns to the same localities year on year. One of these populations is located in the Moray Firth, Scotland (Wilson *et al*., 1997, Thompson *et al*., 2004, Cheney *et al*., 2014) and the other in the coastal waters of Cardigan Bay, the latter historically being the larger (Evans and Pesante, 2008). The Shannon Estuary in Ireland hosts a small resident population (Ingram and Rogan, 2002, 2003; Mirimin *et al*., 2011), and there are small groups that inhabit the Sound of Barra, Inner Hebrides and waters around Southwest England. Much larger numbers of bottlenose dophins inhabit offshore waters along the Northwest European shelf edge (Evans *et al*., 2003, Reid *et al*., 2003; Hammond *et al*., 2013). It is thought that animals living off the edge of the continental shelf form a separate ecotype to the coastal populations (Evans & Teilmann, 2009; Mirimin *et al*., 2011; Oudejans *et al*., 2015).

Bottlenose dolphins are listed under Annex II of the EU Habitats and Species Directive (Council Directive 92/43/EEC), requiring spatial protective measures where critical habitat can be identified. There are two marine Special Areas of Conservation (SACs) in Cardigan Bay with bottlenose dolphin as a feature: Cardigan Bay SAC[5], where bottlenose dolphins are the primary feature, and Pen Llŷn a'r Sarnau SAC[6], where they are a qualifying feature. The species is also listed under Annex IV of the Directive, which requires strict protection for all European cetaceans using wider measures.

Some photo-ID has been undertaken by Sea Watch Foundation (SWF) on the Cardigan Bay bottlenose dolphin population since 1989. Regular dedicated surveys in the Cardigan Bay SAC only started in 2001 and have been maintained ever since largely due to funding by grants and contracts from the Countryside Council for Wales initially and more recently Natural Resources Wales. Monitoring was extended to northern Cardigan Bay in 2007, and systematic line transect surveys began there in 2011.

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[5] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013117

[6] http://jncc.defra.gov.uk/ProtectedSites/SACselection/sac.asp?EUCode=UK0012712

Distribution and abundance of bottlenose dolphins in Cardigan Bay

Abundance estimates have varied over the years, but it is evident that Cardigan Bay and specifically Cardigan Bay SAC, remain important UK habitats for bottlenose dolphins, with large numbers of animals inhabiting the area particularly in the summer months (Ugarte and Evans, 2006; Pesante *et al*., 2008; Feingold and Evans, 2014a; Norrman *et al*., 2015). Although photo-ID data suggest that at least 42 individuals in the Cardigan Bay photo-ID catalogue move north towards the Isle of Man and around Liverpool Bay during the winter months, a proportion of the population (estimated at c. 7%) has only been recorded within Cardigan Bay SAC (Pesante *et al*., 2008a, b; Feingold and Evans, 2013a, b, Lohrengel *et al*., 2014).

The Isle of Man is the northernmost confirmed limit of this population's range (based on photoID matches) but it is likely to extend further north than that since bottlenose dolphins are recorded within the Irish Sea off the coasts of Cumbria, Dumfries & Galloway, and Northern Ireland (Pesante *et al*. 2008a; Veneruso and Evans, 2012b; Feingold and Evans 2013b). Despite comparisons with photo-ID catalogues from the Hebrides, the Moray Firth, Western Ireland, southern England and northern France, to date there have been no matches with the Welsh bottlenose dolphin catalogue (Pesante *et al*, 2008b; Feingold and Evans, 2013 a, b). This suggests that currently there is no exchange between these populations and Cardigan Bay.

In recent years, bottlenose dolphins have also been sighted increasingly in Liverpool Bay and off the coast of mainland North-east Wales, in both winter and summer months. Although only limited photo-ID data are available from this area, of the two encounters that had sufficiently high quality pictures to conduct photo-ID matching, 41% of animals recorded in this area have been positively matched to the Cardigan Bay catalogue (Lohrengel *et al*., 2014; Sea Watch Foundation, unpublished data).

3.1. General Aims

This work has been carried out under contract to Natural Resources Wales with the principal aims:

- To record, document, statistically analyse and report on the condition of bottlenose dolphin and harbour porpoise populations in both the Cardigan Bay SAC and wider Cardigan Bay.
- To collect photographic identification images for comparison to established catalogues, at sites within and outside the key study areas in order to evaluate dolphin movements, abundance estimates, and distribution.
- To monitor the number of bottlenose dolphins using the SACs and to assess the supporting habitat and estimate population structure (age and sex).

3.2. Objectives

The following were the key objectives of the monitoring project:

- Using Photo-ID protocols and Capture Mark Recapture (CMR) analysis, record, document and report numbers of bottlenose dolphins within Cardigan Bay including two SACs, in order to determine the total population using the SACs and Cardigan Bay.
- Report on fine- and broad-scale distribution patterns of bottlenose dolphins and the relative temporal use of different parts of the range, where survey effort allows.
- Document and report on the presence of calves and young juveniles in order to estimate the number of calves born annually by the population.
- Measure both juvenile and calf survival rates for the population on an annual basis by monitoring the proportion of animals still alive and recording known deaths.
- Record numbers of juveniles, female & male bottlenose dolphin adults (on those occasions where gender can be determined), in order to report on population structure parameters (age and sex ratios) and site use (e.g. by family groups).

- Identify the home range distributions of individual identifiable animals, including determination of ranging movements and core areas.
- 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.

4. Methodology

4.1. Study area

Cardigan Bay is the largest bay in the UK measuring over 100km across its westernmost extent and encompassing a total area of 4,986.86 km^2 from the western tip of the Llŷn Peninsula in the north (52˚ 47' 45'' N, 004˚ 46' 00'' W) to St David's Head in the south (51˚ 54' 10'' N, 005˚ 18' 54'' W; see Figure 1). It is a shallow bay, with depths not exceeding 60m and very gentle slopes (Evans, 1995). During this study, surveys were carried out throughout Cardigan Bay SAC (western tip ca. 52˚ 13' 8.8" N, 005˚ 0' 6.52"W, eastern tip ca. 52˚ 29' 9.05") and most of northern Cardigan Bay (northernmost survey point 52˚ 50' N, 05˚ 00' W, southernmost survey point 52˚ 20' N, 05˚ 00' W), covering the majority of the Pen Llŷn a'r Sarnau SAC.

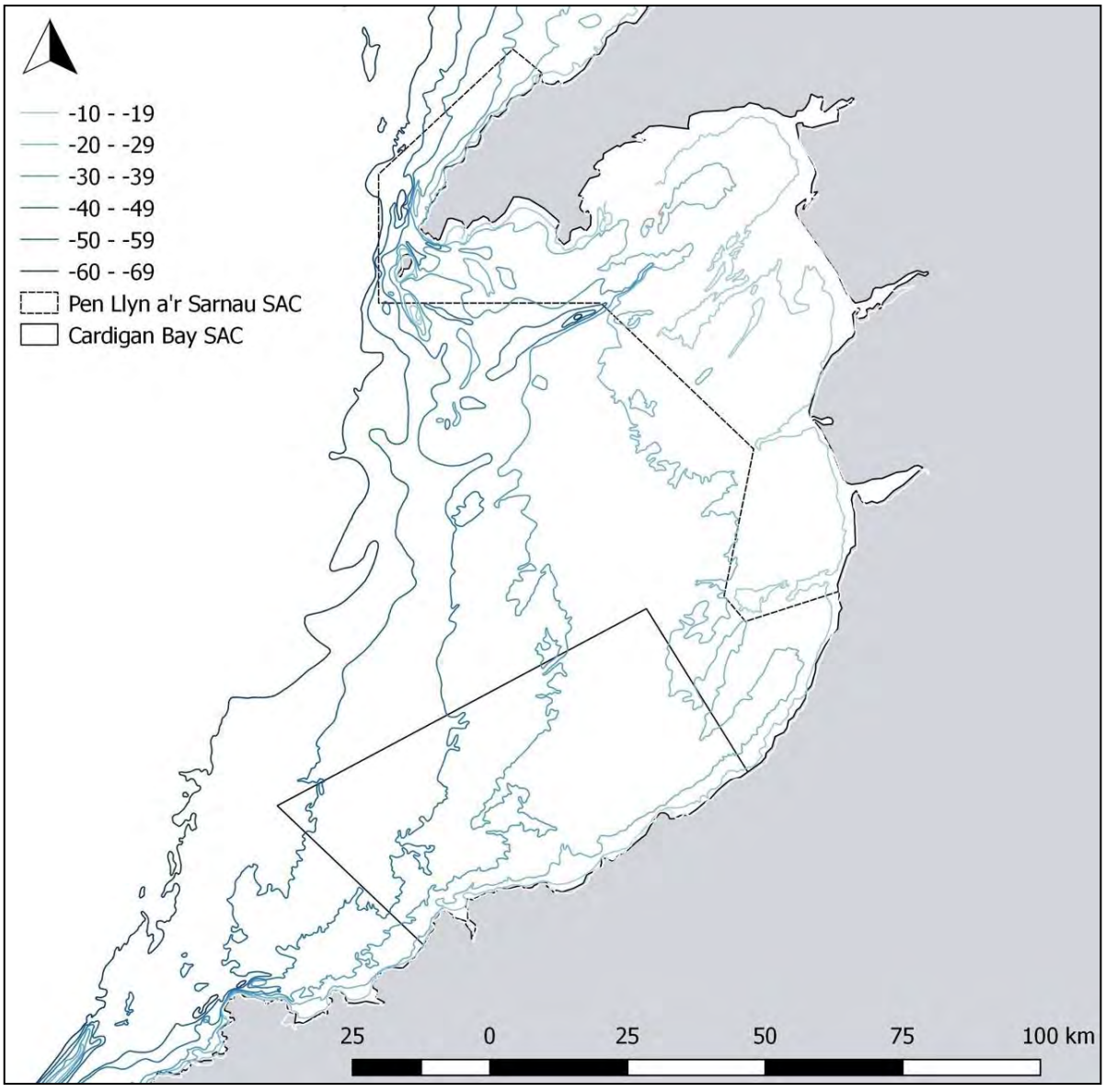


Figure 1: The study area: Cardigan Bay, West Wales. Cardigan Bay SAC boundary lines indicated by continuous line, Pen Llŷn a'r Sarnau SAC by hatched lines

For the purpose of this study, we used three terms to describe the study area: Cardigan Bay SAC referring to the southern SAC in Cardigan Bay, northern Cardigan Bay, referring to Cardigan Bay north of Cardigan Bay SAC up to the Llŷn Peninsula, and the wider Cardigan Bay, referring to both Cardigan Bay SAC and northern Cardigan Bay.

4.2. Data Collection

Data for this study were collected during three different types of surveys: dedicated line transect surveys (LT), dedicated photo-identification or dedicated non-line transect (NLT), also termed *ad libitum* surveys, and observations from platforms of opportunity, as defined below. Details of all survey vessels and associated survey effort are recorded in Appendix 2 (Table 16).

4.2.1. Line transect surveys

SWF staff and a team of trained interns conducted dedicated line transect surveys of the study area between 2014 and 2016, using vessels listed in Table 16 (Appendix 2). While on transect, survey vessels travelled at a constant speed, although average speed varied between vessels (see Table 16, Appendix 2).

Surveys were subject to weather and initiated only in favourable environmental conditions: when Beaufort sea state was ≤3, visibility exceeded 1.5nm, and there was no precipitation. If conditions changed while on survey, data collected in suboptimal conditions were excluded from analysis.

If local environmental conditions (such as visibility) deteriorated significantly while on survey, particularly offshore, an alternative but pre-determined transect line was chosen. In rare cases when conditions became widely untenable, the survey was abandoned.

Transect lines used for Cardigan Bay SAC and northern Cardigan Bay are pre-planned (designed) and repeated annually (Figures 2 & 3).

Transects were conducted using a double platform approach: two pairs of observers, independent from each other, spotting cetaceans. Observers also recorded sightings of other species such as harbour porpoise, grey seal, basking shark, sunfish, and leatherback turtle.

The two primary observers (POs) were located on the roof of the vessel, each scanning primarily with the naked eye from abeam (90°) on their side to 10° on the opposite side. Binoculars were supplied but were used only to investigate or confirm sightings, and species ID.

Independent observers (IOs) scanned the track line ahead using binoculars, each concentrating on 45° on their side to 10° on the other, to detect marine mammals before any responsive movement to the vessel had been made. On one survey vessel, due to space constraints, only one IO was employed, looking forward and concentrating on 90 degrees forward, 45 degrees on either side of the track line.

IOs and POs recorded sightings immediately on spotting an animal, recording the distance to the animal(s), the angle of the animals to the boat, and the boat position using a handheld GPS unit.

Environmental variables (sea state, visibility, swell, boat course, transect leg) were logged separately on an effort form at 15-minute intervals throughout the survey. A GPS unit was used to record the position of the vessel and recorded an automatically generated track. The numbers and types of boats present within the area were recorded with every line of effort, to provide a record of boat traffic in the vicinity.

Four different effort types were recorded: 1) line transect survey (LT) where the vessel travelled along a pre-defined transect line with a double platform set up, both POs and IOs scanning for sightings; 2) dedicated search (DS) - single platform observations, where POs were scanning but the boat was not following a transect line: this occurred when leaving the transect (e.g. to return to port or transit to another transect); 3) casual watch (CW), with no dedicated observers scanning for cetaceans (e.g. when weather conditions were unsatisfactory) and 4) photo-identification (ID), when the boat moved off the transect line temporarily to approach and remain with a group of dolphins at close range in order to obtain photo-ID shots.

When dolphins were encountered, the vessel deviated from the set course to approach dolphins for photo-identification, changes in effort type (from LT to ID) and course being noted on the effort form as a new line of effort. Dolphin fin pictures were taken by two photographers positioned on the bow of the boat using Canon EOS 7D and 40D cameras, with a 75-300mm or 18-200mm telephoto zoom lens. During photo-ID

encounters, dolphins were approached to 20-50m under NRW licence, following protocols established to minimise disturbance (Appendix 2). If animals were unreceptive and reacted negatively by showing signs of significant disturbance such as deliberate avoidance, prolonged dives or repeated tail slaps, encounters were terminated. On completion of photo-ID, the vessel travelled back to the point at which it last left the transect line, and the survey was resumed.

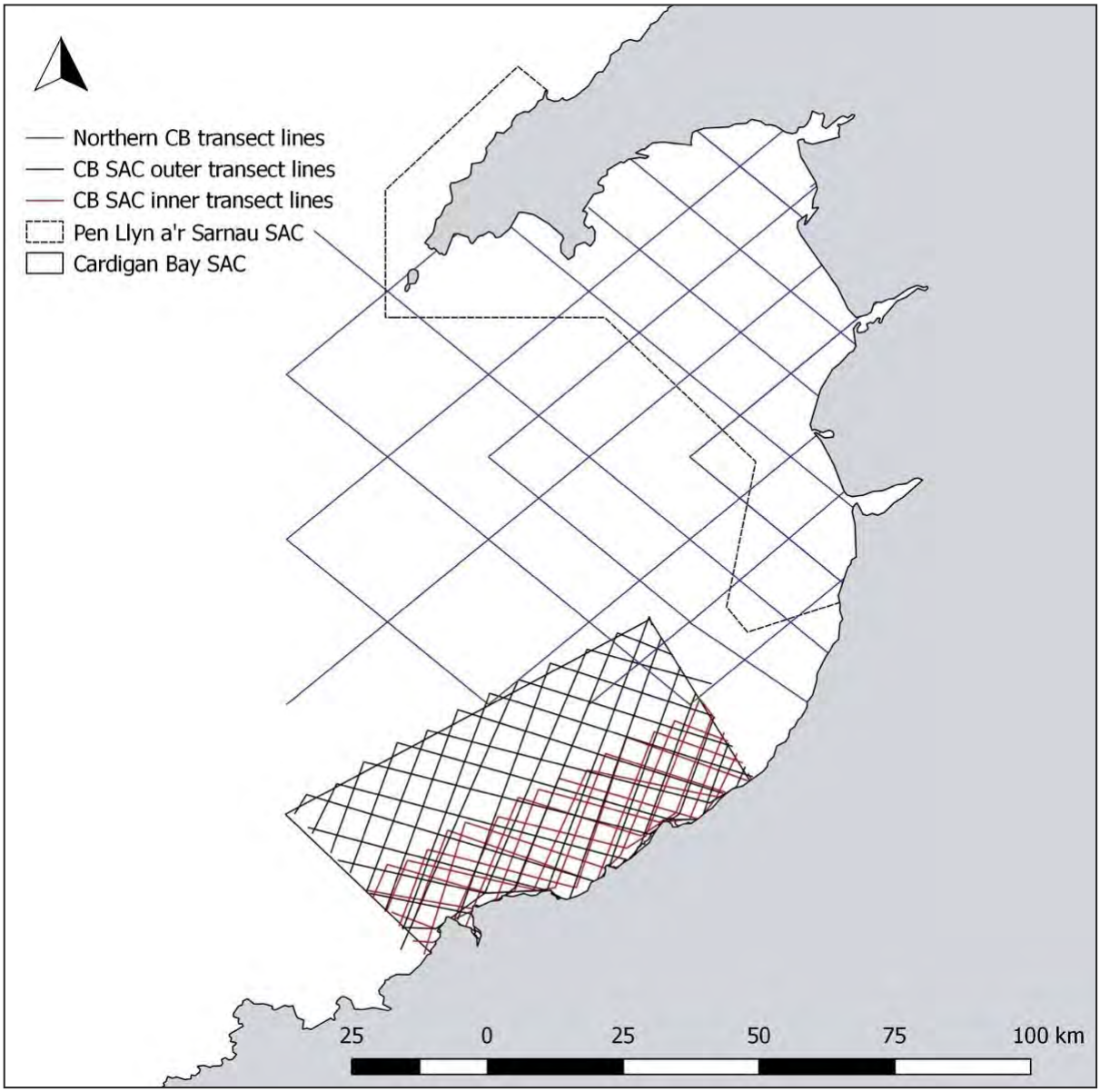


Figure 2: SWF transect routes followed during line transect surveys in Cardigan Bay

4.2.2. Dedicated non-line transect surveys (NLT or *ad libitum* surveys)

NLTs were carried out to obtain additional photo-identification data. Typically, these surveys were undertaken when weather conditions were not sufficiently favourable for a whole day survey or the vessel was only available for a limited period of time. Data collection followed the same general protocols as for line transect surveys but was usually carried out in dedicated search mode, utilising only primary observers. Effort types recorded on these surveys were DS, ID and CW.

4.2.3. Opportunistic observations

Opportunistic observations were made regularly from boats belonging to the local wildlife watching tour operator, *Dolphin Spotting Boat Trips* (DSBT) based in New Quay, recording sightings and behavioural data, and conducting opportunistic photo-ID. Prior to 2015, SWF interns only accompanied trips one or two times a day but this was increased in recent years. In 2015, dedicated 'Dolphin Guides' employed by DSBT recorded data for SWF on a daily basis. Although the role was discontinued in 2016, SWF interns were scheduled instead to make daily observations from DSBT if the weather allowed, staying on the boats throughout the day. Unlike dedicated surveys, these platforms do not approach dolphins but are subject to the Ceredigion Marine Code of Conduct as are all other recreational and commercial vessels (Appendix 2). They do not follow strict tracks but cover approximately the same areas every day, with one-hour trips running from New Quay to Cwmtydu, and two- hour trips from New Quay to Ynys Lochtyn. Effort type on these surveys was always CW. Details of vessels are given in Table 17, Appendix 2.

4.2.4. Behavioural observations

Behavioural data for groups of dolphins encountered were recorded on all survey types. 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). During short encounters and during opportunistic observations when sightings were often very brief, behavioural data were recorded on the generalised sightings form. On line transect and NLT surveys, an additional behaviour form was filled in every 3 minutes by one of the primary observers, recording behaviours, group size and composition. Four main behaviours (adapted from Shane,

1990, and Bearzi, 2005) were recorded, as used throughout the monitoring programme (Feingold and Evans, 2014a):

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. If all these behaviours were observed but no fish was seen, this was termed *suspected feeding* or *foraging*.

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 steadily in a persistent and directional manner, exhibiting regular patterns of surfacing and diving.

Socialising – Characterised by some or all members of the group in frequent physical contact with one another, oriented towards one another with no steady directional movement, and often displaying surface behaviour.

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

4.3. Data Analysis

4.3.1. Line transect surveys

Effort and sightings data were entered into a Microsoft Excel spreadsheet. Survey tracks and sightings were plotted using QGIS 2.4. Abundance estimates for bottlenose dolphins were computed in the program Distance 6.0 using a Multiple Covariate Distance Sampling (MCDS) sampled for sea state using a half cosine model (Buckland *et al*., 2001, 2004) based on the length of each effort leg, sea state, the radial distance, angle and group size of each sighting and the area of each stratum imported into the program. Observations were routinely truncated to an effective search width giving the lowest Akaike Information Criterion (AIC) value, sampling the data for sea state, as recommended by Buckland *et al*. (2001, 2004). However, due to low effort in 2015, a truncation value of 1000 m was used, as applied in some earlier years of low effort in order to increase sample size (Veneruso and Evans, 2012a). In accordance with previous reports, only PO observations were used. There was no evidence from IO observations that bottlenose dolphins were showing responsive movement, and so

there was no need to adjust for this. Line transect sightings collected during suboptimal environmental conditions were excluded from abundance analysis.

Linear regression analysis was run in R on abundance estimates for both Cardigan Bay SAC and the wider Cardigan Bay to determine whether observed variation in abundance yielded any significant positive or negative trend. Where a trend was seen, the likelihood of making an error in ascribing a trend to the data was investigated by simulation. For each of 1,000 simulations, the trend was tested. If >95% of the 1,000 trends were negative (regardless of whether each one was statistically significant), this was treated as equivalent to a statistically significant decline. More details are given in Appendix 2.

Effort and sightings data were also examined to investigate temporal variation in sightings and group composition, and to assess activity budgets (Appendix 2). Photo-identification data obtained from these surveys were used for Capture-Mark-Recapture (CMR) analysis.

4.3.2. Non-line transect surveys

Effort and sightings data were entered into Microsoft Excel and plotted using QGIS 2.4. They were not used in Distance based abundance estimates but were included in analyses relating to temporal variation in sightings, group composition, and activity budgets. Additional photo-identification data obtained during these surveys were included in the CMR analysis.

4.3.3. Opportunistic surveys

Effort and sightings data were entered into Microsoft Excel and plotted using QGIS 2.4 but were not used in Distance based abundance estimates or CMR analysis. However, information collected from opportunistic surveys was used to supplement life history information of individuals in the photo-ID database, and for some aspects of behavioural analysis.

4.3.4. Photo-Identification and Capture Mark Recapture Analysis

Photo-identification was performed using ACDSee-Pro. Matching was done manually by eye and positive matches were always confirmed by a second person. MARK 6 and CAPTURE software were used to calculate CMR population estimates, following

methodologies described by Hammond *et al*. (1990) and Amstrup *et al*. (2010). Only photo-ID data from dedicated LT and NLT surveys were included in analysis.

CMR analysis makes a number of assumptions (Amstrup *et al*., 2010):

- All individuals have an equal chance of being captured across sampling periods; marking does not affect future catchability
- Marks do not change and are not lost over time
- Marks are unique, with no 'twins'
- For closed population models, the population is assumed to be closed to births, deaths, permanent immigration and emigration

These assumptions can prove problematic when applied to cetaceans but there are ways to reduce potential violations (Evans and Hammond, 2004; Amstrup *et al*., 2010):

Equal likelihood of capture: Unlike animals that require capture and physically marking, photo-ID of bottlenose dolphins relies on photography of naturally occurring marks, and therefore marks do not affect future catchability. However, due to individual habitat preferences and behaviour patterns, animals are not always equally likely to be "captured" even photographically since some individuals may tend to approach vessels ('trap happy') and be more likely to be recorded whereas others (such as females with calves) may avoid vessels ('trap shy'). This is referred to as heterogeneity of capture probabilities. Attempts to overcome this involve first counting the group and then trying to ensure every member of the group is photographed well.

Marks do not change over time: Marks in bottlenose dolphins do change over time as they are naturally occurring. However, regular and extensive survey photo-ID effort aims to ensure that such changes are documented as they occur, so that even animals with changed marks remain identifiable over time. Similarly, unmarked animals may become marked, but if these animals are calves of known mothers, the acquisition of marks on the fins can be documented.

Marks are unique: Recognition of marks is not always certain, as this is affected by the distinctiveness of marks and quality of photos (see, for example, Quick *et al*., 2017). To reduce the margin of error, our analyses only include high quality photos of animals that can easily be identified from both sides.

Types of models

1) Closed population models: closed models assume no birth, deaths, permanent emigration or immigration during the year of observation (Chao Mth: Chao *et al*., 1992). If the sampling can be confined to a relatively small part of the year, those assumptions may be largely met. Closed models are favoured where possible as they can account for heterogeneity of capture probabilities.

2) The open robust design allows for abundance estimates over subsequent years, breaking down sampling occasions into primary (years) and secondary (months) sampling occasions. The population is assumed to be open between primary but closed between secondary sampling occasions (Kendall *et al*., 1997).

A closed population model (Chao Mth: Chao *et al*., 1992) was used for the wider Cardigan Bay, and separately for Cardigan Bay SAC to calculate mean annual population estimates and lognormal 95% confidence intervals of each CMR estimate (Haase and Schneider, 2001). Pollock's Open Robust Design Method (Kendall and Nichols, 1995; Kendall *et al*, 1997) was used to calculate emigration rates and mean juvenile survival rates (S).

Linear regression analysis was run in R on CMR abundance estimates for both Cardigan Bay SAC and the wider Cardigan Bay to determine whether observed changes in abundance were significant. Where a trend was seen, the effect of uncertainty was investigated by simulation. One thousand simulations were undertaken, and for each one the trend was tested. If, for example, >95% of the 1,000 trends were negative (regardless of whether each one was statistically significant), this is treated as equivalent to a statistically significant decline. One hundred randomly selected simulations were included in trend plots to illustrate trends. Further details of trend analyses are included in Appendix 2.

4.3.5. Reproductive and mortality rates

Crude birth rates, interbirth intervals, calving season, and calf survival were calculated including data from 2001 to 2016, as this provided a larger sample size.

Crude birth rates were calculated by dividing the number of new calves observed during a field season by the CMR population estimate, assuming a male:female ratio of 1:1.

Interbirth intervals were calculated based on the individual sightings histories of 44 known females, by determining the mean number of years between births of new calves for known females. Only mother-calf pairs with continuous records were included in the analysis; if a female was seen with a calf in one year, not sighted the next, and reappeared with a calf the following year those data were excluded from analysis.

Approximate birth dates of newborn calves in Cardigan Bay were estimated based on the last sighting of a female without a calf and the first sighting of a female with a newborn calf.

Calf survival was analysed for 53 confirmed females that had given birth to at least one calf between 2001 and 2014, based on the sightings history of mother-calf pairs (Mann *et al*., 2000). Those with a calf born after 2014 were excluded as it would be impossible to establish whether its calf will survive to the age of 3 years. Based on the average interbirth interval, calves that disappeared before their third year were considered deceased, although this might have resulted in a more conservative analysis, missing out calves that split early from their mother but in fact survive. Only mother-calf pairs with continuous records were included in the analysis.

5. Results

5.1. Survey effort, sightings rate and spatial analysis

5.1.1. Line transects

From 2014 to 2016, 70 line transect surveys and 23 dedicated photo-identification surveys were undertaken in Cardigan Bay, covering 8030.73km and 1059.71km respectively (Table 1). The most extensive survey effort was achieved in 2016, the lowest in 2015 (Table 1, Figure 3). Although line transects were undertaken in 2014, these did not systematically cover all of the study area since the focus was upon photo-ID, and therefore they were not used to generate an absolute abundance estimate.

Over the study period, a total of 255 bottlenose dolphin sightings were recorded (Figure 4), resulting in an average sightings rate of 0.033 sightings/km for the years 2014 to 2016.

Table 1: Overall and line transect survey effort, bottlenose dolphin sightings and sightings rates in wider Cardigan Bay for 2014-2016

	2014	**2015**	**2016**	**Total (2014-2016)**
No. LT surveys	18	21	32	71
Km travelled	2431.2	1666.7	3933.0	8030.9
Km travelled (on LT mode)	1496.9	996.1	2481.3	4974.4
BND sightings (all effort modes)	69	66	120	255
BND sightings (on LT mode)	39	37	67	143
BND sight/km	0.028	0.040	0.031	0.033
BND sight/km (on LT mode)	0.026	0.037	0.027	0.030

Bottlenose dolphin sightings were scarcer in northern Cardigan Bay than in Cardigan Bay SAC throughout 2014 to 2016. This was reflected in a significant difference in sightings rates between northern Cardigan Bay and Cardigan Bay SAC across the three years ($t=2.77$, $p < 0.05$), the sightings rate in northern Cardigan Bay being consistently less than half that of Cardigan Bay SAC. The largest disparity was observed in 2014: the sightings rate for Cardigan Bay SAC was calculated at 0.056 per

km whereas it was only 0.017 per km for northern Cardigan Bay. In 2015, sightings rates were 0.058 and 0.025 per km for Cardigan Bay SAC and northern Cardigan Bay respectively. The smallest difference was in 2016 when sightings rates were 0.040 and 0.024 per km for Cardigan Bay SAC and northern Cardigan Bay respectively (Table 2).

Table 2: Line transect effort, bottlenose dolphin sightings and sightings rate for Cardigan Bay SAC and northern Cardigan Bay 2014-2016

	2014	**2015**	**2016**	**Total (2014-2016)**
Northern Cardigan Bay BND sightings	29	24	52	107
Northern Cardigan Bay effort (km)	1721.6	941.8	2236.7	5229.6
Northern Cardigan Bay sightings rate (sight/km)	0.017	0.025	0.023	0.022
Cardigan Bay SAC BND sightings	40	42	70	152
Cardigan Bay SAC effort (km)	709.6	724.9	1696.3	3130.8
Cardigan Bay SAC sightings rate (sight/km)	0.056	0.058	0.041	0.052

Bottlenose dolphin sightings in the Cardigan Bay SAC were concentrated inshore, with particularly large numbers around New Quay, Ynys Lochtyn, Aberporth, and Mwnt (Figure 4), suggesting that these areas remain important habitats for bottlenose dolphins as noted in previous years (Pesante *et al.*, 2008b; Feingold and Evans, 2014a). In 2016, in northern Cardigan Bay, there were more bottlenose dolphin sightings beyond the borders of the Pen Llŷn a'r Sarnau SAC, than in previous years when concentrations of sightings were recorded particularly around the Aberdovey estuary.

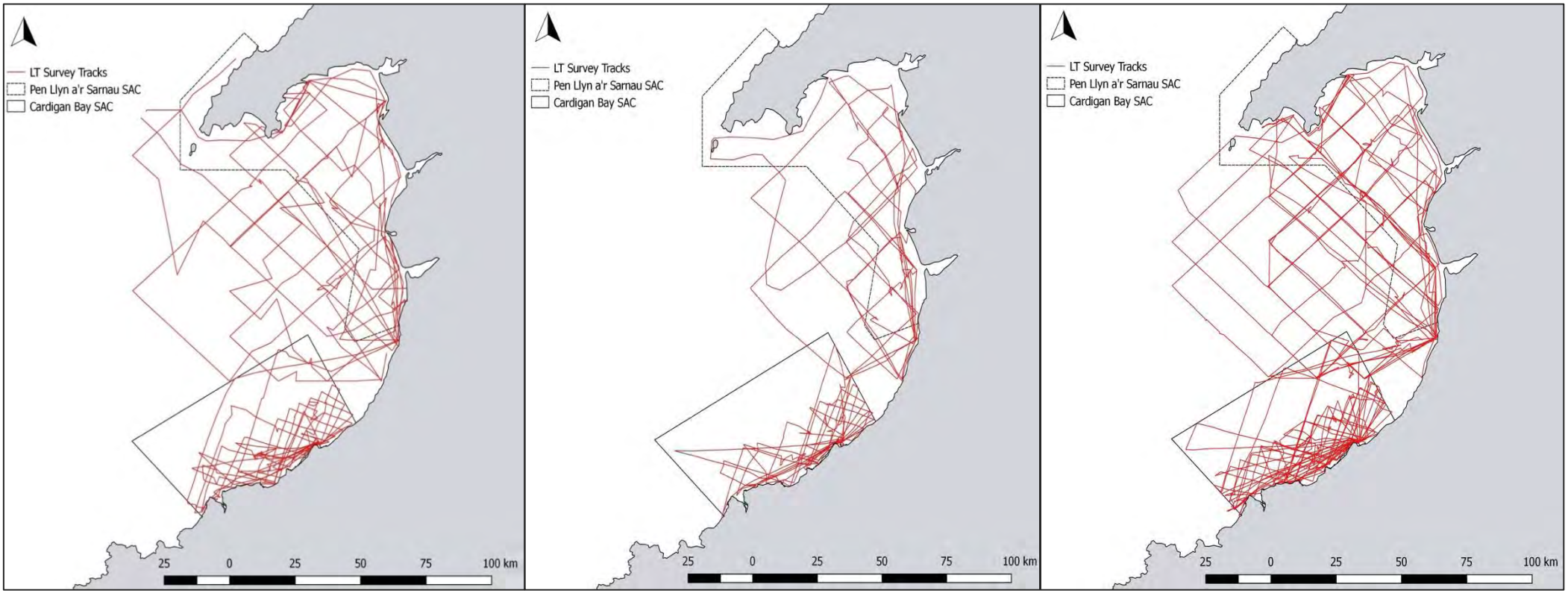


Figure 3: Tracks for line transect surveys undertaken in Cardigan Bay in 2014 (left), 2015 (middle) and 2016 (right)

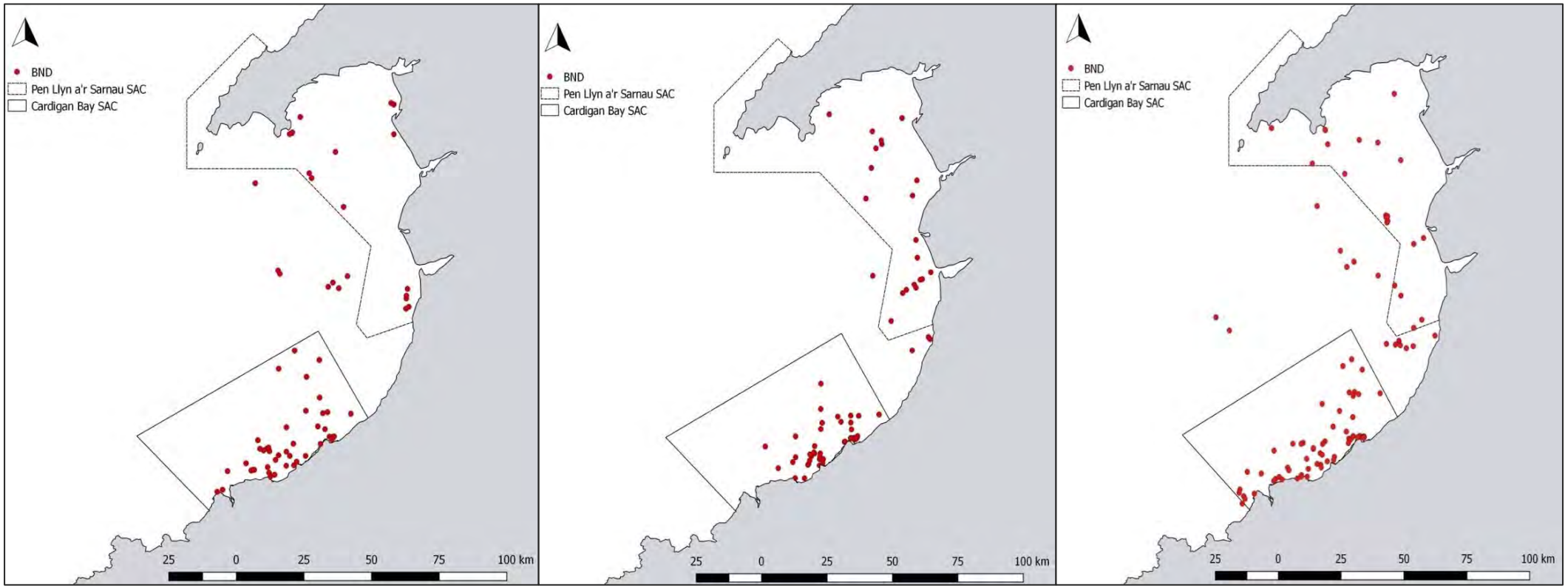


Figure 4: Bottlenose dolphin sightings in Cardigan Bay from line transect surveys conducted in 2014 (left), 2015 (middle), and 2016 (right). BND = bottlenose dolphin

5.1.2. NLT and opportunistic surveys

NLT surveys were conducted in the coastal area of the Cardigan Bay SAC. Only one NLT survey per year was undertaken in northern Cardigan Bay in 2015 and 2016. Although the data collected did not contribute to abundance estimates, it did provide additional photo-identification data. Overall, a total of 30 NLT surveys amounting to 1235.5 km were conducted from 2014 to 2016, resulting in a total of 79 bottlenose dolphin sightings and an average sightings rate of 0.063 sightings/km (Table 3, Figures 5 & 6).

Table 3: NLT survey effort, bottlenose dolphin sightings and sightings rates in wider Cardigan Bay for 2014-2016

Year	2014	2015	2016	Total
No. surveys	5	13	12	30
Km effort	336.3	537.85	361.4	1235.5
BND sightings	28	39	12	79
BND sight/km	0.083	0.073	0.033	0.063

Opportunistic observations from wildlife tour operators were concentrated between New Quay and Ynys Lochtyn. A total of 692 opportunistic surveys were undertaken resulting in 9488.2 km of effort (Table 4, Figure 5), 1002 bottlenose dolphin sightings (Table 4, Figure 6), and an average sightings rate of 0.109 sightings/km from 2014-2016 (Table 4). Although the data collected did not contribute to abundance estimates, it did provide additional data on life history and behaviour.

Table 4: Opportunistic survey effort, bottlenose dolphin sightings and sightings rates in Cardigan Bay SAC for 2014-2016

Year	2014	2015	2016	Total
No. surveys	128	254	310	692
Km effort	2061.08	3431.28	3995.83	9488.19
BND sightings	175	382	445	1002
BND sight/km	0.085	0.111	0.131	0.109

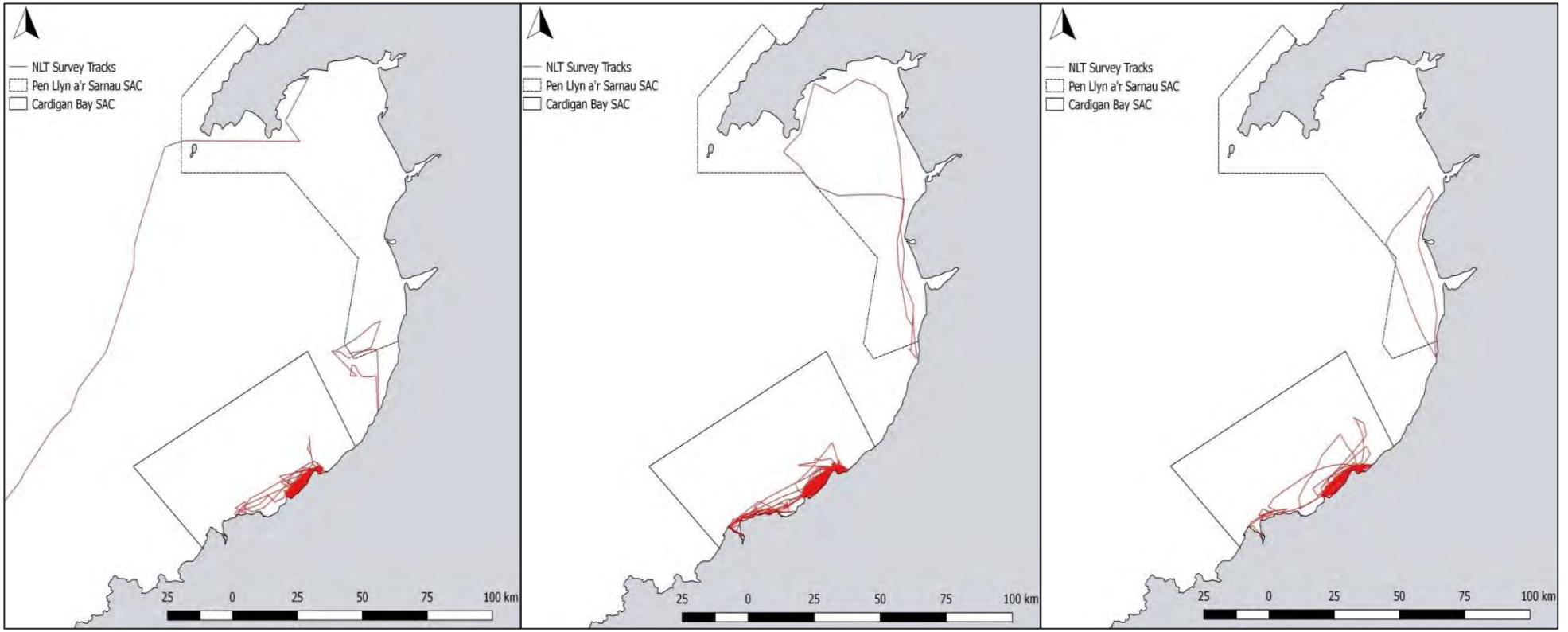


Figure 5: Track for dedicated NLT surveys and opportunistic observations from wildlife tour operators undertaken in 2014 (left), 2015 (middle) and 2016 (right)

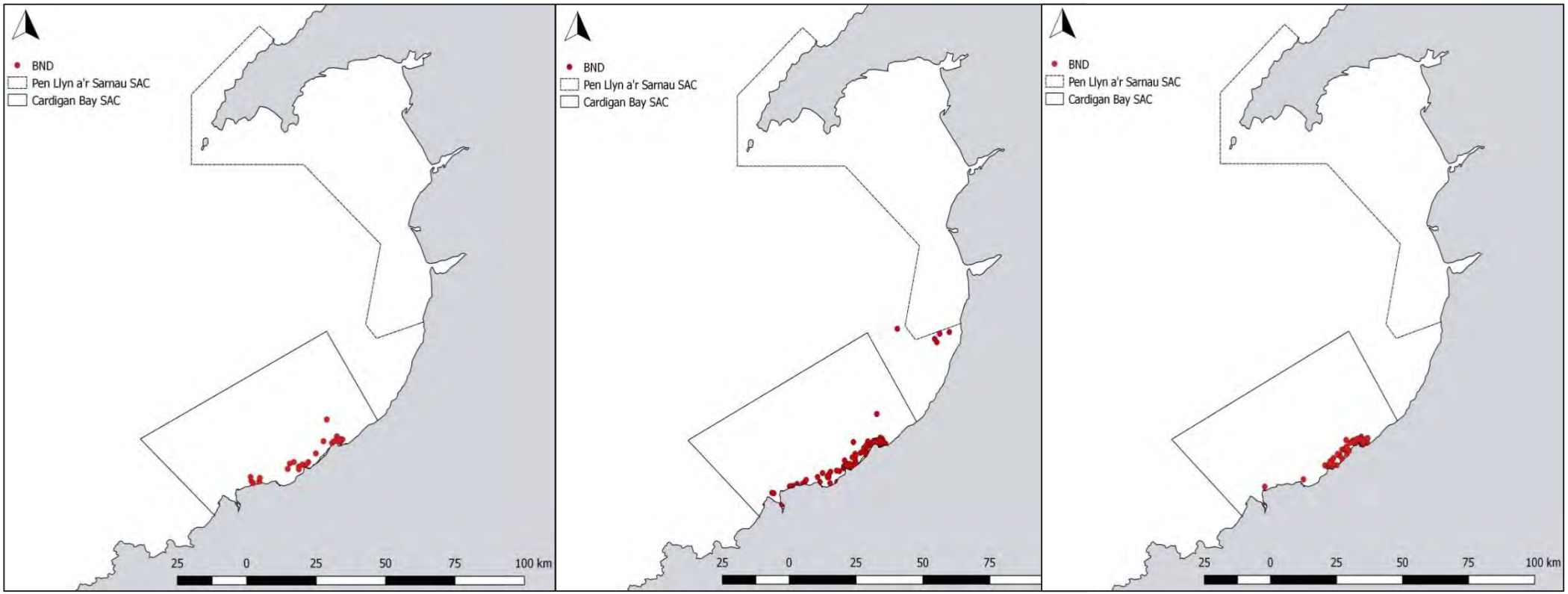


Figure 6: Bottlenose dolphin sightings in Cardigan Bay during dedicated NLT surveys and opportunistic observations from wildlife tour operators in 2014 (left), 2015 (middle) and 2016 (right), BND = bottlenose dolphin

5.2. Bottlenose dolphin group sizes in Cardigan Bay

5.2.1. Average bottlenose dolphin group sizes in Cardigan Bay

The average group size of bottlenose dolphins recorded on line transect across the entirety of Cardigan Bay was 4.33 (range 1-15, SD=3.31) for 2014, 4.75 (range 1-18, SD=4.02) for 2015 and 4.30 (range 1-20, SD=3.9) for 2016, similar to the cumulative average of 4.46 calculated on the full data set from 2001 to 2016 (compare Figure 7).

The majority (between 71 and 84% of sightings per month) of groups encountered from 2014 to 2016 numbered between one and five individuals, which is also comparable to previous years.

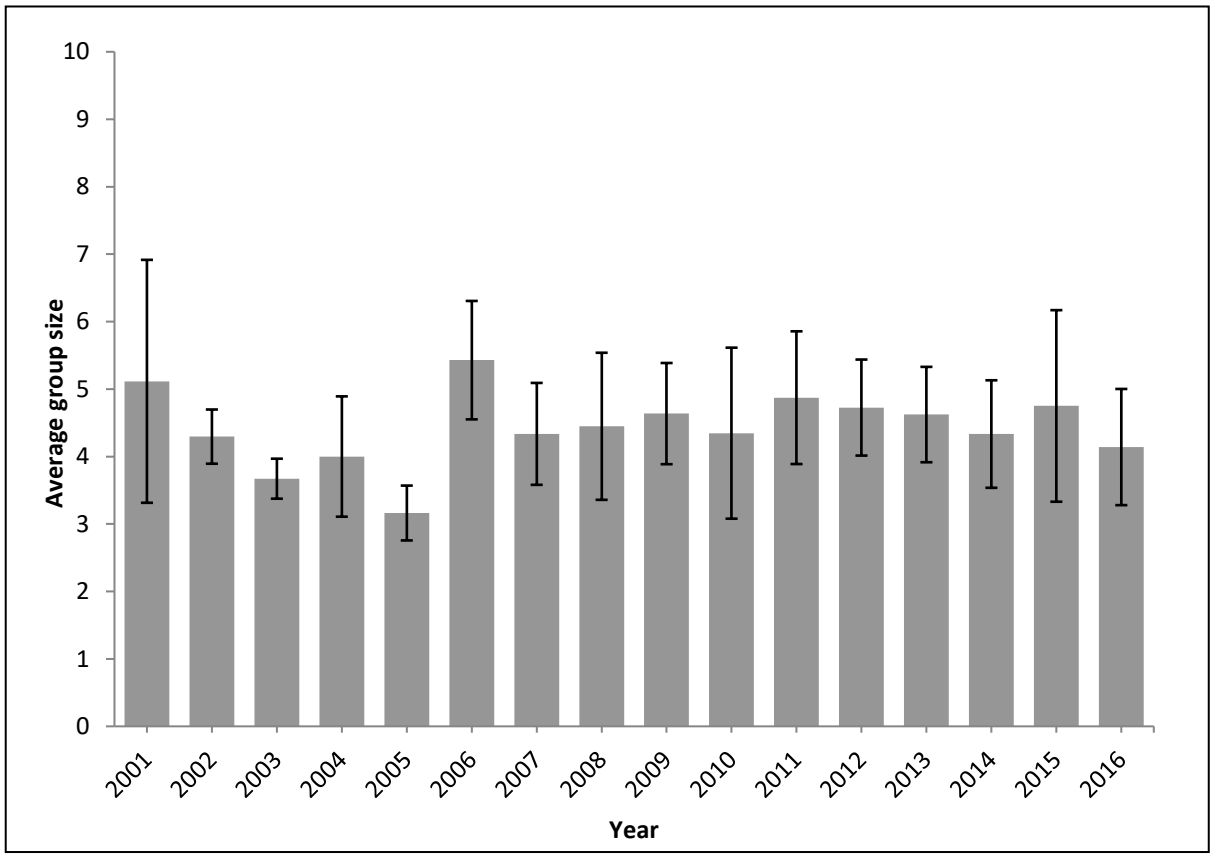


Figure 7: Average group size of bottlenose dolphins by year, recorded from line transect surveys in Cardigan Bay, 2001-16. Error bars denote SEs

5.2.2. Seasonal variation in bottlenose dolphin group sizes in Cardigan Bay

Cumulative data from 2001 to 2016 indicate that large groups (>10 individuals) were most common between April and May and September to October (Figure 8). Some variation in seasonal group size was observed during this study period: both 2014 and 2015 showed a slight increase in group size when comparing group sizes recorded on survey in the period of June to August to the period of September to October, increasing from 4.17 to 4.65 in 2014 and from 3.57 to 5.00 in 2015. However, neither of these represented a significant difference (t=0.51, p=0.61, and t=1.14, p=0.27 respectively). In 2016, group size was slightly larger earlier in the year, from June to August, with an average group size of 4.76 than in September to October which had an average group size of 3.73, although this difference was not significant (t=0.78, p=0.44). Few surveys were conducted in April and May in 2014 to 2016 so it was not possible to meaningfully compare group sizes from these months to later in the season.

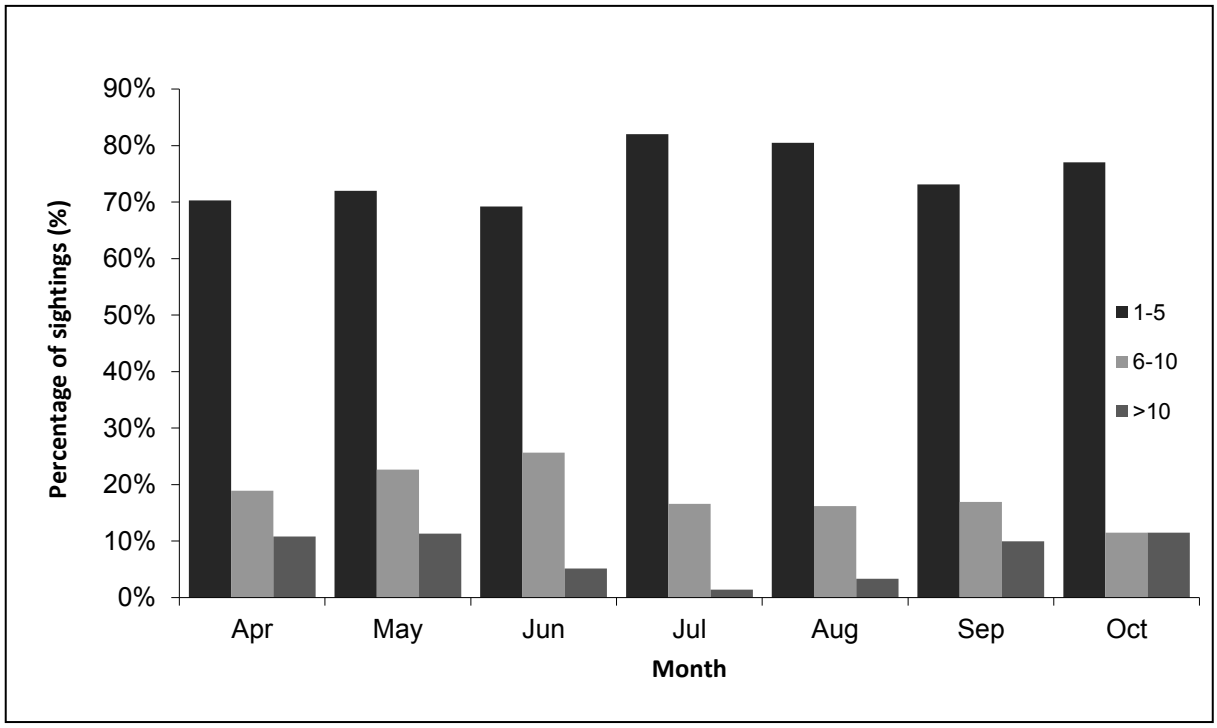


Figure 8: Bottlenose dolphin group sizes (expressed as percentage of sightings) by month recorded from line transect surveys in wider Cardigan Bay, 2001-2016

5.2.3. Geographic variation in bottlenose dolphin group size in Cardigan Bay

Group sizes in northern Cardigan Bay have been consistently larger than in Cardigan Bay SAC since systematic surveys in both areas started in 2007 (Figure 9). In 2014 and 2015, mean group sizes were significantly different between Cardigan Bay SAC and northern Cardigan Bay. In 2014, mean group sizes were calculated at 4.15 and 6.19 (X2 =28.09, df=1, p=0.001) and mean group sizes in 2015 were calculated at 3.86 and 6.07 (X2 =28.09, df=1, p=0.032), for Cardigan Bay SAC and northern Cardigan Bay respectively. In 2016, group sizes were slightly larger in northern Cardigan Bay, with an average of 4.40 compared to 4.22 in Cardigan Bay SAC, but the difference was not statistically significant (t=0.192, p=0.848)).

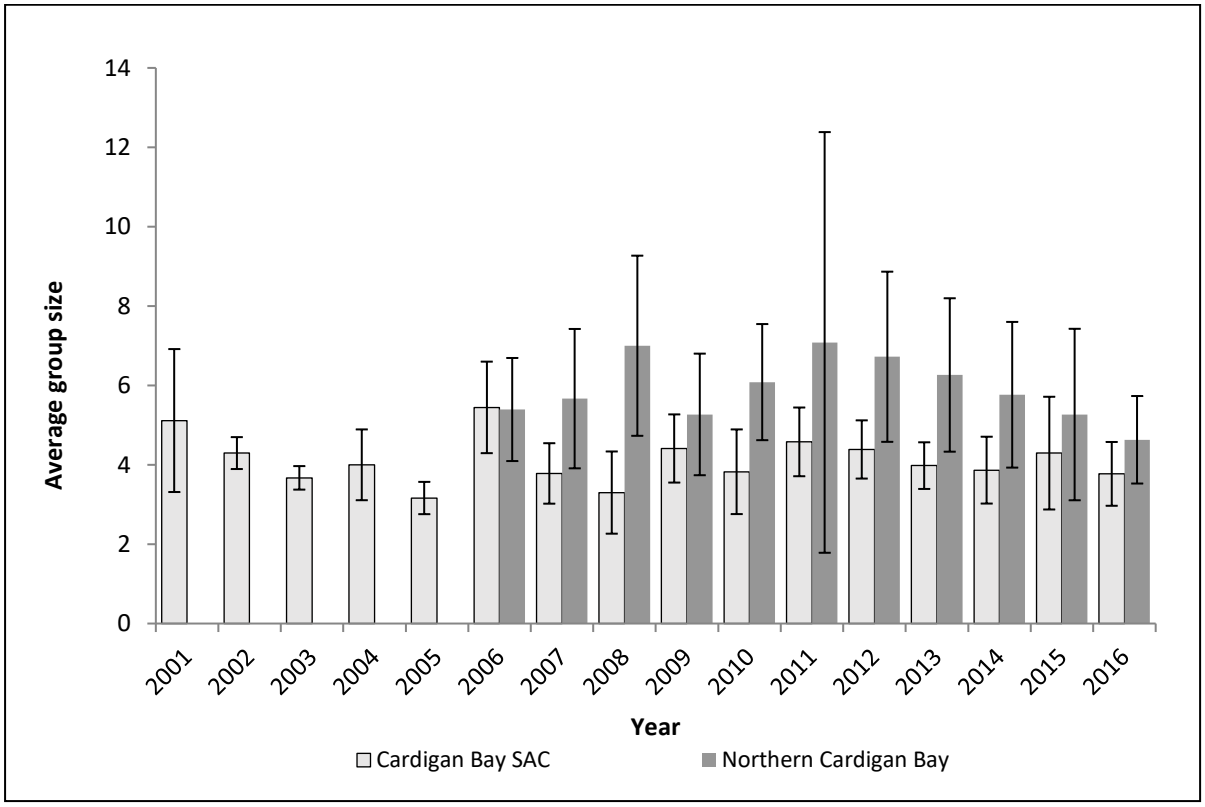


Figure 9: Comparison of average group sizes of bottlenose dolphins recorded from line transect surveys in Cardigan Bay SAC and northern Cardigan Bay, 2001-16. Error bars denote SEs

5.3. Bottlenose dolphin abundance estimates
5.4. Abundance estimates of bottlenose dolphins in Cardigan Bay SAC
5.4.1. Closed Model CMR estimates for bottlenose dolphins in Cardigan Bay SAC

CMR population estimates were calculated using closed population models for both Cardigan Bay SAC and the wider Cardigan Bay. Data derived from previous CMR estimates in Cardigan Bay SAC were also included in order to place current findings into context.

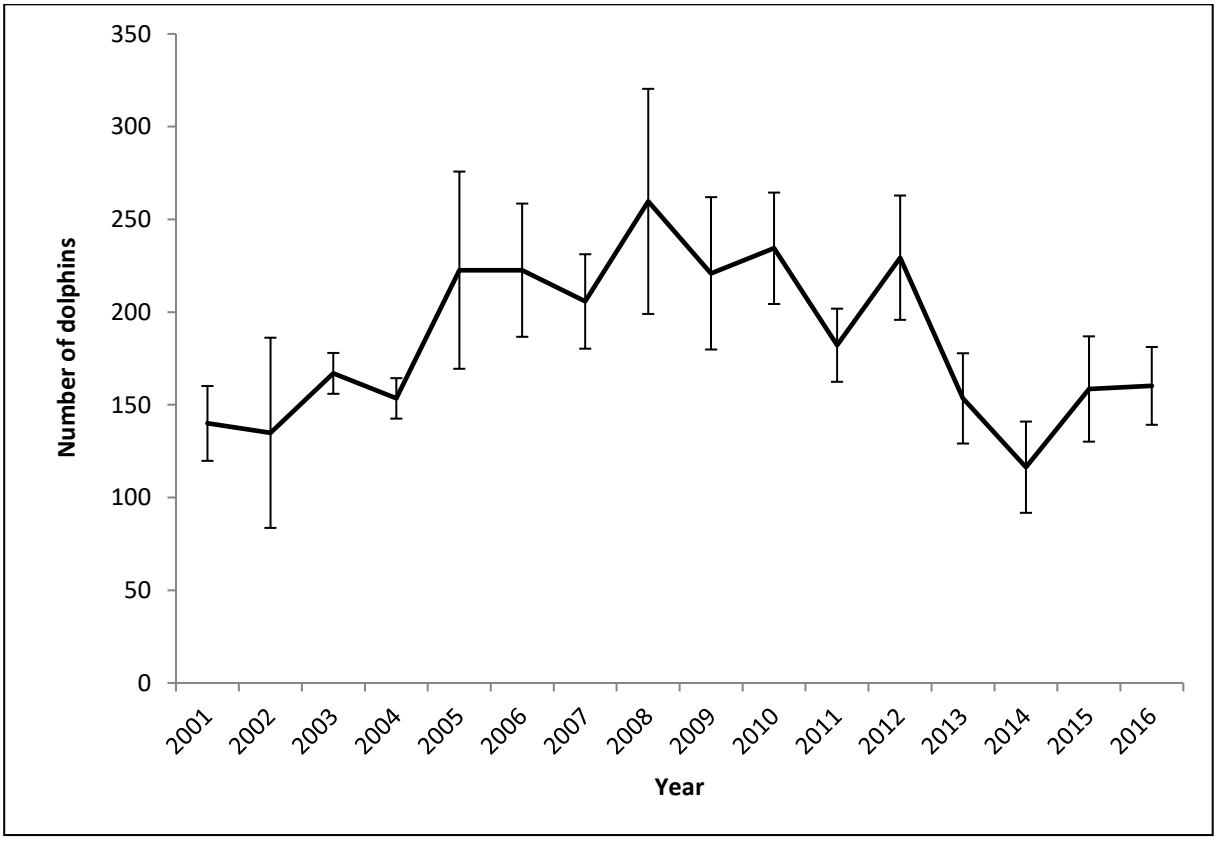


Figure 10: Population estimates for bottlenose dolphins in Cardigan Bay SAC for the years 2001-2016 using a closed population model.Error bars denote 95% CIs

The closed population model for Cardigan Bay SAC yielded estimates of 107 CI= 24.6, 146 (CI=28.40), and 147 (CI=20.98) for 2014, 2015, and 2016 respectively, showing a slight increase from 2014 to 2016. However, 2014 represents the lowest estimate recorded throughout 2001 to 2016 (Figure 10, Table 5).

Table 5: Population estimates of bottlenose dolphins in Cardigan Bay SAC for the years 2001-2016, obtained using a closed population CMR model considering the average marked proportion of individuals

Year	Capture events	Animals photographed	Population estimate	Lower 95% CI	Upper 95% CI	CV
2001	117	64	**129**	112	177	0.27
2002	46	37	**124**	81	253	0.64
2003	234	87	**154**	143	178	0.14
2004	200	80	**141**	132	166	0.17
2005	97	67	**205**	151	321	0.57
2006	136	85	**205**	169	282	0.60
2007	162	91	**189**	165	245	0.28
2008	122	74	**239**	177	369	0.52
2009	142	76	**203**	161	290	0.41
2010	214	94	**216**	183	278	0.29
2011	197	83	**168**	147	210	0.24
2012	186	88	**211**	175	281	0.32
2013	140	61	**141**	116	194	0.35
2014	113	41	**107**	84	161	0.47
2015	116	62	**146**	119	210	0.40
2016	141	72	**147**	127	194	0.29

Estimates have varied widely over the years: the highest estimate of 239 (SE=30.35) was recorded in 2008, with smaller peaks of 216 in 2010 and 211 in 2012. Overall estimates have increased from the start of monitoring to a peak in 2008, and then declined but not to lower than starting estimates (Figure 10, Table 5).

Two time periods were considered: 2001 to 2016 and the last ten years, 2007 to 2016. The period 2001 to 2016 showed no significant trends (42.0% negative trend and 58.0% positive trend), F=0.0015, p=0.969 (Figure 11a). For the period 2007 to 2016, a significant negative trend in model fit (F=10.17, p=0.013) was observed, although only 89.8% of the linear regression simulations were negative (10.2% positive)[7] (Figure 11b).

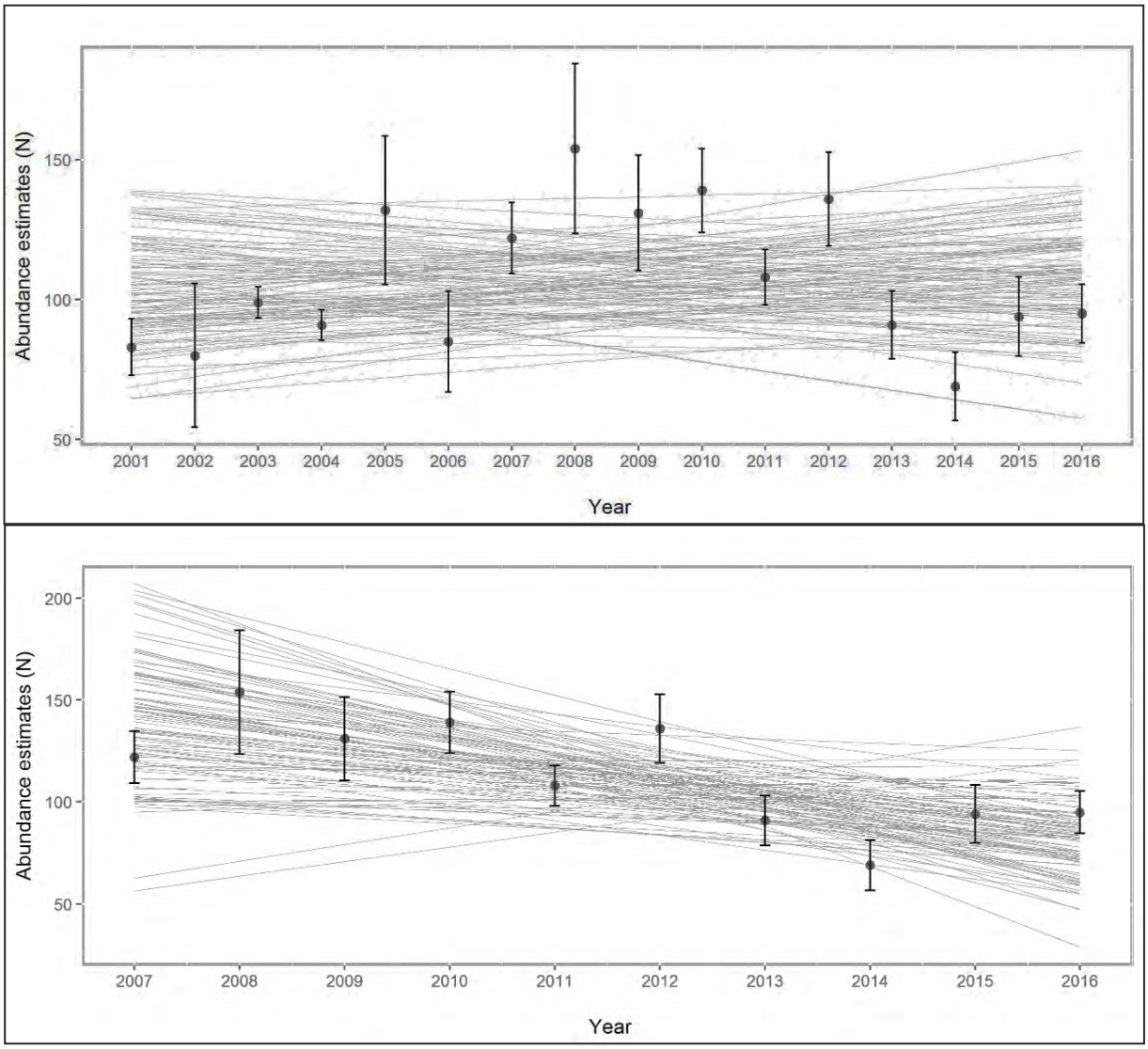


Figure 11: Trend analysis of Cardigan Bay SAC CMR abundance estimates for bottlenose dolphins for 2001-2016 (a, top) and 2007-2016 (b, bottom). Lines depict 100 randomly selected simulation trends. Abundance estimates plotted with SE bars over trend simulations

[7] The global model fit significantly declines at 95% level, but only approximately 90% of the 1000 linear regression simulations were negative (ie, 90% certainty of a decline). Further trend analysis is being carried out.

5.4.2. Residency patterns of bottlenose dolphins in Cardigan Bay SAC derived from a robust CMR model

In addition to a closed CMR model analysis, a robust CMR model was also run to obtain information on emigration, immigration, birth and death rates. Gamma" estimates the likelihood of an animal emigrating from the study area from one year to the next whereas Gamma' estimates the probability of staying out permanently (Figure 12). These vary considerably since the start of surveys, with peaks in 2004, 2008, and 2013 (Figure 12)

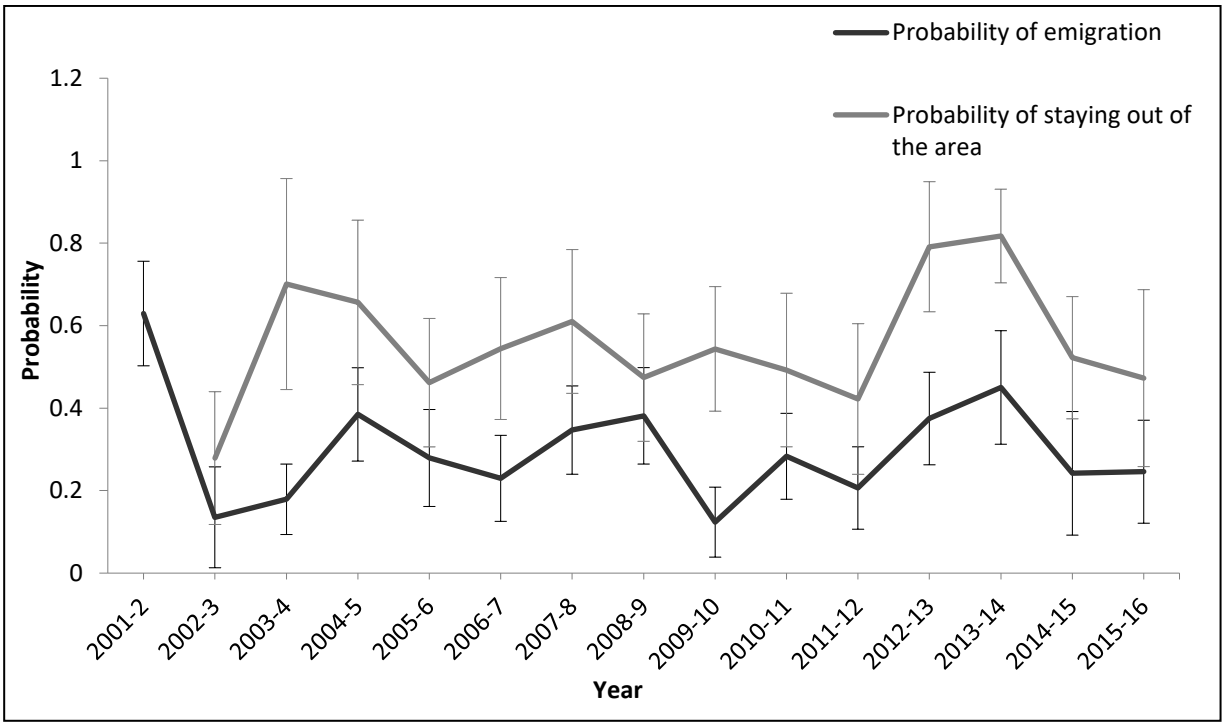


Figure 12: Bottlenose dolphin residency patterns in Cardigan Bay SAC using a robust population model (See Table 18 in Appendix 2 for actual SE values)

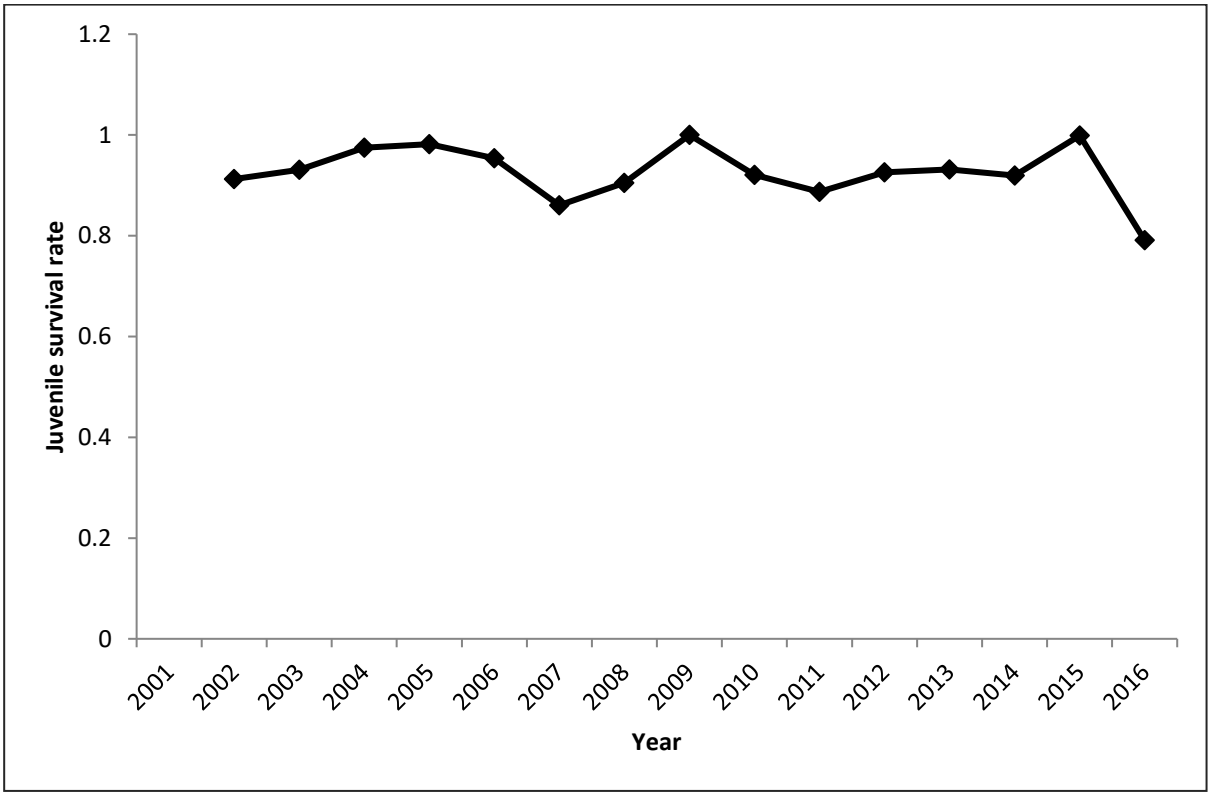


Figure 13: Bottlenose dolphin juvenile survival rates in Cardigan Bay SAC, 2001-2016, calculated by a robust population model

The steep rise in permanent emigration in 2013 coincides with a sharp decrease in survival rates (Figure 12) and directly precedes the lowest closed CMR abundance estimate of dolphins since the beginning of the study, calculated at 41 individuals in 2014. Overall, the probability of an animal staying out of the study area has followed similar patterns to the probability of emigration.

Juvenile survival rates have remained relatively constant between 2001 and 2015 (Figure 13). Although survival rates have apparently declined between 2015 and 2016, this most recent value has greater uncertainty associated with it because there are no future data from which to estimate probabilities. It is likely that this value will return to a general trend (as has occurred with previous years' estimates) in future years.

5.4.3. Distance sampling estimates of bottlenose dolphins in Cardigan Bay SAC

Bottlenose dolphin abundance estimates (Table 6, Figure 14) and detection curves (Appendix 2) were also calculated for Cardigan Bay SAC for 2015 and 2016, from line transect Distance sampling. Data from 2014 were unsuitable for analysis due to lack of systematic line transect coverage. Observations further than 600m from the track line were considered outliers and truncated from further analysis in 2016, for optimal AIC value (indicating model fit), while still incorporating the majority of the data set. In 2015, the data set was limited and therefore a wider limit, 1000m, was set.

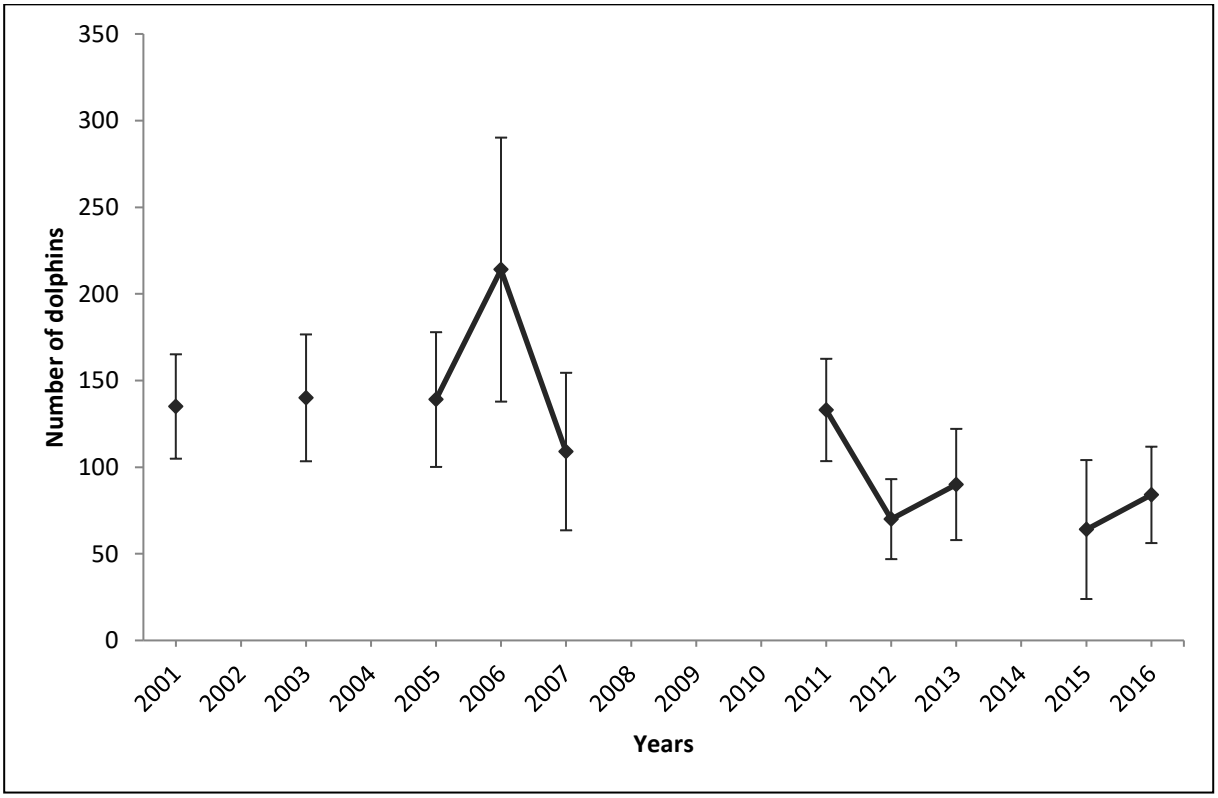


Figure 14: Abundance estimates of bottlenose dolphins from line transect surveys in Cardigan Bay SAC, 2001-2016. Years without distance sampling estimates left blank. Error bars denote 95% CIs

Abundance estimates obtained through Distance analysis show similar trends as results obtained through CMR analysis, bearing in mind the temporal gaps in the line transect estimates: an initial increase in numbers in the early years of the study from 2001 to 2006, a gradual decline between 2011 and 2013, and a slight increase in numbers between 2015 and 2016.

CMR estimates across all years, based on closed population models, for both Cardigan Bay SAC and the wider Cardigan Bay exhibit a similar trend: an initial increase in estimates from the beginning of the study in 2001 and 2005 respectively, declining in later years and reaching some of the lowest estimates on record in 2014.

The main difference between the results obtained through CMR analysis and Distance is that the CMR closed model showed a peak in estimates in 2012 (Table 5, Figure 10), whereas the Distance estimate for that year is nearly half that of previous years (Table 6, Figure 14).

Table 6: Abundance estimates of bottlenose dolphins based on distance sampling from line transect surveys in Cardigan Bay SAC

Year	Abundance	95% CI	CV	Observations
2001	**135**	85-214	0.24	93
2003	**140**	69-284	0.37	19
2005	**139**	88-218	0.23	49
2006	**214**	108-422	0.36	30
2007	**109**	49-239	0.42	24
2011	**133**	75-235	0.30	22
2012	**70**	37-131	0.33	19
2013	**90**	45-179	0.37	22
2015	**64**	19-220	0.65	12
2016	**84**	44-160	0.33	18

Abundance estimates were examined for significant trends in the same way as for CMR estimates. Two time periods were considered: the full time period, 2001 to 2016, and the last ten years, 2007 to 2016. The period 2001 to 2016 showed a significant negative trend ($F=6.75$, $p=0.033$), confirmed from the 1,000 trend simulations, (98.7% negative, 1.3% positive) (Figure 15). Surveys during the period 2007 to 2016 also showed a weak negative trend (84.7% negative and 15.3% positive) but this was not significant ($F=2.144$, $p=0.217$) (Figure 15).

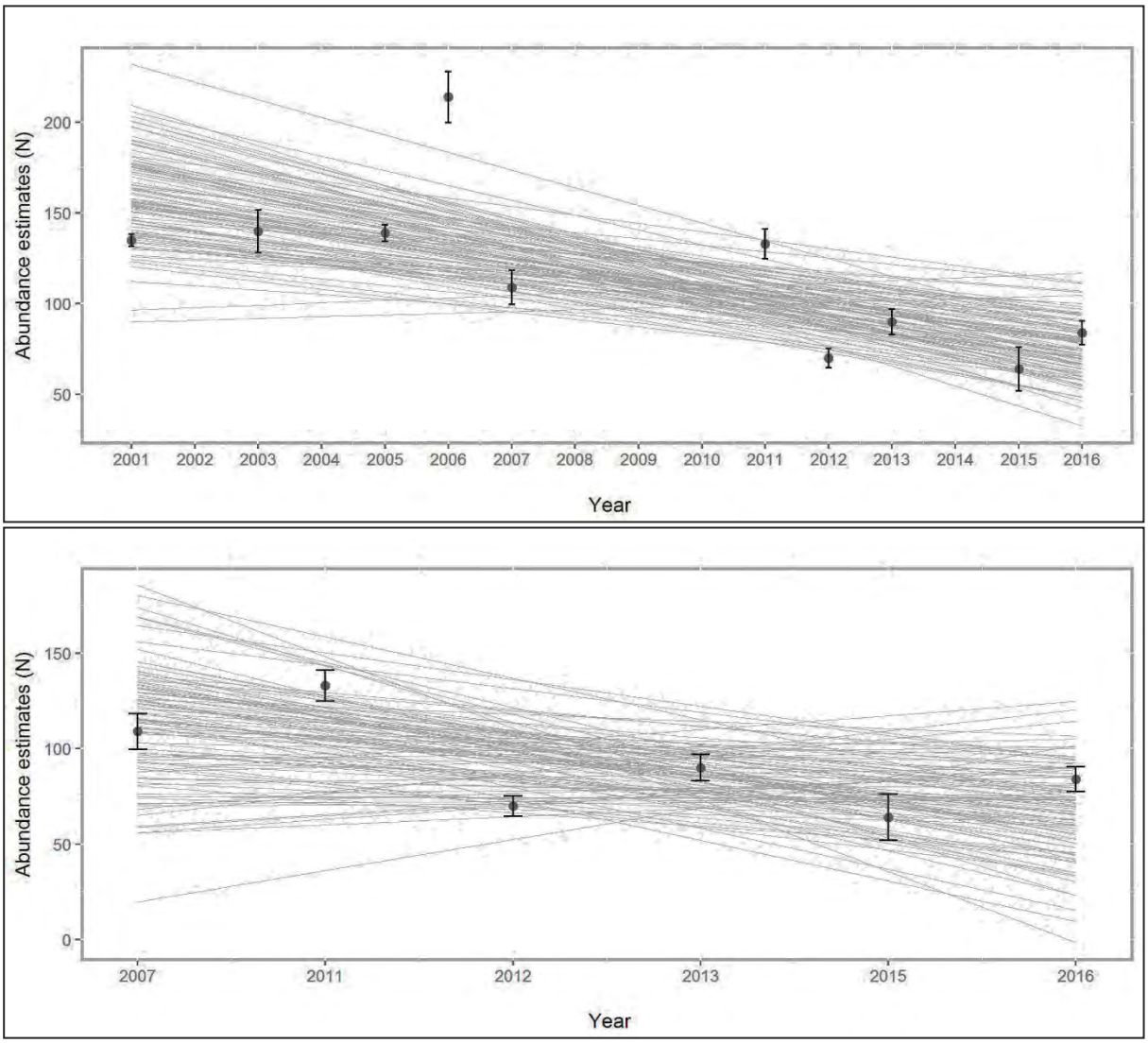


Figure 15: Trend analysis of Cardigan Bay SAC abundance estimates for bottlenose dolphins for 2001-2016 (top) and 2007-2016 (bottom) based on distance sampling. Lines depict 100 randomly selected simulation trends. Abundance estimates plotted with SE bars over trend simulations

5.5. Abundance estimates for bottlenose dolphins wider Cardigan Bay

5.5.1. Closed Model CMR estimates of bottlenose dolphins in wider Cardigan Bay

Population estimates were also obtained for the wider Cardigan Bay area for the years 2005-16 (Figure 16, Table 7). The year 2005 marked the beginning of systematic line transect surveys in northern Cardigan Bay and is therefore the first year that sufficient data for analysis were available.

Population estimates for the wider Cardigan Bay based on the closed population model show a steady increase in dolphin numbers, peaking at 318 (CI = 61.9) in 2009, before

slowly declining. Estimates for the last three years vary, increasing from 141 (CI = 39.80) in 2014 to 206 (CI= 28.40) in 2015, followed by a small decline from 2015 to 2016 with an estimate of 174 (CI = 25.68) in 2016 (Figure 16, Table 7). The general pattern was similar to Cardigan Bay SAC, with an initial increase, peaking and then decreasing to the historically lowest estimate in 2014 since the start of systematic surveys in 2005.

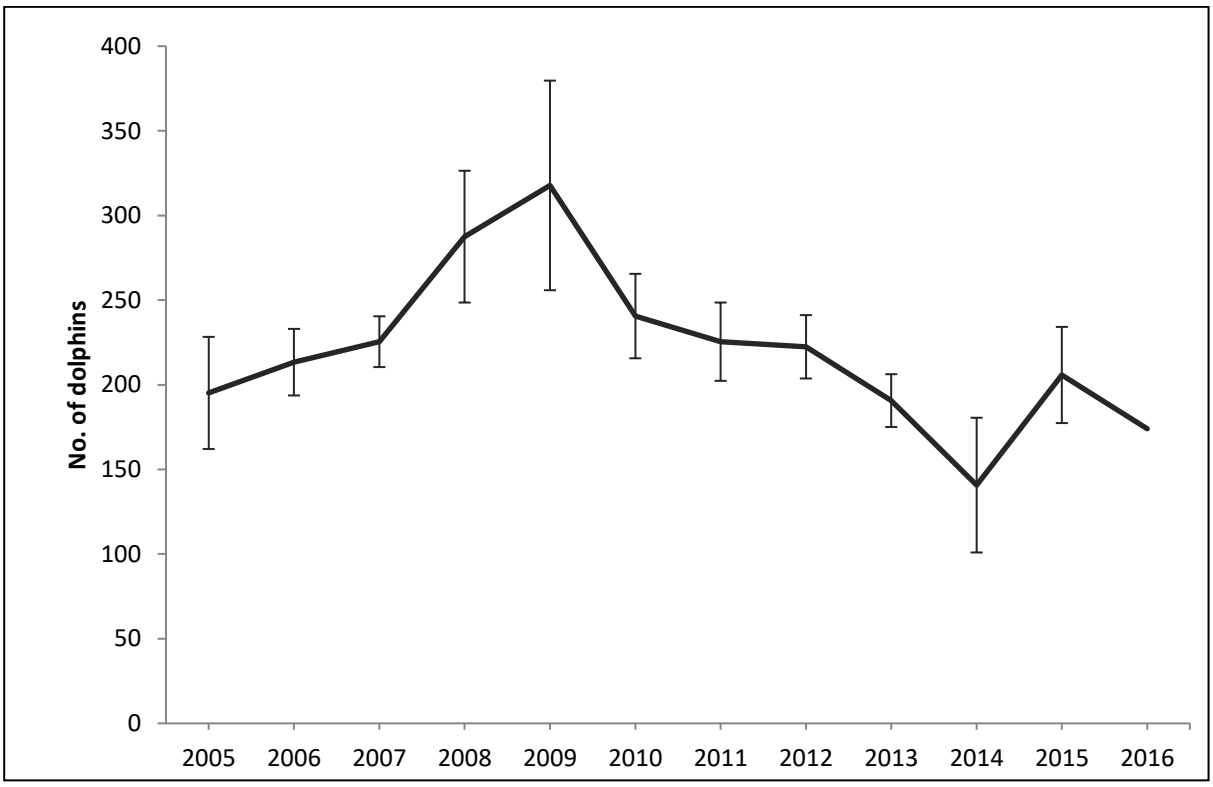


Figure 16: CMR population estimates for bottlenose dolphins in the wider Cardigan Bay area from 2005 to 2016. Error bars denote 95% CIs

Table 7: Population estimates of bottlenose dolphins occupying wider Cardigan Bay, calculated using a closed population CMR model taking into account the average marked proportion of individuals

Year	Capture events	Animals captured	Population estimate	Lower 95% CI	Upper 95% CI	CV
2005	142	85	**195**	162	263	0.36
2006	221	118	**213**	199	256	0.20
2007	291	132	**225**	212	259	0.13
2008	248	124	**287**	245	363	0.27
2009	191	111	**318**	251	440	0.39
2010	283	120	**241**	215	289	0.21
2011	265	114	**225**	201	271	0.21
2012	293	122	**222**	204	260	0.17
2013	262	107	**191**	176	224	0.16
2014	127	73	**141**	117	262	0.57
2015	162	90	**206**	171	278	0.28
2016	162	83	**174**	150	246	0.30

CMR based abundance estimates for wider Cardigan Bay were tested for significant trends in the same way as for Cardigan Bay SAC for the period 2007 to 2016. There were no systematic surveys in northern Cardigan Bay prior to 2007.

A significant negative trend (95.7% negative, 2.3% positive; F=9.51, p=0.015,), was detected, between 2007 and 2016 (Figure 17a). A second trend analysis was undertaken based on data from 2011 to 2016 to be able to directly compare results to the trend analysis of distance sampling estimates for wider Cardigan Bay. Although a significant negative trend in model fit was detected for this period (F=13.14, p=0.022), the linear regression simulations indicated only a weak trend (82.2% negative, 17.8% positive)8 (Figure 17b).

[8] The global model fit significantly declines at the 95% level, but only approximately 80% of the 1000 linear regression simulations were negative (ie, there is an 80% certainty that the population declined). Further trend analysis is being carried out

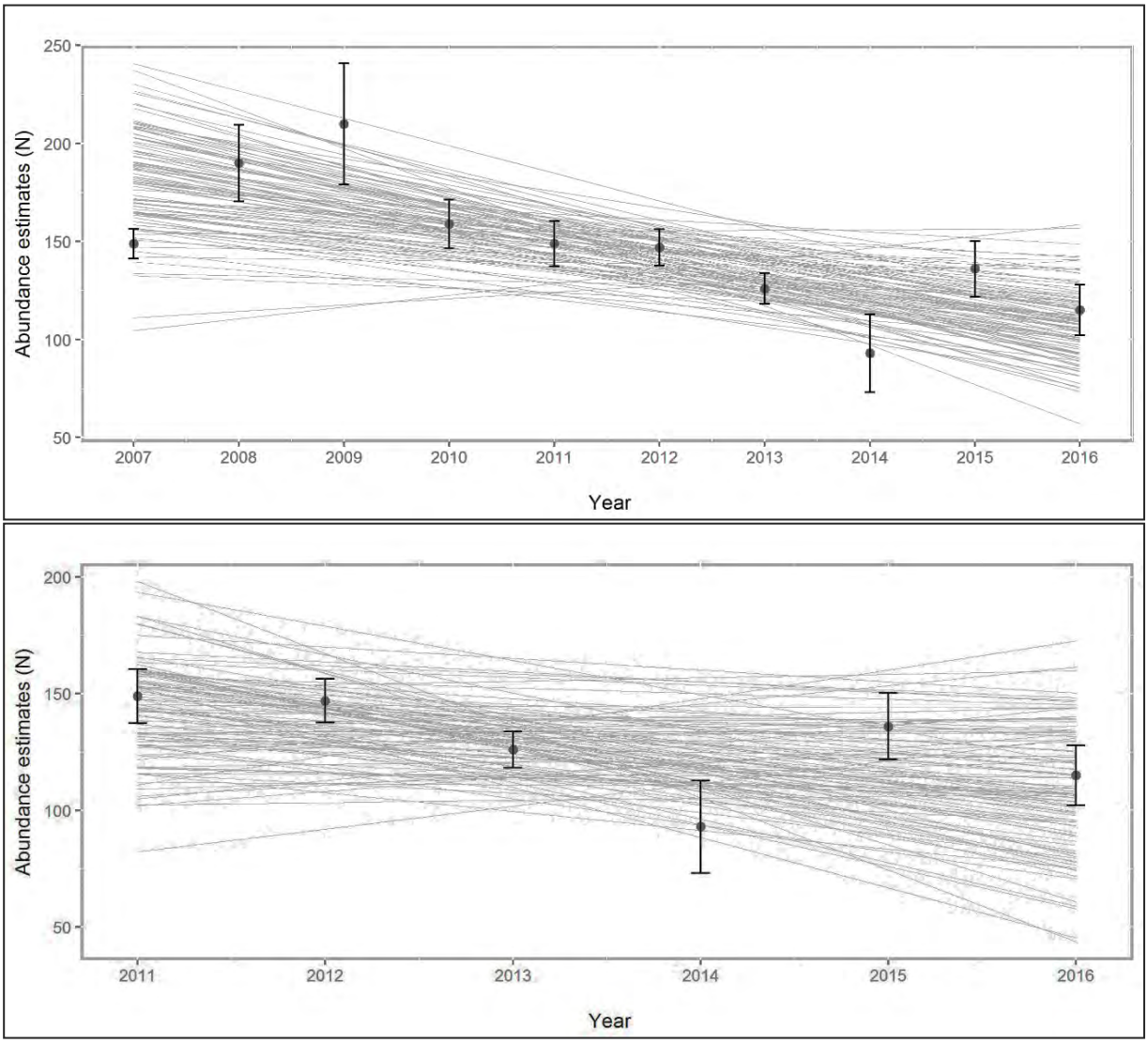


Figure 17: Trend analysis of wider Cardigan Bay CMR abundance estimates for bottlenose dolphins for 2007-2016 (a, top) and 2011-2016 (b, bottom). Lines depict 100 randomly selected simulation trends. Abundance estimates plotted with SE bars over trend simulations.

5.5.2. Residency patterns of bottlenose dolphins in wider Cardigan Bay derived from a robust CMR model

Estimates of the probability of emigration have risen slightly overall since the beginning of the study, spiking in 2013. The likelihood of animals staying out of the bay also shows a high level of variation. Having risen overall since the start of the study, it shows peaks in 2009, 2012 and 2013, before dropping off again slightly in 2015. Overall, neither the probability of emigration, nor the probability of animals staying out of the bay, has shown any clear trend over the study period (Figure 18).

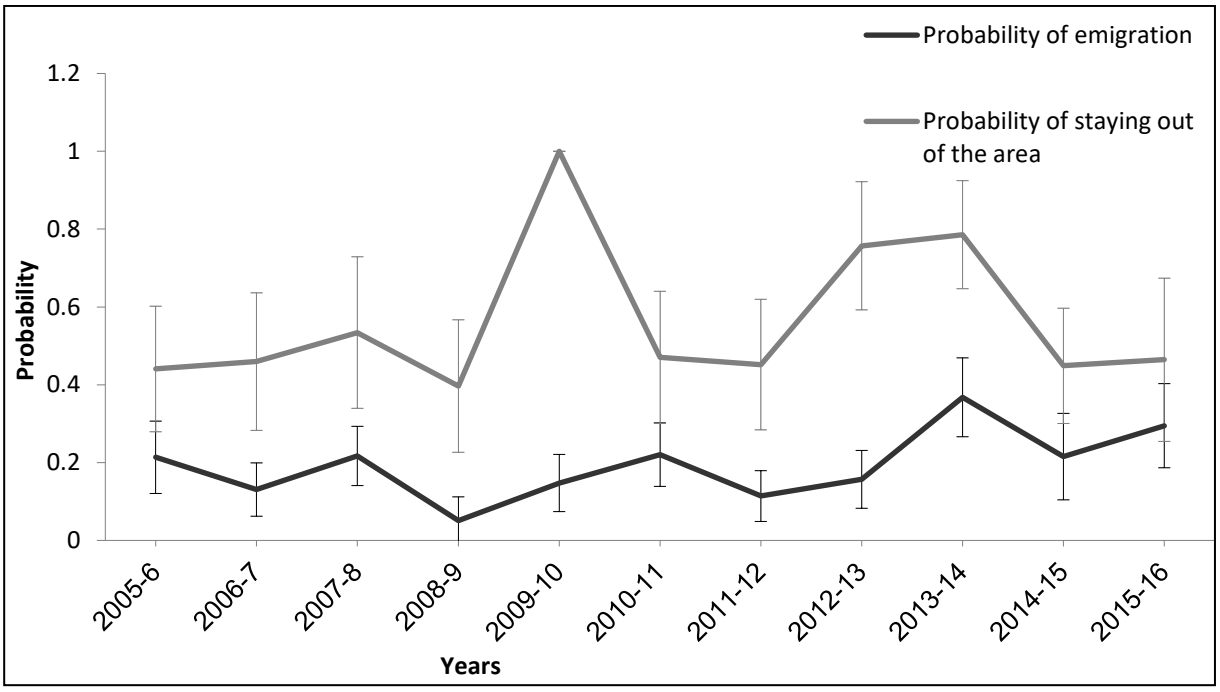


Figure 18: Bottlenose dolphin residency in wider Cardigan Bay, 2005-2016, derived using a robust population model. (See Appendix 2 for SE values)

5.5.3. Distance sampling estimates of bottlenose dolphins in wider Cardigan Bay

Bottlenose dolphin abundance estimates and detection curves were also calculated for the wider Cardigan Bay (Table 8, Appendix 2). Observations were truncated at 600m from the track line than 600m; providing the lowest AIC value while still including the majority of the data. In 2015, the data set was limited and therefore a wider limit, 1000m, was set in order to be able to include more observations. Data from 2014 could not be used for analysis since the request that year was to focus upon photo-ID and not systematic line transect survey. Estimates for the wider Cardigan Bay only go back to 2011 when systematic line transect surveys began, and are therefore more difficult to interpret. They are more variable with no obvious trends (Table 8, Figure 19).

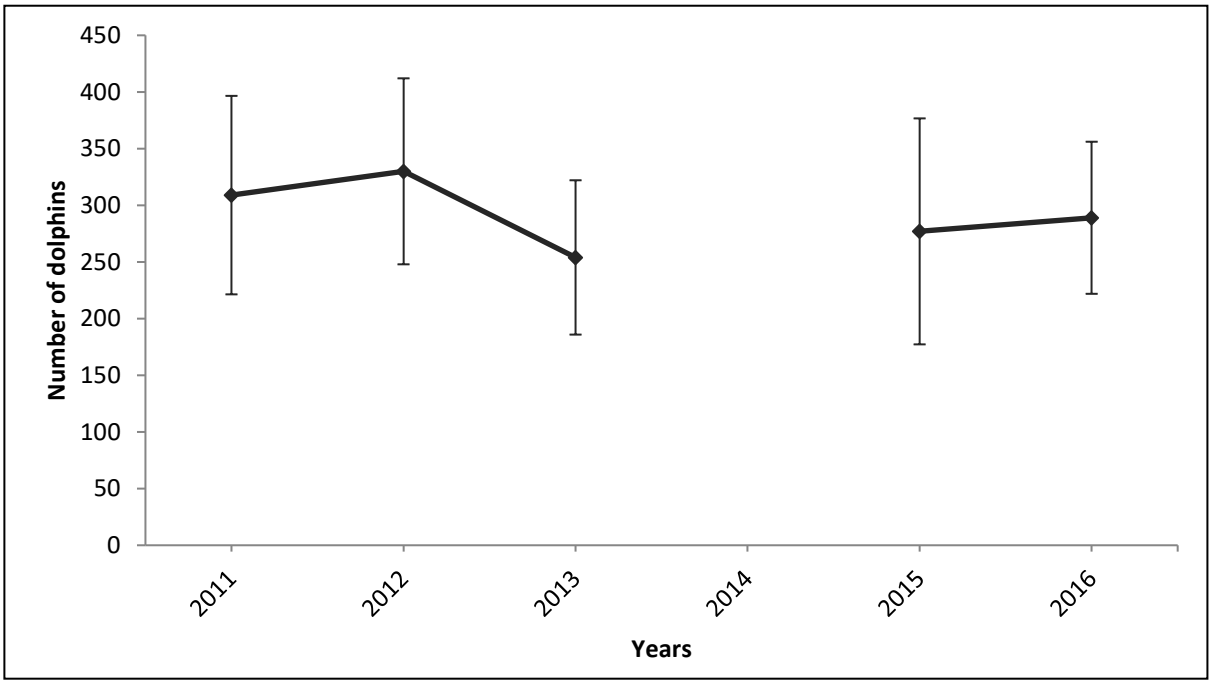


Figure 19: Abundance estimates of bottlenose dolphins (BND) from line transect surveys in wider Cardigan Bay, 2011-2016. Years without distance sampling estimates left blank. Error bars denote 95% CIs

Table 8: Abundance estimates of bottlenose dolphin (BND) from line transect surveys in wider Cardigan Bay

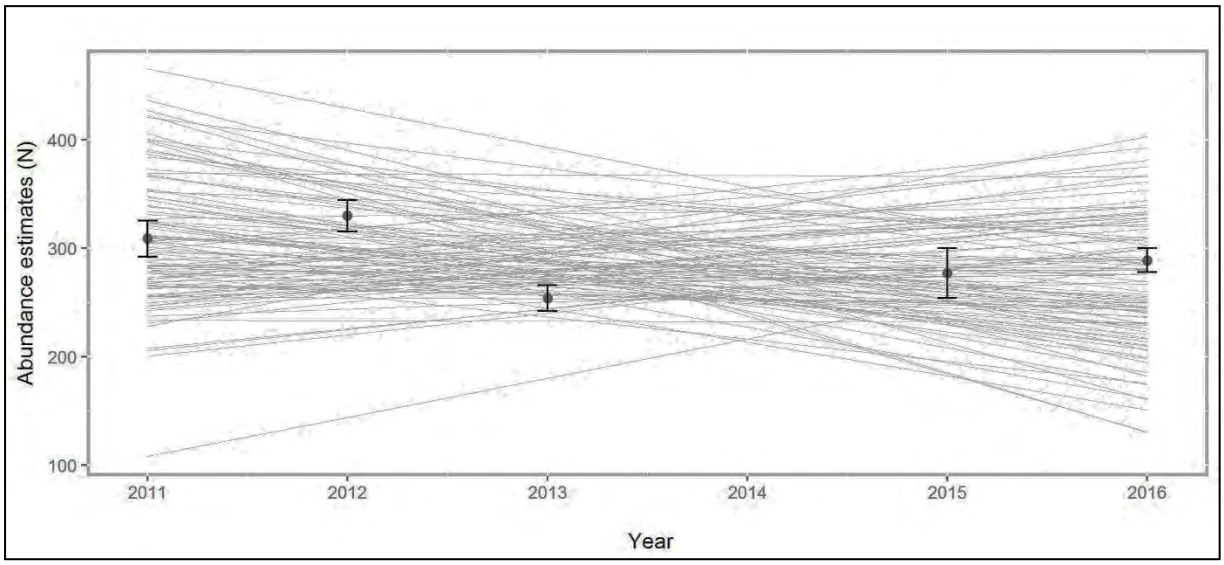
Year	Abundance	95% CI	CV	Observations
2011	**309**	179-353	0.28	27
2012	**330**	203-534	0.25	32
2013	**254**	151-427	0.27	33
2015	**277**	138-555	0.36	19
2016	**289**	184-453	0.23	36

Similar to the results of the CMR analysis in the wider Cardigan Bay area, the distance analysis suggests a peak in population size in 2012 followed by a decline. However, the continued increase in numbers from 2015 to 2016 is at odds with the CMR analysis (although the closed CMR model showed an increase from 2014 to 2015) with a decrease in numbers in 2016.

Distance sampling based abundance estimates for wider Cardigan Bay were tested for significant trends in the same way as for Cardigan Bay SAC. However, due to a lack of systematic line transect surveys in northern Cardigan Bay prior to 2011, trends were only analysed for 2011 to 2016.

No significant trend was observed from regression analysis (F=0.79, p=0.44), and although the majority of simulations suggested a negative trend, this was very weak (62.1% negative and 37.9% positive) (Figure 20). This is in accordance with trend analysis for CMR estimates for the same period which although finding a significant negative trend (F=13.14, p=0.022), the simulations showed it to be relatively weak (82.2% negative, 17.8% positive) (Figure 17). As line transects across the wider Cardigan Bay only started in 2011, it is too early to establish trends.

Figure 20: Trend analysis of wider Cardigan Bay abundance estimates for bottlenose dolphins for 2011-2016 based on distance sampling. Lines depict 100 randomly selected simulation trends. Abundance estimates plotted with SE bars over trend simulations



5.6. Power to monitor trends in bottlenose dolphin abundance estimates

In addition to testing for significance in trends, it is important in any monitoring programme to establish the level of effort needed to be confident that a trend can be detected. There is a close relationship between power, survey effort and the precision of the estimate determined by the monitoring. Here we explore these relationships for our two main approaches to monitoring: annual CMR estimates from photo-ID and systematic line transect surveys involving Distance sampling.

Studies have a high statistical power when they are very precise (i.e. a low coefficient of variation, CV) or the size effect is large (i.e. any change occurring accounts for a substantial proportion of the variation). As survey effort is increased, so the precision of estimates is increased (i.e. CV decreases) and consequently the power to detect trends improves. Expending more effort at each sampling occasion or sampling more frequently will increase survey effort over time with the result of improving CVs.

5.6.1. Monitoring trends in bottlenose dolphin abundance in Cardigan Bay SAC from CMR analysis

Photo-identification studies using CMR techniques of analysis are commonly used as a monitoring method for assessing abundance in small local populations. Thompson *et al.* (2000) concluded that a 5% decline per annum could be detected over an 11-year period with a power of 95% if abundance surveys were carried out annually and were precise (CV = 0.15).

The CV around the abundance estimate depends upon survey effort but also upon the number of capture events, which is reflected in the population size. If the population declines, then the number of capture events will likely do so also, even if the level of survey effort is maintained. We therefore explore here the relationship between CV, capture events and survey effort. Since surveys may vary in coverage, we also consider the actual distance travelled in km.

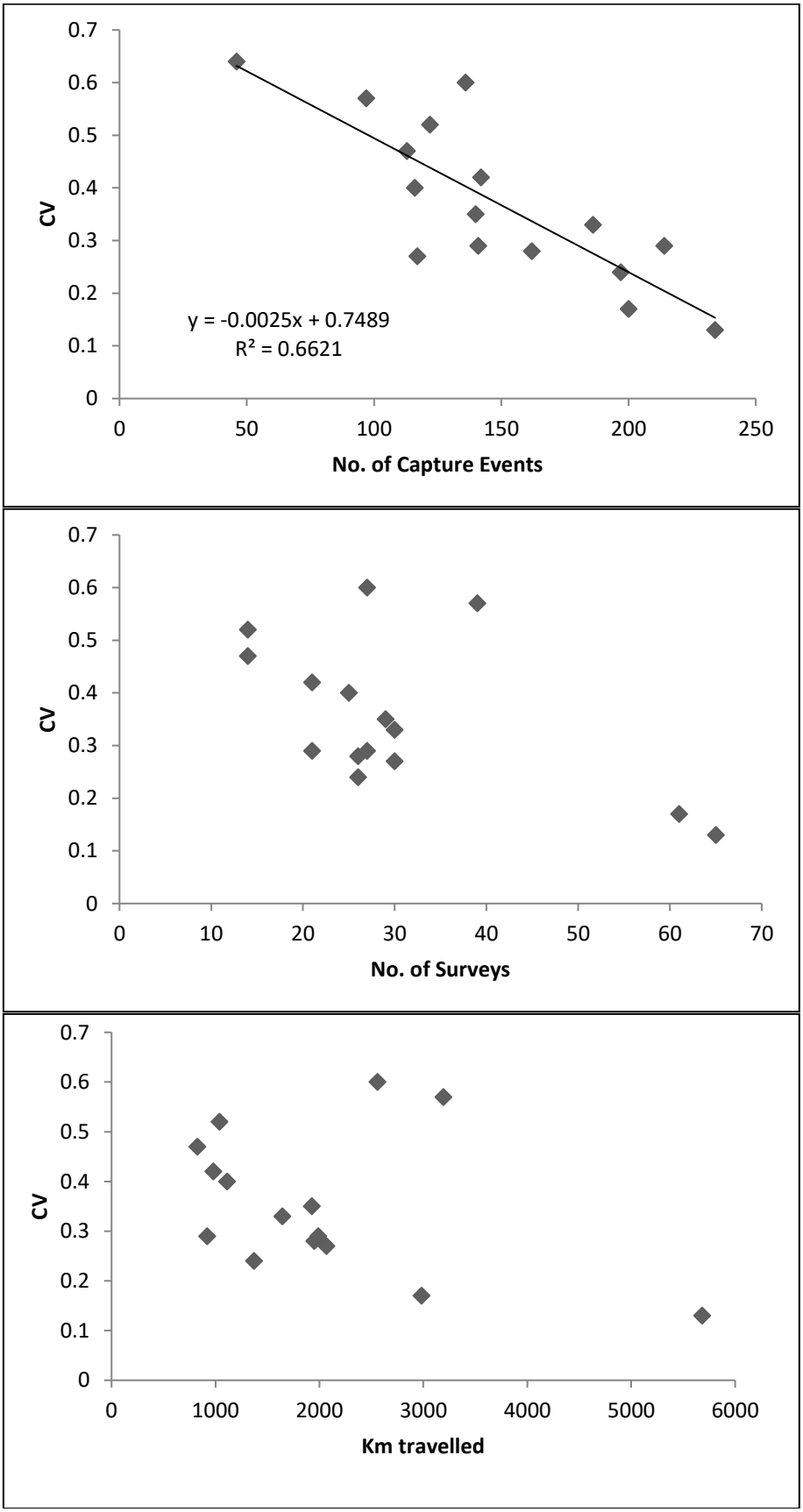


Figure 21: Relationships between a) number of capture events, b) number of surveys, c) km travelled, and CVs of CMR abundance estimates for Cardigan Bay SAC. Only significant ($P<0.05$) correlation lines shown

Figure 21a shows the expected negative relationship between CV and number of capture events. CVs of 0.1 to 0.2 are reached in the Cardigan Bay SAC population only when the number of capture events exceeds around 200 in a season. This translates into a quantity of around 60 surveys (Figure 21b), equivalent to somewhere between 3,000 and 6,000 km travelled (Figure 21c).

5.6.2. Monitoring trends in bottlenose dolphin abundance for the wider Cardigan Bay from CMR analysis

Similar to the Cardigan Bay SAC, we explore here the relationship between CV, capture events, and survey effort for the wider Cardigan Bay. Since surveys may vary in coverage, we also consider the actual distance travelled in kilometres. In the case of the wider Cardigan Bay we have a much smaller time series as historically the focus of survey effort has been upon the Cardigan Bay SAC rather than the wider region. However, since the species occurs throughout the bay, and in the northern part, it is a qualifying feature within the Pen Llŷn a'r Sarnau SAC, resources have been made available to extend our survey effort in recent years.

Figure 22a again shows the negative relationship between CV and number of capture events. CVs of 0.1 to 0.2 are reached in the wider Cardigan Bay population only when the number of capture events exceeds around 200 in a season. In this case, that translates into a quantity of around 45 surveys (Figure 22b), equivalent to somewhere between 4,000 and 5,000 km travelled (Figure 22c).

5.6.3. Monitoring trends in bottlenose dolphin abundance in Cardigan Bay SAC by line-transect Distance sampling surveys

Abundance estimates derived from line transect surveys also show greater precision (low CVs) with higher survey effort, and again, the precision depends upon encounter rates (i.e. the number of observations) so that small study populations require greater effort than large populations for an equivalent low CV.

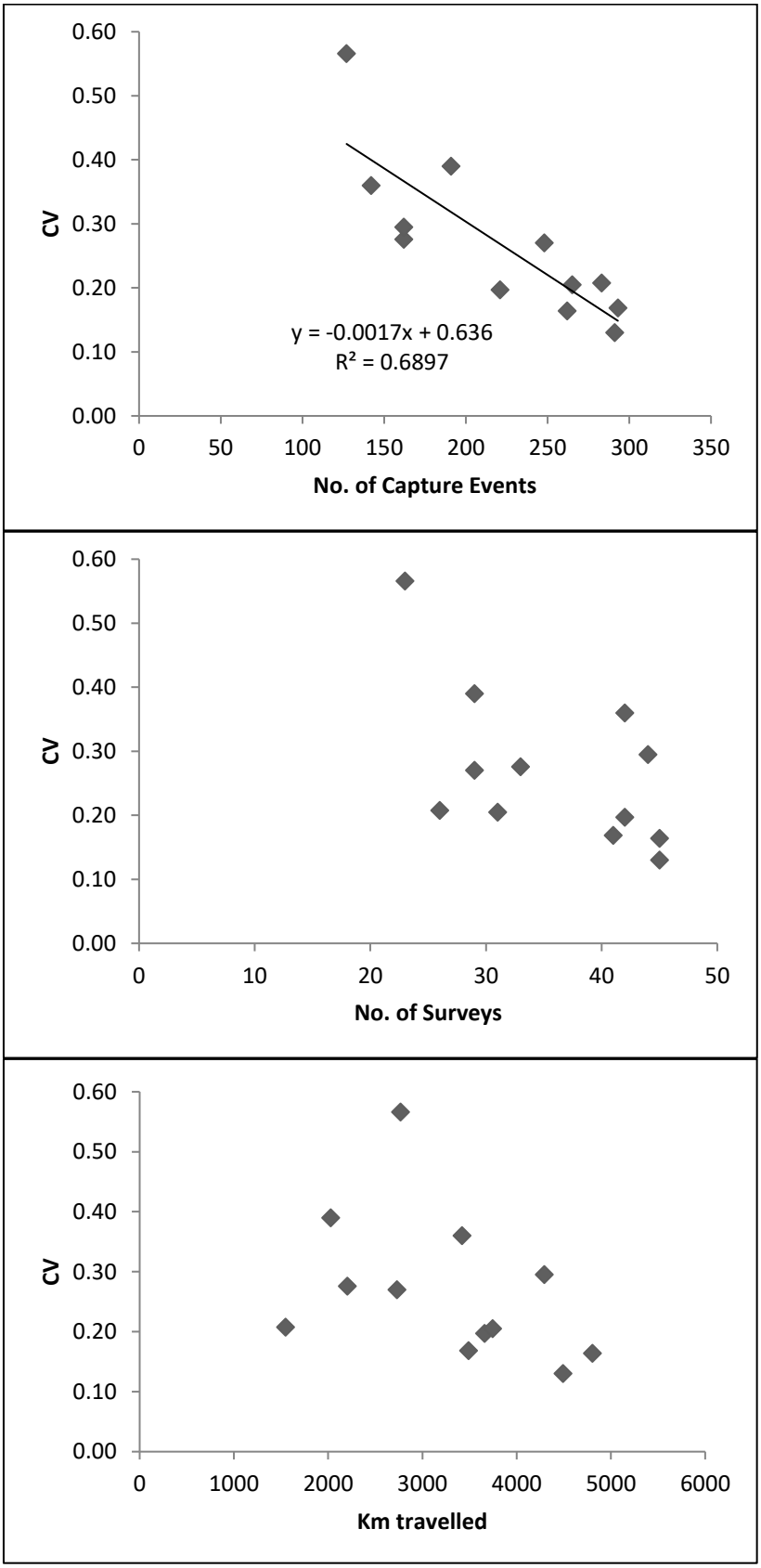


Figure 22: Relationships between a) number of capture events, b) number of surveys, c) km travelled, and CVs of CMR abundance estimates for the wider Cardigan Bay. Only significant (P<0.05) correlation lines shown

Ideally, CV values should fall between 0.15-0.20 to allow for a more precise prediction of population trends (Gerrodette, 1987; Thomas, 2009). However, this is often difficult to achieve in cetacean populations using line transect surveys. CVs in the range of 0.20 have been achieved in Cardigan Bay SAC in only two years, when the number of observations exceeded forty (Figure 23a) and line transect survey effort exceeded c. 1,500km (Figure 23b). As one might expect, there is a positive relationship between the number of observations and amount of survey effort, even accounting for variation in encounter rates due to varying annual population size (Figure 23c).

It is also important to consider survey intervals. Currently, SWF conduct systematic line transect surveys across Cardigan Bay on an annual basis. The Habitats Directive reporting interval is 6 years.

Thomas (2009) calculated the power to detect a range of annual population declines (or increases) over 6 years, given CVs in the range 0.2-1.0, and assuming a level of significance (alpha level) of 10%.

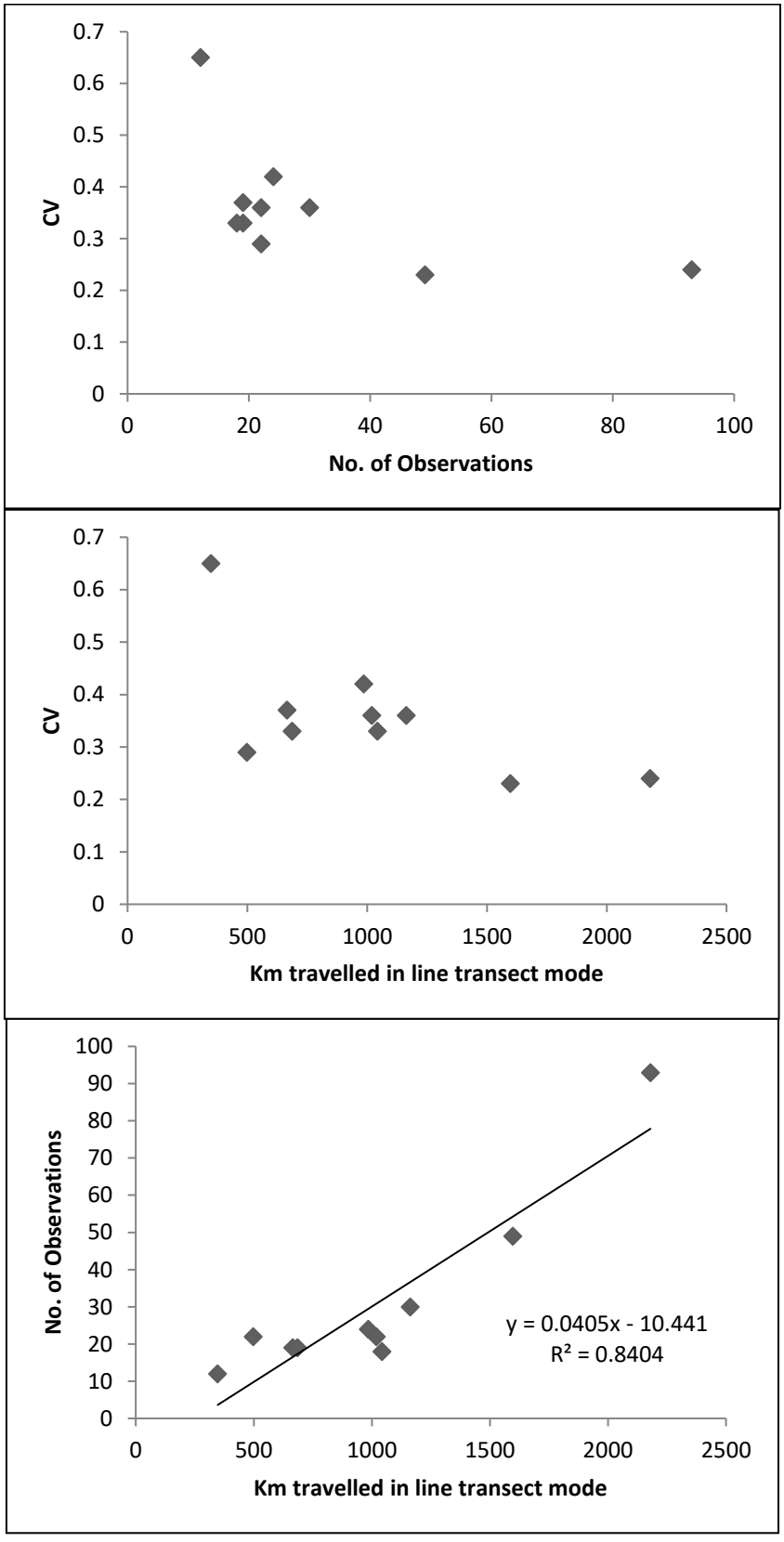


Figure 23: Relationships between CVs and a) number of observations and b) line transect survey effort (km travelled), and between c) number of observations and survey effort (km travelled) in bottlenose dolphin abundance estimates for Cardigan Bay SAC. Only significant (P<0.05) correlation lines shown

For example, assuming the target power of a monitoring programme to be 80% (as adopted by ICES WGMME, 2014), if the programme achieved the best conceivable CV (0.2), then an annual rate of decline of 0.15 would be required for that level of power (Figure 24). A decline of this rate over 6 years corresponds to the loss of approximately 60% of the population. If the CV was 0.4, an annual rate of decline of 0.33 would be required for a power of 80%; this corresponds to the loss of approximately 90% of the population over 6 years. His conclusion was that the Habitats Directive reporting interval of six years is unrealistic, and should be extended, and ICES (2016), advising OSPAR on MSFD indicators, has proposed assessment of trends over a ten- year period.

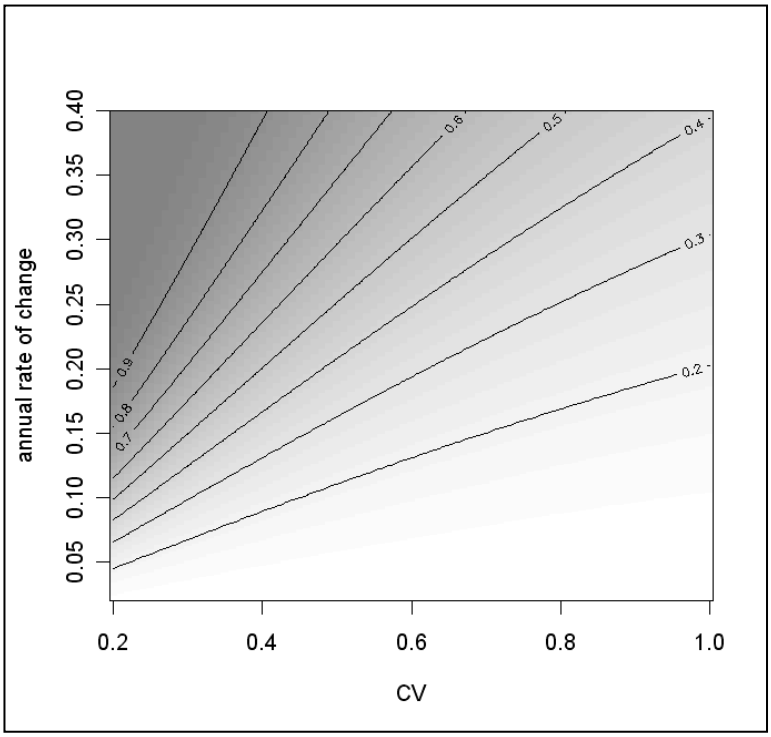


Figure 24: Statistical power to detect a log-linear population trend after 6 years of annual monitoring, over a range of annual rates of change and residual coefficients of variation (CVs), assuming a constant CV, an alpha-level of 0.1 and a two-tailed t-test for trend (from Thomas, 2009)

Using the line transect bottlenose dolphin abundance estimates for Cardigan Bay SAC where we have a fuller time series, we have calculated the survey intensity required to achieve a power of 80% and varying significance levels. Whereas achieving a significance level of 5% is not feasible (as demonstrated already by Thomas, 2009), a level of significance of 10% is approached by an annual survey frequency, and a significance level of 20% (the other option proposed by the ICES WGMME, 2014) is easily achieved (Figure 25).

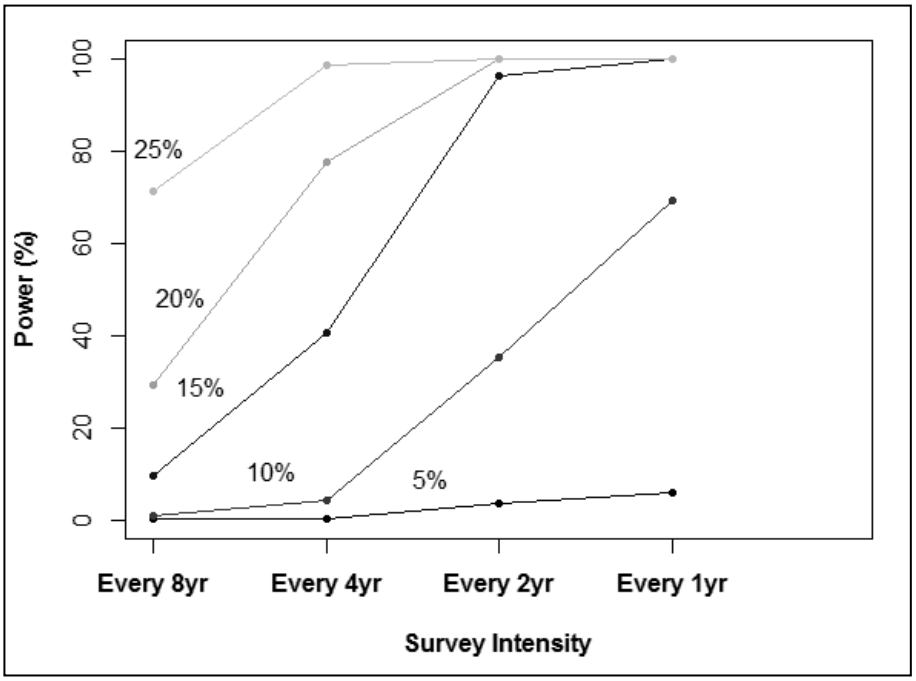


Figure 25: Power to detect a trend in bottlenose dolphin abundance from line transect Distance sampling surveys at different frequencies (every 1, 2, 4 & 8 years) and levels of significance (5%, 10%, 15%, 20% & 25%)

The process of hypothesis testing is intrinsically prone to error. The two main forms of error are Type I and Type II errors. A Type I error occurs when a null hypothesis has been incorrectly accepted (i.e. a significant effect detected when not actually occurring) and a Type II one when it has been incorrectly rejected (i.e. when no significant effect is detected when actualy there is one). The arbitrary significance level of 5% is skewed towards reduction of Type I errors so if one is to take a precautionary approach, it is prudent to use a lower significance level, hence the options proposed of 10% or 20%.

5.6.4. Monitoring trends in bottlenose dolphin abundance in the wider Cardigan Bay by line-transect Distance sampling surveys

For the wider Cardigan Bay, we have only five years of data so exploring relationships between CV, number of observations, and survey effort is limited. CVs in the range of 0.20 have not been achieved in the wider Cardigan Bay during the years that the area has been surveyed by line transect. However, CVs of c. 0.25 were achieved when the number of observations exceeded c. 30 (Figure 26a) and line transect survey effort over this wider region exceeded c. 1,800km (Figure 26b).

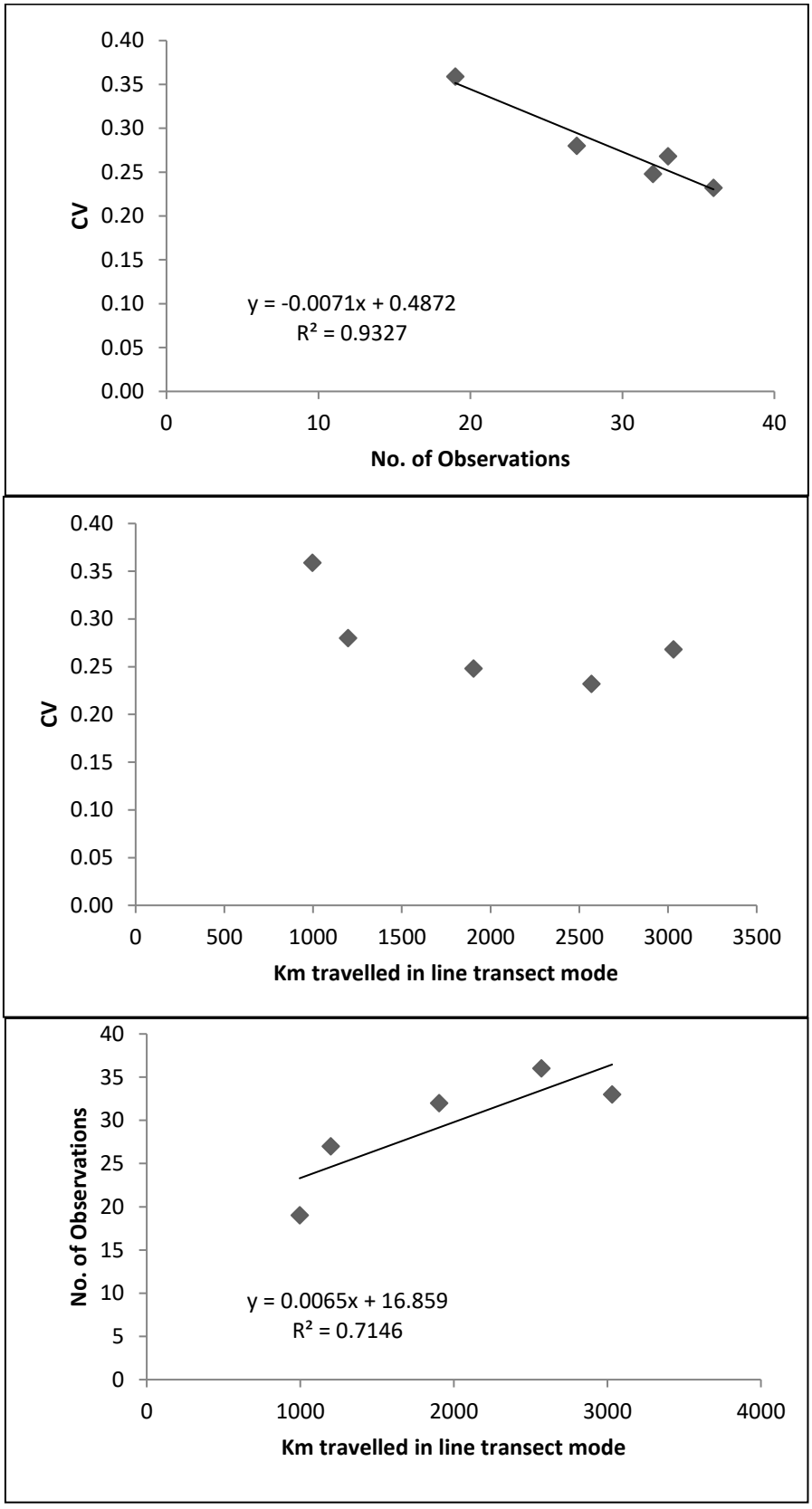


Figure 26: Relationships between CVs and a) number of observations and b) line transect survey effort (km travelled), and between c) number of observations and survey effort in bottlenose dolphin abundance estimates for the wider Cardigan Bay. Only significant (P<0.05) correlation lines shown

As one might expect, there is a positive relationship between the number of observations and amount of survey effort, even accounting for variation in encounter rates due to varying annual population size (Figure 26c).

5.7. Reproductive and mortality rates

5.7.1. Crude Birth rates

Crude birth rates and number of newborns are presented below for both Cardigan Bay SAC and wider Cardigan Bay (Tables 9 & 10).

Table 9: Number of newborns recorded in the Cardigan Bay SAC and crude birth rates calculated for the sites using CMR population estimates for closed population model

Year	No. newborns	Population estimate (closed)	Birth rate (closed)%
2001	7	129	5.43
2002	8	124	6.45
2003	10	154	6.49
2004	12	141	8.51
2005	12	205	5.85
2006	13	205	6.34
2007	11	189	5.82
2008	5	239	2.09
2009	3	203	1.48
2010	14	216	6.48
2011	15	168	8.92
2012	13	211	6.16
2013	6	141	4.26
2014	5	107	4.67
2015	10	146	6.84
2016	4	147	3.40
Average	9.43		5.54

Table 10: Number of newborns recorded in wider Cardigan Bay and birth rates calculated for the sites using CMR population estimates for closed population model

Year	No. newborns	Population estimate (closed)	Birth rate (closed)%
2005	15	195	7.69
2006	18	213	8.45
2007	17	225	7.56
2008	14	287	4.88
2009	12	318	3.77
2010	21	241	8.71
2011	25	225	11.11
2012	20	222	9.01
2013	6	191	3.14
2014	6	141	4.25
2015	12	206	5.83
2016	5	174	2.87
Average	14.25		6.43

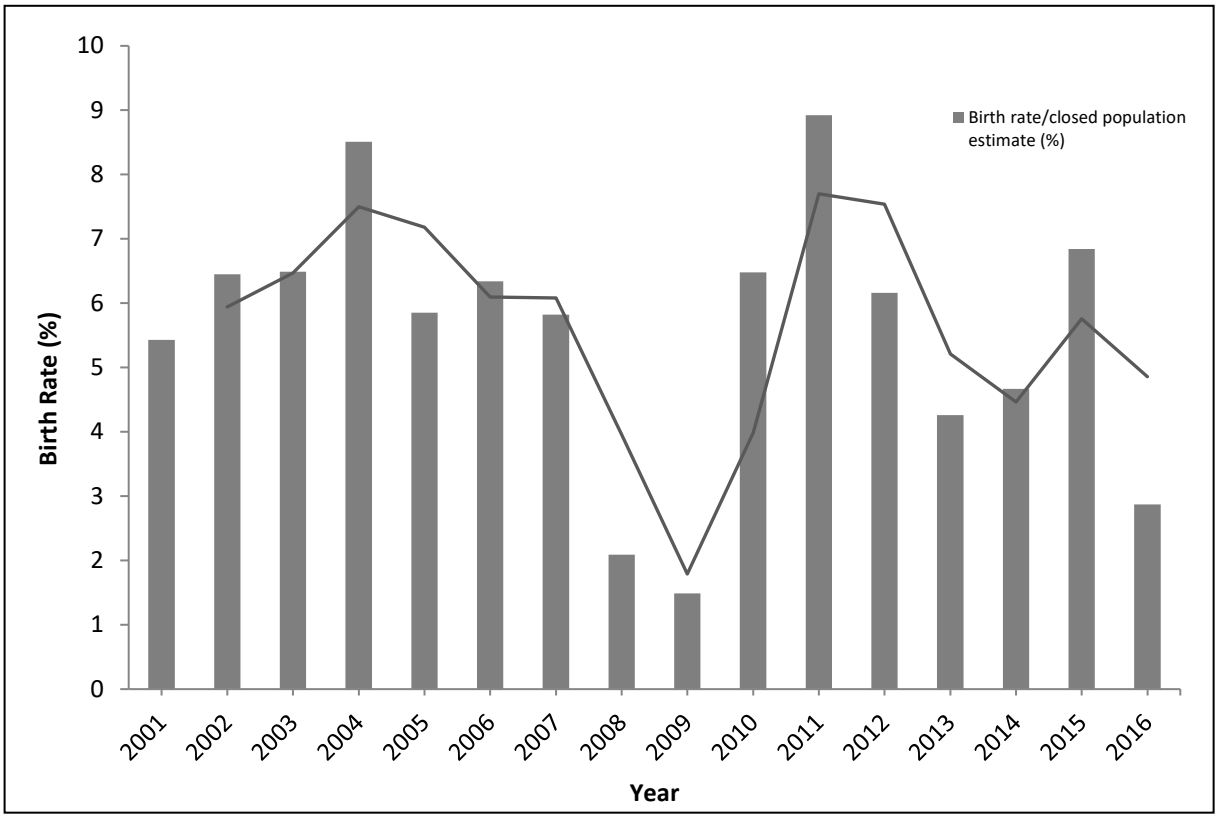


Figure 27: Birth rates of bottlenose dolphins in the Cardigan Bay SAC calculated using closed population estimates (grey line = moving average)

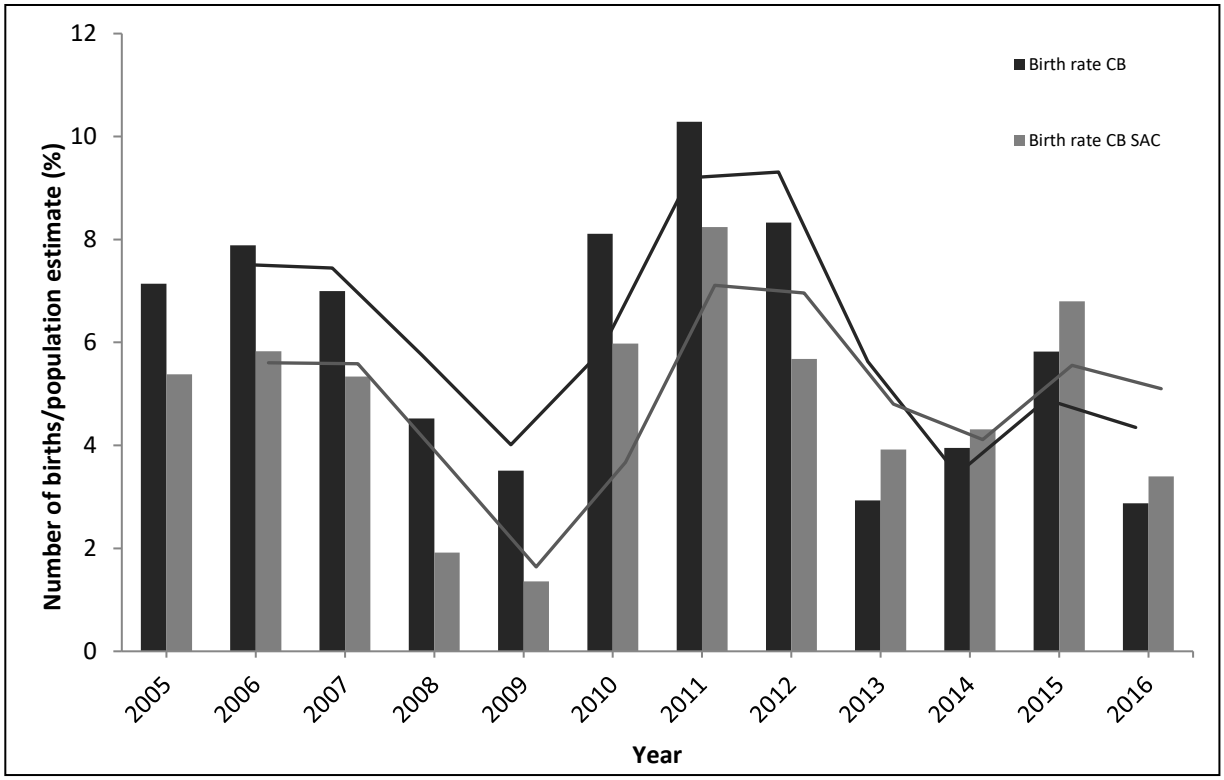


Figure 28: Birth rates of bottlenose dolphins in Cardigan Bay vs Cardigan Bay SAC calculated using closed population estimates (light grey line = moving average for CB SAC, dark grey line = moving average for the wider CB)

Annual birth rates in Cardigan Bay SAC were estimated to be 4.7% (2014), 6.8% (2015), and 3.4% (2016) using capture-mark-recapture closed population model estimates (Table 9, Figure 27). Average crude birth rate across the full study period, 2001 to 2016, was calculated at 5.5% (Table 9).

When considered across the 11 years of survey effort, the average birth rate for the wider Cardigan Bay was calculated at 6.5% based on a CMR closed population model. Birth rates for the wider Cardigan Bay were all below this over the last three years at 4.3% (2014), 5.8 % (2015) and 4.0% (2016) (Table 10, Figure 28).

Figure 28 shows crude birth rates for both Cardigan Bay SAC and the wider Cardigan Bay calculated annually from 2005 onwards when survey coverage increased to include northern Cardigan Bay. 2013, 2015 and 2016 have been the only years since 2005 that birth rates in Cardigan Bay SAC have been lower than birth rates in the wider Cardigan Bay (Figure 28).

5.8. Interbirth intervals, reproductive success and calf mortality

Interbirth intervals calculated for the 44 known females with at least two calves, ranged from 2 to 7 years, with the majority of females giving birth every three years (mean = 3.4, Figure 29), which is unchanged from previous years (Evans, 2014; Feingold and Evans, 2014a; Norrman *et al*., 2015).

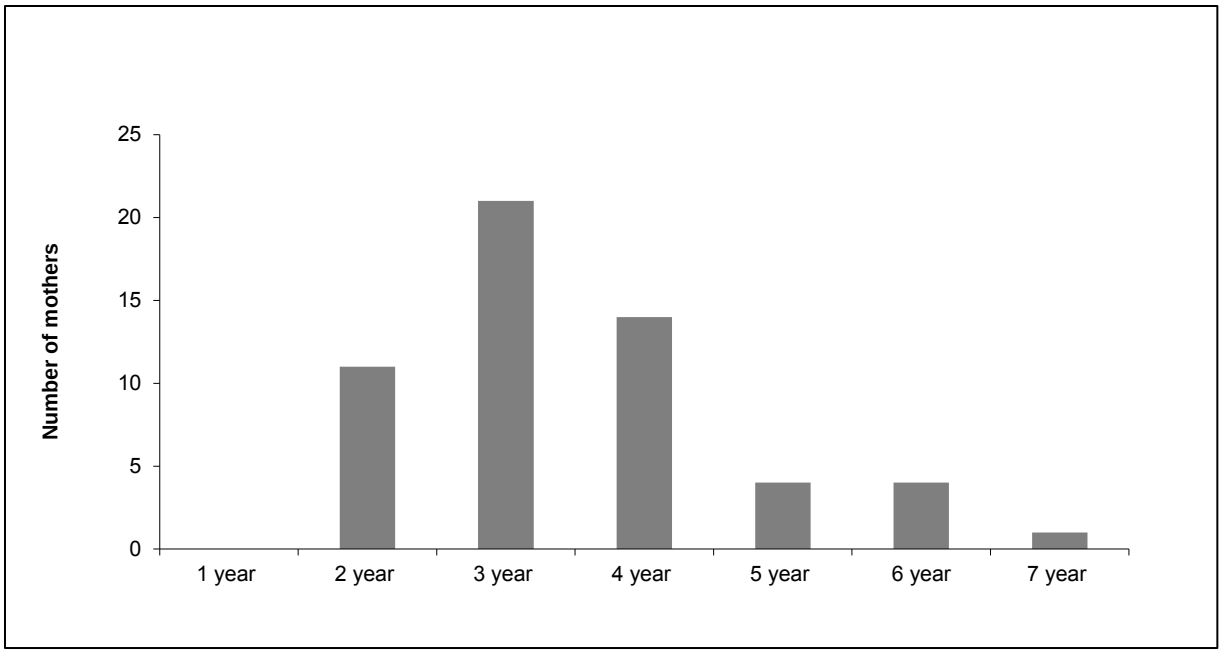


Figure 29: Interbirth intervals of 44 known females in Cardigan Bay between 2001 and 2016

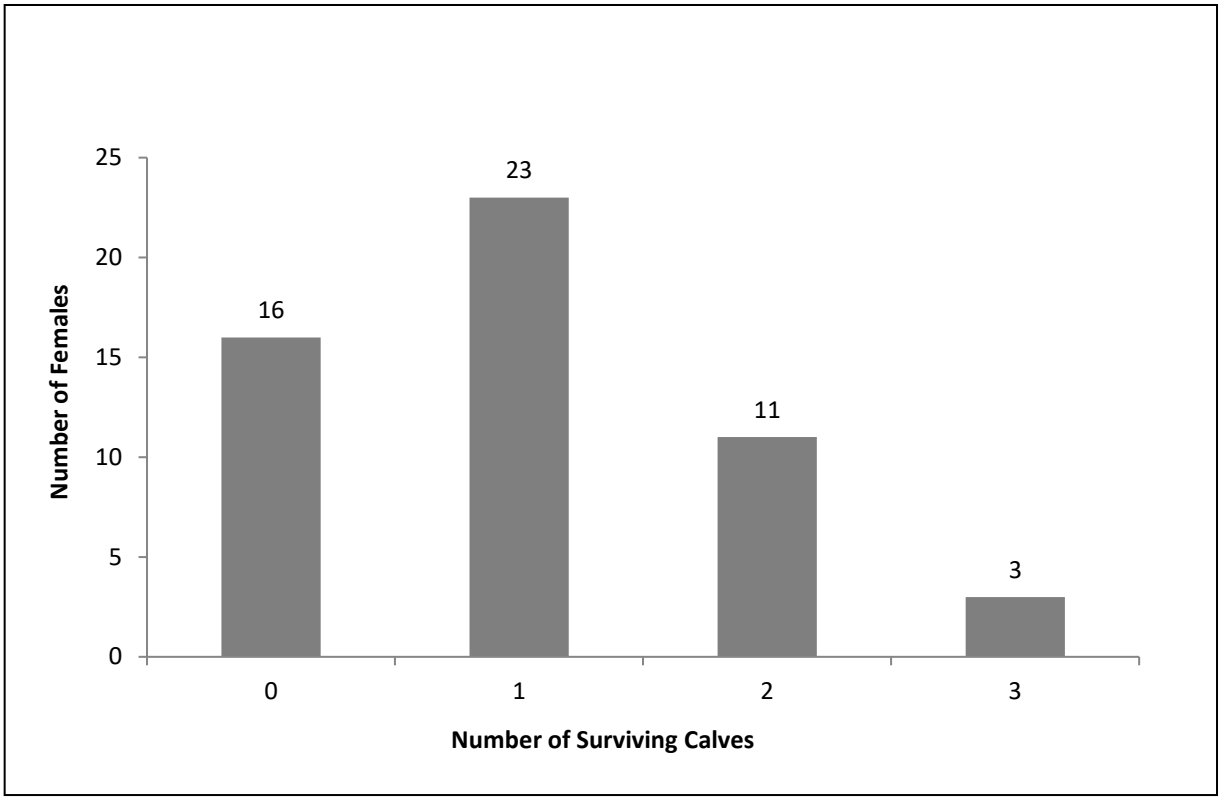


Figure 30: Female reproductive success: number of calves surviving to the age of three within Cardigan Bay, 2001-16

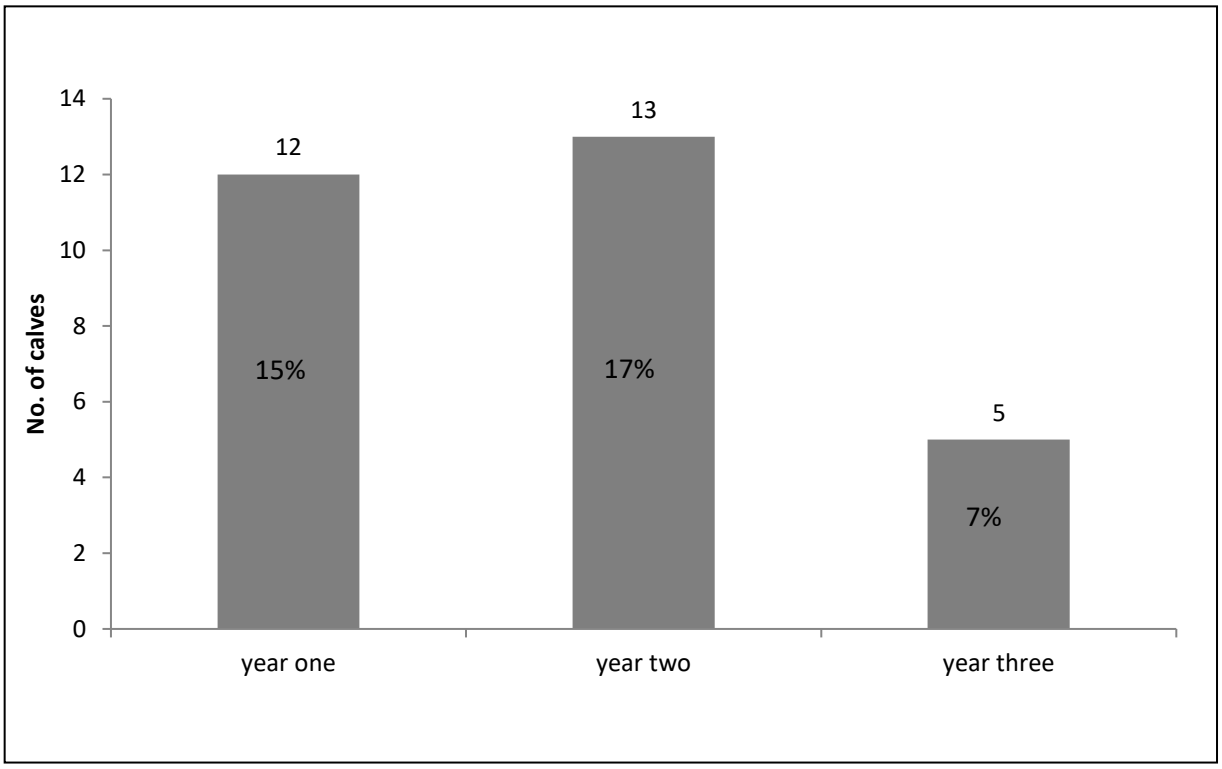


Figure 31: Number and percentages of calves that have died between the age of 1 and 3 years between 2001 and 2014

The majority of females had at least one surviving calf: 43% of females had one, 21% had two, 6% had three, and 30% had no surviving offspring. This is likely to be a conservative estimate as some calves may not be identifiable once they leave their mother, resulting in a negative bias in the data (Figure 30).

Calf mortality up to three years of age was calculated for 76 mother-calf pairs, based on calves born between 2001 and 2013. Calf mortality was particularly high in the first two years of life, at 15% and 17% respectively, dropping off by more than half in year three to 7%. (Figure 31).

5.9. Calving season

Births have been recorded as occurring throughout the season (the only months without recorded births are January, February and October), with a peak between July and September, when 65% of births occured (Figure 32). It should be noted that although there are no births recorded for certain winter months, this is likely to reflect a lack of survey effort. Some newborns in fact have been spotted in January outside of Cardigan Bay, in Anglesey (PGH Evans, personal observations).

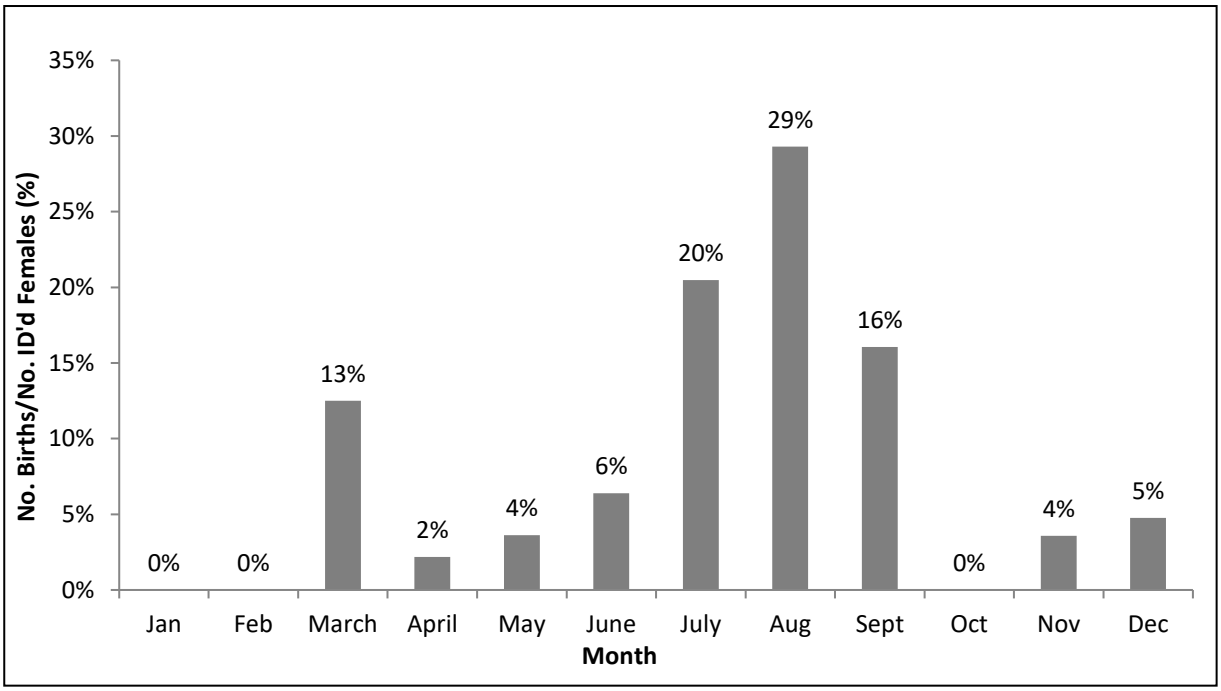


Figure 32: Number of births recorded by number of identified females each month in Cardigan Bay between 2001 and 2015

5.10. Population dynamics and residency patterns

A total of 1180 bottlenose dolphin encounters were made between 2012 and 2016. This resulted in the positive identification of 101 in 2014, 98 in 2015 and only 97 in 2016 (Table 11). The Welsh Photo-ID catalogue holds a minimum of 379 individuals (Table 12).

Table 11: SWF photo-identification catalogue content in 2016

Well marked (WM)	103
Slightly marked (SM)	145
Left (L)	120
Right (R)	131
WM + SM + L	368
WM + SM + R	379

A discovery curve was plotted for marked individuals identified between 2001 and 2016 (Figure 33). This shows a steep rise at the start of the study in 2001, when all dolphins encountered on survey would have been considered 'new'. Two further rises in discovery rates can be detected in 2005 and 2007 when systematic surveys of the northern and opportunistic surveys off North Wales began respectively. In recent years, the curve has levelled off, particularly within Cardigan Bay SAC, with few new dolphins being discovered

Frequencies of re-sightings of individual dolphins varied widely from 1 to 180 (mean = 21.62, SD = 23.84). Multiple sightings of the same individual on the same day were excluded from analysis (Figure 34).

Table 12: SWF photo-identification in 2014-2016

	2014	2015	2016
Total no. encounters	271	186	190
Total maximum no. dolphins identified	101	98	97
No. marked dolphins identified	99	83	85
No. unmarked dolphins (left) identified	0	13	10
No. unmarked dolphins (right) identified	2	15	12

The Cardigan Bay bottlenose dolphin population is thought to comprise a combination of transients, occasional visitors, and resident animals (Feingold and Evans, 2014a). Residents were defined as individuals sighted over 12 times, or in 7 to 14 years. Occasional visitors were defined as animals seen between 4 and 11 times or in three to six years. Transients were defined as animals sighted between one and three times or in only one or two years. In the wider Cardigan Bay, the majority of animals were considered resident, 70% of all animals sighted having at least 12 previous sightings and 56% being seen in at least 7 years. Between 20% and 28% of individuals were considered occasional visitors, having been sighted a minimum of four times and seen in at least three years, whilst between 16% and 18% were considered transient, having been seen at most 3 times or in only one or two years (Figures 35 and 36). About 60% of residents have been sighted on more than 20 occasions, and two individuals (074-03W and 004-90W) have been sighted a total of 180 times.

Although the majority of dolphins within Cardigan Bay SAC were also considered as residents, there is a higher proportion of transients and occasional visitors compared to the wider Cardigan Bay area. Residents made up between 38% and 42% of animals sighted in the SAC, having been seen a minimum of 7 years or at least on 12 different occasions. Transients are the second largest group present in the SAC, 33% having not been sighted on more than three occasions, and 34% seen only in one or two years. Occasional visitors made up the smallest group at between 25% and 28%.

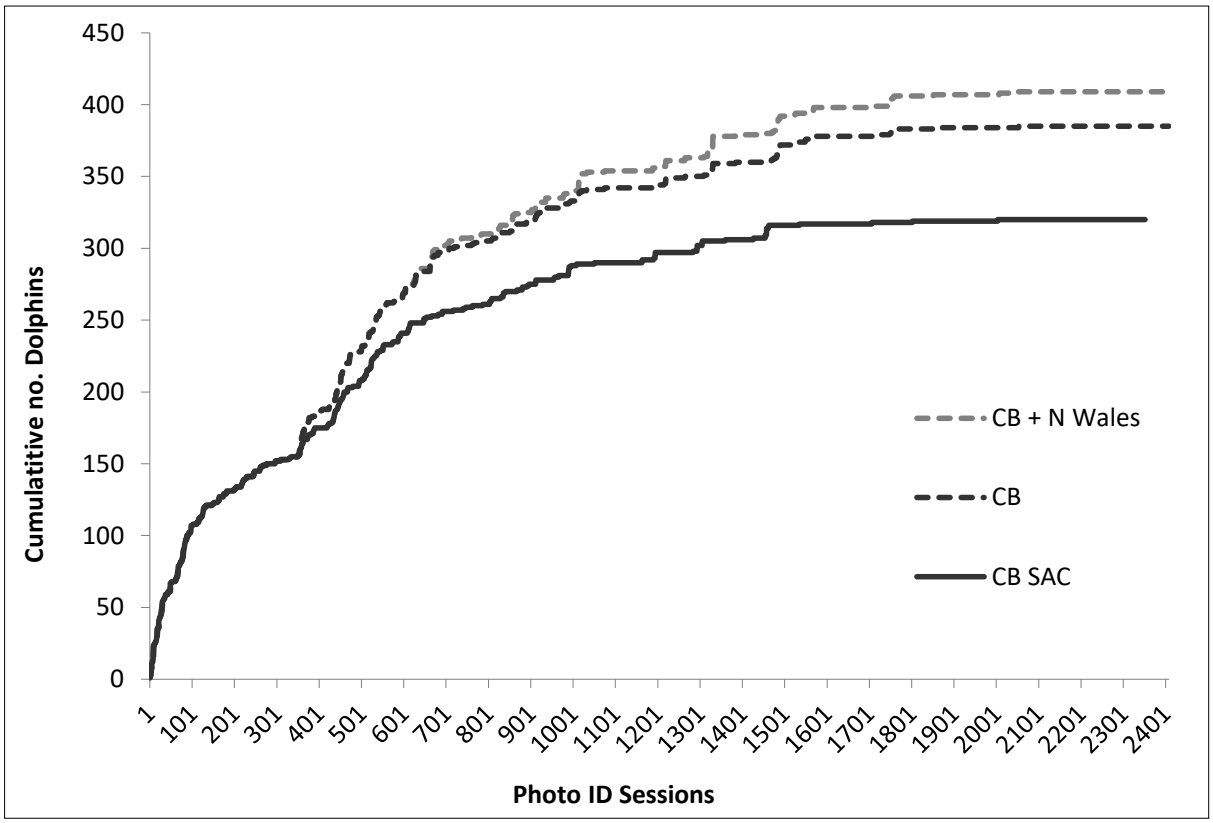


Figure 33: Discovery curve of bottlenose dolphins in Cardigan Bay SAC (CB SAC – black line), wider Cardigan Bay (CB – black dashed line) and North Wales (CB + N Wales – grey dashed line)

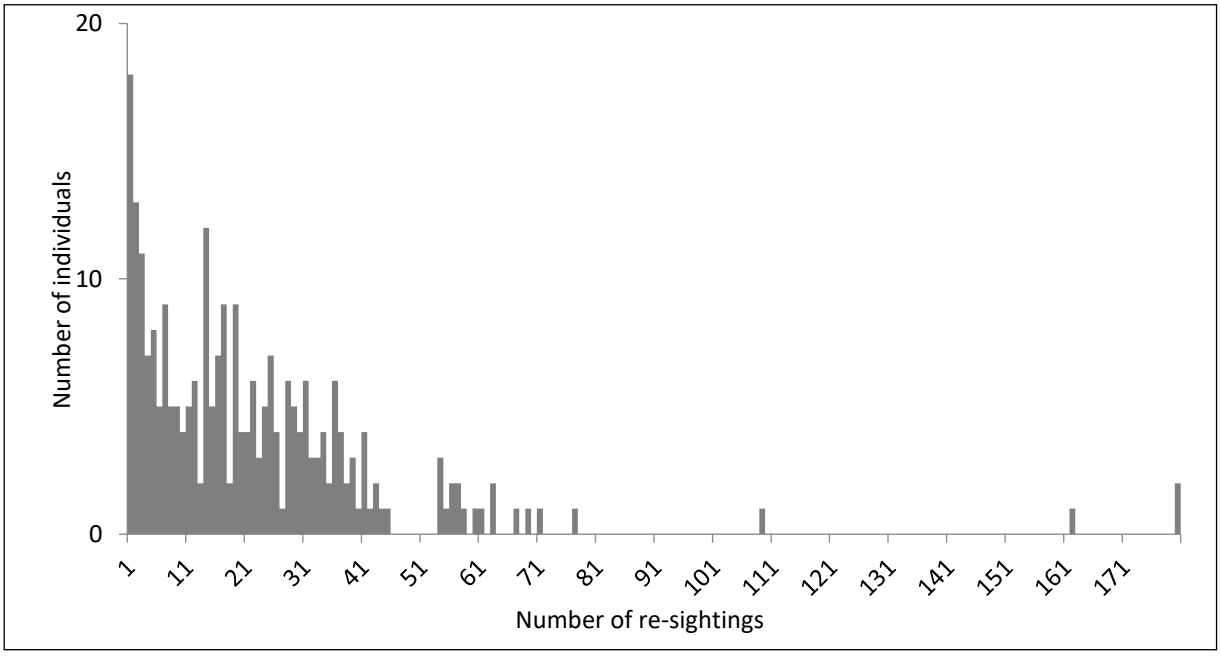


Figure 34: Frequency of re-sightings of known individuals in Cardigan Bay, 2001 to 2016

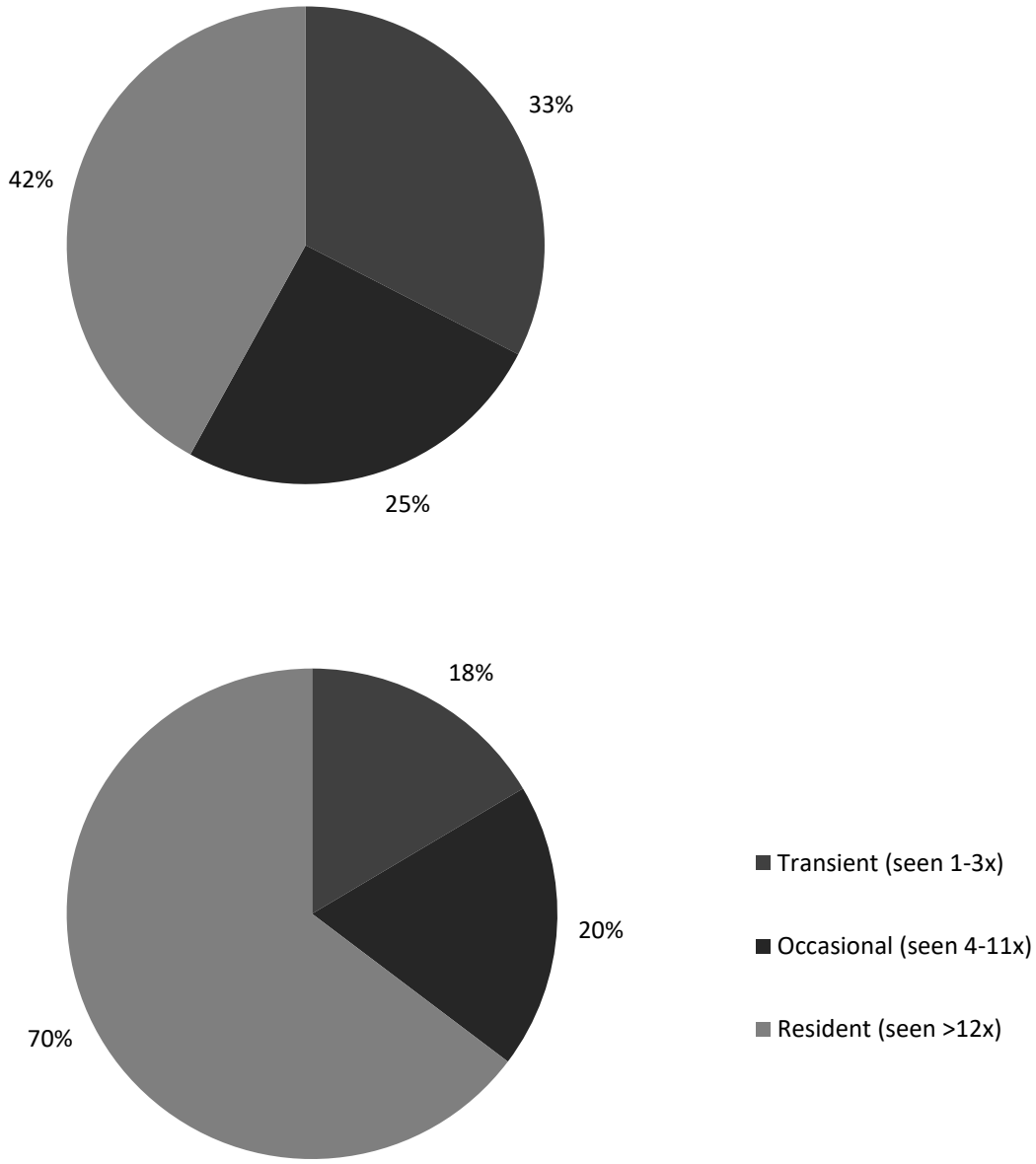


Figure 35: Percentage of individual re-sightings in Cardigan Bay SAC (top) and wider Cardigan Bay (bottom) from 2001 to 2016

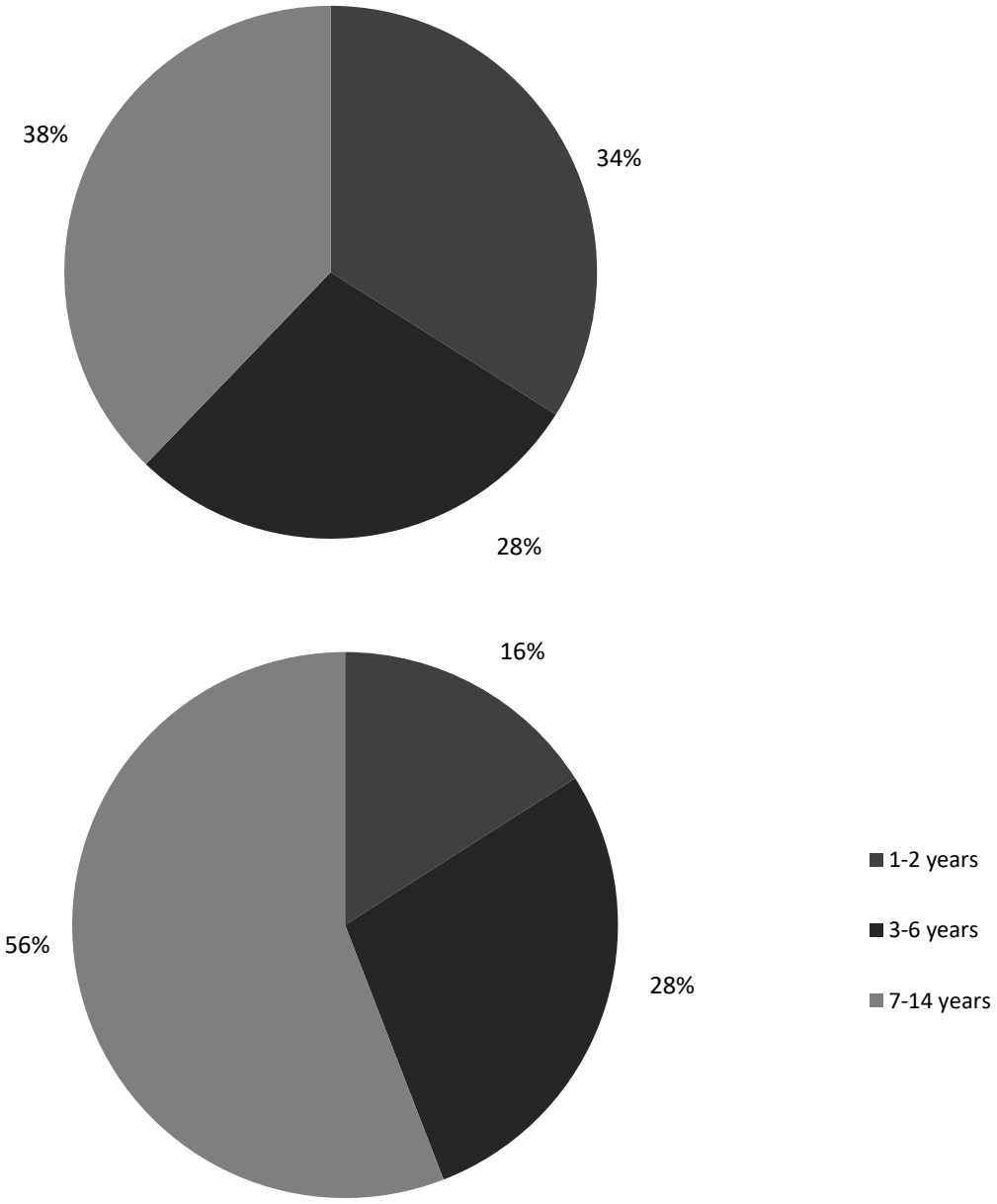


Figure 36: Percentage of yearly re-sightings in Cardigan Bay SAC (top) and wider Cardigan Bay (bottom) from 2001 to 2016

5.11. Home Ranges

Since 2007, survey effort and photo-identification have been extended to encompass not only Cardigan Bay but also, opportunistically, parts of North Wales, with a particular focus on the coastal waters to the north of the Isle of Anglesey, with on average five surveys per year since 2007, and a total of eight between 2014-16. Due to positive photo-identification matches, it is now widely accepted that individuals from Cardigan Bay are regularly sighted also off North Wales and as far as the Isle of Man (Pesante *et al*., 2008a, b; Veneruso and Evans, 2012b; Feingold and Evans, 2013, 2014b).

During a survey in Liverpool Bay in July 2013, a group of eighteen bottlenose dolphins was encountered and opportunistically photographed offshore of the Dee Estuary. Nine (50%) of the individuals photographed in the encounter were matched to the SWF catalogue. Of the nine identified individuals, three had previously been recorded throughout Cardigan Bay, North Wales, and the Isle of Man, whereas four had been spotted only off Anglesey, and the remaining two had been recorded in Pen Llŷn a'r Sarnau SAC and Anglesey but not Cardigan Bay SAC or the Isle of Man (Lohrengel, *et al*., 2012) (see Appendix 2, Figure 66).

During a further survey in May 2014, twelve (32%) of 38 individuals photographed were also positively matched to the Sea Watch catalogue, including one individual, 051-89W, who had previously been sighted frequently in Cardigan Bay SAC but had been 'missing' for three years prior to this sighting (Sea Watch Foundation, unpublished data) (Appendix 2, Figure 67).

Some well-known individuals that were formerly commonly observed in Cardigan Bay SAC have been observed much less frequently in the last few years. The two most frequently sighted individuals, 074-04W and 004-90W (180 sightings each), were not observed in Cardigan Bay at all in 2016, and 074-04W has not been seen since 2014. Although it is possible that these animals are deceased, the sighting of former Cardigan Bay SAC residents in North Wales suggest that some animals may be substantially shifting their home ranges more significantly than previously recorded. Another frequently sighted individual, 048-90W, which had been commonly observed around New Quay Head before 2015, was sighted only in the southernmost part of Cardigan Bay SAC and further south in Fishguard in 2015 and 2016.

From 2001 to 2016, 77.3% (167 individuals) of marked dolphins sighted in the wider Cardigan Bay) have also been sighted in North Wales, and 19.4% (42 individuals) have been recorded around the Isle of Man. Although many dolphins in the Cardigan Bay catalogue range across Cardigan Bay SAC, Pen Llŷn a'r Sarnau SAC, and North Wales, some individuals exhibit much more localised home ranges. Seven percent (15 individuals) have been sighted only in Cardigan Bay SAC, 7% (15 individuals) solely around Anglesey and 3% (6 individuals) only in Pen Llŷn a'r Sarnau SAC. Thus although the majority of the population have large home ranges, encompassing Cardigan Bay and beyond, a small proportion of individuals show a high degree of site fidelity, with relatively small home ranges (compare Figure 37 and maps in Appendix 2).

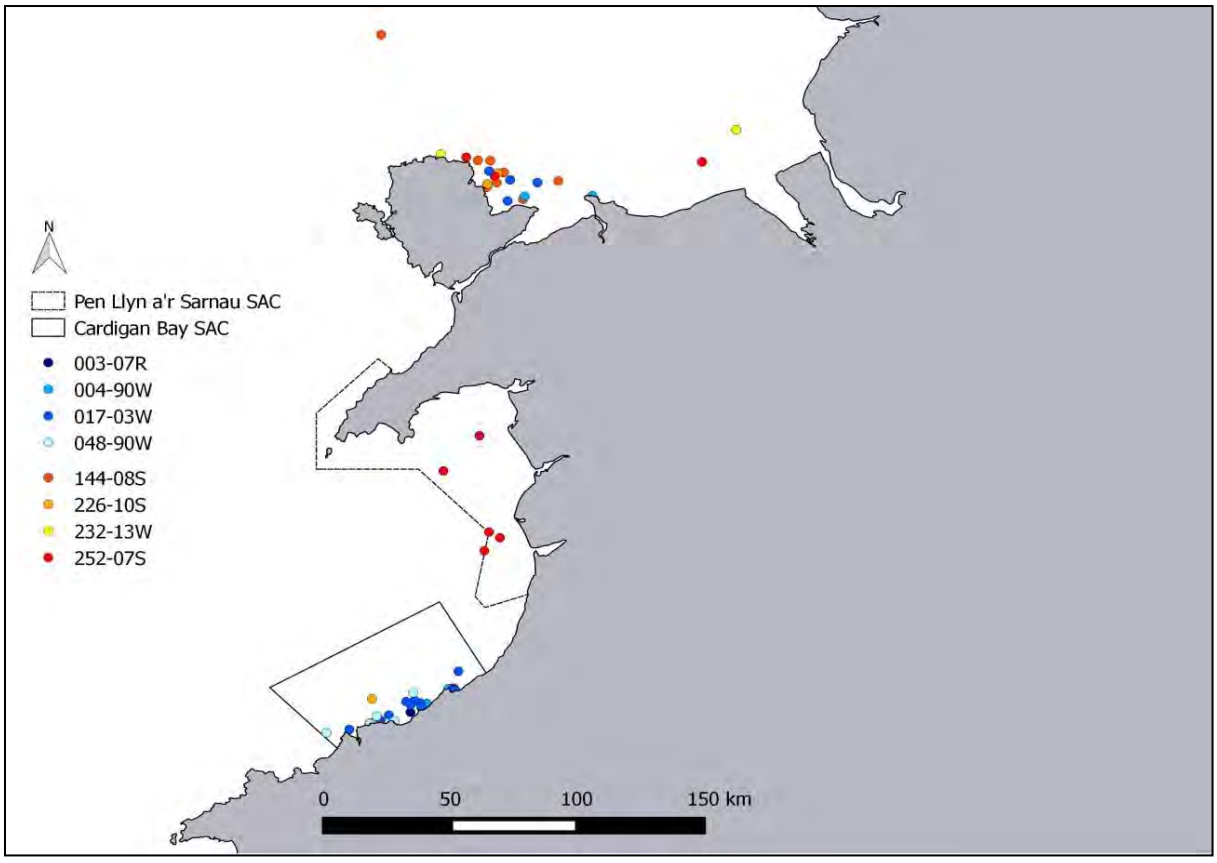


Figure 37: Individual sightings histories of eight bottlenose dolphins from 2001 to 2016, exhibiting individual habitat preferences

5.12. Body Condition and Injuries

Most animals observed in Cardigan Bay between 2014 and 2016 were in good body condition, not obviously underweight, or encumbered with visible injuries. However, there were a few exceptions. For the purpose of this report, 'good' body condition is defined as an animal not visibly underweight, with no visible ribs or post nuchal depression (Gryzbek, 2013; Joblon *et al*., 2014), and with no obvious external injury.

5.12.1. Underweight individuals

On the 20th September 2016, a large group of dolphins was encountered off Aberporth within the Cardigan Bay SAC. One of the animals appeared underweight with the rib cage clearly showing in several images of the animal breaching.

This individual is a known female, 025-01W or 'Haf', who was accompanied by a calf (Figure 38). Multiple pictures were taken of her during this encounter and ribs were not visible in all of them, suggesting that although the animal may be underweight, the body positioning may have exaggerated the appearance in some of the pictures.

Figure 38: Left: September 2016, individual 025-01W breaching, rib cage clearly visible Right: September 2016, individual 025-01W with calf, although partially obscured, ribcage not obvious. Photos: copyright Sea Watch Foundation

5.12.2. Injured individuals

In May 2014 a bottlenose dolphin with an assumed propeller cut on its peduncle was opportunistically photographed off Prestatyn, North Wales by SWF staff (Figure 39). An individual with a nick in exactly the same location on the peduncle had earlier been photographed by SWF off Anglesey on 13 Jan 2013. No fin pictures were obtained of the animals on either occasion so individual identity could not be confirmed.

Figure 39: Left: An injured dolphin photographed off North Wales. Right: Possibly the same individual seen in the same region in 2013. Photos: copyright Sea Watch Foundation

In March 2015, a well-known female, 035-03W or “Dodo”, with a severely damaged peduncle was sighted off the Isle of Anglesey (Figure 40). She was first recorded in 2003 and her injury was first photographed in 2007. The injury does not seem to inhibit her significantly and she has been regularly sighted in recent years, on several occasions, accompanied by young calves.

Figure 40: Individual 035-03W, “Dodo”, with long-lasting peduncle injury observed first in 2007 (left) in the Cardigan Bay SAC and sighted again in 2015 (right) in Anglesey. Photos: copyright Sea Watch Foundation

A large juvenile with a distinctive nick in the leading edge of the dorsal fin was recorded off the Llŷn Peninsula in October 2015 (Figure 41). The injury is identical to that recorded in a very young calf (under a month in age) in 2012 and both the location and shape of the injury as well as the animal's age would suggest that this is the same individual. The calf's mother is a known individual, 225-09S or "Arya", and this was the first calf she was recorded with. It was also observed on numerous occasions in Pen Llŷn a'r Sarnau SAC during 2016, and has been added to the catalogue as 262-12W or "Falkor".

Figure 41: Left: Calf of 225-09S or 'Arya' with dorsal injury photographed in 2012 Right: juvenile with similar injury in 2016. Both photographed in the Pen Llŷn a'r Sarnau SAC. Photos: copyright Sea Watch Foundation

Figure 42: Left: calf with deformity in the dorsal area photographed in the Cardigan Bay SAC in 2015. Right: calf with deformity in the dorsal area photographed in Pen Llŷn a'r Sarnau SAC in 2016. Photos: copyright Sea Watch Foundation

A calf with a deformity around the dorsal area was observed on several occasions in 2015, both within Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC, and then again in Pen Llŷn a'r Sarnau SAC in 2016 (Figure 42). The mother is a known female, 199-07S.

Finally, a marked (but unidentified) dolphin with a long white cut along its side was observed during a survey in North Wales in May 2016 (Figure 43). The cut is inconsistent with conspecific rake marks, which usually result in a row of parallel cuts. The cause of the lesion is unknown.

Figure 43: Bottlenose dolphin with long shallow cut on side, observed off Anglesey in 2016. Photo: copyright Sea Watch Foundation

6. Discussion

6.1. Bottlenose dolphin sightings rates and group sizes

Sightings rates in northern Cardigan Bay have historically been lower than in southern Cardigan Bay (Feingold and Evans, 2014a) and this was the case throughout 2014 to 2016.

Average group sizes remained stable over the last three years and were similar to the long-term average of 4.2. In line with this, most groups (ca. 75%) encountered numbered between one and five individuals, with few larger than ten. During previous years there was often a marked difference in group size between the start and the end of season as well as between Cardigan Bay SAC and northern Cardigan Bay. Although this was also the case in 2014 and 2015, neither applied in 2016.

Group sizes have historically been larger in northern Cardigan Bay than in Cardigan Bay SAC (Feingold and Evans, 2014a). This held true for 2014 and 2015 when group sizes were significantly different between the two areas. However, although groups encountered in northern Cardigan Bay in 2016 were slightly larger on average than in Cardigan Bay SAC, no significant difference was found and in fact the largest group encountered, of 20 animals, was recorded in Cardigan Bay SAC in September. It has been suggested that smaller group sizes in the late summer may correlate with the calving season (Reynolds *et al*., 2000). Since birth rates were very low in 2016 this might have had an effect on group sizes since fewer small nursery groups were being recorded. As the larger groups recorded in northern Cardigan Bay often coincided with significantly lower sightings rates in previous years, as indeed they did in both 2014 and 2015, it has been suggested that the animals use the two different SACs in different ways, using Cardigan Bay SAC particularly as a nursery ground and northern Cardigan Bay as an area for more social activity (Feingold and Evans, 2014a), resulting in smaller groups being recorded in the south compared to the north. This would be supported by the observation that in the last three years, the majority of newborn calves were first sighted in Cardigan Bay SAC.

6.2. Abundance estimates

Abundance estimates of bottlenose dolphins have varied widely over the years, with differences between models and areas examined (Cardigan Bay SAC compared with

the wider Cardigan Bay). Overall, the last ten years have seen primarily negative trends across all models and areas, although not all of them statistically significant.

6.2.1. Bottlenose dolphin abundance estimates (CMR)

Bottlenose dolphin abundance estimates in Cardigan Bay SAC have fluctuated over the years, rising initially from 2001 to a peak in 2008 (239) then falling to the lowest value in 2014, which coincided with a peak in emigration, although there was no associated steep decline detected in juvenile survival. Trend analysis over the longer term, from 2001-2016 found no significant trend. Although the most recent estimates for Cardigan Bay SAC are slightly higher than estimates at the start of the study, they do represent a decline from the peak value in 2008. This is reflected in the trend analysis which shows a significant negative trend in the last 10 years (2007-2016), but with 1,000 simulations the negative trend was only 90% certain.

Estimates for the wider Cardigan Bay follow broadly similar trends to those within Cardigan Bay SAC, with an initial rise in abundance estimates from 2005, reaching a peak of 318 in 2009, followed by a decline in more recent years, the overall lowest estimates being recorded in 2014 at 141 for the CMR closed model. Within the last three years, abundance estimates for Cardigan Bay initially rose from 2014 to 2015 but fell again in 2016. This is in contrast to Cardigan Bay SAC, which showed an increase over that period. This could indicate that of late, dolphins have been preferentially using the SAC and this accords with residency patterns, calculated using a robust model, which show a steep drop in the likelihood of emigration and in the probability of the animal remaining out of the area from 2014 to 2015, declining further from 2015 to 2016. However, values for 2016 need to be viewed with caution in terms of emigration. Overall, estimates for the wider Cardigan Bay fall short of peak values recorded in 2009 which is reflected in the results of the trend analysis that found a significant decline between 2007 and 2016.

Based upon sightings patterns of individual dolphins that were previously sighted regularly in Cardigan Bay, some animals appear to have left the area or are at least spending the majority of their time in other parts of Wales or beyond (see Appendix 2). Furthermore, behavioural analysis has seen a sharp increase in travel and a corresponding decrease in foraging behaviour in all areas besides coastal Cardigan Bay SAC over the last three years (Appendix 2). In 2016, as much as three times the

amount of time was spent travelling (70.3%) compared to foraging (20.9%). By comparison, in 2012, which was a peak year in abundance estimates across most models, high levels of foraging (51%) and relatively low levels of travelling (44%) were recorded.

Prey abundance and availability has been identified as an important factor affecting cetacean abundance and distribution in several species, including bottlenose dolphins (Irvine, 1981; Heithaus and Dill, 2002; Davis *et al*., 2002; Friedlander *et al*., 2006) and this may well also be the case in Cardigan Bay. When taken in context of behavioural budgets and sightings patterns, trends in abundance may indicate that some animals are staying out of the area or emigrating from the wider Cardigan Bay while the remaining animals are spending more time in coastal areas of Cardigan Bay SAC in foraging hotspots such as New Quay Head, Aberporth and Ynys Lochtyn (Appendix 2), to meet their dietary needs.

6.2.2. Bottlenose dolphin abundance estimates (Distance sampling)

Annual abundance estimates in Cardigan Bay SAC peaked in 2014 and were at their lowest in 2012 which coincided with the highest Distance estimate for the wider Cardigan Bay area. Overall, trend analysis found a significant decline in abundance estimates for Cardigan Bay SAC from 2001 to 2016 and a weaker (non significant) negative trend for the period of 2007 to 2016. This was somewhat in contrast to trend analysis on the CMR abundance estimates; although a negative trend was detected for both time periods for CMR estimates, it was stronger from 2007 to 2016 than from 2001 to 2016 (though neither was significant).

Annual abundance estimates of bottlenose dolphins in the wider Cardigan Bay have fluctuated over the years, featuring an initial increase followed by a small decrease, and an increase in 2015. The year with highest abundance estimates was 2012 at 330, the lowest 2013 at 254. CMR abundance estimates for wider Cardigan Bay show a peak in 2011, rather than 2012, but as for Distance estimates there was a slight decline in numbers from 2012 to 2013. However trend analysis of Distance sampling estimates found no significant negative trend for 2011 to 2016.

6.2.3. Recommendations for monitoring trends in abundance in Cardigan Bay

Both photo-ID surveys and line transects are able to monitor trends in abundance of Cardigan Bay bottlenose dolphins with sufficient power at significance levels of 5% and between 10-20% respectively if conducted on an annual basis. There are a number of reasons for adopting both monitoring approaches.

First, photo-ID CMR and line transect distance analyses provide independent estimates as they measure different things; photo-ID estimates the number of different individuals occurring within the study area over a particular period whereas line transects provide an estimate of the average number of animals within the study area. CMR relies on the identification of well-marked individuals to estimate the total number of animals present in the area and if a large proportion of animals that are encountered do not have distinguishing marks this is likely to affect the estimate negatively. Conversely, if identifiable animals visiting the area only briefly are photographed whist there, this may increase the estimate.

Each method also contributes additional information. Photo-ID provides valuable data on life history parameters such as birth rates and juvenile survival, which are important for assessing condition of the population (but only if conducted on an annual basis), as well as determining individual home ranges and movements. A study by University College Cork on the population off bottlenose dolphins in the Shannon Estuary, Ireland, suggested that although low CV values improve the probability of detecting a trend in the population, surveys conducted at intervals longer than a year were not sensitive enough to detect a change in the population before serious declines have already taken place (Englund *et al*., 2007). In line with this study and those in the Moray Firth (Thompson *et al*., 2004), we therefore recommend that survey frequency be maintained on an annual basis, and that survey effort within the Cardigan Bay SAC should strive for at least 60 surveys. The number of surveys estimated to achieve equivalent values for wider Cardigan Bay is lower, 45, possibly because this estimate includes more surveys conducted on faster vessels than available in Cardigan Bay SAC, allowing for a wider coverage in fewer trips.

Systematic line transect surveys provide important information on habitat preferences, identifying hotspots. They can also generate abundance estimates for species such as harbour porpoise, which rarely have unique markings and therefore are not amenable

to photo-ID. They can be undertaken at less than annual frequencies but not if the target significance for rate of change with anywhere approaching 80% power is to be within 10 or 15%.

6.3. Reproductive and mortality rates

Cardigan Bay SAC has historically been considered an important nursery area for bottlenose dolphins (Feingold and Evans, 2014a; Norrman *et al*., 2015). Between 2011 and 2013, around 50% of groups encountered in Cardigan Bay SAC had one or more calves present compared to 41% between 2014 and 2016, reflecting a reduced number of births during this period. Birth rates for the wider Cardigan Bay and Cardigan Bay SAC show a cycle of several years of above average birth rates (2003-07, 2010-12) followed by a number of years with low birth rates (2008-09, 2013-14). These 'baby booms' may be the result of a number of females simultaneously becoming reproductively mature, as has been documented in the Adriatic Sea and New Zealand (Bearzi *et al*.,1997; Haase and Schneider, 2001).

Table 13: 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
Sado Estuary, Portugal	5.4	Gaspar, 2003
Sarasota Bay, Florida	5.5	Wells & Scott, 1990
Cardigan Bay SAC, Wales	**5.5**	**This study (2001-16)**
Moray Firth, Scotland	6.0	Wilson *et al*., 1999
Cardigan Bay, Wales	**6.4**	**This study (2001-15)**
Port River Estuary, Australia	6.4	Steiner & Bossley, 2008
Doubtful Sound, New Zealand	6.6	Haase & Schneider, 2001
Southern California	7.2	Hansen, 1990
Northern Gulf of Mexico	7.7	Leatherwood, 1977
Florida	8.2	Irvine *et al*., 1981
Argentina, South Atlantic Coast	9.6	Würsig, 1978
Tampa Bay, Florida	9.7	Weigle, 1990

In previous years, there was increasing evidence that northern Cardigan Bay was an important nursery area for bottlenose dolphins as well, some females with newborns never being sighted in Cardigan Bay SAC and overall birth rates for the wider Cardigan Bay being higher on average than for Cardigan Bay SAC (Feingold and Evans, 2014a).

By contrast, data from 2013 to 2016 show an opposite trend. During the last four years, the majority of newborn calves have been sighted within Cardigan Bay SAC, and the birth rates based on closed CMR population estimates, for that SAC have been higher or equal to those of the wider Cardigan Bay for the first time since 2001.

Mean birth rates were calculated for Cardigan Bay SAC (5.5%) and for the wider Cardigan Bay (6.5%) using a closed population model. The birth rate for the Moray Firth, the other main semi-resident population of bottlenose dolphins in the UK, is estimated at 6% and thus falls between the closed birth rates for Cardigan Bay and Cardigan Bay SAC (Wilson *et al*., 1999; Grellier, 2000; Thompson *et al*., 2004).

The mean interbirth interval between 2001 and 2016 was determined to be 3.4 years, similar to intervals recorded in other bottlenose populations around the world (Table 19). Birth rates and interbirth intervals compare favourably with international estimates suggesting a reasonably healthy female population. This is supported by the fact that the majority of females known to have given birth have at least one surviving calf (70.5%).

Calving in Cardigan Bay occurred primarily in the summer months, with 65% of newborn calves being recorded between July and September. Calf mortality rates between 2001 and 2016 were highest in the first two years of life, 15% and 17% respectively, and then more than halved in the third year. It is perhaps surprising that the calf mortality rates in Cardigan Bay are not lower given that most populations assessed in comparable studies (Table 15), are subject to significant predation by sharks (Thayer, 2008; Cockcroft and Ross, 1990; Mann *et al*., 2000) which is not known to be a significant cause of mortality in the UK. By comparison, 19% of adult bottlenose dolphins in North Carolina (which has a lower first year mortality than Cardigan Bay, see Table 14) show scarring from shark bites, whereas there is little evidence of shark predation on bottlenose dolphins in coastal UK (Stockin *et al*., 2006).

Previous studies have found high levels of organochlorines in Cardigan Bay bottlenose dolphins, which can be transferred from mother to calf through lactation (Law *et al*., 1995; Law *et al*., 2012).

Table 14: Interbirth intervals from bottlenose dolphin studies around the world

Location	Mean (years)	Range (years)	Source
North Carolina, USA	2.9	2-7	Thayer, 2008
Doubtful Sound, New Zealand	3.0	2-5	Haase & Schneider, 2001
Natal, South Africa	3.0	2-6	Cockcroft & Ross, 1990
Moray Firth, Scotland	3.2	3-6	Mitcheson, 2008
Cardigan Bay, Wales	**3.4**	**2-7**	**This study**
Port River Estuary, Australia	3.8	3-6	Steiner & Bossley, 2008
Shark Bay, Australia	4.1	3-6	Connor *et al*., 2000
Sarasota Bay, Florida	5.4	2-11	Wells & Scott, 1999

Table 15: Juvenile mortality rates from studies of bottlenose dolphins around the world

Location	First year	Second Year	Third Year	Source
North Carolina, USA	11%	-	-	Thayer, 2008
Indian & Banana rivers, Florida	11%	-	-	Hersh *et al*., 1990
Cardigan Bay, Wales	**15%**	**17%**	**7%**	**This study**
Sarasota Bay, Florida	19%	-	-	Wells & Scott, 1990
Natal, South Africa	22%	-	-	Cockcroft *et al*., 1989
Shark Bay, Australia	29%	18%	3%	Mann *et al*., 2000
Port River Estuary, Australia	30%	-	-	Steiner & Bossley, 2008
Doubtful Sound, Australia	31%	14%	-	Brough *et al*., 2016

Amongst other factors, high levels of organochlorides have been linked to high calf mortality in first time mothers in Sarasota Bay, as females purge themselves of PCBs

by passing on a high load of contaminants to calves through lactation (Wells *et al*., 2005). It is possible that this could also be a contributing factor to first year mortality in Cardigan Bay, although more evidence would be needed to verify this.

6.4. Home ranges, residency patterns and population dynamics

The Cardigan Bay photo-identification catalogue contains a minimum of 379 individuals. A discovery curve of marked dolphins shows a gradual levelling off during the last few years, suggesting that the catalogue now comprises the majority of marked dolphins inhabiting Welsh waters. Most dolphins added to the catalogue in recent years have been juveniles that have acquired identifiable marks, although well-marked adult individuals have been added as well, particularly from the North Wales region.

The Cardigan Bay population can be described as a mixture of residents, occasional visitors, and transients. Differences in residency patterns between the wider Cardigan Bay and Cardigan Bay SAC suggest that in past years a higher proportion of individuals were resident in wider Cardigan Bay. Overall, residency seems to have decreased in Cardigan Bay SAC over the years, estimates from 2001 to 2007 recording 58% residency (based on individual re-sightings) within the SAC, declining to 44% (2001 to 2013) and 42% (2001 to 2016), with a concurrent rise in occasional visitors and transients. As abundance estimates in the SAC show an overall increase in bottlenose dolphin numbers since 2001, this could indicate that ‘new’ dolphins have started frequenting the area in recent years.

Most individuals in the Cardigan Bay population have been shown to have large home ranges, being sighted in both the SACs as well as off Anglesey, in Liverpool Bay, and around the Isle of Man. In the past, sightings in North Wales and around the Isle of Man were mainly confined to the winter months suggesting that most sightings in these areas were due to seasonal movements of Cardigan Bay residents (Pesante *et al*., 2008) but, more recently, sightings of groups of dolphins in northeast Wales and in Liverpool Bay have been recorded during the summer as well (Lohrengel *et al*., 2014; SWF, unpublished data). Of the animals identified in Liverpool Bay in 2013, six out of nine had never been observed in Cardigan Bay SAC; with prior sightings only recorded in Anglesey or Pen Llŷn a’r Sarnau SAC. During an encounter in northeast Wales in 2014, 12 animals were positively matched to the Sea Watch catalogue. Three out of 12 animals had only been seen in North Wales but all others had previously been

sighted in Cardigan Bay SAC, including individual 051-089W which used to be sighted frequently in Cardigan Bay SAC before disappearing in 2011. Notably, in 2008 this individual was one of the most frequently sighted individuals in Cardigan Bay SAC.

The increase in surveys in North Wales in recent years has resulted in the continued discovery of new animals, but has also highlighted that Cardigan Bay residents may be using a larger area than once thought, not only in the winter but throughout the year. Although bottlenose dolphins are a protected species, there are no Special Areas of Conservation designated for them in North Wales, Liverpool Bay or the Isle of Man, to afford them additional monitoring and protection which could have conservation implications. It emphasises the need to further extend photo-identification efforts to other parts of Wales in order to more completely understand the distribution and habitat preferences of the Welsh dolphin population.

6.5. Body condition and injuries

Only one underweight bottlenose dolphin was observed throughout 2014 to 2016. The underweight individual in question was a female with a calf and it is possible that her low weight was related to her suckling. However, no other underweight mothers have been seen. Feeding and foraging behaviour (Appendix 2) have declined considerably in recent years but most animals appear to still be in good body condition which would suggest they are currently still finding sufficient prey.

Five dolphins with visible injuries were observed in the last three years: 035-03W, a female with an old peduncle injury; an unknown individual with a deep nick in the peduncle; a juvenile with a deep nick in the leading edge of its dorsal fin (now added to the catalogue as 262-12W), a juvenile with a deformity in the dorsal area; and an unidentified individual with a long single scratch along the side. Of these five animals, three are likely to have been involved in boat traffic accidents: 035-05W, 262-13W and the unknown individual with the nick in the peduncle. The nature of their injuries, deep and clean cuts, is consistent with injuries caused by propellers.

Furthermore, during the first sighting of 262-12W, the mother and her very young calf at the time were observed bow-riding for prolonged stretches of time which is unusual for a calf of that age. It is possible that the inexperience of the mother may have inadvertently led to the calf to being injured by getting too close to a boat. Although it

is not impossible that the other two animals were also injured by boats, this cannot be confirmed.

A potential source of injury in the calf with the dorsal deformity is interspecific aggression, as documented in a case in Scotland where a young calf was recorded surviving an attack from conspecifics but went on to develop a severe case of scoliosis resulting in spinal deformity resembling the injury observed here (Robinson, 2014). The high rate of scoliotic calves observed in the Moray Firth has been suggested as linked, at least partially, to the high rate of calf-directed aggression by infanticidal males (Robinson, 2014). A young calf with very similar injuries was also observed in 2013 in Cardigan. Infanticide has not been observed in Cardigan Bay before (Appendix 2). However, in 2016, CSIP confirmed that an infant bottlenose dolphin that washed up had traumatic injuries consistent with this cause of death (Appendix 2). An aggressive (but non-fatal) interaction between an adult bottlenose dolphin and a mother and newborn pair was also observed in 2015 (Appendix 2).

Although serious boat strikes are not as common in Cardigan Bay as in other bottlenose dolphin populations such as Sarasota (Florida) where they occur frequently (Barleycorn, 2013, 2014), they are a cause for concern, particularly with increasing levels of recreational boat traffic in Cardigan Bay (Pierpoint *et al*., 2009; Veneruso *et al.,* 2011; Richardson, 2012; Frinault, 2015; Perry, 2016). Continued monitoring of boat traffic levels, public education and enforcement of the code of conduct is important to ensure the long term welfare of Cardigan Bay bottlenose dolphins.

6.6. Acknowledgements

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8. Appendix 1 Data Archive

Data outputs associated with this project are archived as Project 479, Media 1556 on server–based storage at Natural Resources Wales.

The data archive contains:

[A] PhotoID images (jpg) taken while conducting NRW funded surveys in current Sea Watch Foundation folder structure in .jpg format

[B] PhotoID catalogue – NRW funded records only

[C] Sighting and Effort data in .xls spreadsheet format for NRW funded surveys

[D] GPS tracks in .xls format (projection WGS 84)

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue https://libcat.naturalresources.wales (English Version) and https://catllyfr.cyfoethnaturiol.cymru (Welsh Version) by searching 'Dataset Titles'. The metadata is held as record number 119255.

Appendix 2 – Held in separate PDF

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