Cyfoeth Naturiol Cymru
Natural Resources Wales

Bottlenose Dolphin and Harbour Porpoise Monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2011 - 2013

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Yn yr adroddiad hwn rydym yn crynhoi'r astudiaeth maes a gynhaliwyd gan y Sea Watch Foundation yn 2011-13 ar ran Cyfoeth Naturiol Cymru. Nod ein hymchwil oedd monitro niferoedd dolffiniaid trwyn potel a llamhidyddion ym Mae Ceredigion. Amcanion yr ymchwil oedd: darparu gwybodaeth am gyflwr dolffiniaid trwyn potel a llamhidyddion ym Mae Ceredigion yn cynnwys Safleoedd o Ddiddordeb Gwyddonol Arbennig (SDdGA) Bae Ceredigion, Pen Llŷn a'r Sarnau ac ardaloedd môr mawr; defnyddio technegau ID ffotograffig i werthuso symudiadau, dosbarthiad a niferoedd dolffiniaid; asesu strwythur y boblogaeth; casglu tystiolaeth o weithgareddau anthropogenig ar y safle; ac asesu cynefinoedd ategol. Cynhaliwyd cyfres o arolygon ar gwch ym Mae Ceredigion gan ddefnyddio technegau trawslunio llinell ac ID ffotograffig er mwyn casglu data fyddai'n gwireddu'r amcanion hyn.

Cynhaliwyd arolygon trawslunio llinell ym Mae Ceredigion rhwng Gorffennaf a Hydref 2011 a rhwng Ebrill a Hydref yn 2012 a 2013, a bu'r cwmpas yn arbennig o dda yn 2013. Cynhaliwyd cyfanswm o 83 o arolygon trawslunio llinell ym Mae Ceredigion yn ystod cyfnod yr astudiaeth, sy'n gyfystyr ag ymdrechion teithio o dros 10,000km mewn amodau ffafriol (cyflwr y môr <3 Beaufort, ymchwydd isel, a dim glaw).

Mae'n ymddangos bod yr holl ardal arfordirol o Aberaeron i Aberteifi yn arbennig o arwyddocaol yn achos dolffiniaid trwyn potel, yn arbennig yng nghyffiniau penrhyn Cei Newydd, Ynys Lochtyn, Mwnt, Pen Peles ac Aberporth. Canfuwyd canolfannau eraill o weithgaredd ym Mae Tremadog ac o gwmpas riffiau a thraethellau Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn a bwi Patches.

Amcangyfrifwyd bod niferoedd y dolffiniaid trwyn potel yn SDdGA Bae Ceredigion yn 133 o unigolion (CV = 29.5) yn 2011, 70 (CV = 33.0) yn 2012, a 90 (CV = 35.6) yn 2013, a'r niferoedd hynny wedi eu crynhoi yn y parth arfordirol. Amcangyfrifwyd niferoedd uwch ar gyfer y Bae cyfan, gyda 309 (CV = 28.3) yn 2011, 390 (CV = 24.9) yn 2012, a 254 (CV = 26.8) yn 2013. Gan mai unwaith yn unig yr arolygwyd y Bae ers 2011, a bod bwlch o dair blynedd (2008-10) a dim arolygon trawslunio llinell wedi eu cynnal yn SDdGA Bae Ceredigion, nid yw'n bosibl cynnal dadansoddiad tuedd. Ond, mae'r niferoedd isel yn SDdGA Bae Ceredigion yn 2012 a 2013 (yr isaf ers dechrau monitro yn 2001) yn achos pryder. Gall hyn gynrychioli newid defnydd gan y dolffiniaid yn yr ardal, oherwydd yn ystod y blynyddoedd diweddar, mae dolffiniaid trwyn potel wedi cael eu gweld yn rheolaidd am y tro cyntaf yn ystod misoedd yr haf yng Ngogledd Cymru, yn arbennig o gwmpas Ynys Môn, ond yn ymestyn hefyd i'r dwyrain i Fae Lerpwl ac i'r gogledd hyd at o leiaf Ynys Manaw. Mae nifer o'r unigolion a arsylwyd wedi cael eu ffoto-adnabod fel anifeiliaid oedd yn arfer treulio'r haf ym Mae Ceredigion. Y maint grŵp cymedrig ym Mae Ceredigion oedd 4.2 (ystod 1-333).

Amcangyfrifwyd bod niferoedd y llamhidyddion yn SDdGA Bae Ceredigion yn 340 o unigolion (CV = 46.4) yn 2011, 169 (CV = 29.1) yn 2012, a 146 (CV = 21.3) yn 2013. Amcangyfrifwyd bod niferoedd llawer uwch yn bodoli yn y Bae cyfan, sef 1074 (CV = 28.7), 565 (CV = 20.4), a 410 (CV = 20.4) yn 2013.

Cynhaliwyd arolygon ID ffotograffig penodol o ddolffiniaid trwyn potel drwy gydol y tymor, yn bennaf yn SDdGA Bae Ceredigion, tra manteisiwyd ar gyfleoedd i gynnal sesiynau ffoto-andabod pan fo hynny'n bosibl yn ystod yr arolygon trawslunio llinell. Ar hyn o bryd mae ein catalog ID ffotograffig yn dal delweddau o leiafswm o 378 o unigolion (248 o unigolion wedi'i marcio, 120 ar yr ochr chwith a 130 ar yr ochr dde). Cynhaliwyd dadansoddiadau gan ddefnyddio dulliau dal-marcio-ail-ddal, ac ystyriwyd cyfartaledd cyffredinol o 59% o unigolion wedi'u marcio yn y SDdGA, a 61% ym mhob rhan o Fae Ceredigion.

Mae amcangyfrifon blynyddol o niferoedd dolffiniaid trwyn potel sy'n defnyddio SDdGA Bae Ceredigion rhwng 2001 a 2013, gan ddefnyddio model cadarn o boblogaeth agored, wedi amrywio o 77 (yn 2002) i 168 (yn 2012). Roedd defnyddio ffwythiant polynomaidd ar yr amcangyfrifon yn dangos cynnydd hyd at 2007, y gromlin yn cyrraedd gwastad ac yna'n gostwng. Y gwerthoedd ar gyfer y tair blynedd diwethaf oedd 147 (2011), 168 (2012), a 101 (2013). Roedd yr amcangyfrif diwethaf yn cyd-daro â chynnydd mawr yn y gyfradd allfudo yn ystod y flwyddyn honno a'r cynnydd yn y tebygolrwydd bod anifeiliaid yn aros y tu allan i'r SDdGA, yn ogystal â chyfraddau goroesi isel.

Dim ond ers 2005 y gellir cyfrifo niferoedd y dolffiniaid trwyn potel sy'n defnyddio pob rhan o Fae Ceredigion, oherwydd dyna pryd yr ymestynnwyd cwmpas yr arolwg i gynnwys SDdGA Pen Llŷn a'r Sarnau ac ardaloedd cyffiniol yng ngogledd Bae Ceredigion. Hyd yn oed bryd hynny, mae'r diffyg ariannu yn ystod rhai blynyddoedd ac amrywiadau o ran amodau tywydd wedi golygu nad yw'r cwmpas wedi bod yn hollol gyson. Mae'r amcangyfrifon o'r niferoedd, gan ddefnyddio model cadarn o boblogaeth agored, wedi amrywio o 128 (2005) i 232 (2012). Fel yn achos SDdGA Bae Ceredigion, bu i ddefnyddio ffwythiant polynomaidd ar yr amcangyfrifon ddangos cynnydd, yn yr achos hwn yn cyrraedd ei begwn tua 2009, y gromlin yn cyrraedd gwastad ac yna'n gostwng. Y gwerthoedd ar gyfer y tair blynedd diwethaf oedd 193 (2011), 232 (2012), a 167 (2013).

Bu i fodelau o boblogaeth gaeedig ar gyfer SDdGA Bae Ceredigion a Bae Ceredigion yn ei gyfanrwydd roi canlyniadau tebyg yn gyffredinol, ond gyda gwerthoedd oedd yn gyson uwch.

Cynhaliwyd arolygon ffoto-adnabod oddi ar arfordir Ynys Môn yn 2007, ac ynghyd â data a ddarparwyd o Ynys Manaw a Bae Lerpwl, maent wedi darparu tystiolaeth bod dolffiniaid trwyn potel unigol o Fae Ceredigion yn ymestyn cwmpas eu cartref, yn arbennig yn ystod y gaeaf, hyd at Ynys Manaw o leiaf yng Ngogledd Môr Iwerddon. Mae bron i 40% (n=82) o unigolion wedi cael eu cofnodi yn SDdGA Bae Ceredigion a SDdGA Pen Llŷn a'r Sarnau ac i'r gogledd o Benrhyn Llŷn - o gwmpas Ynys Môn, Bae Caernarfon ac Ynys Manaw. Gwelwyd bron i 26% (n=55) yn SDdGA Bae Ceredigion a Gogledd Cymru, ond nid yn SDdGA Pen Llŷn a'r Sarnau. Mae'n fwy tebygol bod hyn oherwydd nad yw'r cwmpas mor drylwyr yn y SDdGA gogleddol hwn, yn arbennig yn yr ardal môr mawr. Mae'r data hwn yn darparu tystiolaeth sy'n cadarnhau bod ystod ddaearyddol y boblogaeth hon yn cynnwys holl foroedd arfordirol Gorllewin a Gogledd Cymru, a holl Fôr Iwerddon o bosibl. Ar hyn o bryd, nid oes yna unrhyw dystiolaeth ID ffotograffig sy'n cysylltu poblogaeth Bae Ceredigion â'r Alban, Gweriniaeth Iwerddon na De Lloegr.

Cyfrifwyd bod niferoedd preswyl SDdGA Bae Ceredigion ar gyfer 2001-07 rhwng 47-58%, ond mae hynny wedi gostwng i 37-43% yn ystod y blynyddoedd diweddar, sy'n awgrymu bod rhai unigolion yn symud allan o'r ardal. Er hyn, mae dolffiniaid benywaidd yn y SDdGA yn dangos cyfradd geni syml cymharol uchel o 5.3%, yn seiliedig ar fodel o boblogaeth gaeedig, a 7.65% wrth ddefnyddio model o boblogaeth agored. Gwelir cyfraddau geni uwch ym Mae Ceredigion yn ei gyfanrwydd, gyda gwerthoedd o 7.65% a 8.9% ar gyfer modelau caeedig ac agored yn ôl eu trefn, sy'n awgrymu bod y Bae cyfan yn ardal bwysig o ran bwrw lloi i'r boblogaeth hon. Mae arsylwadau o ddolffiniaid benywaidd sydd gyda lloi a heb loi yn y gorffennol wedi amlygu pwysigrwydd SDdGA Bae Ceredigion fel ardal bwrw lloi. Mae'r dadansoddiadau presennol yn dangos bod o leiaf ddwy ardal fwrw lloi arwyddocaol eraill yn bodoli - yn SDdGA Pen Llŷn a'r Sarnau ac o gwmpas Ynys Môn, Gogledd Cymru.

Gall lloi gael eu geni ar unrhyw adeg o'r flwyddyn, ond mae hynny'n digwydd amlaf rhwng Gorffennaf a Medi, pan gofnodir 76% o'r holl enedigaethau. Mae dolffiniaid benywaidd yn geni bob tair blynedd ar gyfartaledd (ystod 2-7 mlynedd). Cyfrifwyd cyfradd marwolaethau lloi o sampl o 71 o barau o famau a lloi a anwyd rhwng 2001 a 2013. Canfuwyd cyfraddau marwolaethau uwch yn ystod y ddwy flynedd gyntaf (15% yn y flwyddyn gyntaf a 17% yn yr ail flwyddyn) a chyfraddau is yn ystod y drydedd flwyddyn (7%), a chyfanswm o 60% o'r lloi yn cyrraedd eu pedwaredd flwyddyn.

Mae arolygon ffoto-adnabod ers 2007 yn dangos bod rhai unigolion wedi cael eu gweld yn lleol fwy nag unwaith, gyda 7% o'r unigolion yn cael eu gweld yn SDdGA Bae Ceredigion yn unig, 8% yn unig o gwmpas Ynys Môn, a 3% yn SDdGA Pen Llŷn a'r Sarnau yn unig. Mae isafswm polygon amgrwm a mapiau amcangyfrif dwysedd cnewyllyn o gwmpas cartref ac ardal graidd wedi'u creu ar gyfer unigolion a grwpiau. Roedd ardaloedd cwmpas dolffiniaid gwryw ychydig yn fwy, ond nid yn arwyddocaol, na rhai'r dolffiniaid benywaidd (16,420 km^2 o'i gymharu â 15,270 km^2). Roedd dolffiniaid benywaidd yn tueddu i ddefnyddio ardal cwmpas cartref ac ardal graidd lai os byddai un neu ragor o'r priodoleddau canlynol yn eu nodweddu: cyfradd uchel o ran cynhyrchu lloi, cyfradd uchel o ran lloi yn goroesi, a chyfnod byrrach rhwng genedigaethau.

Er bod cyfran fechan o boblogaeth y dolffiniaid trwyn potel o hyd yn dangos cyfraddau preswyl uchel yn SDdGA Bae Ceredigion, mae yna dystiolaeth gynyddol bod unigolion yn defnyddio llai ar y SDdGA hwn. Mae esboniadau posibl yn cynnwys newid yn yr ysglyfaeth sydd ar gael a/neu gynnydd mewn aflonyddwch gan bobl. Dau weithgaredd dynol sy'n hysbys yn yr ardal allai o bosibl effeithio'n negyddol ar y boblogaeth yw llusgrwydo am gregyn bylchog (o ganlyniad i niweidio cynefinoedd pysgod sy'n byw ar waelod y môr) a gweithgareddau hamdden ar y môr (drwy aflonyddu). Ar hyn o bryd, nid yw'n bosibl dweud gydag unrhyw bendantrwydd a yw'r naill neu'r llall yn effeithio ar y boblogaeth. Fodd bynnag, yn dilyn cynnydd sylweddol mewn llusgrwydo am gregyn bylchog ym Mae Ceredigion cafwyd cyfraddau geni isel iawn ymysg dolffiniaid trwyn potel yn y Bae yn 2008 a 2009, yr isaf a gofnodwyd drwy gydol cyfnod yr astudiaeth o 13 blynedd. Mae astudiaethau blaenorol yn yr ardal wedi casglu bod presenoldeb cychod yn dylanwadu'n negyddol ar ba mor aml y gwelir dolffiniaid trwyn potel, ac mae un o'r safleoedd prysuraf, o gwmpas tref Cei Newydd yn SDdGA Bae Ceredigion, wedi gweld gostyngiad cyson yn niferoedd y dolffiniaid

trwyn potel sydd wedi cael eu gweld ers 1994, gyda niferoedd cymharol y rhywogaeth yn gostwng wrth i nifer y cychod a gyfrifid godi. Mae ymchwiliadau pellach wedi canfod tystiolaeth bod traffig cychod yn effeithio ar strwythur cymdeithasol dolffiniaid trwyn potel a nodweddion chwibanu.

Er mwyn asesu tueddiadau'r boblogaeth yn gywir drwy ddulliau samplo o bell ac ID ffotograffig, mae'n hanfodol monitro Bae Ceredigion yn ei gyfanrwydd yn gyson dros dymor hir, ac ardaloedd eraill yng Ngogledd Cymru y mae'n hysbys bod dolffiniaid trwyn potel yn byw ynddynt.

2. Executive Summary

In this report, we summarise the field research conducted by the Sea Watch Foundation in 2011-13 on behalf of Natural Resources Wales. Our research goal was to monitor bottlenose dolphin and harbour porpoise populations in Cardigan Bay. The aims of this research were: to provide information on the condition of bottlenose dolphins and harbour porpoises in Cardigan Bay including both the Cardigan Bay and Pen Llyn a'r Sarnau Special Areas of Conservation (SACs) and offshore areas; to use photographic ID techniques to evaluate dolphin movements, distribution and abundance; to assess population structure; to gather evidence of anthropogenic activities within the site; and to assess supporting habitats. A series of boat-based surveys were conducted in Cardigan Bay using both line-transect and Photo ID techniques in order to collect data that would achieve these objectives.

Line-transect surveys in Cardigan Bay took place between July and October 2011 and between April and October in 2012 and 2013, with coverage being particularly good in 2013. A total of 83 line-transect surveys were conducted in Cardigan Bay throughout the study period, amounting to over 10,000 km of effort travelled in favourable conditions (sea states <3 Beaufort, low swell, and no rain).

The entire coastal area from Aberaeron to Cardigan appears to be of particular significance to bottlenose dolphins, especially in the vicinity of New Quay headland, Ynys Lochtyn, Mwnt, Pen Peles and Aberporth. Other centres of activity were found in Tremadog Bay and around the reefs and sandbanks of Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy.

Bottlenose dolphin abundance in Cardigan Bay SAC was estimated at 133 individuals (CV = 29.5) in 2011, 70 (CV = 33.0) in 2012, and 90 (CV = 35.6) in 2013, concentrated in the coastal zone. Higher abundance was estimated for the entire Bay, with 309 (CV = 28.3) in 2011, 390 (CV = 24.9) in 2012, and 254 (CV = 26.8) in 2013. Since the entire Bay has only been surveyed since 2011, and there was a gap of three years (2008-10) with no line-transect surveys in Cardigan Bay SAC, it is not possible to conduct trend analyses. Nevertheless, the low abundance values within Cardigan Bay SAC in 2012 and 2013 (the lowest since monitoring began in 2001) give some cause for concern. This may represent a shift in usage by the dolphins in the region since in recent years, bottlenose dolphin sightings have been reported regularly for the first time during summer months in North Wales, particularly around the Isle of Anglesey but extending east into Liverpool Bay and north to at least the Isle of Man. Several of the individuals observed have been photo-identified as animals

previously spending the summer in Cardigan Bay. Mean group size within Cardigan Bay was 4.2 (range 1-33).

Harbour porpoise abundance in Cardigan Bay SAC was estimated at 340 individuals (CV = 46.4) in 2011, 169 (CV = 29.1) in 2012, and 146 (CV = 21.3) in 2013. Much higher abundance estimates existed for the entire Bay with 1074 (CV = 28.7), 565 (CV = 20.4), and 410 (CV = 20.4) in 2013.

Dedicated photo ID surveys of bottlenose dolphins were conducted throughout the season, mainly in Cardigan Bay SAC, whilst opportunistic photo-identification sessions occurred whenever possible during line-transect surveys. Our photo ID catalogue currently holds images of a minimum of 378 individuals (248 marked, 120 left side and 130 right side individuals). Analyses were completed using capture-mark-recapture methods, and took into consideration an overall average of 59% of marked individuals in the SAC, and 61% in the whole of Cardigan Bay.

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

Estimates for the number of bottlenose dolphins using the entire Cardigan Bay can only be calculated since 2005, when survey coverage was extended to include Pen Llyn a'r Sarnau SAC and adjacent areas in northern Cardigan Bay. Even then, lack of funding in some years and variation in weather conditions have meant that coverage has not been entirely consistent. Population estimates using a robust open population model have ranged from 128 (2005) to 232 (2012). As was the case with Cardigan Bay SAC, fitting a polynomial function to the estimates indicated a rise, in this case peaking around 2009, the curve flattening off and then declining. Values for the last three years were 193 (2011), 232 (2012), and 167 (2013).

Closed population models for both Cardigan Bay SAC and all of Cardigan Bay gave broadly similar results but with consistently higher values.

Photo-identification surveys off the coast of Anglesey commenced in 2007, and along with data provided from the Isle of Man and Liverpool Bay, have provided evidence that bottlenose dolphin individuals from Cardigan Bay extend their home ranges, particularly in winter, to the northern Irish Sea at least as far as the Isle of Man. Nearly 40% (n=82) of individuals have been identified in both Cardigan Bay and Pen Llŷn a'r Sarnau SACs and north of the Llŷn Peninsula - around the Isle of Anglesey, Caernarfon Bay and Isle of Man. Nearly 26% (n=55) were seen in Cardigan Bay SAC and North Wales, but not in Pen Llŷn a'r Sarnau SAC. This is most probably due to lower coverage in this northern SAC, particularly in the offshore area. These data provide evidence confirming that the geographic range of this population includes all of the coastal waters of West and North Wales, and

possibly the entire Irish Sea. At this time, there is no photo ID evidence matching the Cardigan Bay population to Scotland, the Republic of Ireland or Southern England.

Residency within Cardigan Bay SAC for 2001-07 was calculated as between 47-58%, but in recent years has declined to 37-43%, suggesting that some individuals are moving out of the area. Nevertheless, females with the SAC exhibit a relatively healthy crude birth rate of 5.3%, based upon a closed population model, and 7.65% using an open population model. Higher birth rates are seen for the wider Cardigan Bay, with values of 7.65% and 8.9% for closed and open models respectively, suggesting that the entire Bay is an important calving ground for this population. Observations of females with and without calves have, in the past, highlighted the importance of Cardigan Bay SAC as a calving ground. The present analyses indicate that at least two more significant calving areas exist – in Pen Llŷn a'r Sarnau SAC and around the Isle of Anglesey, North Wales.

Calves may be born at any time of year, but peak calving occurs between July and September, when 76% of all births are recorded. Females give birth on average every three years (range 2-7 years). Calf mortality rates were calculated from a sample of 71 mother-calf pairs born between 2001 and 2013. Higher mortality rates were found in the first two years (15% in year one and 17% in year two) with lower rates in the third year (7%), and a total of 60% of calves surviving into their fourth year.

Photo-identification surveys since 2007 reveal that some individuals exhibited localised re-sightings, with 7% of individuals sighted only in Cardigan Bay SAC, 8% solely around the Isle of Anglesey, and 3% seen only in the Pen Llyn a’r Sarnau SAC. Minimum convex polygon and kernel density estimation maps of home range and core area were created for individuals and groups. Mean male range areas were slightly but not significantly larger than females (16,420 km^2 versus 15,270 km^2). Females tended to use a smaller home range area and core area if characterised by one or more of the following attributes: a high calf production rate, a high calf survival rate, and a short inter-birth interval.

Although a small proportion of the bottlenose dolphin population still shows high residency to Cardigan Bay SAC, there is increasing evidence that individuals are using this SAC less. Potential explanations include a change in prey availability and/or increased anthropogenic disturbance. Two human activities known to be present in the area that potentially could have a negative influence are scallop dredging (through damage to the habitats of bottom-dwelling fish) and marine recreation (through disturbance). At present, it is not possible to say with any confidence if either is having a population effect. However, the marked increase in scallop dredging activity in Cardigan Bay in 2007 was followed by very low birth rates for bottlenose dolphins within the Bay in 2008 and 2009, the lowest recorded throughout the 13-year study period. Previous studies in the area have concluded that boat presence is negatively linked to bottlenose dolphin sighting frequencies, and one of the busiest sites, around the town of New Quay within the Cardigan Bay SAC, has seen a steady decline in bottlenose dolphin occurrence since 1994, with the relative abundance of the species inversely related to the number of boats counted. Further investigations have found evidence for boat traffic affecting both bottlenose dolphin social structure and whistle characteristics.

In order to accurately assess population trends through distance sampling and photo ID methods, it is essential to have consistent long-term monitoring of all of Cardigan Bay, and preferably other areas in North Wales, that are known to be occupied by bottlenose dolphins.

3. Introduction

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

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

History of dolphin research in Cardigan Bay

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

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

Since 2007, photo ID has been conducted also in the northern part of Cardigan Bay including Tremadog Bay, encompassing the Pen Llŷn a'r Sarnau SAC (Pesante *et al*., 2008b). These were *ad-libitum* surveys, whilst additional important information from the region has come from Alan Gray of Shearwater Coastal Cruises, operating out of Pwllheli. In 2011, line-transect surveys were commenced across all of northern Cardigan Bay, thus also providing photo ID information for the entire Bay (Veneruso and Evans 2012a).

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

Distribution and abundance of bottlenose dolphins in Cardigan Bay

There is some evidence for an overall increase in abundance since 2001, with summer population estimates ranging from 150-250 individuals (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al*., 2008b; Feingold *et al.* 2011). Cardigan Bay, and particularly Cardigan Bay SAC, is thought to be important in the summer months. However, a proportion of the population is known to remain in the region year-round (Baines *et al.,* 2002; Pesante *et al*., 2008b). It has become increasingly evident that a significant number of animals leave Cardigan Bay in winter months, moving northwards (Pesante *et al*, 2008a; Veneruso and Evans, 2012b). Many individuals have been reported off the north coast of the Isle of Anglesey, in Liverpool Bay and around the Isle of Man, involving animals that have been previously and often regularly identified by Photo ID within Cardigan Bay (Pesante *et al.,* 2008a; Veneruso and Evans, 2012b, Feingold and Evans, 2013b). At present, the waters around the Isle of Man represent the northern range limit of this population confirmed by photo ID (although bottlenose dolphins are seen regularly in the Solway Firth, no photographs exist suitable for matching), and, as of yet, Photo ID catalogues from Ireland, Hebrides, Moray Firth, Cornwall, or the English Channel have yielded no matches with the SWF Photo ID catalogue, showing no evidence of exchange outside of the Irish Sea (Pesante e*t al.,* 2008b; Sea Watch, unpublished data).

In addition to winter sightings of the species in the northern Irish Sea, bottlenose dolphins have recently been recorded off the North Wales coast and across to Liverpool Bay also in summer (Sea Watch Foundation, unpublished data, Veneruso and Evans, 2011a,b).

Pressures and impacts and the need for monitoring

Due to the anthropogenic pressures resulting from offshore renewable developments off the North Wales coast and possible pollution from industrial activities in Liverpool Bay - areas that are spatially unprotected for bottlenose dolphins - there is some concern as to what impact these pressures may have on the Irish Sea population as a whole. In Cardigan Bay, scallop dredging has intensified in recent years (Woolmer, 2009; Evans and Hintner, 2010; see Figures 59 & 60), and the effects of this activity on bottlenose dolphins are currently unknown. Further monitoring encompassing the whole coast of Wales, including offshore areas, is necessary to assess potential impacts.

With several areas of the Irish Sea currently being developed for offshore renewable energy projects, ongoing scallop dredging, and other human activities such as recreation increasing (Pierpoint *et al*., 2009; ABPmer, 2005, 2006; Evans and Hintner, 2010; Lohrengel *et al*., 2012), it is important that we accurately identify where and when particular localities are

used by bottlenose dolphins and in what magnitude or frequency so that NRW can advise on appropriate measures to minimise threats to their conservation status.

Monitoring requirements

Different types of measurements are required to characterise features (species presence, densities and habitat use); monitor impacts (numbers disturbed/displaced/ injured; reduction in densities); and determine significant changes in populations (time-series).

It is important for nature conservation management and measurement of the achievement of Favourable Conservation Status that reliable estimates of the number of dolphins, their trends, and the effects of human activity on the population in the SACs, are made. The UK's Common Standards Monitoring (CSM) programme led by the Joint Nature Conservation Committee (JNCC, 2004) suggests monitoring of mandatory attributes in SACs across Britain. For bottlenose dolphins, the mandatory attribute is 'numbers of bottlenose dolphins using the SAC'. Population dynamics, physiological health, natural range and distribution, supporting habitat and management of human activities are indicators identified as attributes for monitoring bottlenose dolphins in Welsh SACs (JNCC, 2005).

An attribute considered essential to assessing the condition of the bottlenose dolphin species feature of the SAC is the 'number of individual dolphins using the SAC' and is assessed for all sites. Monitoring individual animals using Photo ID techniques, especially from boat based surveys, will build on previous research to determine bottlenose dolphin abundance, seasonal habitat use, range, distribution and population demographics such as reproductive success. Also, given financial constraints, it is important that the cost-effectiveness of the survey work is maximised and opportunistic monitoring occurs for other marine mammal species that inhabit the study area, notably the harbour porpoise (*Phocoena phocoena*) and grey seal (*Halichoerus grypus*), but also common dolphin, Risso's dolphin, and minke whale that occasionally visit the Bay.

Annual assessments of absolute abundance for bottlenose dolphin and harbour porpoise in Cardigan Bay SAC have been made by SWF from 2001 to 2007, mostly funded by the Countryside Council for Wales (now known as NRW) as part of a systematic monitoring programme. Since then, a scaled back programme of monitoring, which concentrated on Photo ID, along the coastal strip of the Cardigan Bay SAC with limited coverage elsewhere, was continued by SWF up to 2010. This provided an estimate of the numbers of animals using that area but was insufficient to determine overall trends or whether some areas of Cardigan Bay were being used less now than others. Thus, there has been a gap of three years in monitoring this primary feature of Cardigan Bay SAC and qualifying feature of Pen Llŷn a'r Sarnau SAC. A mixture of line-transect and photo monitoring undertaken by Sea Watch Foundation has given a systematic and scientifically robust means of assessing changes in status and distribution. The current project combines vessel-based surveys and Photo ID throughout Cardigan Bay on a regular basis (minimum once a month) throughout the summers of 2011-2013.

3.1 General Aims

- To record, document, statistically analyse and report indicators of the condition of bottlenose dolphins and harbour porpoises in both the Cardigan Bay and Pen Llŷn a'r Sarnau SACs.
- To collect photographic ID images and refer to those from established catalogues, at sites within and outside the key study areas, to evaluate dolphin movements, abundance estimates and distribution.
- To monitor the number of bottlenose dolphins using the SACs, and to assess the supporting habitat and estimate population structure (age and sex).
- To gather evidence of any anthropogenic activities within the sites, while monitoring bottlenose dolphins. This will contribute to the determination of impacts on bottlenose dolphins in Cardigan Bay SAC and threats to population status in terms of population size, structure, and demographics (production), and distribution, range and area use.

3.2 Objectives

The following were the main objectives of this monitoring programme:

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

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

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

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

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

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

g) In order to investigate the nature of the supporting habitats, e.g. estuary, headland or reef, record the number of bottlenose dolphins in each of the respective habitats and the location of each habitat within the site if necessary. Record all environmental and physical parameters at the time of recordings, e.g. tides, beach aspect, wind direction & speed, sea state, air temperature, and relevant biological information, e.g. aggregations of feeding birds or

shoaling fish. The combination of information on habitat type and some of the above list will allow a preliminary assessment of habitat in the SACs. Results from this work will inform more targeted evaluation of both habitat and prey species.

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

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

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

j) To interpret past and current data, in order to provide a reasoned opinion on the condition and status of bottlenose dolphins in the SACs and Cardigan Bay and develop targets for monitoring.

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

4. Methodology

4.1 The Study Area

Cardigan Bay is the largest bay in the UK, measuring over 100 km (60 miles) across its westernmost extent and encompassing a total area of 4986.86 km^2 from the western tip of the Llŷn Peninsula in the north (52˚ 47’ 45’’ N, 004˚ 46’ 00’’ W) to St David’s Head in the south (51˚ 54’ 10’’ N, 005˚ 18’ 54’’ W, Figure 1). It is a shallow bay, with waters nowhere deeper than 60 metres and very gentle slopes (Evans, 1995).

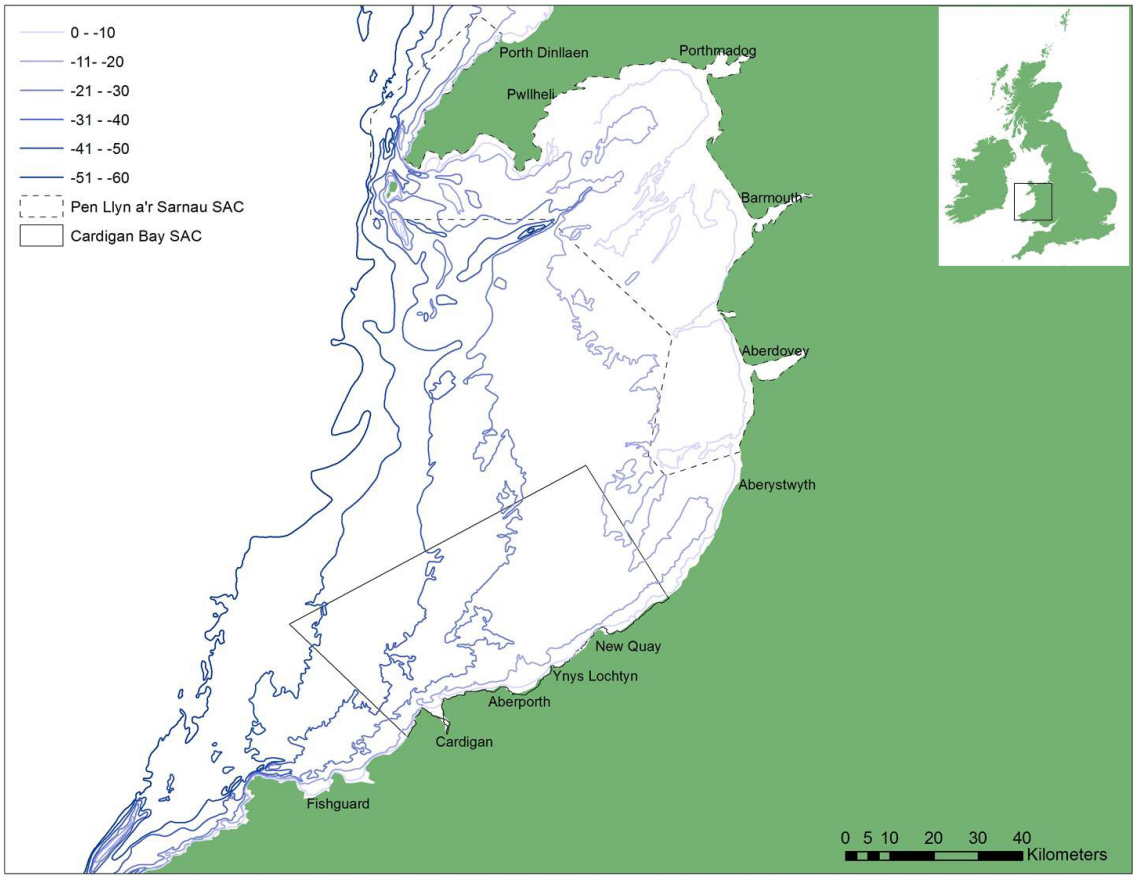


Figure 1: The study area: Cardigan Bay in West Wales.
The boundaries to Cardigan Bay SAC are indicated by continuous lines, and for Pen Llŷn a’r Sarnau SAC by hatched lines

A population of bottlenose dolphins forms a primary interest of the Bay and it was for this that the Bay was first selected as a Special Area of Conservation. Cardigan Bay SAC is located in the south of the bay and encompasses 958.65 km^2 (Figure 1). Besides being recognised as important for bottlenose dolphins, it is also thought to be a key area for Atlantic grey seals (*Halichoerus grypus*) as well as important for some fish and invertebrate species (Anon, 2007; CCW, 2009). The SAC has also been designated for various features that qualify under Annex I and Annex II of the Habitats Directive such as reefs, submerged or partially submerged sea caves, sandbanks which are slightly covered by seawater all the time,

grey seals, river lampreys (*Lampetra fluviatilis*), and sea lampreys (*Petromyzon marinus*) (Anon, 2007; CCW, 2009).

The Pen Llŷn a'r Sarnau SAC encompasses areas of sea, coast and estuary that support a wide range of different marine habitats and wildlife. It is situated in the north of Cardigan Bay and covers an area of 1460.35 km^2. The latitudinal range of the SAC is 52.43˚N to 52.97˚N. Some additional qualifying features in this SAC include coastal lagoons, estuaries, mudflats and the otter (*Lutra lutra*) (Anon, 2007; CCW, 2009). *Ad libitum* surveys have taken place in the northern SAC since 2006 although not to the same extent as in Cardigan Bay SAC (Evans and Pesante, 2008; Pesante *et al.*, 2008b; Feingold *et al.*, 2011). Line-transect surveys extending throughout the Bay commenced in the summer of 2011 and continued in the summers of 2012 and 2013.

There is a significant area remaining in Cardigan Bay that is not covered by the SACs (Figure 1) and few boat-based surveys have been conducted here in the past. During 2011 to 2013, primarily in 2013, we managed, for the first time, to cover the majority of the offshore areas of the Bay where winter aerial surveys conducted in Cardigan Bay in 2007 (Pesante *et al.*, 2008b), detected bottlenose dolphins, harbour porpoise and grey seals. Bottlenose dolphins had appeared to show a stronger preference for this offshore area in winter (Pesante *et al.*, 2008b). It is important therefore to understand whether in those summers when bottlenose dolphins were scarcer within the coastal zone, they were remaining within Cardigan Bay but moving offshore, or were they moving out of Cardigan Bay altogether. Furthermore, there was a need to establish whether various human activities might be affecting bottlenose dolphin occupancy of the Bay.

4.2 Line-transect surveys

Line-transect surveys were used as the data collection method from which abundance estimates can be derived for bottlenose dolphin and harbour porpoise. Line-transect surveys in Cardigan Bay SAC have been performed successfully in previous years, providing abundance estimates not only for bottlenose dolphins but also harbour porpoise and Atlantic grey seals that are known to be abundant in the region (Baines *et al.*, 2002; Ugarte and Evans, 2006; Pesante *et al.*, 2008b; Veneruso and Evans, 2012a; Feingold and Evans, 2013). The methodology used between 2011-13 was comparable to surveys performed in previous years in order to ensure consistency between monitoring periods.

Table 1: Vessels used for line-transect surveys in Cardigan Bay in 2011-2013
(* Cardigan Bay SAC; ** Pen Llŷn a'r Sarnau SAC)

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

Dedicated line-transect surveys were conducted between 2011 and 2013 by SWF staff and a team of trained volunteers. These were all undertaken in favourable conditions: Beaufort sea state <3, visibility >1.5 km, and no precipitation. The surveys were conducted in Cardigan Bay SAC, Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay. Vessels used during these surveys are listed in Table 1.

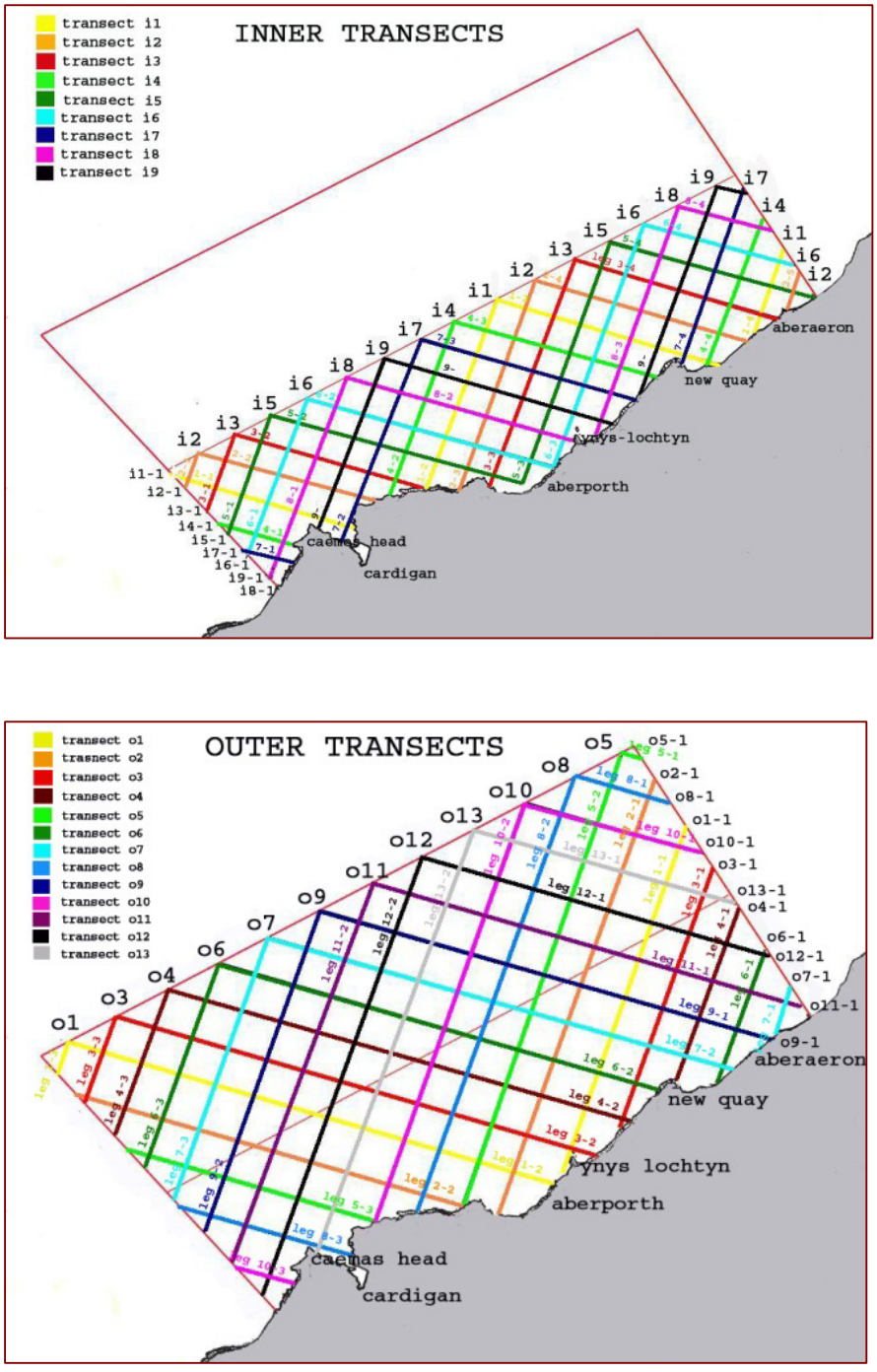


Figure 2: Transect lines used for line-transect surveys in Cardigan Bay SAC (inner –top and outer – bottom)

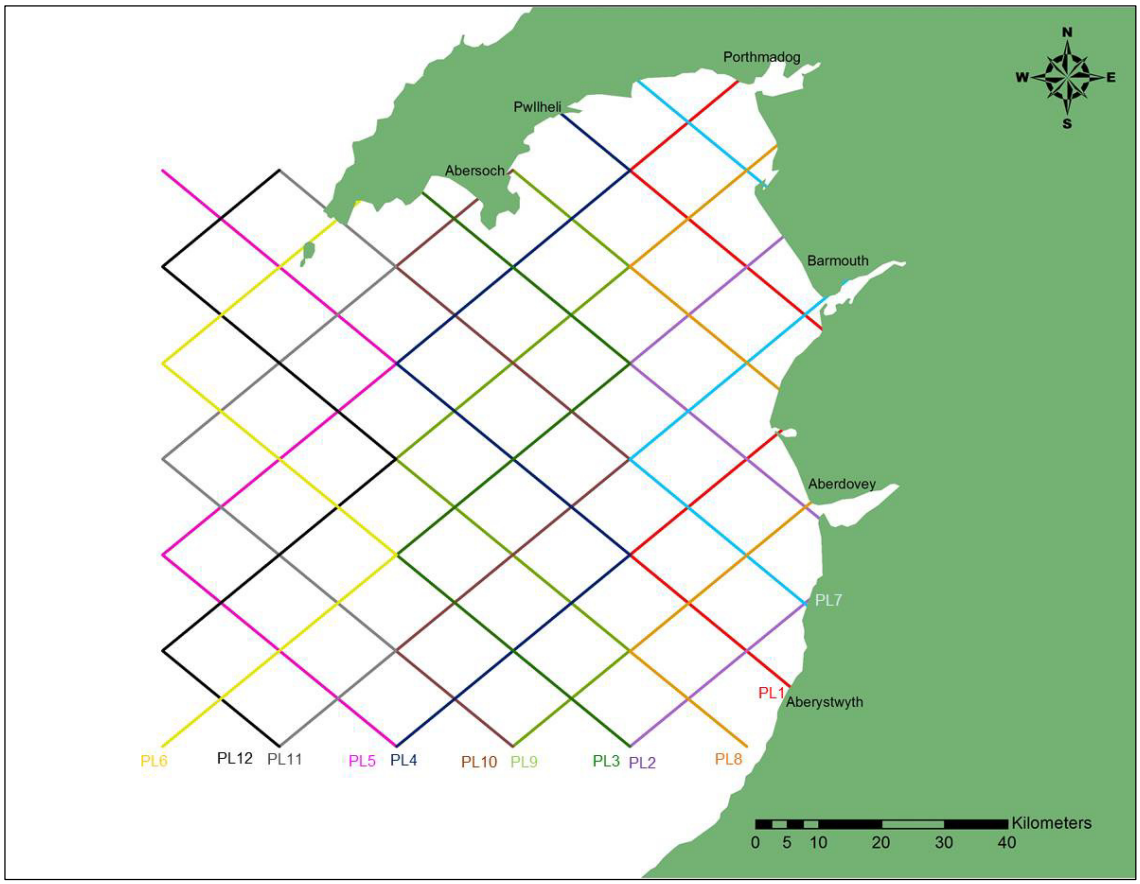


Figure 3: Transect lines designed for Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay
(Transect numbers: PL1- red; PL2- purple; PL3- green; PL4- blue; PL5- pink; PL6- yellow; PL7-light blue; PL8-orange; PL9-light green; PL10-brown PL11-grey; PL12-black)

The same survey design that was used in previous years in Cardigan Bay SAC was adopted. Transect lines previously used by Ugarte *et al*. (2006) and Pesante *et al.* (2008b) were used (Figure 2). Transects were divided into two strata - inner and outer transects (split at 52.15°N, 4.89°W and 52.33°N, 4.31°W), since bottlenose dolphin density within Cardigan Bay SAC has been shown to be highest in inshore waters (Baines *et al.*, 2002; Ugarte *et al.*, 2006; Pesante *et al.*, 2008b; Feingold *et al.*, 2010). Continuing the efforts of 2011, line-transects were conducted in Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay during 2011-2013. Transects drawn up in 2011 were used, and transects were added to give greater coverage across the Bay in 2012 (Figure 3).

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

When on transect, the vessel travelled at a constant speed. This speed, of necessity, varied between vessels (Table 1). Any significant change in speed was noted on the effort form (Appendix 4), as was any movement away from the transect line, such as to conduct Photo

ID. When this occurred, the vessel returned as close as possible to the position where the track line was left, and the transect was resumed.

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

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

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

In our surveys, two independent observers (IOs) were positioned where they could have the best view of the track line without being seen by the Pos, thus obtaining information about the probability of detecting animals along the track-line (G(0)) and the extent of responsive movement. The key to distance sampling analysis is to fit a detection function to the observed distances, and use this fitted function to estimate the proportion of objects missed by the survey. On *Dunbar Castle II*, IOs could only be positioned near the stern of the vessel, where the view of the track line was partially blocked by the wheelhouse. IOs aboard *Ma Chipe Seabrin* and *Pedryn* were positioned further forward and had a clear field of view. IOs concentrated their effort on the track line, scanning from 45° on their side to 10° on the other, for one-hour shifts. Scanning was conducted entirely with binoculars in an attempt to detect

sightings at a distance, mainly to spot the animals before any potential responsive movement. Sightings were reported on an 'independent observer' form (Appendix 3). It was important that the IO did not communicate their sightings to the POs. Once the sighting had passed the beam, the person dedicated to effort checked with the POs whether they had detected that particular sighting and recorded this on the IO form as a duplicate sighting. Duplicates were then removed from the database for analytical purposes to avoid over estimating sighting rates.

Both POs and IOs estimated the distance to the animals when first detected. The survey team was given regular distance training sessions by testing them with objects at known ranges. For the majority of sightings, distances were checked by SWF staff. The distances from the boat to an anchored buoy were estimated using a handheld GPS. During these trials, the boat stopped at different distances from the buoy, ranging from only a few metres to nearly 800 metres. At each point, the observers estimated the distance to the buoy and wrote it down without communicating with each other. An example for a plot of the distance to the buoy measured by the GPS against the distance estimated by two experienced observers (Monitoring Officer and Research Assistant) are presented in Figure 4. A regression line fitted to these data and set to intercept at the origin, had an average slope of 0.924. Slopes revealed no significant differences between the actual and estimated differences and before analysis, all the distances estimated during the study in 2012 were transformed by multiplying them by the inverse of 0.928, or 1.07. Distances were calibrated for all years according to the regression lines of the two experienced observers for each year.

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

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

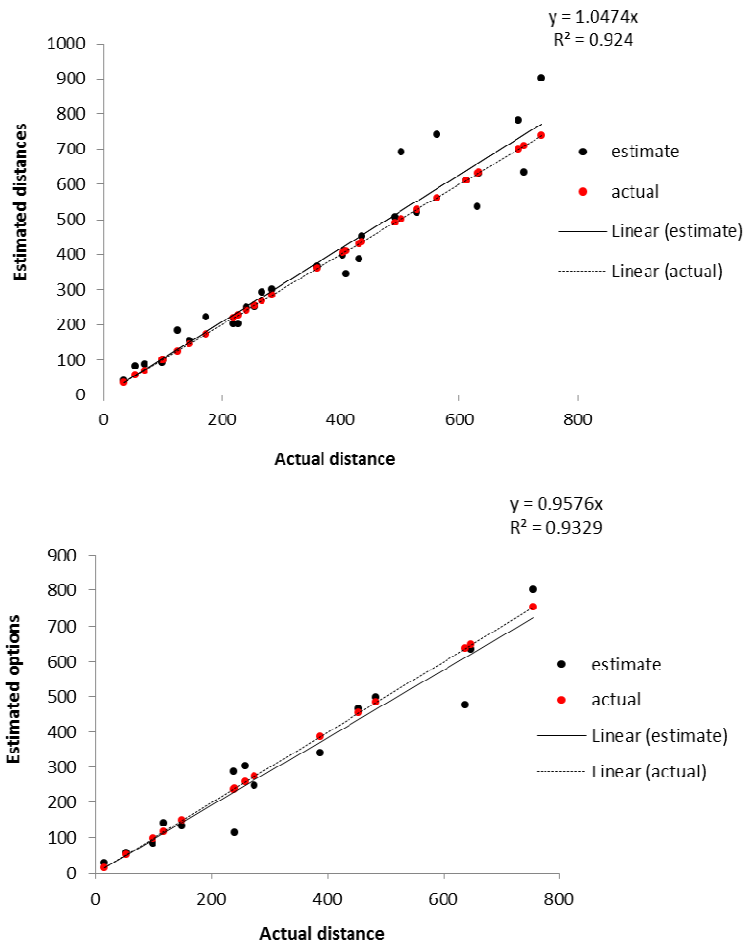


Figure 4: Plot of distance to the buoy measured by the GPS. Estimated by two experienced observers in 2012

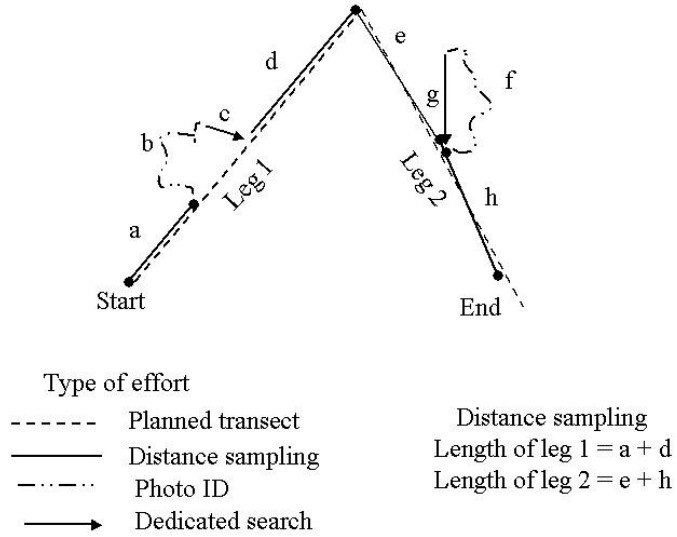


Figure 5: Schematic representation of two transect legs temporarily interrupted for Photo ID

When dolphins were detected, where possible, the line-transect survey was paused and the vessel left the track line in order to approach the animals for photo identification. The method used for Photo ID is explained in section 4.6. Once the group had been comprehensively photographed, the vessel travelled to the point that the vessel last left the transect line and resumed the line-transect survey (Figure 5).

4.3 Data Analysis - Line-transect surveys

Effort and sightings data were entered into Microsoft Excel, and plotted using ArcGIS v. 10.1. Following Ugarte and Evans (2006), the distance of each sighting was adjusted according to the results of the distance test and calibration experiment taken by SWF staff. Perpendicular distances of animals from the track-line are calculated from measures of the angle and distance of each sighting from the observer, so that the effective strip width can be calculated (since this varies with observation height and sea conditions prevailing at the time) using version 6.0 of the software program Distance (Buckland *et al*., 2001, 2004; Thomas *et al*., 2010). All calculations were made using a 'Multiple Covariate Distance Sampling test (MCDS)' sampled for 'Sea State' (cf. Buckland *et al*., 2001, 2004; Thomas *et al*., 2010), with 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. In our case, the platform heights of all three vessels used were very similar. Abundance estimates were calculated for bottlenose dolphin and harbour porpoise using sightings recorded only by the PO's. A half normal cosine Multi Covariates Distance Sampling model was used, sampling the data for sea state, and truncating all observations to 600 m, which usually provided the lowest AIC value, as recommended by Buckland *et al*. (2001, 2004). Previous data from 2005-07 and from 2011-13 were treated similarly. For some years, however, it was not possible to truncate to 600 m due to low sample size of sightings, and in those cases a 700 m truncation was used instead.

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

4.4 *Ad libitum* surveys

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

Table 2: Vessels used during *ad libitum* surveys in Cardigan Bay in 2011-2013

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

4.5 Data Analysis - *Ad Libitum* surveys

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

4.6 Photo Identification

Photo ID is a mark-recapture method that makes use of naturally produced markings. Bottlenose dolphins are an ideal study species for this technique since many acquire nicks and scratches on the dorsal fin and body from interactions with other individuals. These are unique to individual animals and, with good quality photographs, are recognisable over time. In the early 1990's, Sea Watch Foundation began its own catalogue of images collected in Cardigan Bay. Since 2001, this has grown and been maintained to the present day by regular dedicated Photo ID surveys. In 2007, the catalogue was extended to include data from surveys conducted in North Wales and around the Isle of Man, resulting in a catalogue of individuals reported for the wider Irish Sea. This non-invasive method has proved very successful and has been used to assess abundance and population trends, define habitat use and fidelity, and home ranges, as well as to investigate social structures and study life history (such as birth and death rates) (Ugarte *et al.*, 2006; Pesante and Evans, 2008; Pesante *et al.*, 2008b; Feingold *et al.*, 2011, Veneruso and Evans 2012a, b; Feingold and Evans, 2013a, b).

Between 2011-13, images used for Photo ID were collected during dedicated surveys (line-transect and *ad libitum*), onboard passenger trips, and land-based watches from New Quay Harbour. In some cases, images were also provided by others, including Janet Baxter (Friends of Cardigan Bay), Alan Gray (Shearwater Cruises), and Tom Felce (Manx Whale and Dolphin Watch). Members of the public were also encouraged to send in their photos, taken during sightings from passenger trips or from New Quay Pier, so long as some basic sightings information was provided, including date, location and group size.

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

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

always, engaged in the same activity (Shane, 1990). Behaviours were recorded on a standardised 'sighting form' (see Appendix 2). Four main behaviours were collected:

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

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

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

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

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

4.7 Data analysis - Photo ID

Photo ID matching was performed using ACDSee Pro (ACD Systems International Inc.). All matched encounters were confirmed by a second person. Software programs MARK 6 and CAPTURE (Gary C. White, Dept of Fish, Wildlife, and Cons. Bio. Colorado State University, USA) were used to calculate population estimates using mark-recapture analysis. A closed population model (Chao Mth: Chao *et al*., 1992) was used for Cardigan Bay, and separately for Cardigan Bay SAC. A Robust Design Method (Kendall and Nichols, 1995; Kendall *et al*, 1997) was also conducted for the open population model on data acquired from both areas. Having a long data set for Cardigan Bay SAC (2001-13) has enabled us to run the robust model and let it estimate all parameters. Then for the second model, a mean survival rate (S) value calculated from all years was taken and constrained to a constant value for each year. MARK cannot distinguish between permanent emigration and mortality, and without constraining survival rates, some unreasonable estimates for S may occur suggesting a high mortality in the winter between field seasons, whereas in fact it may just be that animals have moved away permanently. The data set for wider Cardigan Bay is not as large, containing data from 2005-13, and, therefore, S values were not constrained to a constant value for the robust model in this case.

Behaviour data were analysed by comparing percentages of all behaviours recorded (see section 5.3). Behaviour analyses were combined for all surveys in Cardigan Bay SAC (line-transects and *ad-libitum*), and also analysed separately for surveys in the wider Cardigan Bay area. Sightings in which behaviours were not recorded or unidentified, were omitted.

5. Results

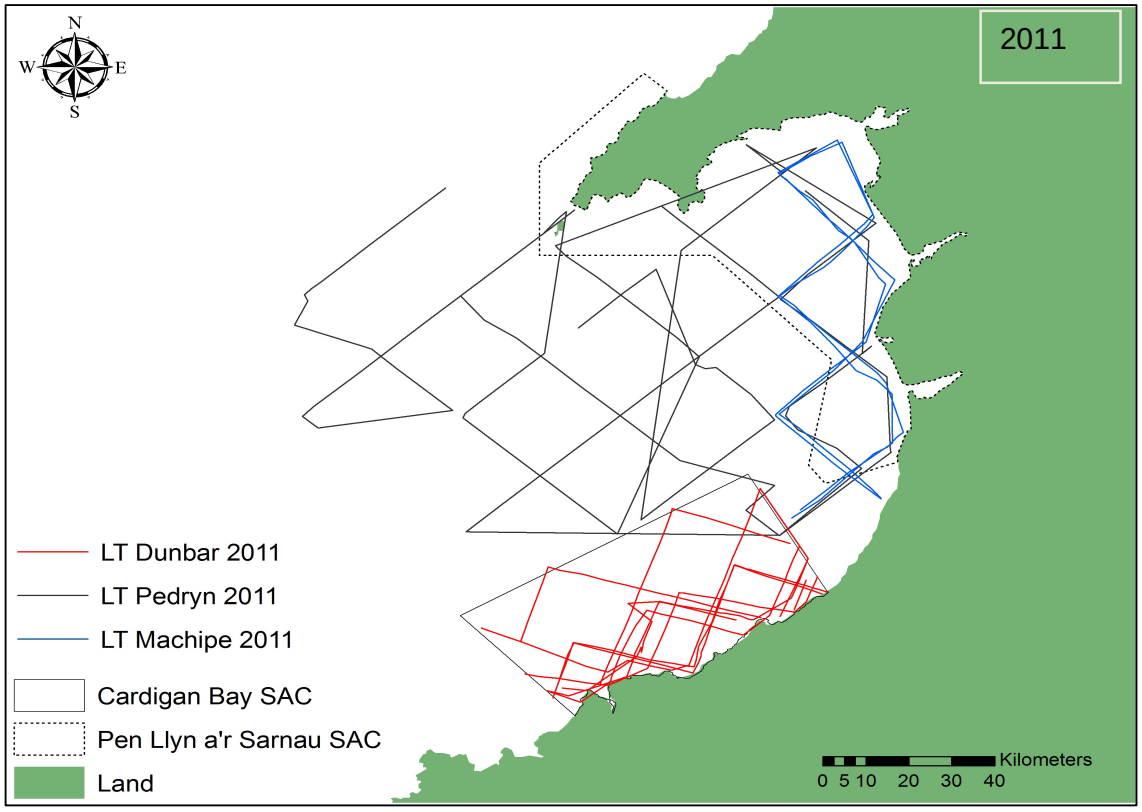
5.1 Line-transect surveys

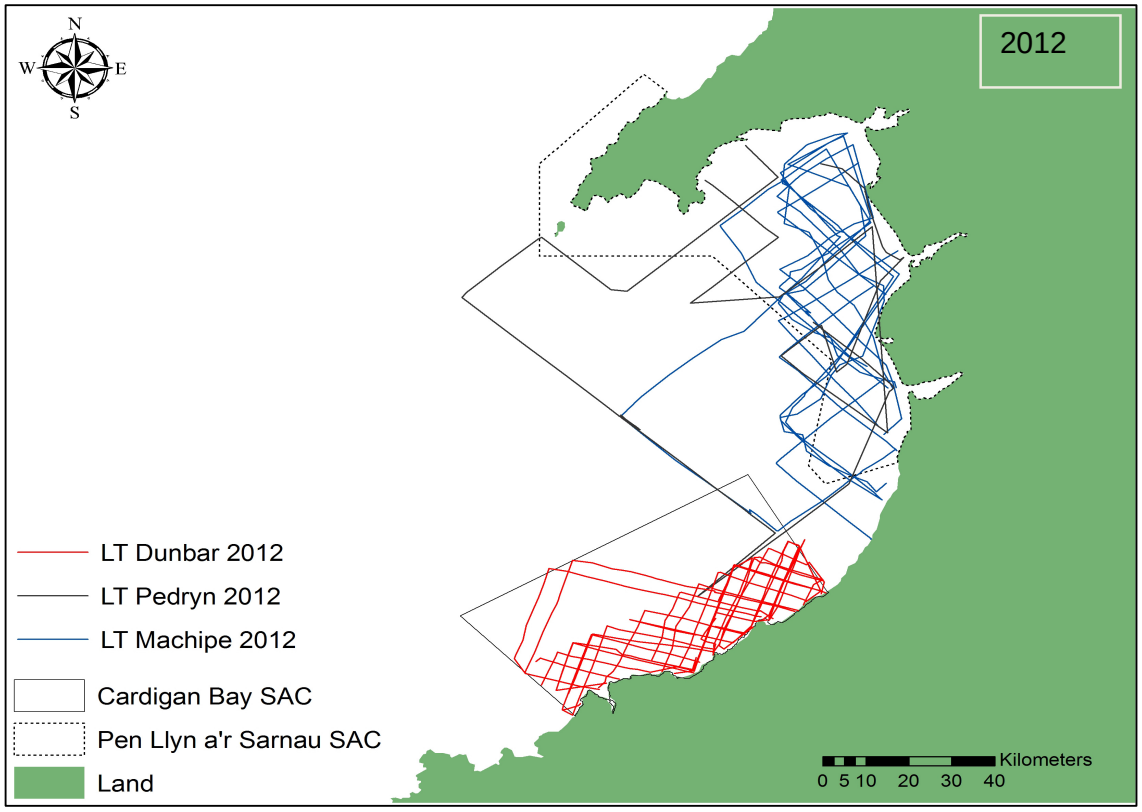
A total of 83 line-transect surveys took place in favourable conditions during the summer months between July 2011 and October 2013, covering over 10,000 km of survey effort. Of these, 6160 km were conducted in line-transect mode (Table 3, Figure 6). A total of 295 bottlenose dolphin, 289 harbour porpoise, and 354 grey seal sightings were recorded. Of these, 128 bottlenose dolphin, 243 harbour porpoise and 216 grey seal sightings were detected from the transect line. Due to line-transect surveys commencing rather late in the season in 2011, the majority of the data was obtained during 2012-13 (Table 4).

Bottlenose dolphin As observed in previous years (Ugarte & Evans, 2006; Pesante *et al*., 2008b), our surveys indicate that bottlenose dolphins have a strong preference for inshore waters. We have managed to survey some offshore areas which are not covered by the two SAC's during 2011-13 in Cardigan Bay (primarily in 2013) and although much lower effort was invested in these offshore surveys, six bottlenose dolphin sightings were recorded offshore, outside of Pen Llŷn a'r Sarnau SAC, and an additional five bottlenose dolphin sightings were recorded within the area gap between the two SACs (Figure 7).

The analysis of the spatial distribution of bottlenose dolphins revealed high encounter rates in several areas (Figure 8). The entire coastal area from Aberaeron to Cardigan seems to be of particular significance to bottlenose dolphins, in particular in the vicinity of New Quay headland, Ynys Lochtyn, Mwnt, Pen Peles and Aberporth. Other centres of activity were found in Tremadog Bay and around the reefs and sandbanks of Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy. A number of these areas were also found to be important for the species between 2001-07 (Pesante *et al*., 2008b).

Bottlenose dolphin abundance estimates for the whole of Cardigan Bay (calculated using Distance v. 6) are presented in Table 5, with the associated detection functions shown in Figure 9. Abundance estimates vary between years from 309 in 2011, 330 in 2012, and 254 individuals in 2013. Since survey effort was much reduced between 2008-10, it is not possible to statistically test for trends. The estimate for 2013 is much lower than the previous two years despite better coverage that year (3031 km vs 1865 km in 2012), a comparable number of sightings (Table 4), and similar CVs around the estimates (Table 5).


N
W
E
S
2011
LT Dunbar 2011
LT Pedryn 2011
LT Machipe 2011
Cardigan Bay SAC
Pen Llyn a'r Sarnau SAC
Land
Kilometers
0 5 10 20 30 40


N
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2012
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LT Machipe 2012
Cardigan Bay SAC
Pen Llyn a'r Sarnau SAC
Land
Kilometers
0 5 10 20 30 40

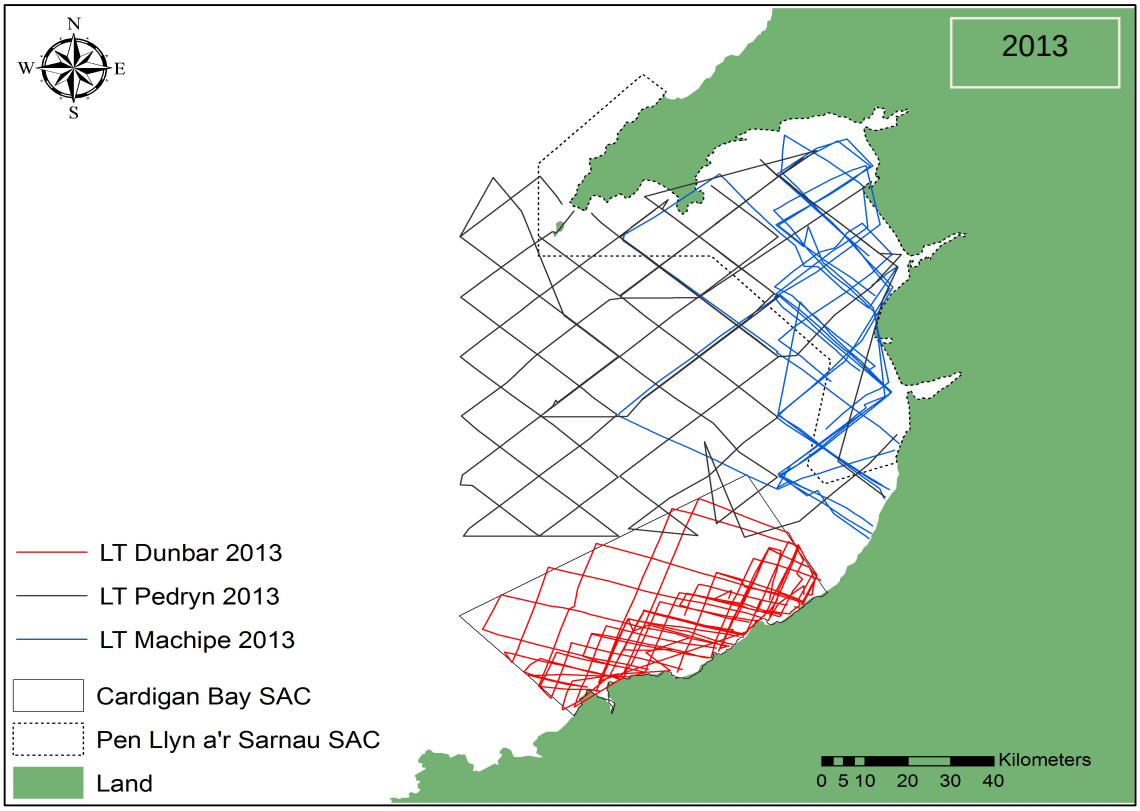


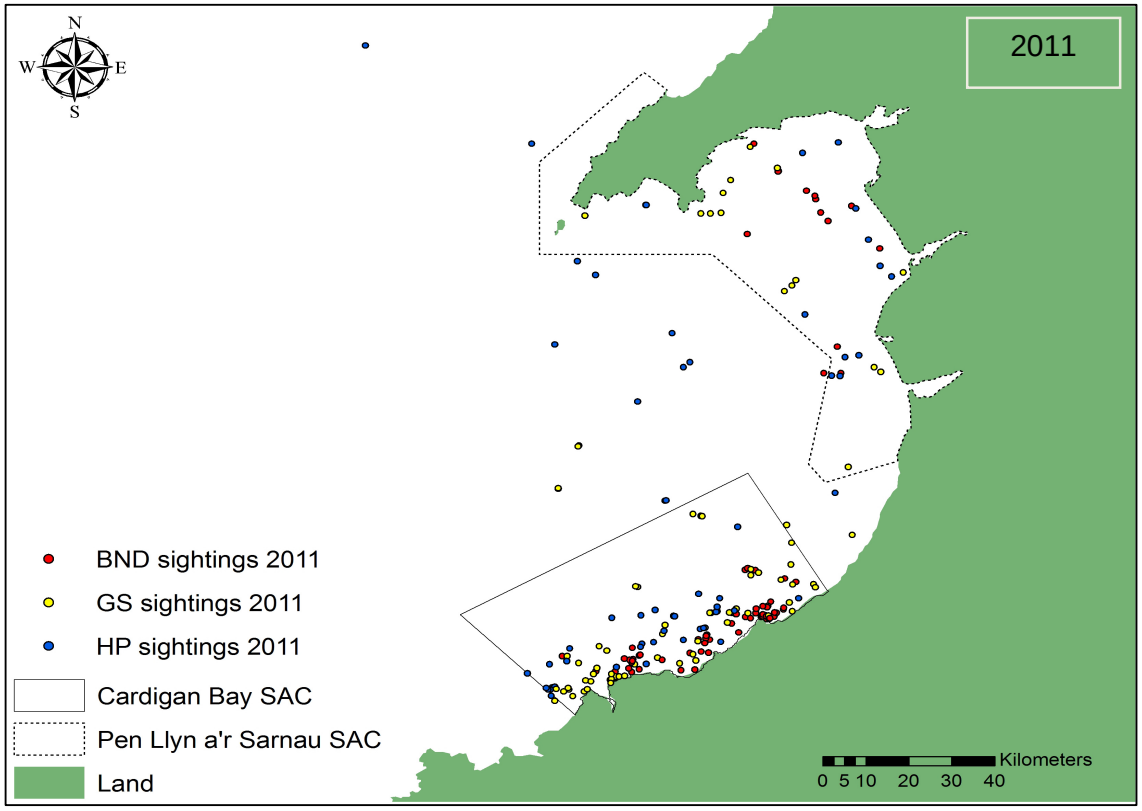
Figure 6: Tracks of line-transect (LT) surveys conducted in Cardigan Bay in 2011 (top), 2012 (middle) and 2013 (bottom).
Coloured lines represent tracks from different vessels

Table 3: Line-transect (LT) survey effort conducted in Cardigan Bay in 2011-2013

	Vessel	**2011**	**2012**	**2013**	**Total**	**Total 2011-13**
No. of Surveys	Dunbar Castle II	10	18	26	54	83
	Ma Chipe Seabrin	2	7	8	17	
	Pedryn	3	2	7	12	
Km travelled	Dunbar Castle II	897.42	1364.05	1843.54	4105.00	10007.57
	Ma Chipe Seabrin	382.82	1222.75	1201.90	2807.47	
	Pedryn	939.55	522.75	1632.80	3095.10	
Km travelled in LT mode	Dunbar Castle II	450.85	686.06	1019.26	2156.17	6160.00
	Ma Chipe Seabrin	258.71	852.37	896.57	2007.65	
	Pedryn	554.81	326.37	1115.00	1996.18	
Km in inner transects	Dunbar Castle II	289.92	565.53	706.65	1562.10	3799.41
	Ma Chipe Seabrin	258.71	699.69	838.12	1796.53	
	Pedryn	111.76	172.22	156.81	440.78	
Km in outer transects	Dunbar Castle II	160.93	120.53	312.61	594.07	2282.99
	Ma Chipe Seabrin	-	152.68	58.45	211.12	
	Pedryn	443.06	154.15	880.58	1477.79	

Table 4: Marine mammal sightings yielded from line-transect (LT) surveys conducted in Cardigan Bay in 2011-2013 (BND - bottlenose dolphin; HP - harbour porpoise; GS - Atlantic grey seal)

Vessel	Year	No. BND sightings	No. BND in LT mode	No. HP sightings	No. HP in LT mode	No. GS sightings	No. GS in LT mode
Dunbar Castle II	2011	55	24	30	21	56	31
	2012	84	31	47	39	76	39
	2013	91	29	87	74	128	62
Ma Chipe Seabrin	2011	7	5	6	4	2	2
	2012	13	13	32	29	33	32
	2013	18	12	29	26	23	21
Pedryn	2011	5	2	20	18	16	11
	2012	4	4	8	7	6	5
	2013	18	8	30	25	14	13
Total 2011-13		**295**	**128**	**289**	**243**	**354**	**216**



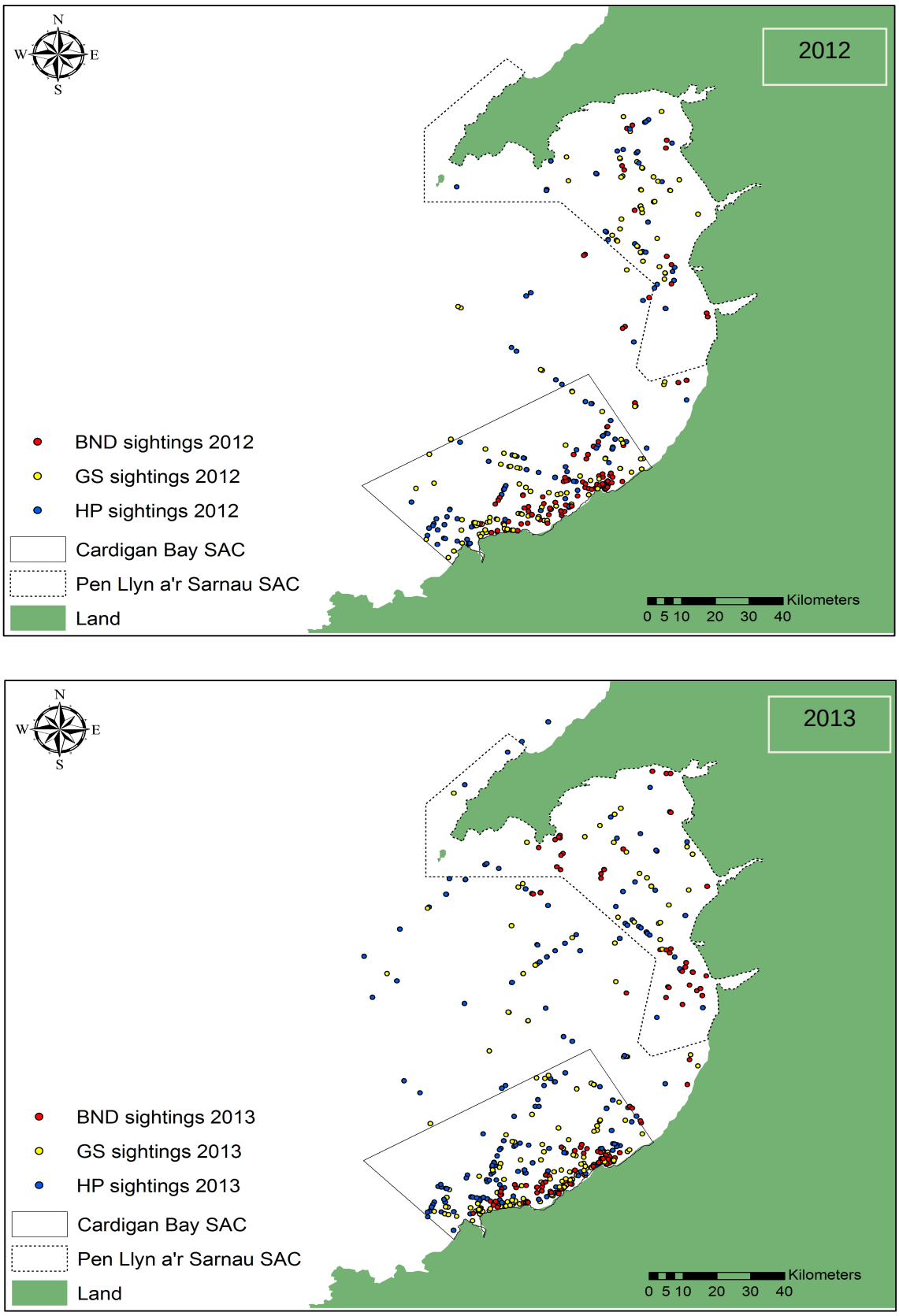
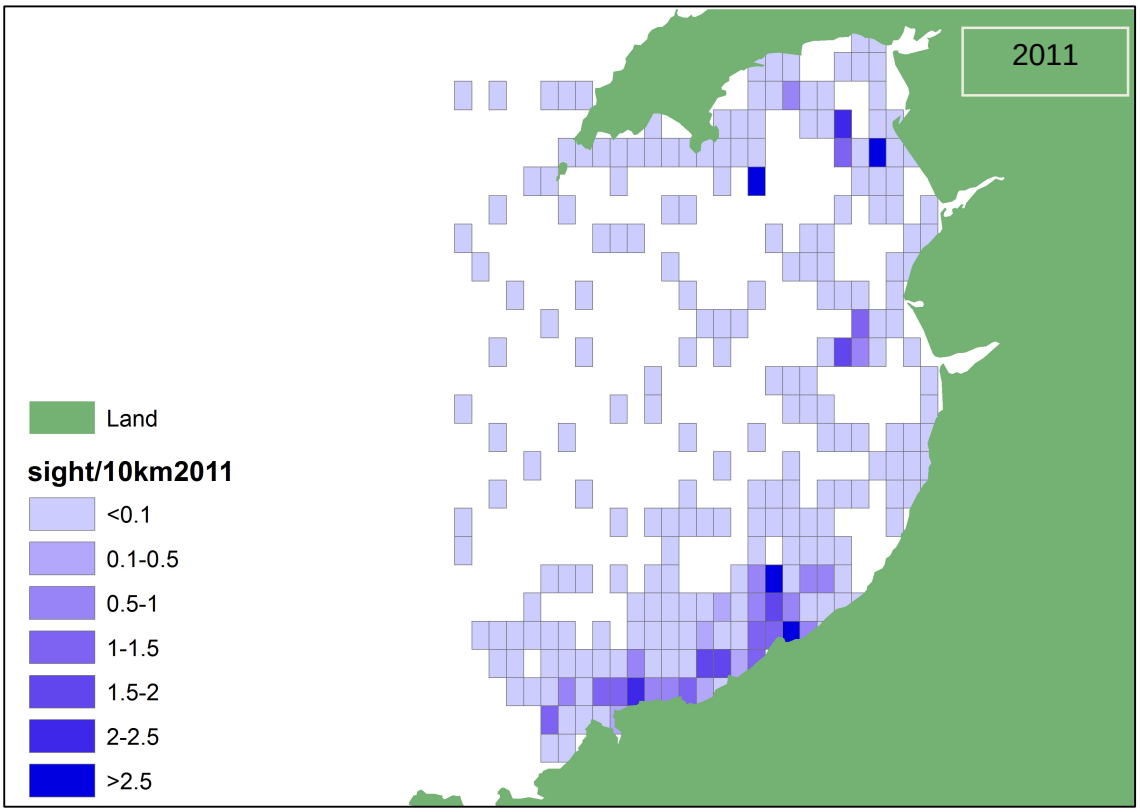


Figure 7: Sightings recorded during line-transect surveys in Cardigan Bay in 2011 (top), 2012 (middle) and 2013 (bottom).
(BND = bottlenose dolphin - red; HP = harbour porpoise - blue; GS =Atlantic grey seal - yellow)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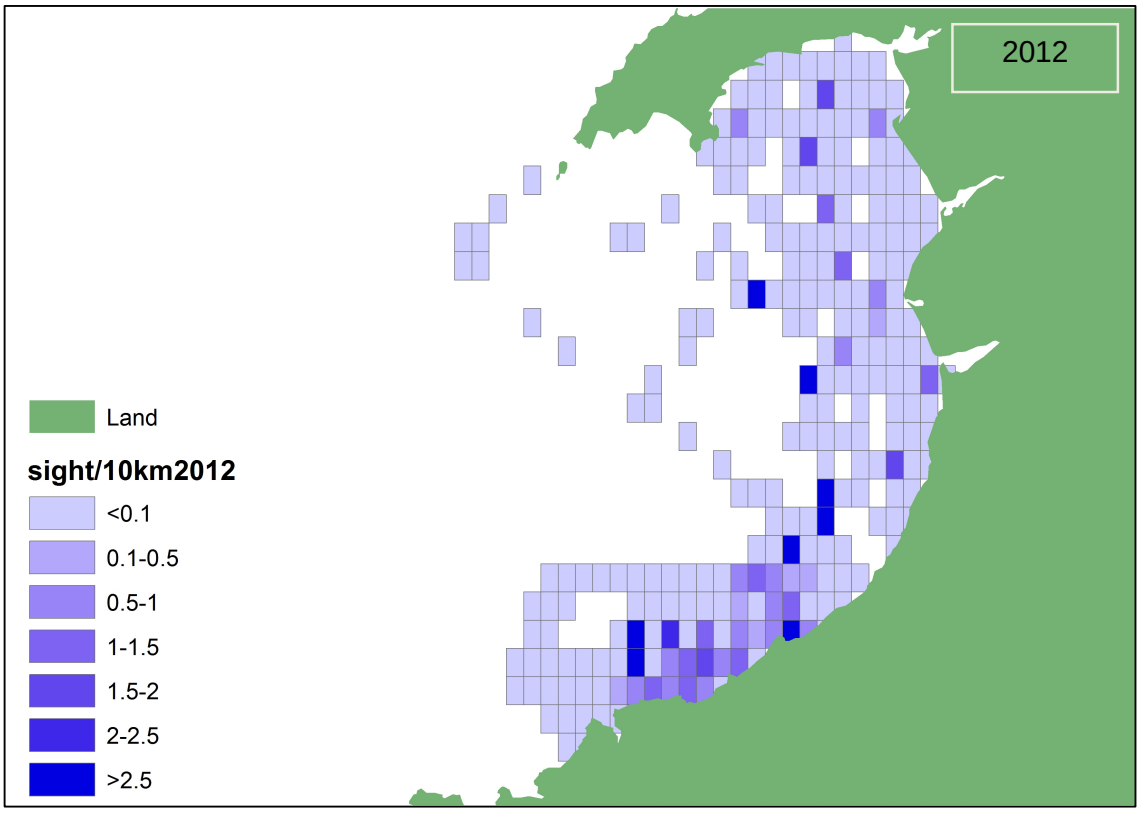
Land
sight/10km2011
<0.1
0.1-0.5
0.5-1
1-1.5
1.5-2
2-2.5
>2.5


2012
Land
sight/10km2012
<0.1
0.1-0.5
0.5-1
1-1.5
1.5-2
2-2.5
>2.5

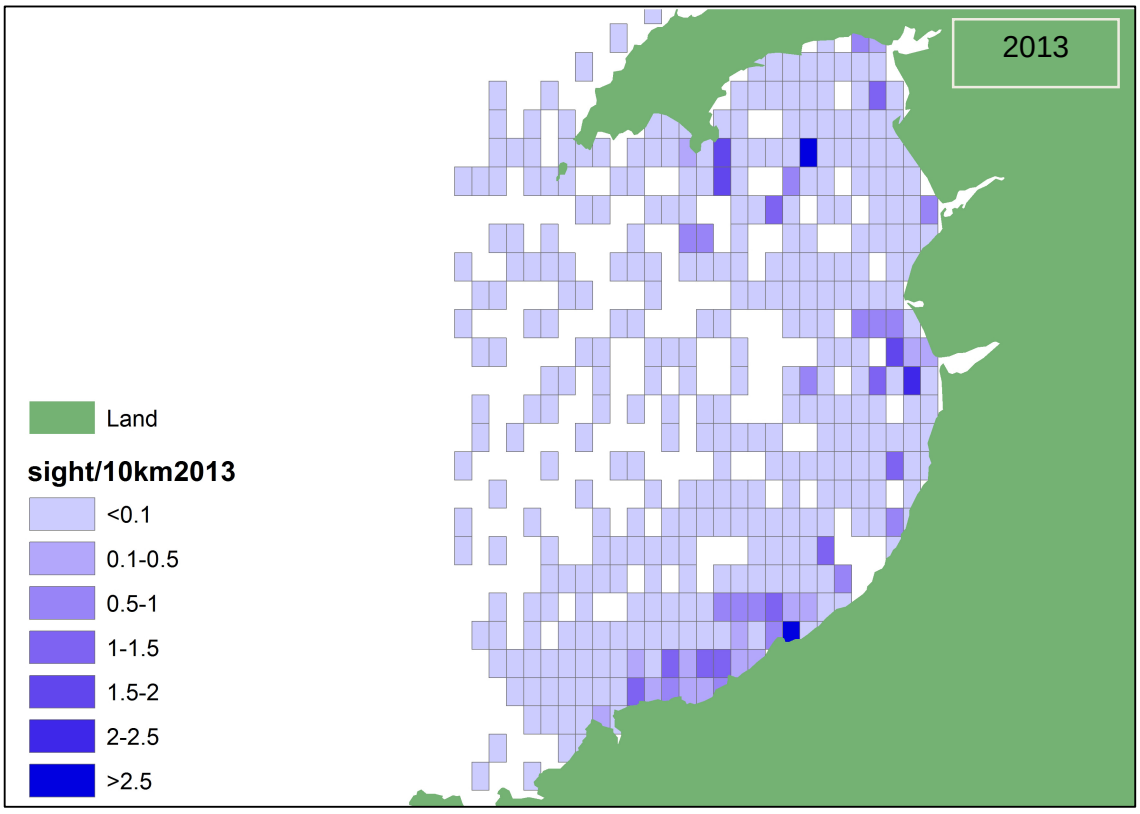


Figure 8: Bottlenose dolphin encounter rates weighted for effort in 2011 (top), 2012 (middle) and 2013 (bottom).
The darker the cell, the higher the encounter rate

Table 5: Abundance estimates of bottlenose dolphin (BND) from line-transect surveys in Cardigan Bay, 2011-13

Definition	BND 2011	BND 2012	BND 2013	BND 2013 (no Pedryn offshore transects)
Abundance	309	330	254	284
95% CI	179-353	203-534	151-427	173-465
CV	28.34	24.87	26.83	25.47
Observations	27	32	33	33

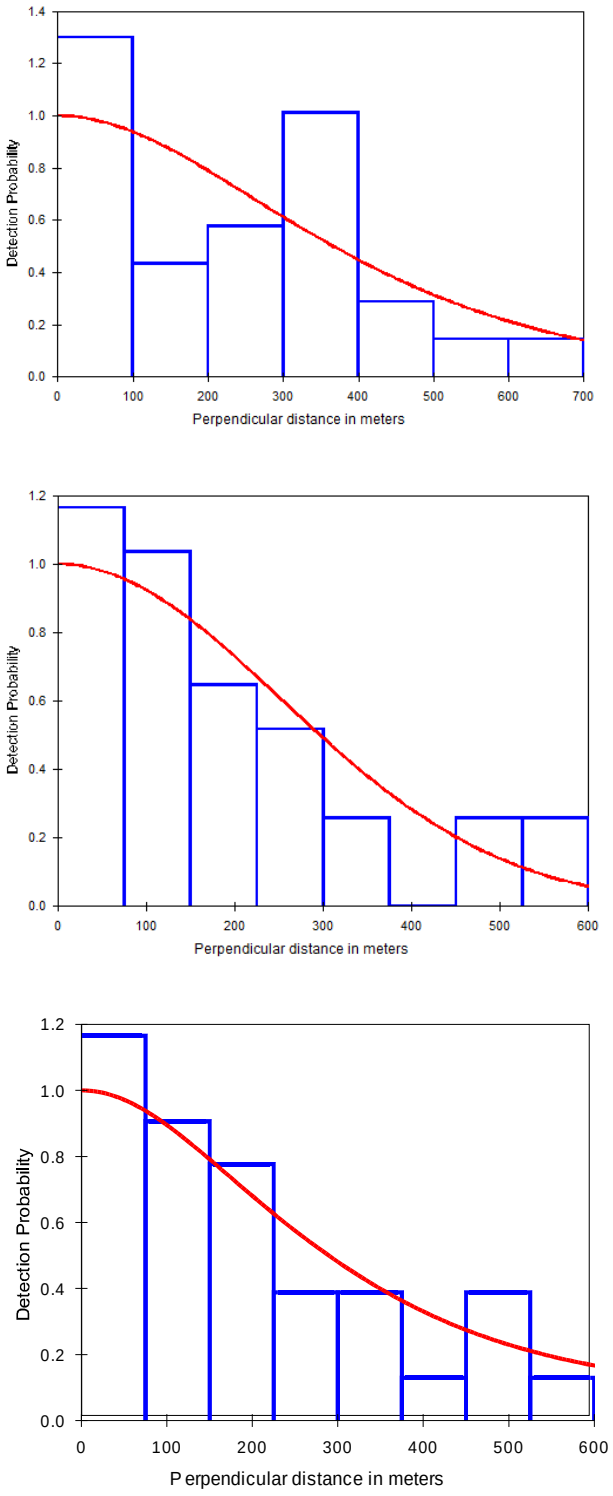


Figure 9: Detection function of bottlenose dolphins in Cardigan Bay In 2011 (top), 2012 (middle) and 2013 (bottom)

Initial efforts during the first years of the Cardigan Bay monitoring programme were concentrated primarily within Cardigan Bay SAC, contributing to a long-term population estimate data set for this area. Therefore, abundance estimates (Table 6) and associated detection functions (Figure 11) were also calculated for Cardigan Bay SAC alone. In previous years, when regular line-transect surveys were undertaken, a general increase in abundance was observed between 2001 and 2006, but in 2007 numbers dropped markedly (Ugarte *et al.*, 2006; Pesante *et al.*, 2008b; see also Figure 10), Unfortunately there were no funds available to undertake line-transect surveys between 2008-10, hence we have no abundance estimates between those years. The abundance estimate (133) in 2011 was very similar to that in 2007 (109), but in the last two years has been much lower (70 in 2012, and 90 in 2013), the lowest numbers recorded using Cardigan Bay SAC since the study started (Figure 10). Again, with only three years of consistent survey effort since 2007, it is not possible to statistically test for trends.

Table 6: Comparison of abundance estimates between years of bottlenose dolphins in Cardigan Bay SAC in 2001-13

Year	Abundance	95% CI	CV	Observations
2001	135	85-214	23.7	93
2003	140	69-284	36.6	19
2004	-	-	-	-
2005	139	88-218	23.2	49
2006	214	108-422	35.6	30
2007	109	49-239	41.7	24
2011	133	75-235	29.5	22
2012	70	37-131	33.0	19
2013	90	45-179	35.65	22

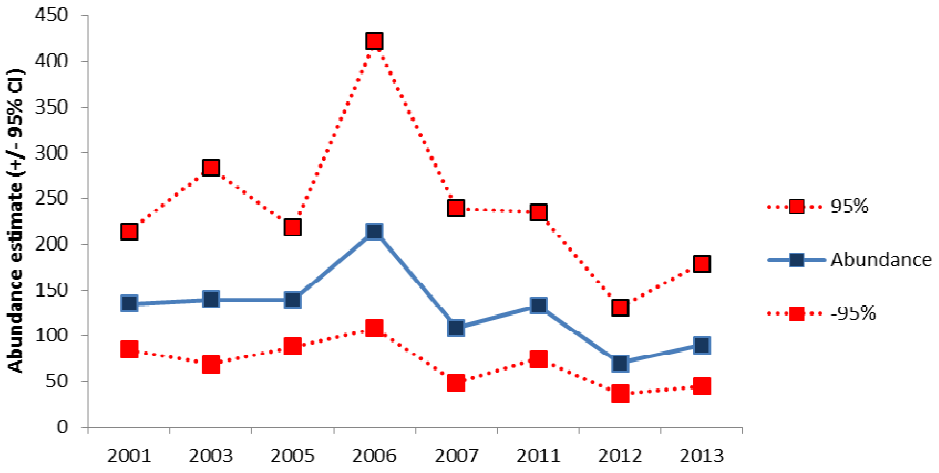


Figure 10: Abundance estimates between years of bottlenose dolphins in Cardigan Bay SAC in 2001-13

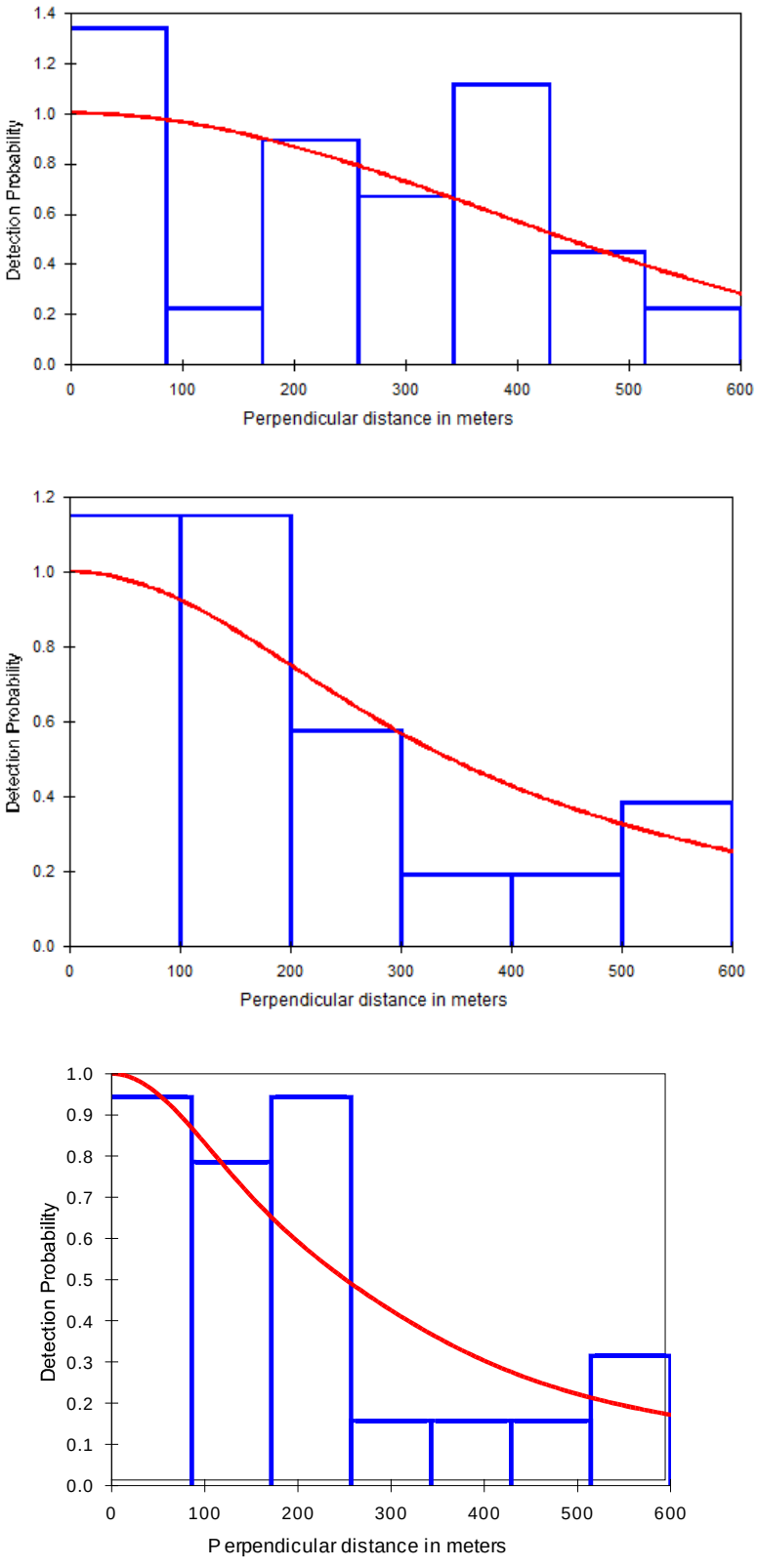


Figure 11: Detection functions of bottlenose dolphins in Cardigan Bay SAC in 2011 (top), 2012 (middle) and 2013 (bottom)

Annual bottlenose dolphin sighting rates (sightings per km effort per year) were calculated for Cardigan Bay SAC between 2001 and 2013. These show variation across the years, with peaks in 2001-03 and 2009-11, and lows in 2004, 2006-07, and 2012-13 (Figure 12), the latter paralleling the low abundance estimates recorded (Figure 10).

Seasonal patterns of sighting occurrence (sightings per km effort travelled per month) were collected during line-transect surveys in Cardigan Bay undertaken between April and October 2011-13. These showed a peak in sightings in July in 2011 and 2012, but a very low sightings rate that month in 2013 (Figure 16). August had the lowest average sightings rate over the three years.

Average group size of bottlenose dolphins, calculated for the whole of Cardigan Bay between 2001-13, is 4.23 (Range 1-33, SD = 4.08), remaining consistent throughout the years (Figure 14). However, there were significant differences in group sizes between years (X^2 = 41.86, df = 12, p <0.001). Average group size was highest in 2006 (5.43, SD = 4.02) and significantly different to that calculated in 2003 (Bonferroni corrected). 2006 was also the year in which the highest population abundance in Cardigan Bay SAC was estimated (N=214, Table 6). 2005 had the lowest average group size (3.16; SD = 2.67), significantly different (Bonferroni corrected) to most years, and a relatively low population estimate (N=139, Table 6). Group sizes in all other years besides 2005 and 2006 were not significantly different.

Most group sizes varied between 1-5 individuals, with few groups numbering over ten individuals (Figure 15). Significant differences in group sizes occurred between months (April-October, 2001-13: X^2 = 30.68, df = 6, p <0.001). Average group sizes were higher in spring (April & May) and autumn (October), and lower between June and August (Figure 16). In 2006, higher than average group sizes were seen throughout the summer; the lowest average group size was recorded in August 2013.

Regular surveys (*ad-libitum* and, later, line-transects) have taken place off the Llŷn Peninsula since 2005. A comparison between the two SAC's indicated significantly higher average group sizes within the Pen Llŷn a'r Sarnau SAC (mean = 6.19) than in Cardigan Bay SAC (mean = 4.15) (X^2 =28.09, df =1, p <0.001). Higher average group sizes between the two areas remain consistent throughout the years (Figure 17), with the exception of 2006, which as noted earlier was characterised by higher average group sizes throughout the Bay.

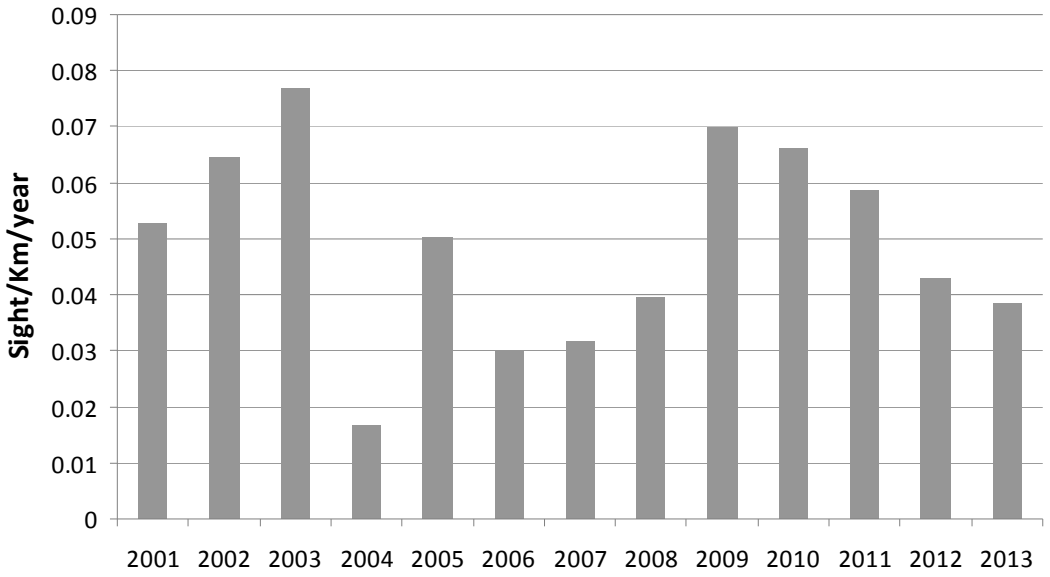


Figure 12: Mean number of bottlenose dolphin sightings per kilometre per year travelled, recorded from line-transect and *ad libitum* surveys each year in Cardigan Bay SAC, 2001-13

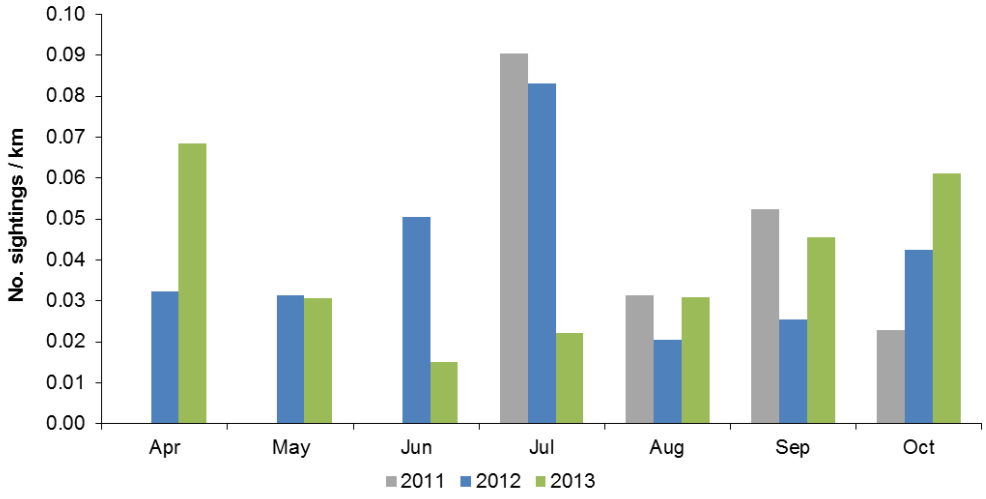


Figure 13: Number of bottlenose dolphin sightings per kilometre travelled by month, recorded from line-transect surveys in Cardigan Bay, 2011-13

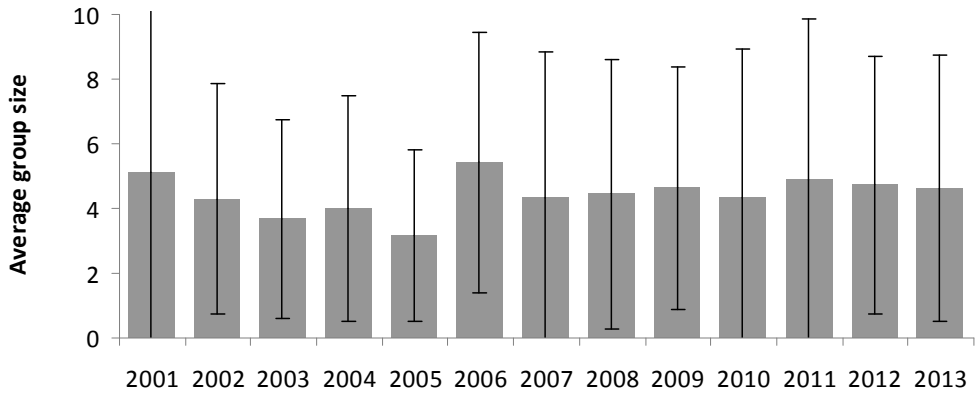


Figure 14: Average (±SD) group size of bottlenose dolphins by year, recorded from line-transect surveys in Cardigan Bay, 2001-13

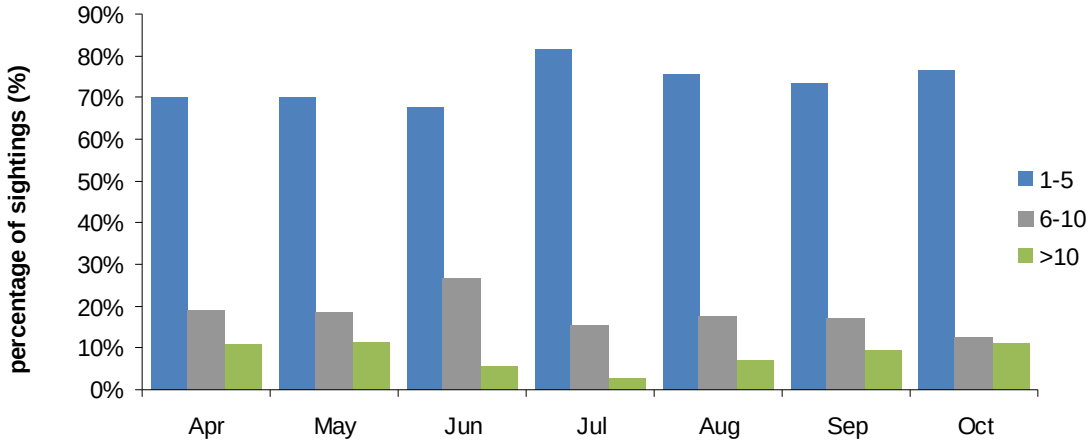


Figure 15: Bottlenose dolphin group sizes (expressed as a percentage of sightings) by month, recorded from line-transect surveys in Cardigan Bay, 2001-13

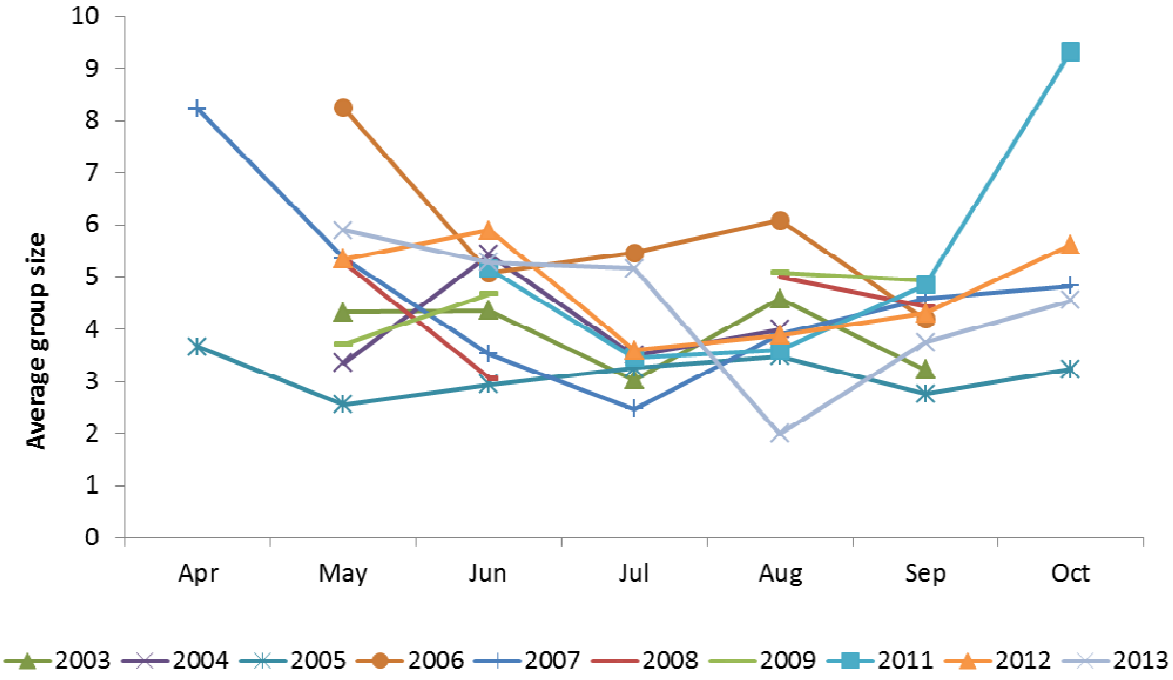


Figure 16: Bottlenose dolphin average group sizes by month and by year, recorded from line-transect surveys in Cardigan Bay, 2001-13

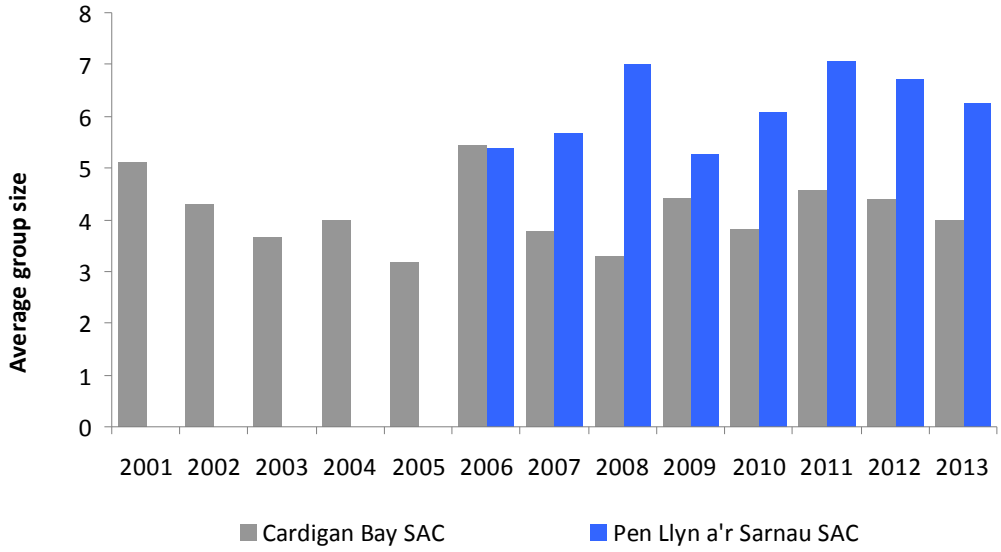


Figure 17: Comparison of average group size of bottlenose dolphins recorded from line-transect surveys **i**n Cardigan Bay and Pen Llŷn a'r Sarnau SAC's, 2001-13

Harbour Porpoise Harbour porpoises (and grey seals) were widely distributed throughout the study area, with detections in both inshore and offshore waters (Figure 7). Harbour porpoise clusters were observed in the southern part of Cardigan Bay SAC around Cemaes Head, Pembrokeshire, and regularly spotted offshore in both SACs.

Harbour porpoise abundance estimates for the whole of Cardigan Bay (calculated using Distance v. 6) between 2011 and 2013 are presented in Table 7, with the associated detection functions shown in Figure 19. Harbour porpoise abundance estimates have more than halved over the last three years: 1074 in 2011, 565 in 2012 and 410 individuals in 2013, yet with similar levels of precision (Table 7).

Table 7: Abundance estimates of harbour porpoise (HP) from line-transect surveys in Cardigan Bay, 2011-13

Definition	HP 2011	HP 2012	HP 2013
Abundance	1074	565	410
95% CI	634-1821	379-840	298-564
CV	28.73	20.42	20.42
Observations	42	57	88

Table 8: Comparison of abundance estimates between years of harbour porpoise in Cardigan Bay SAC, 2001-13

Year	Abundance	95% CI	CV	No. of sightings
2001	108	81-146	15.15	144
2003	236	148-337	24.0	50
2004	215	136-339	23.1	46
2005	170	121-240	17.5	81
2006	161	109-238	20.1	57
2007	182	123-269	20.2	49
2011	340	140-828	46.4	20
2012	169	96-296	29.1	32
2013	147	97-222	21.3	52

Within Cardigan Bay SAC, harbour porpoise abundance estimates have changed little over the years, the only exception being in 2011 (Table 8, Figure 18). However, the relatively high estimate (340) in that year had a very high CV due to low effort coverage, and the number of actual observations was low (n=20) whereas the estimates for 2012-13 are similar to those obtained in earlier years (2005-07). The associated detection functions for the abundance estimates are shown in Figure 20.

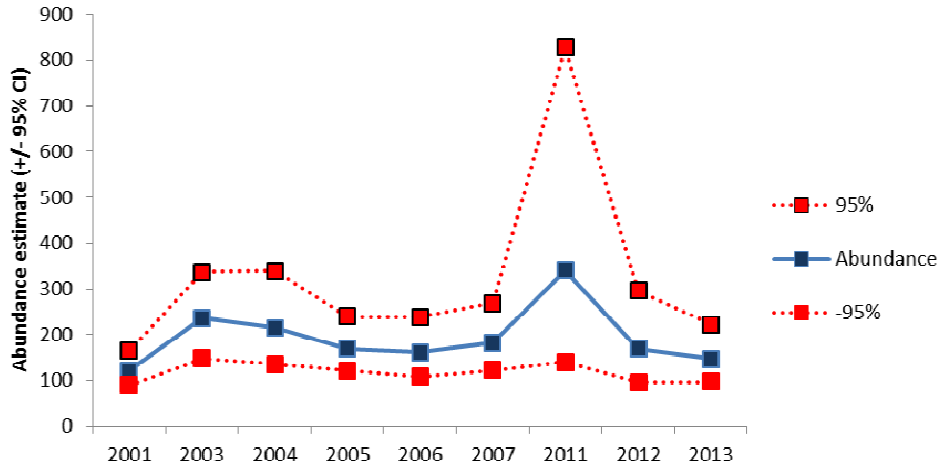


Figure 18: Abundance estimates between years of harbour porpoise in Cardigan Bay SAC, 2001-13

5.1 *Ad Libitum* surveys

Ad libitum surveys were undertaken by Sea Watch Foundation volunteers and interns. Table 9 summarises data from vessels used for dedicated surveys that included at least one primary researcher on board (monitoring officer/sightings officer/research assistant), while Table 10 summarises surveys aboard local commercial operator vessels and undertaken by SWF trained interns and volunteers.

Table 9: Total effort and sightings recorded during *ad libitum* dedicated surveys in Cardigan Bay in 2011-13

Vessel	year	No. surveys	Km of effort	BND sight.	BND sight/km
Dunbar Castle II	2011	7	282.51	22	0.078
	2012	0	0	0	0
	2013	3	83.89	5	0.060
Boat Gallois	2011	6	148.69	14	0.094
	2012	12	280.24	22	0.079
	2013	0	0	0	0
Pedryn	2011	0	0	0	0
	2012	2	99.56	1	0.010
	2013	1	42.23	2	0.047
Bay Explorer	2011	3	41.63	4	0.096
	2012	0	0	0	0
	2013	0	0	0	0

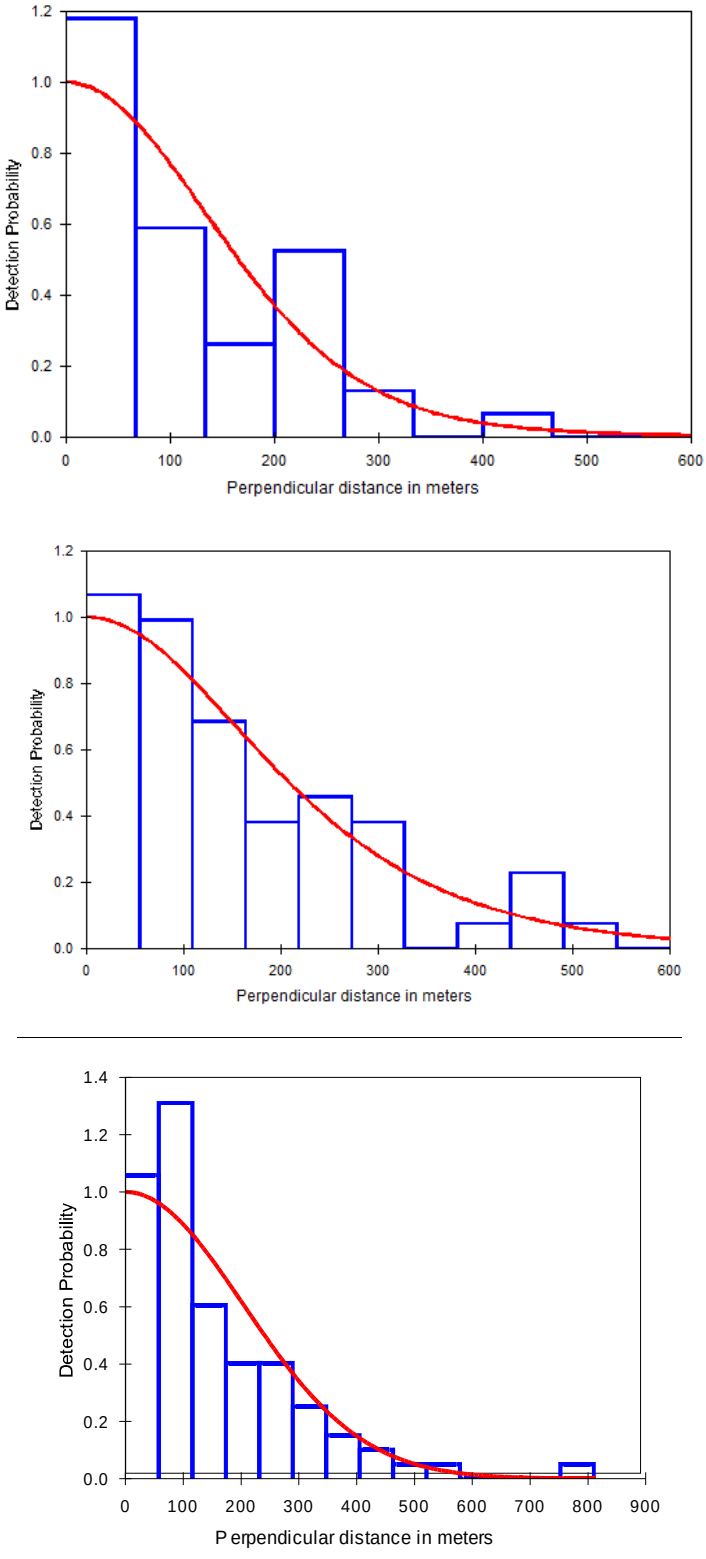


Figure 19: Detection function of harbour porpoise in Cardigan Bay in 2011(top), 2012 (middle) and 2013 (bottom)

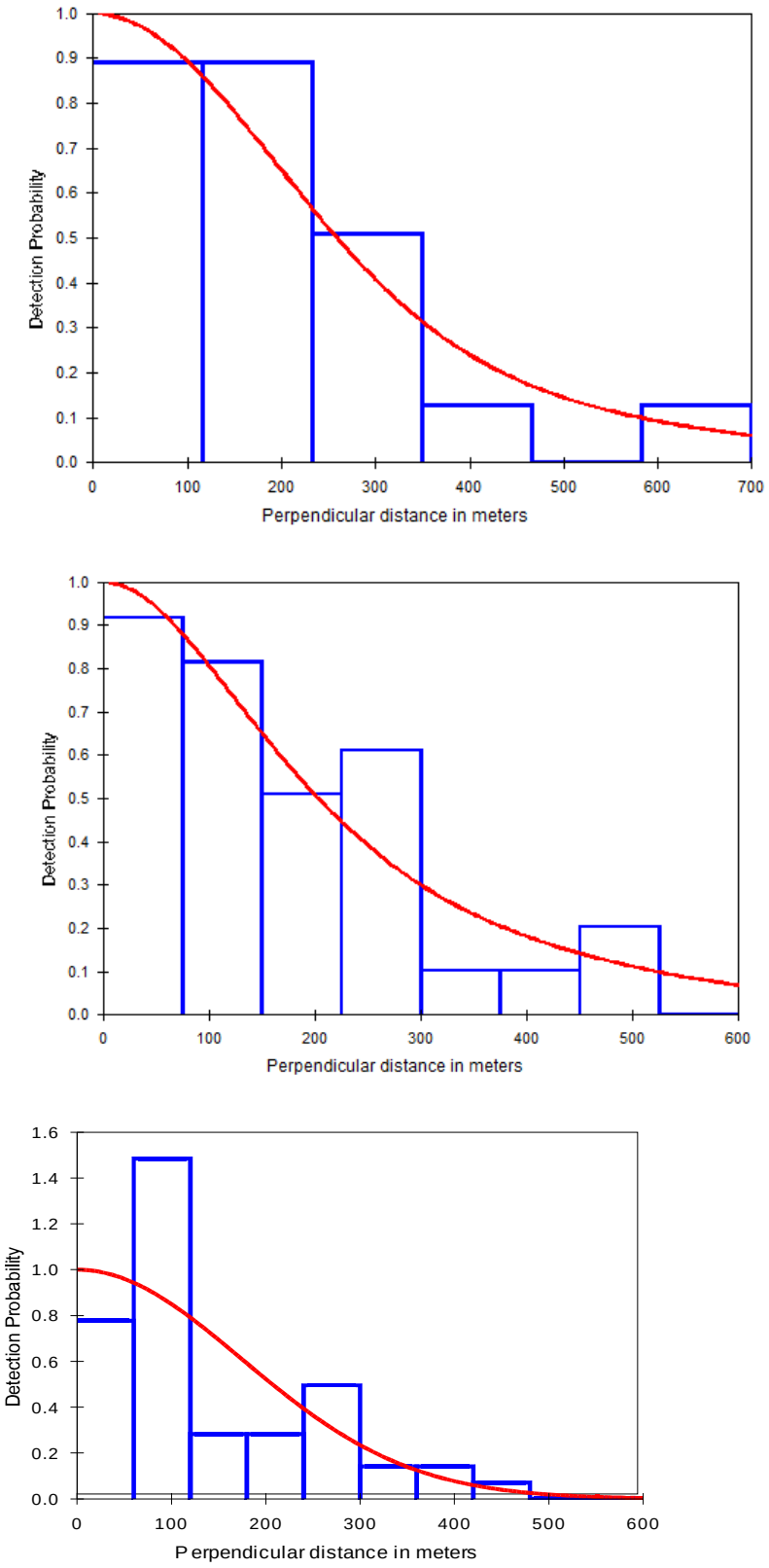


Figure 20: Detection functions of harbour porpoise in Cardigan Bay SAC in 2011 (top), 2012 (middle) and 2013 (bottom)

Table 10: Total effort and sightings recorded during surveys on board platforms of opportunity within Cardigan Bay SAC in 2011-13

vessel	year	No. surveys	Km of effort	BND sight.	BND sight/km
Ermol V	2011	30	515.07	41	0.080
	2012	33	633.51	51	0.081
	2013	34	597.24	67	0.112
Ermol VI	2011	46	379.11	47	0.124
	2012	34	288.94	41	0.142
	2013	83	795.00	103	0.130
Islander	2011	14	109.23	7	0.064
	2012	20	138.39	38	0.275
	2013	4	66.45	8	0.120

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

5.2 Activity Budgets

Bottlenose dolphin behaviours collected during line-transect and *ad-libitum* surveys in Cardigan Bay SAC in 2011-13, are presented in Figure 21. The majority of activity budgets in 2011 were spent travelling (74%) while in 2012 and 2013 most were spent foraging/feeding (64% and 56% respectively). As generally found in studies of dolphin activity patterns, the lowest proportions of time were recorded socialising (20% in 2011; 14% in 2012; and 7% in 2013) and resting - recorded only in 2012 (2%). A comparison of activity budgets within Cardigan Bay SAC across years also indicated travel and feeding/foraging to be the predominant behaviours recorded (Figure 22). The highest percentage occurrence of travel was seen in 2001 and 2006, which were also the years in which highest average group sizes were recorded (Figure 14).

Feeding activities varied, showing no apparent trend throughout the years, although peaks were seen in 2002 and 2012. A general rise in 'foraging/feeding' has been observed since 2006, suggesting dolphins may be spending a greater amount of time foraging for food, although not necessarily with success, and this is indicated also by an increase in foraging observed since 2006 (Figure 23). There is also a decline through the season in actual feeding with a corresponding rise in foraging (Figure 24), suggesting that dolphins may be spending more time searching for prey but not necessarily being successful in the latter part of the season.

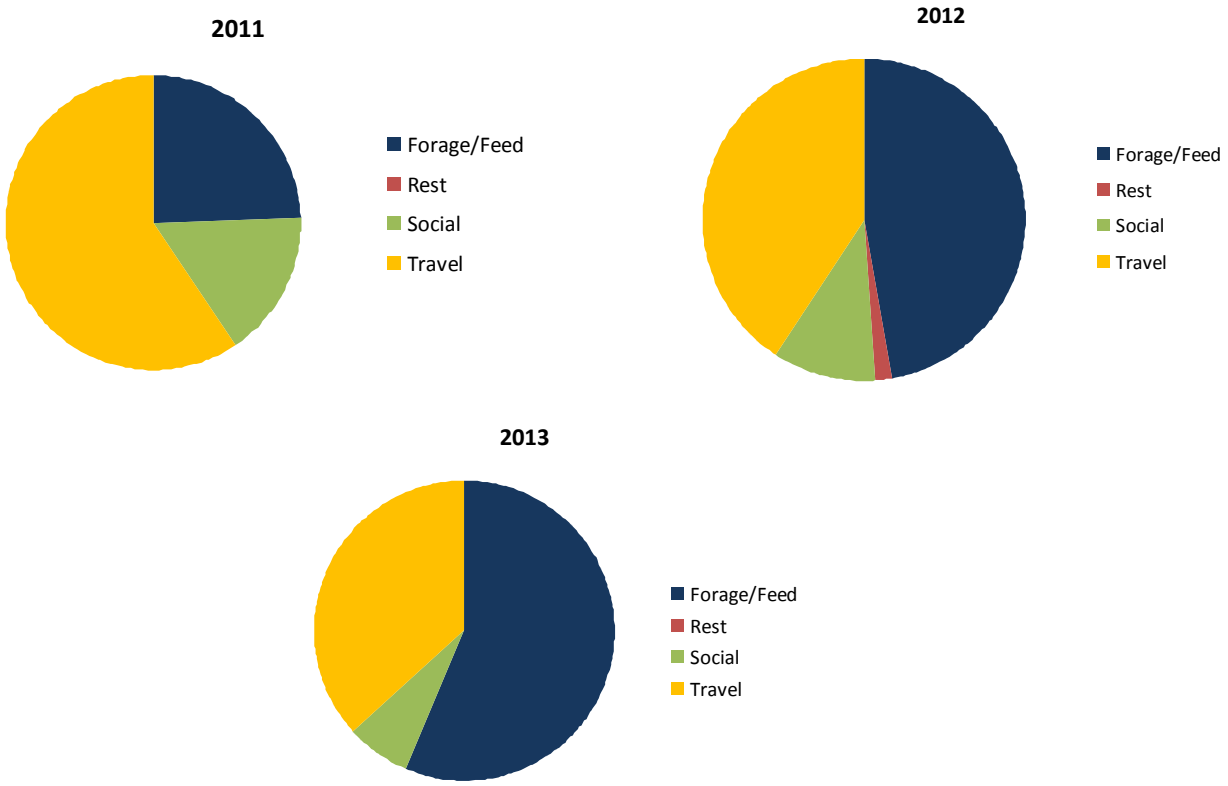


Figure 21: Behavioural budget of bottlenose dolphins recorded from line-transect and dedicated surveys in Cardigan Bay SAC in 2011, 2012 and 2013.
(n = 83, 99, 101 respectively)

Behaviours collected during line-transect and *ad-libitum* surveys in Pen Llŷn a'r Sarnau SAC in 2011-13 are presented in Figure 25, and show that the highest proportion (81-86%) of activity in all years was spent travelling. However, relatively high proportions are also spent in social behaviour (21%, 29% and 25% respectively), percentages which are higher than those seen in Cardigan Bay SAC (14%, 20% and 7% respectively). Behavioural data in Pen Llyn ar Sarnau SAC should be treated with caution as sample sizes are relatively low, but nonetheless, these data suggest that the two SAC's may be used differently by the population.

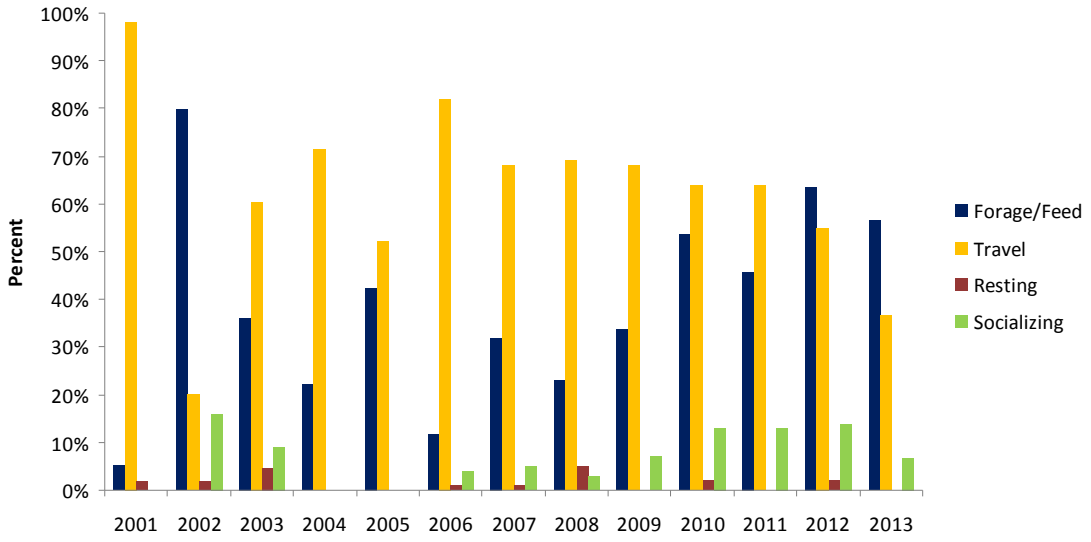


Figure 22: Comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2001-2013
(n = 115, 227, 357, 21, 87, 77, 88, 39, 59, 56, 83, 99, and 101 respectively, for each year)

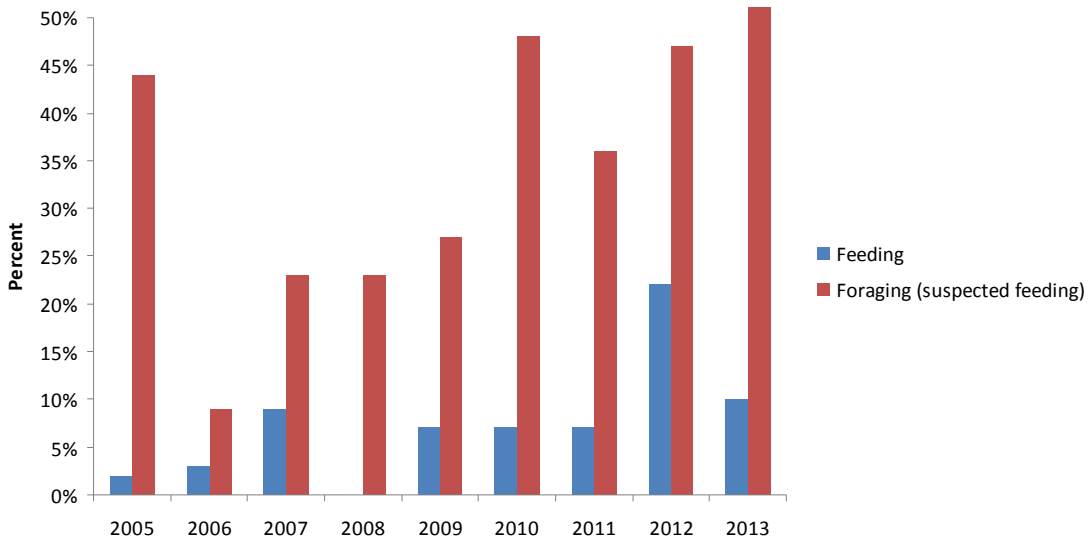


Figure 23: Yearly comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-13 (feeding and suspected feeding only)
(n = 87, 77, 88, 39, 59, 56, 83, 99, 101 respectively, for each year)

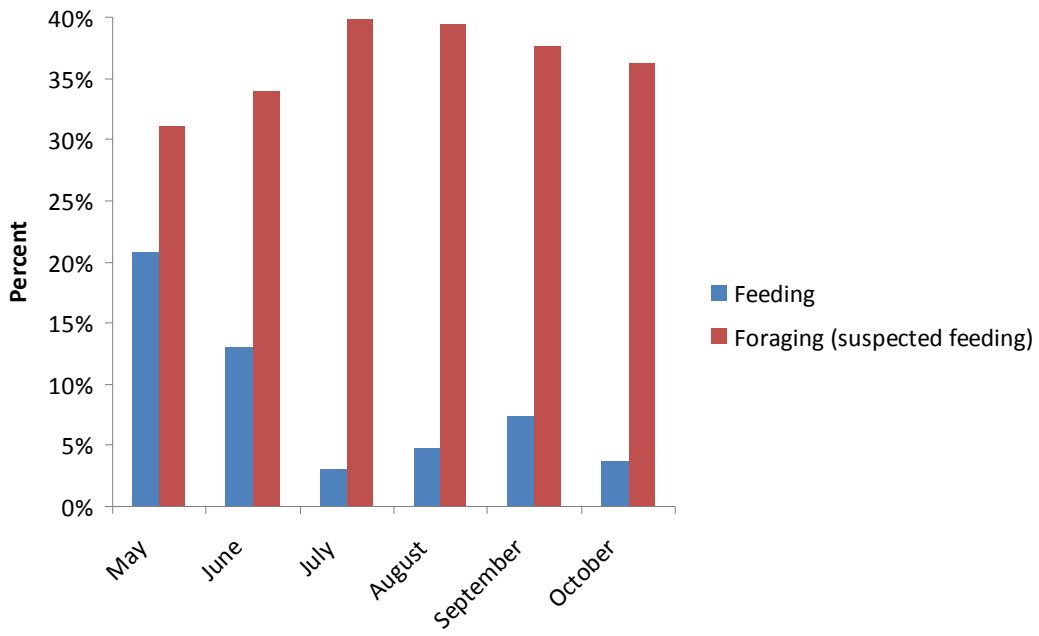


Figure 24: Seasonal comparison of behavioural budget of bottlenose dolphins recorded from line-transect and *ad-libitum* surveys in Cardigan Bay SAC between 2005-13 (feeding and suspected feeding only) (n = 77, 115, 128, 124, 162, 55; April was omitted from analyses due to low sample size, n = 9)

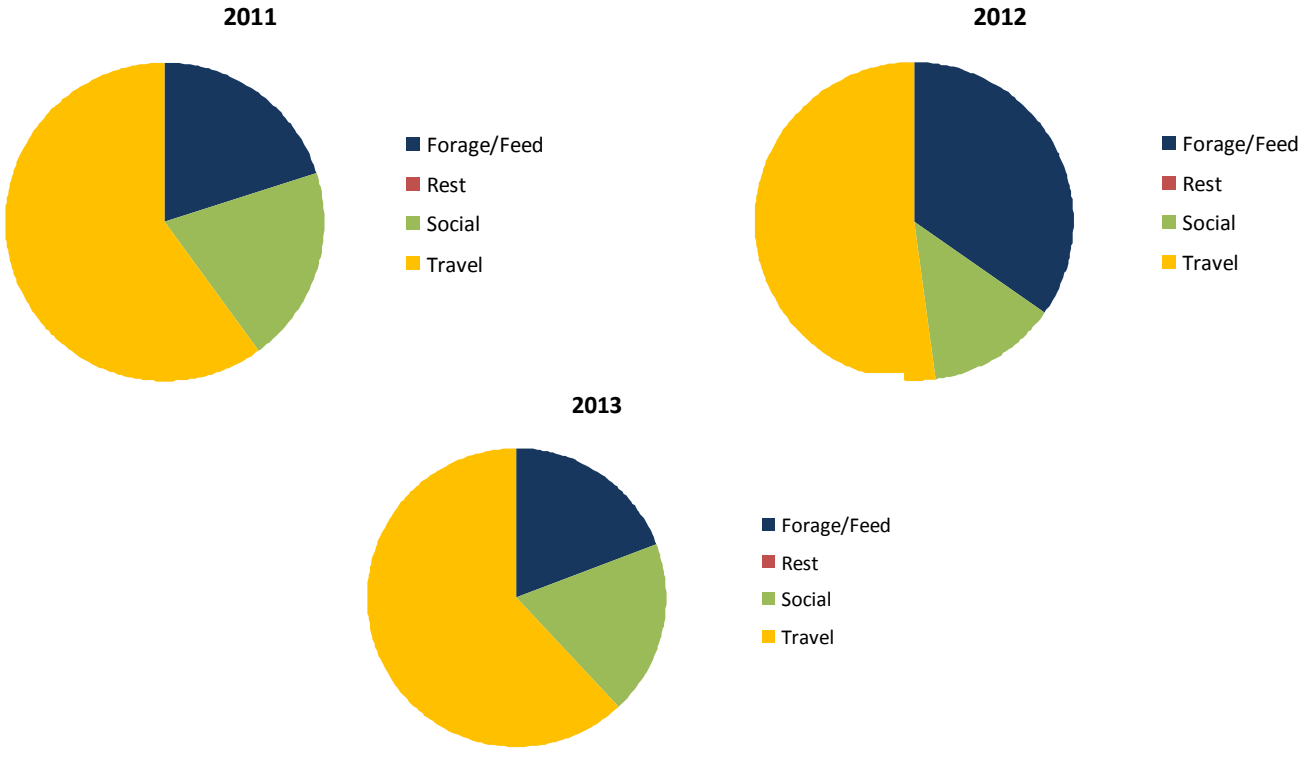


Figure 25: Behavioural budget of bottlenose dolphins recorded from line-transect and dedicated surveys in Pen Llŷn a'r Sarnau SAC in 2011, 2012 and 2013. (n=7, 14 & 32 respectively)

5.3 Reproductive & Mortality Rates

It has been reported previously that Cardigan Bay SAC serves at least in part as a nursery ground for bottlenose dolphins and is thus an important area for mothers and calves (Ugarte and Evans, 2006; Pesante, 2008b; Veneruso and Evans, 2012a; Baylis, 2013; Feingold and Evans, 2013a,b). Around 50% of groups encountered within Cardigan Bay SAC had one or more calves present between 2011 and 2013 (47%, 51% and 53% respectively), once again confirming the importance of this area, with 15 and 13 newborns recorded in 2011 and 2012 respectively. In contrast, only six newborns were recorded so far in 2013. However, this number will in fact be an underestimate as some newborns born after October or those that have not been seen this year, will be seen as young calves in 2014, and therefore designated as newborns of the previous year (Table 11). An average of almost ten calves were born per year between 2001-13 and a calculation of birth rates for the population was compared by year (Figure 20). Peaks are seen in 2002, 2005 and 2011, and very low numbers in 2008-09 which may corresponding to years of low survey effort however, a high number of newborns was recorded in 2010 (14) which was also a year with low survey effort suggesting this may not be the reason for the low values. Crude birth rates were calculated in Cardigan Bay SAC, averaging 5.26% per annum using mark-recapture population estimates with a closed model, and 7.65% per annum using an open population model (Table 11). Birth rates estimated with the closed model showed an increase between 2001 and 2004, peaking at 7.84%. They then steadily declined, reaching their lowest value in 2009, at 1.36%. An increase in birth rates can be seen between 2009 and 2011, with highest rates reaching 8.24% in 2011. Birth rates in 2012 declined to 5.7% and a further decline was seen in 2013 (3.9%). Although the 2013 birth rate values are likely to be an underestimate as they do not account for winter births during 2013-14, this is unlikely to boost the percentage by much. Birth rates calculated using the open model population estimates show peaks in 2005 (11.32%) and 2011 (10.20%). A decline occurred between 2005 and 2009, with very low rates that year (2.56%). Birth rates in 2010 and 2011 showed an increase on earlier years, but then declined to 7.74% in 2012 and 5.94% in 2013 (Table 11, Figure 26).

Crude bottlenose dolphin birth rates for all of Cardigan Bay were calculated for the years 2005-12 when effort was extended to the entire Bay, including Pen Llŷn a'r Sarnau SAC. Average annual birth rates using a mark-recapture open population model, are 8.92%. A steady decline from 11.72% in 2005 to 7.19% in 2009 is apparent, with birth rates increasing since then, peaking to 12.95% in 2011. However, birth rates in most recent years declined to 8.62% in 2012 and further to 3.59% in 2013 (Table 12, Figure 27). Higher birth rates for the whole of Cardigan Bay can be observed (Figure 28). The exception was in 2013, the only year in which no additional newborns (to the ones seen in Cardigan Bay SAC) were seen off the Llŷn Peninsula. A recent project analysed female-calf sightings between 2007 and 2012 in Cardigan Bay SAC, Pen Llŷn a'r Sarnau SAC, and North Wales, and showed no significant differences in calf sightings, once corrected for effort, between the three areas (Feingold and Evans 2013a). Another recent project selected twenty-two females with long-term histories, for home range analysis and comparison of sightings of individuals with/without a calf (Baylis, 2013). These showed no significant differences in home range or core areas between

the two categories. The 22 selected females were then divided into subgroups for the following comparisons of reproductive success: high versus low calf production (four calves versus two calves produced during the study period); high versus low calf survival (survived into third year versus seen only as a newborn); and long versus short inter-birth interval (4 to 6 years versus 1.5 to 3 years). Based on these comparisons, the results suggest that females use a smaller home range area and core area when calf production rate is high, calf survival rate is high, and inter-birth interval is short (Baylis, 2013; Feingold and Evans, 2013a).

Inter-birth intervals in Cardigan Bay were calculated using data from 33 definite females, all of which produced at least two calves between 2001 and 2013. Females, which were not seen in successive years, were excluded from the analysis. Inter-birth intervals varied between two and seven years, with most mothers giving birth to a new calf every three years (Figure 29).

Female reproductive success was analysed for 47 confirmed females giving birth to at least one calf between 2001 and 2013. Analyses included calculation of the number of offspring surviving to the age of three within a three-year time period. Most females (78%) had one or no calves surviving (18 and 17 respectively). Ten females (22%) had two, and only two females (4%) had three calves surviving to the age of three within a three-year period (Figure 30).

Calf mortality rates were calculated from a sample of 71 mother-calf pairs born between 2001 and 2013. Higher mortality rates were found in the first two years (15% in year one and 17% in year two) with lower rates in the third year (7%) (Figure 31) and a total of 60% of calves surviving into their fourth year.

5.3.1 Calving Season

The calving season in Cardigan Bay between 2001 and 2013 was analysed by estimating birth dates based on the last sighting of a female without a calf and the first sighting of a female with a newborn (n=66). Birth dates were estimated for females who were seen with and without a calf within a three-four month period. These were corrected for the number of identified females each month. Calves are born in all months of the main field season (March-October), with the exception of October. Some newborns have also been observed during the winter months off north Anglesey, and although few surveys take place during this time, group sizes are larger and include many sightings of females. Hence, winter birth rates are most probably well represented. Peak calving season in Cardigan Bay occurs between July and September, when 76% of all births are recorded (Figure 32).

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

Year	No. newborns	Population estimate (closed)	Population estimate (open)	Birth rate (closed)%	Birth rate (open)%
2001	7	140	99	5.00	7.07
2002	8	135	77	5.93	10.39
2003	10	167	141	5.99	7.09
2004	12	153	154	7.84	7.79
2005	12	223	106	5.38	11.32
2006	13	223	139	5.83	9.35
2007	11	206	165	5.34	6.67
2008	5	260	118	1.92	4.24
2009	3	221	117	1.36	2.56
2010	14	234	153	5.98	9.15
2011	15	182	147	8.24	10.20
2012	13	229	168	5.68	7.74
2013	6	153	101	3.92	5.94

Table 12: Number of newborns recorded in the wider Cardigan Bay and birth rates calculated for the sites using mark-recapture population estimates for closed and open population models

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
No. newborns	15	18	17	14	12	21	25	20	6
Population estimate (closed)	210	230	243	310	342	259	243	240	205
Population estimate (open)	128	182	222	181	167	192	193	232	167
Birth rate (closed)%	7.14	7.89	7.00	4.52	3.51	8.11	10.29	8.33	2.93
Birth rate (open)%	11.72	9.89	7.66	7.73	7.19	10.94	12.95	8.62	3.59

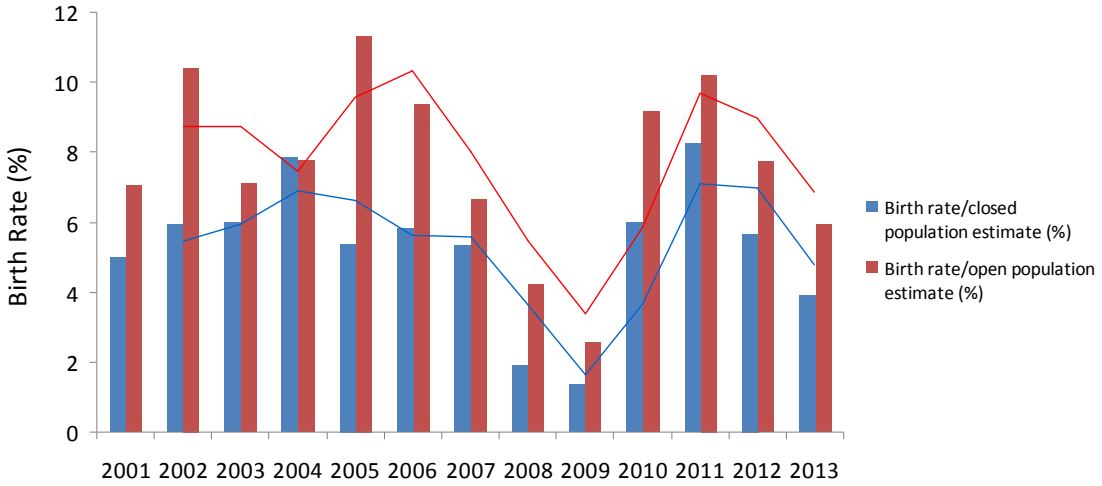


Figure 26: Birth rates of bottlenose dolphin calves in Cardigan Bay SAC calculated using closed and open population estimates

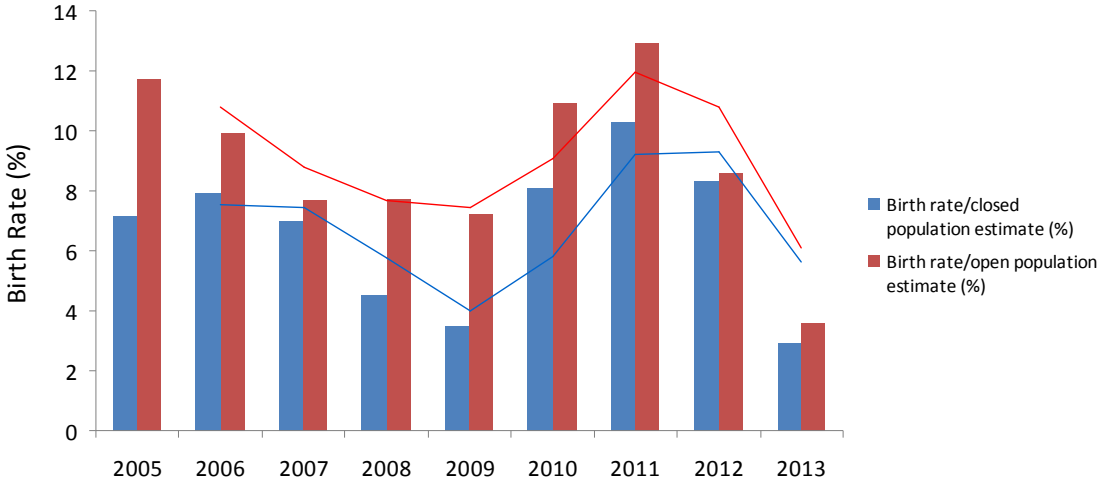


Figure 27: Birth rates of bottlenose dolphin calves in Cardigan Bay calculated using closed and open population estimates

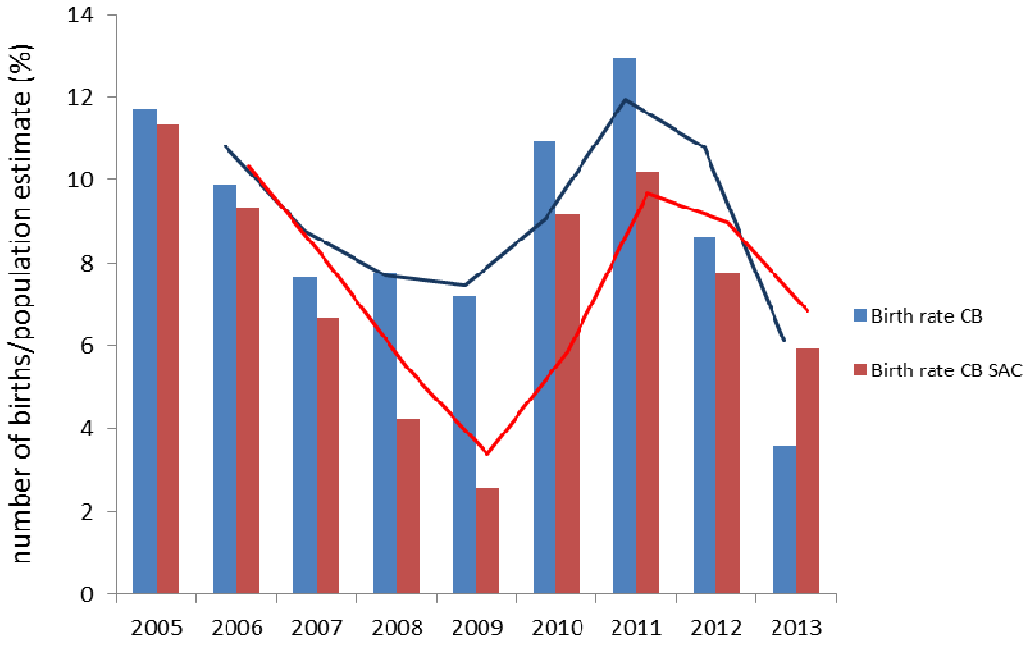


Figure 28: Birth rates of bottlenose dolphin calves in Cardigan Bay vs. Cardigan Bay SAC, calculated using open population estimates

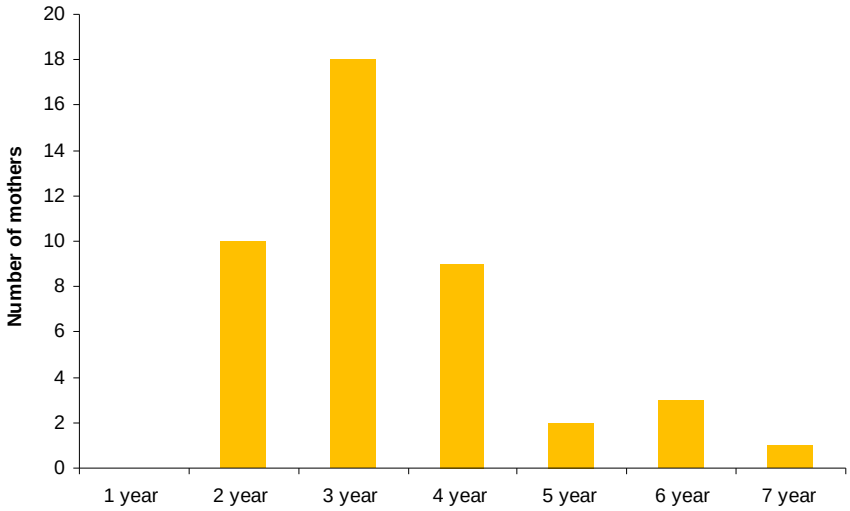


Figure 29: Inter-birth intervals of 33 known mothers in Cardigan Bay between 2001 and 2013

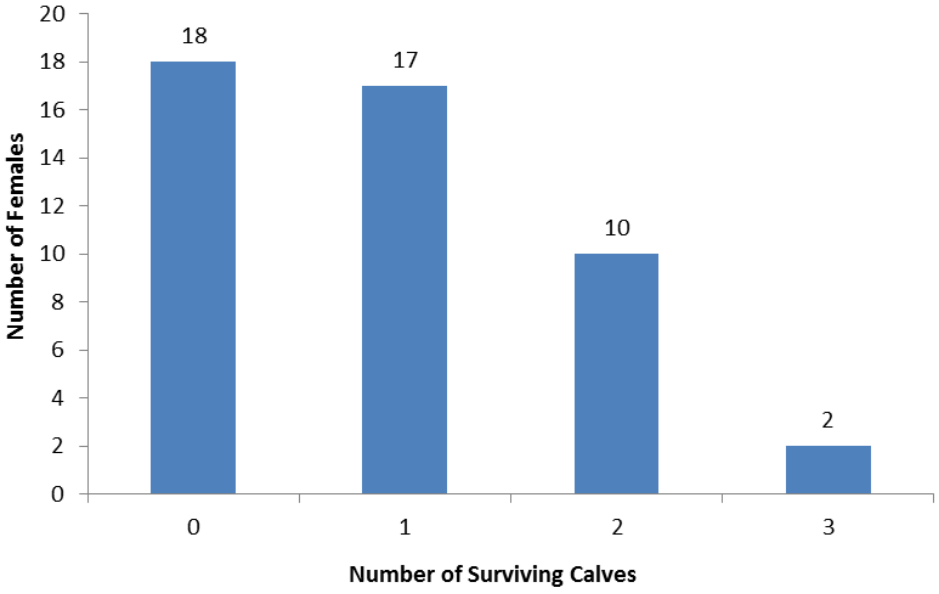


Figure 30: Female reproductive success: number of calves surviving to the age of three within a three-year time period, in Cardigan Bay between 2001 and 2013

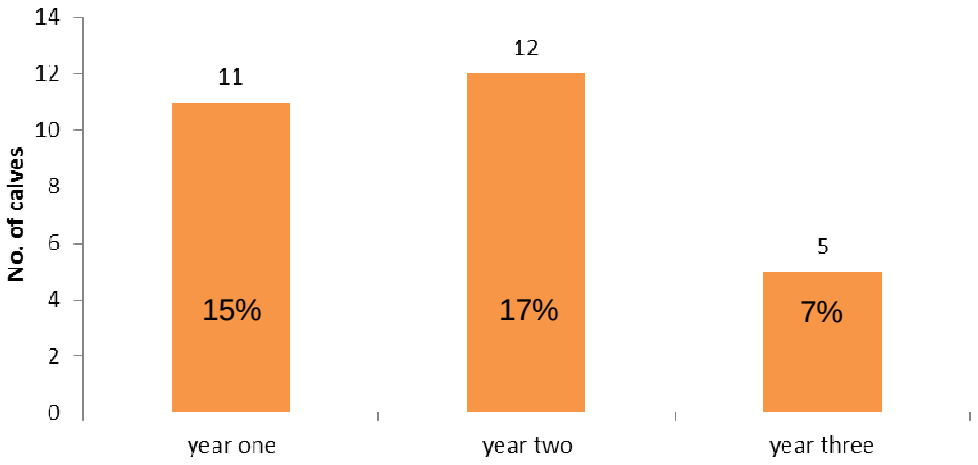


Figure 31: Number and percentages of calves that have died between age 1 and 3 years, between 2001 and 2013

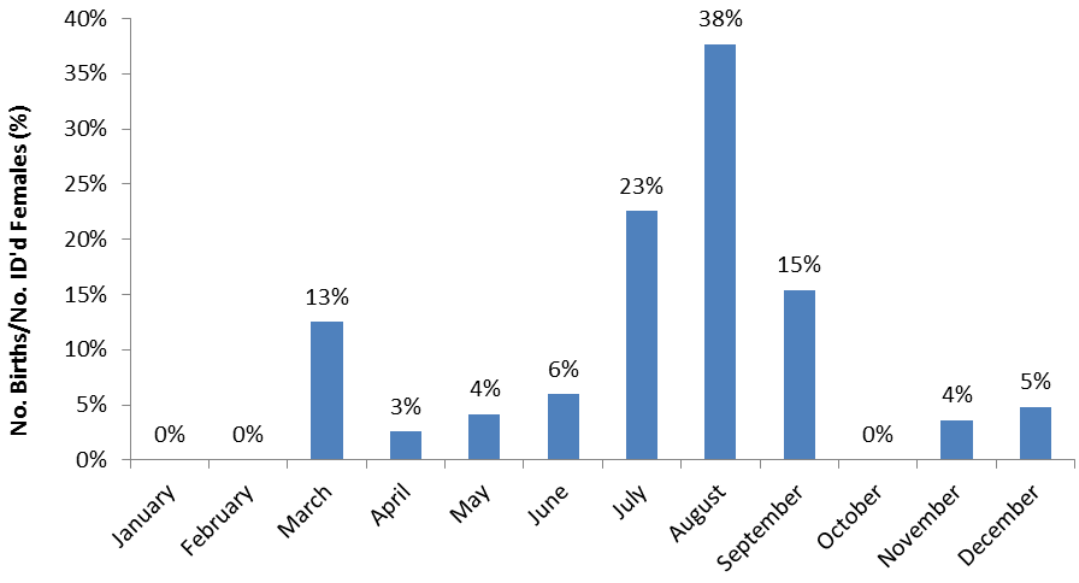


Figure 32: Number of births recorded by number of identified females each month in Cardigan Bay, between 2001 and 2013 (expressed as percentages)

5.4 Photo ID

A total of 766 bottlenose dolphin encounters were made between 2011-13 throughout Cardigan Bay and off North Wales. From these, 197 dolphins were identified in 2011, 200 in 2012 and 161 in 2013 (Table 13). The Welsh Photo ID catalogue now holds a minimum of 378 individuals (Table 14).

Table 13: Bottlenose dolphin encounters in 2011-13

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

Table 14: SWF catalogue content in 2013

Well marked (WM)	105
Slightly marked (SM)	143
Left (L)	120
Right (R)	130
WM+SM+L	368
WM+SM+R	378

A discovery curve of marked individuals plotted from encounters between 2001 and 2012 confirms that new dolphins are regularly being identified in all areas. This is particularly true for the beginning of the study when all dolphins were considered ‘new’. Two other steeper increases in the detection curve are seen in 2005 when surveys expanded to Pen Llŷn a’r Sarnau SAC, and in 2007 when extended effort into North Wales commenced. The detection curve is expected to rise regularly anyway, due to transient dolphins entering the study area, and juveniles and calves gaining their first dorsal fin marks, and thus being added to the marked category. The curve appears to have reached a plateau in recent years, suggesting that the majority of the marked dolphins in the region have been photographed and identified (Figure 33).

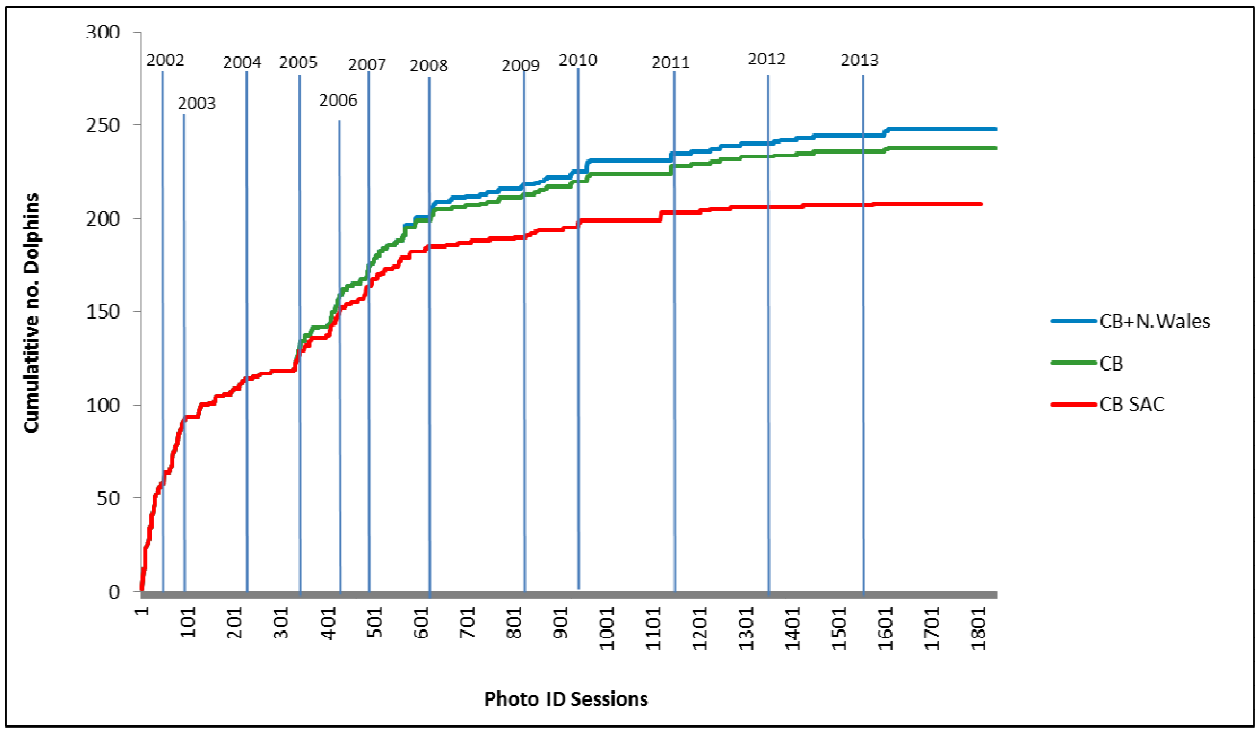


Figure 33: Discovery curve for marked bottlenose dolphins from 2001-2013
(CB SAC - Cardigan Bay SAC, CB - all Cardigan Bay; CB + N Wales - Cardigan Bay and North Wales)

It has been reported previously that the bottlenose dolphin population in Cardigan Bay SAC can be described as a combination of transients, occasional visitors, and resident animals (Pesante, 2008b, Feingold and Evans, 2013b). Extended surveys across Pen Llŷn a'r Sarnau SAC and adjacent areas in recent years enable us to evaluate whether this hypothesis applies also for the entire Bay. Between 16 and 19% of the population are considered transient, being seen less than four times and in only one or two years; between 21 and 31% are considered occasional, spotted between 4-11 times and in 3-6 years; and between 52 and 63% are considered resident inhabitants of the Bay, having been seen in more than six years and on more than 12 occasions throughout the study period, with three individuals seen as many as 132, 158 and 170 times (017-03W, 074-03W and 004-90W respectively), and four individuals seen in all thirteen years of the study period (Figures 34, 35). Frequencies of re-sightings have ranged from 1 to 170 (mean = 19.62, SD = 21; Figure 36). Multiple sightings per day for any individual were omitted and new individuals added between 2011-13 were not included in this analysis. Comparing these results with those for Cardigan Bay SAC alone, the percentages are rather different (Figures 34, 35). A higher percentage of between 35 and 37% are considered transient and a lower percentage of between 37 and 43% are considered resident inhabitants of Cardigan Bay SAC suggesting animals which are using the Bay are not necessarily entering the southern SAC.

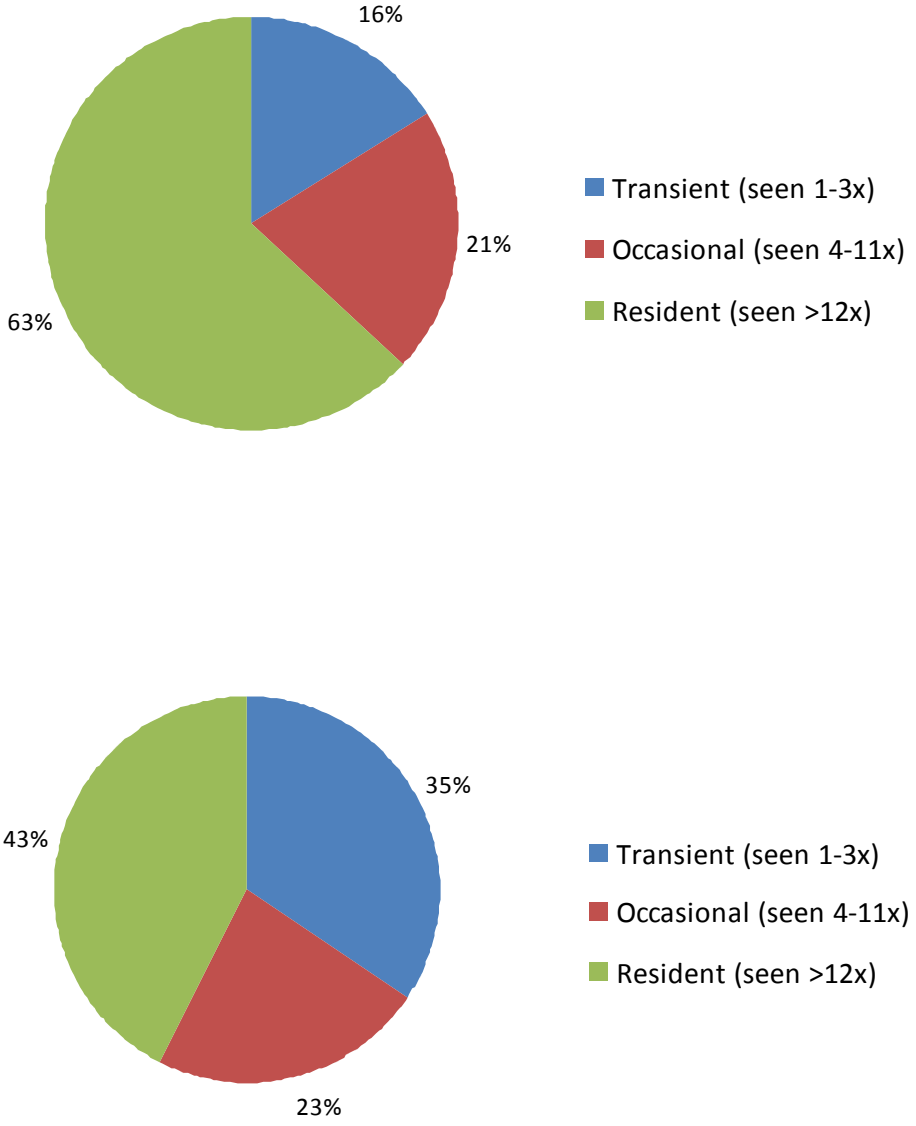


Figure 34: Percentage of individual re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)

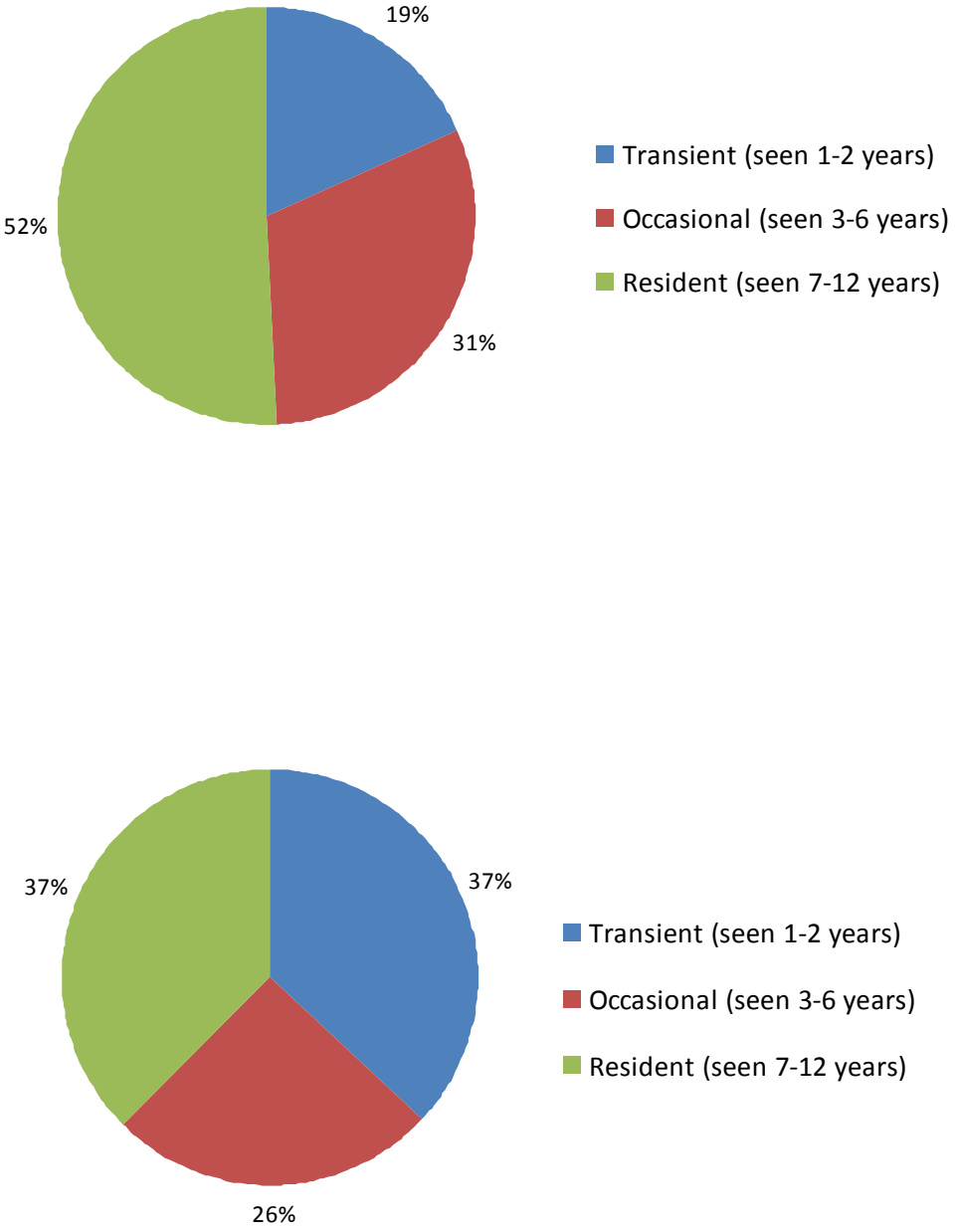


Figure 35: Percentage of yearly re-sightings in Cardigan Bay (top) and Cardigan Bay SAC (bottom)

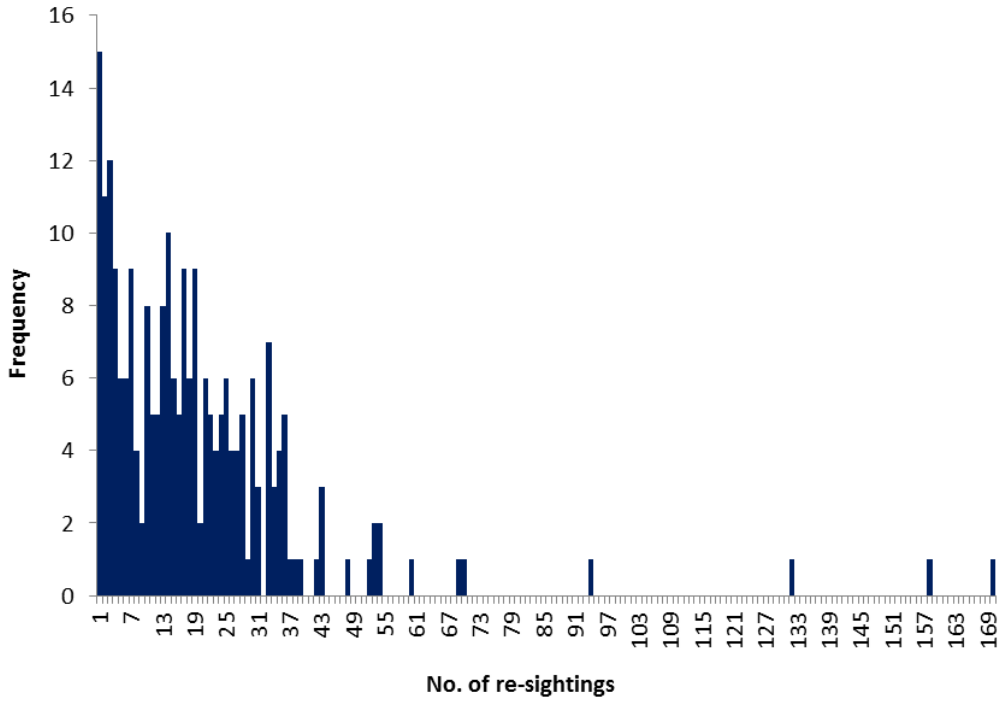


Figure 36: Frequency of re-sighted individuals in Cardigan Bay, 2001-13

Cardigan Bay SAC has had regular and relatively even coverage over the last 13 years, which therefore provides more accurate population estimates for this area. Population estimates using a robust open population model between 2001 and 2013 reveal no apparent long-term trend, reaching a peak of 165 and 168 individuals in 2007 and 2012 respectively, and lowest numbers of 106 and 101 individuals in 2005 and 2013 respectively (Table 15). Low estimates in 2001 and 2002 are most probably due to limited effort in the area. A polynomial trend line reveals an increase in population size between 2006 and 2011 and a decrease in recent years. However, a moving average trend line revealed no apparent trends (Figure 37). The open population model also considers emigration, immigration, and birth & death rates. A general decrease in the probability of emigration from Cardigan Bay SAC can be seen since 2006 (although a couple of fluctuations are seen between 2007-8 and 2009-10). Emigration probability reached a low of 17% in 2012, and the probability of dolphins remaining entirely outside of the study area decreased to 22% in that same year, probably due to individuals returning to the SAC after one or more years of absence. However, a rise in emigration is seen in 2013 reaching almost 35%, along with a sharp rise in probability of animals staying outside of the study area that same year (64%) (Figure 38, Table 16) and a sharp decrease in survival rates (S) (Figure 39). In addition, 2013 had the lowest number of dolphins identified that year (161) compared to 197 and 200 dolphins identified in 2011 and 2012 respectively.

Table 15: Population estimates for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-13, obtained using an open population model and considering the marked proportion of individuals

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

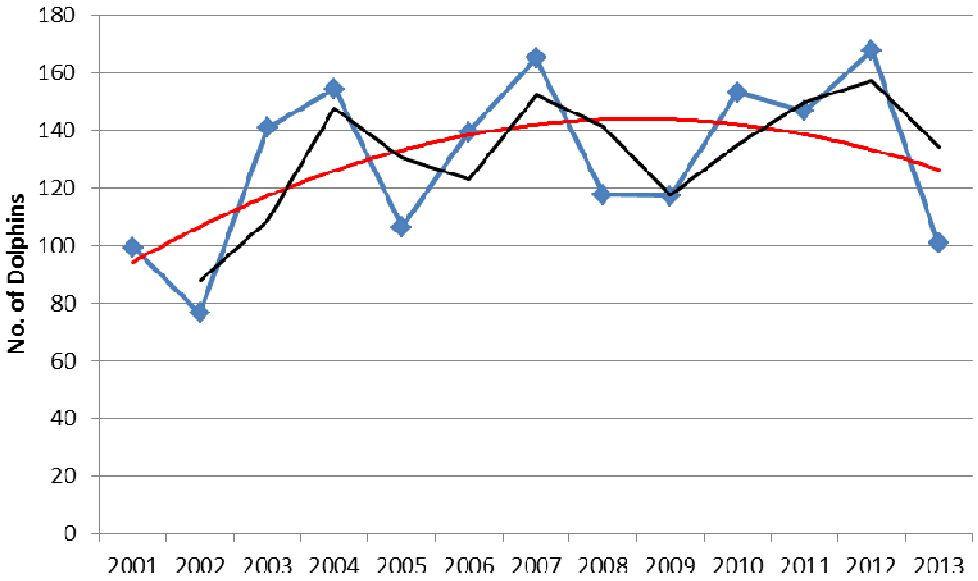


Figure 37: Population trend for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-13, obtained using an open population model and an average survival rate of S=0.89
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

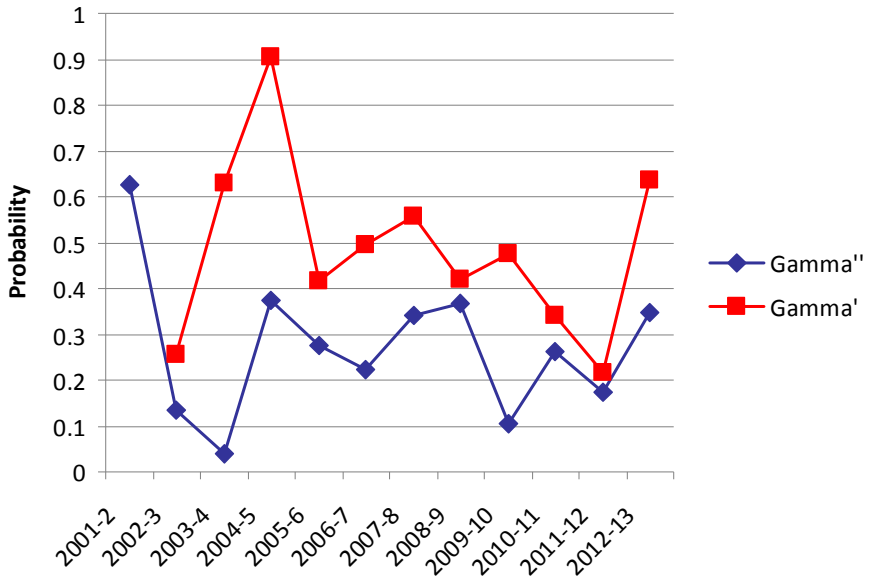


Figure 38: Bottlenose dolphin residency patterns in Cardigan Bay SAC using an open population model; (gamma"- probability of an animal emigrating out of the study area; gamma'- probability of an animal staying out of the study area)

Table 16: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay SAC, using an open population model; (gamma"-probability of an animal emigrating out of the study area; gamma'- probability of an animal staying out of the study area)

Period	Gamma"	Standard Error	Gamma'	Standard Error
2001-2	0.625	6.41E-02		
2002-3	0.135	6.10E-02	0.26	0.08
2003-4	0.038	5.00E-02	0.63	0.16
2004-5	0.375	0.0565448	0.90	0.14
2005-6	0.276	5.86E-02	0.42	0.08
2006-7	0.224	0.0516658	0.49	0.09
2007-8	0.343	5.34E-02	0.56	0.09
2008-9	0.367	0.0590249	0.42	0.08
2009-10	0.106	4.01E-02	0.48	0.08
2010-11	0.263	5.35E-02	0.34	0.10
2011-12	0.173	5.41E-02	0.22	0.11
2012-13	0.349	5.91E-02	0.64	0.15

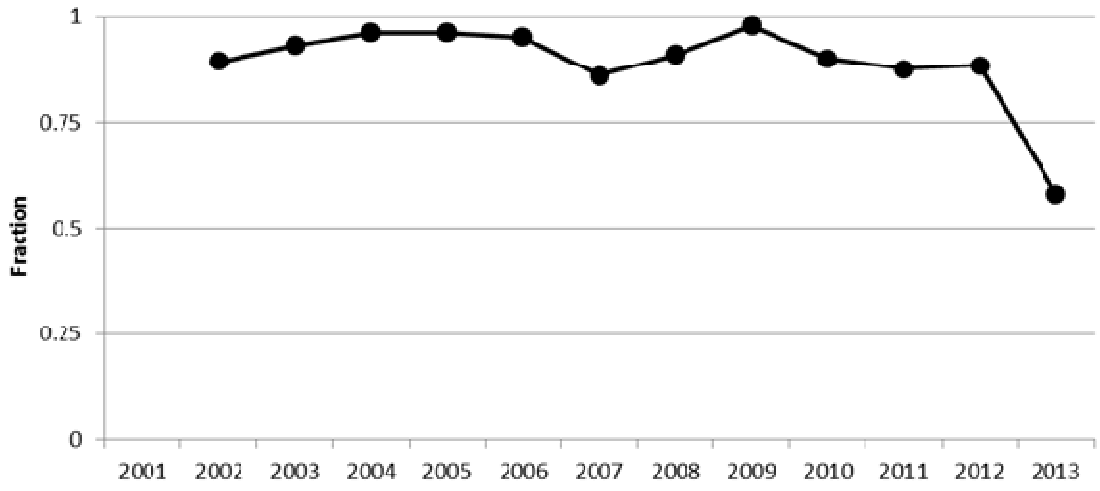


Figure 39: Bottlenose dolphin juvenile survival rates in Cardigan Bay SAC, using an open population model, between 2001 and 2013

Population estimates using a closed population model between 2001 and 2013 reveal a similar general trend with an increase, peaking at 260 individuals in 2008, and then steadily declining to only 153 individuals in 2013 (Table 17, Figure 40).

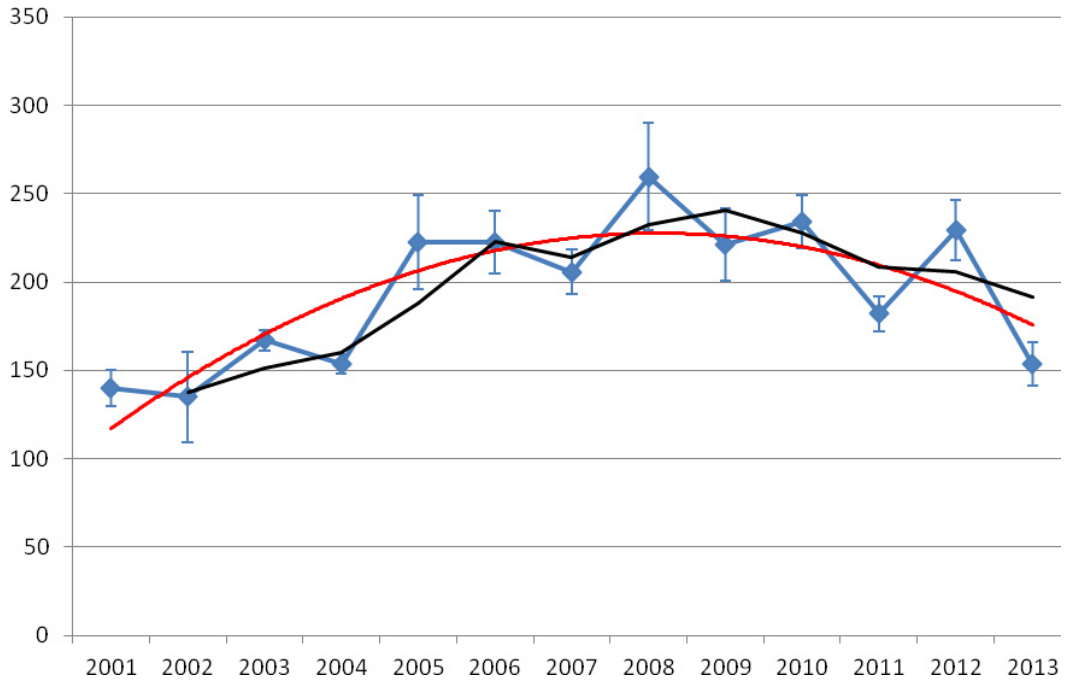


Figure 40: Population trend for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-13, obtained using a closed population model and an average survival rate of S=0.593.
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

Table 17: Population estimates for bottlenose dolphins in the Cardigan Bay SAC for the years 2001-13, obtained using a closed population model and considering the marked proportion of individuals

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

Population estimates for all of Cardigan Bay were made using the robust open model. Only data from 2005-13 will be presented for this purpose since coverage in Pen Llŷn a'r Sarnau SAC was more regular during these years. A peak of 232 individuals was reached in 2012 with a similar estimate of 222 in 2007 (Table 18). A general decline in the population size appears to have occurred from 2007-09, perhaps due to lower effort (with a more restricted area surveyed) between 2008 and 2010. Survey efforts were higher in 2011 than 2010 yet population estimates in 2011 (193) are almost identical to estimates in 2010 (192) suggesting low survey effort may not be the reason for the low values. There is no doubt that consistent effort across years is vital if we are to interpret trends accurately.

The estimates in 2010-11 are then followed by a small, though consistent, rise to 232 individuals in 2012 (Figure 41), decreasing to 167 individuals in 2013. The smooth polynomial function shows a trend of an increased population estimate between 2008-2010, while the moving average trend line gives a different message of a decrease in population estimate during those years.

Emigration and immigration rates in Cardigan Bay between 2005 and 2012 fluctuate and show no apparent trends. Similarly to Cardigan Bay SAC, a general decrease in emigration rates can be seen in the whole of Cardigan Bay since 2008, with a very low rate of c. 10% in 2012, and the probability of dolphins remaining entirely outside of the study area decreasing to 9.6% in the same year, probably due to individuals returning to the area after one or more years of absence. However, a rise in both emigration and immigration is seen in 2013, reaching similar rates to those in 2011 (Figure 42, Table 19).

Table 18: Population estimates for bottlenose dolphins in Cardigan Bay for the years 2005-11, obtained using an open population model, and considering the marked proportion of individuals

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

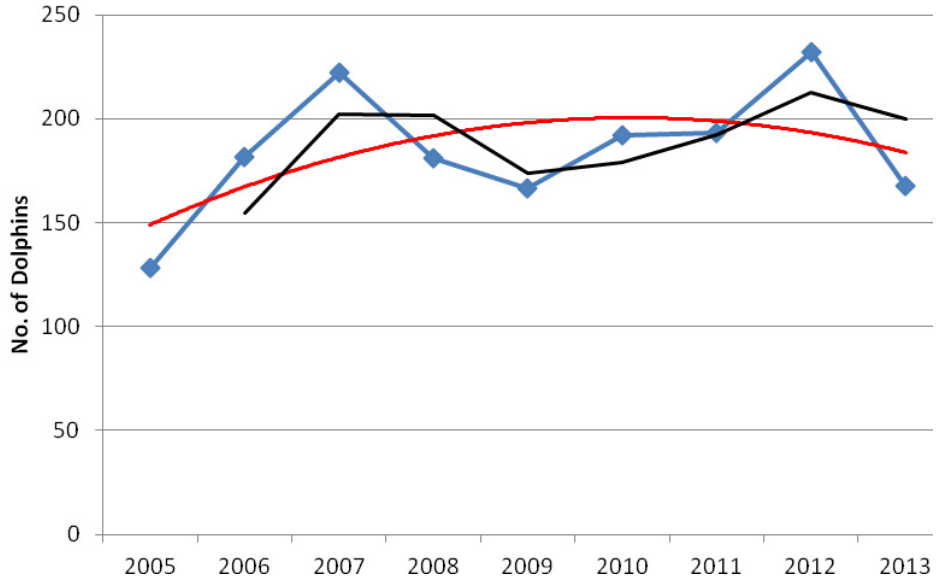


Figure 41: Population trend for bottlenose dolphins in the Cardigan Bay for the years 2005-13, obtained using an open population model
blue line –whole population estimate; red line – polynomial trend; black line – moving average trend

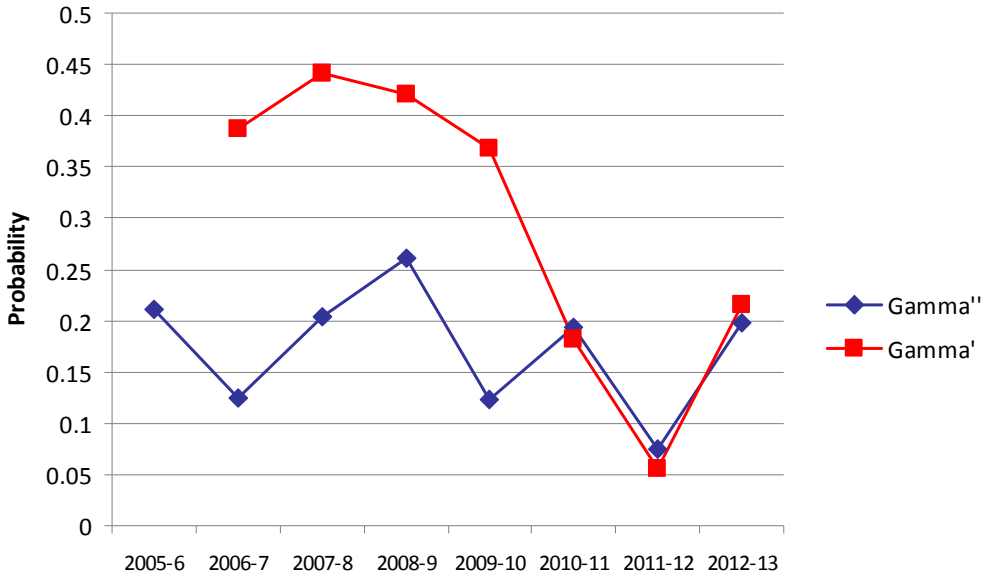


Figure 42: Bottlenose dolphin residency patterns in Cardigan Bay using an open population model (gamma" is the probability of an animal emigrating out of the study area; gamma' is the probability of an animal staying out of the study area)

Table 19: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay, using an open population model (gamma" is the probability of an animal emigrating out of the study area; gamma' is the probability of an animal staying out of the study area)

Period	Gamma"	Standard Error	Gamma'	Standard Error
2005-6	0.211	4.80E-02		
2006-7	0.125	0.033772	0.387	0.094
2007-8	0.204	3.87E-02	0.442	0.107
2008-9	0.261	4.37E-02	0.421	0.090
2009-10	0.123	3.46E-02	0.368	0.080
2010-11	0.194	0	0.182	0.000
2011-12	0.075	0	0.056	0.000
2011-13	0.197	9.83E+00	0.216	0.000

We analysed population estimates for all of Cardigan Bay using the mark-recapture closed population model, taking into account the average marked proportion of individuals (61.3%). Table 20, Figure 43). In contrast to the open robust model, which revealed low estimates of the population in 2009 (167), the closed model gave a high estimate of 342 dolphins in 2009. Estimates then steadily declined, reaching 205 individuals in 2013. Recent years have shown that some dolphins emigrate from Cardigan Bay as a whole, and from the SAC alone throughout the summer. As a consequence, although a closed population model is normally the more robust option (Boyd *et al*, 2010), using one in this scenario would be misleading (especially for Cardigan Bay SAC). Consequently, in this case, the open population model estimates are likely to be more accurate.

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

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

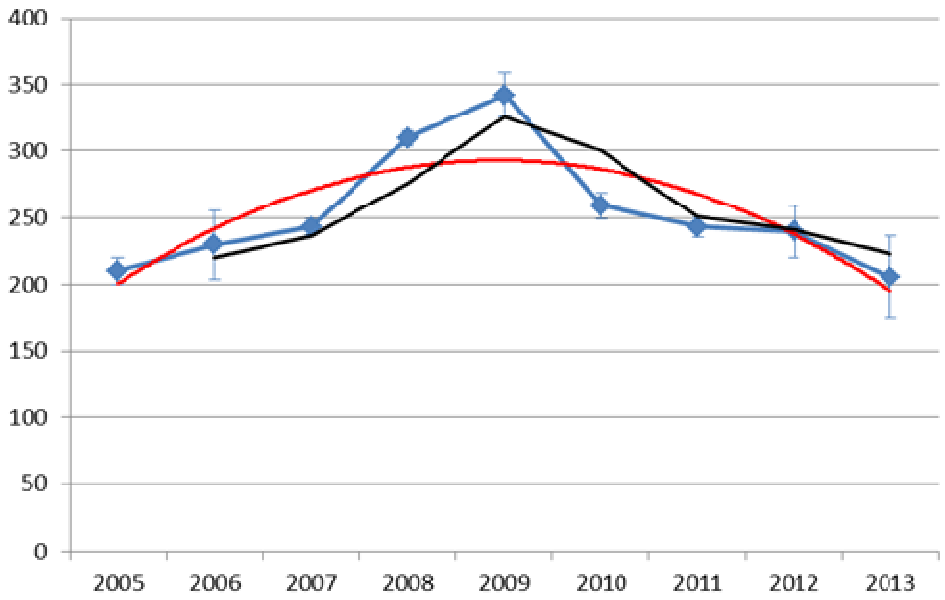


Figure 43: Population trend for bottlenose dolphins in Cardigan Bay for the years 2005-13, obtained using a closed population model
(blue line –whole population estimate; red line – polynomial trend; black line – moving average trend)

5.5 Home ranges

Since 2007, extended effort has taken place in North Wales, particularly around the Isle of Anglesey, and it is now well established that individually identifiable bottlenose dolphins from Cardigan Bay can be seen regularly at least on a seasonal basis off North Wales and the Isle of Man (Pesante *et al.*, 2008a, b; Veneruso and Evans, 2012b, Feingold and Evans, 2013). A preliminary analysis of bottlenose dolphin home ranges was completed using photo ID data from 211 dolphins seen between 2007 and 2013. Dolphins, which were not sighted during this time period, were excluded. Nearly 40% of individuals have been identified in both SACs and north of the Llŷn Peninsula - around the Isle of Anglesey, Caernarfon Bay and Isle of Man. Nearly 26% were seen in Cardigan Bay SAC and North Wales, but not in Pen Llŷn a'r Sarnau SAC. This is most probably due to lower coverage in this SAC, particularly in the offshore area. Some individuals exhibited localised home ranges, with 7% of individuals sighted only in Cardigan Bay SAC, 8% solely around the Isle of Anglesey, and 3% seen only in the Pen Llŷn a'r Sarnau SAC. These results suggest that the majority of the population have large home ranges encompassing all of Cardigan Bay and North Wales, and possibly also all of the northern Irish Sea, although a proportion of the population appears to be relatively site faithful with small home ranges. These more sedentary animals may occur in any part of the study area, not solely within Cardigan Bay SAC. Further analysis will be reported in the Bottlenose Dolphin Connectivity report.

A Masters project investigated the home ranges of individual bottlenose dolphins in relation to reproductive success using photo ID data collected between 2001 and 2012 (Baylis, 2013; see Appendix 1). Minimum convex polygon and kernel density estimation maps of home range and core area were created for individuals and groups. Mean male range areas were slightly but not significantly larger than females (16,420 km^2 versus 15,270 km^2). Females tended to use a smaller home range area and core area if characterised by one or more of the following attributes: a high calf production rate, a high calf survival rate, and a short inter-birth interval. These results indicate a correlation between home range and reproductive success (Baylis, 2013).

5.6 Body condition

Underweight and injured dolphins were encountered during Sea Watch Foundation research surveys and further photo ID data provided to us by Janet Baxter (Friends of Cardigan Bay) and Alan Gray (Shearwater cruises) were analysed.

<u>Underweight dolphins seen in 2011</u>

On the 13th October 2011, a group of 34 bottlenose dolphins was encountered during a survey in Tremadog Bay, within Pen Llŷn a'r Sarnau SAC. Of these, four animals were noticeably underweight with rib cages clearly showing: 027-06S, 132-03W, 176-05W and 179-91W (Figure 44). Two of these individuals (132-03W and 179-91W) are known mothers and had dependent calves of approximately one year of age at the time. The sex of the other two individuals is unknown. All four individuals were seen in healthy condition in later years

(2012 and/or 2013). One other underweight dolphin was noted in 2011 in Cardigan Bay SAC on the 27th October. However, the identity of this dolphin is unknown (Figure 45).

Figure 44: Underweight dolphins recorded during an encounter in Pen Llŷn a'r Sarnau SAC on the 13th October 2011

Figure 45: An underweight individual recorded off Cemaes Head in Cardigan Bay SAC on the 27th October 2011

Underweight and injured dolphins seen in 2012

One underweight individual was photographed by Janet Baxter on June 19th 2012 (Figure 37). We have identified this individual to be 038-90W, a well-marked female seen regularly in the area since 1990 and had a dependent calf at the time.

This female was photographed in Cardigan Bay SAC in 2010 and 2011 and was seen in a healthy condition (Figures 46, 47); however, she was not spotted in 2013.

Figure 46: Underweight dolphin (038-90W) recorded during an encounter in Cardigan Bay SAC on 19th June 2012 (Photo: Janet Baxter)

Figure 47: Dolphin 038-90W photographed in June 2010 (left) and July 2011 (right) in Cardigan Bay SAC (Photos: Sea Watch Foundation)

Two injured dolphins were encountered during 2012. One individual, well known to us, has been recorded inhabiting the area since 2003 (035-03W) (Figure 48). It appears that the injury, first recorded in 2007, has had little impact on this individual's mobility or reproductive capability as she has been seen accompanied by a calf (Figure 49), and regularly throughout the study period. During 2012, she was photographed in Cardigan Bay, off Anglesey, and the Isle of Man. The second individual is a very young calf, only one month old, spotted in Pen Llŷn a'r Sarnau SAC on 22nd Sept 2012 (Figure 50). This is the first calf we have recorded for this particular female, first recorded by us in 2009. The female was

sighted one month previously, on 19th Aug 2012, without a calf present, suggesting the injury to the calf took place sometime within the first month of its life. Since this is quite rare, it may be that the calf was born with the disfiguration on its fin. During this encounter, the two animals were observed bow riding for long periods of time, which is also uncommon for a young calf. The mother of this young calf may have been inexperienced, and, allowed it to get too close to one of the many vessels that uses the northern part of Cardigan Bay during the summer months. Both mother and calf have been seen since, on 30th Nov 2012 around Anglesey in North Wales, and on various occasions in 2013 (Figure 51).

Figure 48: An individual (035-03W) with a long-lasting injury recorded in Cardigan Bay SAC. Injury first recorded in 2007 (left) and on the 18th June 2012 (right)

Figure 49: An individual (035-03W) with a long-lasting injury accompanied by a calf, recorded in Cardigan Bay SAC in 2007

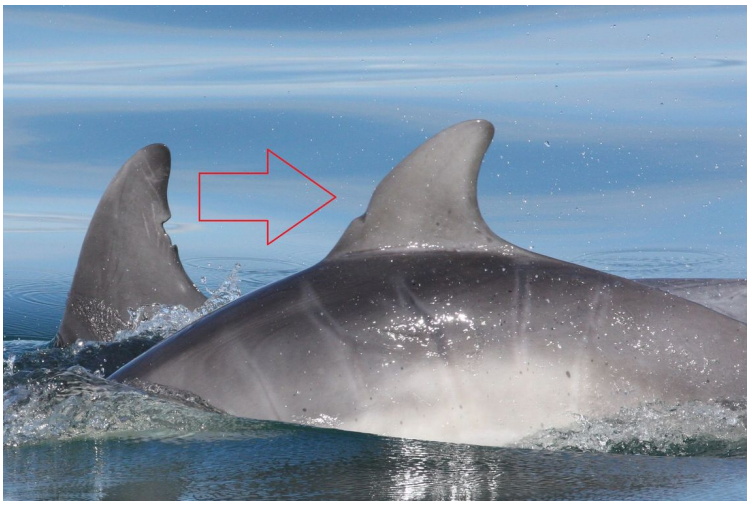


Figure 50: A young calf injured on his dorsal fin, recorded in Pen Llŷn a'r Sarnau SAC on 22nd September 2012

Figure 51: A young calf injured on his dorsal fin, recorded in Pen Llŷn a'r Sarnau SAC on 11th July 2013

<u>Underweight and injured dolphins seen in 2013</u>

One underweight female dolphin (164-90S) was spotted in Cardigan Bay SAC on 12th September 2013, accompanied by a young calf (Figure 52), and one other underweight dolphin of unknown sex (165-07S) was photographed by Alan Gray in Pen Llŷn a'r Sarnau SAC on 16th July 2013 (Figure 53). One injured dolphin was seen in Anglesey during a trip on-board Seekat; the identity of the dolphin could not be confirmed (Figure 54).

Figure 52: Dolphin 164-90S photographed in 12th September 2013 in Cardigan Bay SAC

Figure 53: Dolphin 165-07S
photographed by Alan Gray in 16th July 2013 in Pen Llŷn a'r Sarnau SAC

Figure 54: An injured dolphin spotted around the Isle of Anglesey
on 13th January 2013

6. Discussion

6.1 Line-transect surveys

Surveys between 2011 and 2013 took place throughout Cardigan Bay during the entire field season (April-October), with the exception of 2011 in which surveys started later in the season (July). Our primary aim was to obtain absolute abundance estimates for bottlenose dolphin and harbour porpoise in the area. Monitoring efforts in previous years had concentrated upon Cardigan Bay SAC but in recent years additional transects have been undertaken in Pen Llŷn a'r Sarnau SAC and adjacent waters, enabling better coverage of the northern part of Cardigan Bay.

The harbour porpoise is known to be more abundant and widespread in the Irish Sea than bottlenose dolphin (Hammond, 2008; Pesante *et al*., 2008b; Baines and Evans, 2009, 2012). This was also found to be the case within Cardigan Bay, with bottlenose dolphins concentrated in the coastal sector and harbour porpoises more evenly distributed. Abundance estimates for the whole Bay were obtained for the first time in 2011-13. Harbour porpoise numbers were highest in 2011 and lowest in 2013, although due to relatively low effort in 2011, the confidence limits (CVs) were high in that year. However, the same pattern was observed in Cardigan Bay SAC with abundance estimates higher in 2011 than in any other year between 2001-13. Surveys across the whole Bay in future years would help establish any trends.

The ability to detect a trend in a monitoring project depends upon the precision of the survey estimates (Gerrodette, 1987; Barnes 2002), and generally the goal is to build up a sample size that reduces the CV to c. 15-20%. With cetacean line-transect surveys, this is rarely feasible. The SCANS II survey, for example, obtained a CV of 27% for bottlenose dolphin across the entire ASCOBANS Agreement Area (P.S. Hammond, *pers. comm.*), and once regional estimates are obtained, the CV goes up further. Clearly, from a conservation point of view, it is desirable to have as small a CV as possible. This can be challenging if the number of sightings is reduced as a result of the population not using the area so much.

Annual bottlenose dolphin abundance estimates for the whole of Cardigan Bay in 2011-13 ranged from 254 to 330, with the lowest value in 2013 and the highest in 2012. Within Cardigan Bay SAC, abundance estimates ranged from 70 to 133, with the highest value in 2006 and low values in 2012 and 2013, the lowest in fact ever recorded since 2001. Very low numbers of sightings (n=19 in 2012, and n=22 in 2013) resulted in relatively high CV values (32.98% in 2012, and 35.65% in 2013), and therefore not very robust estimates of the population in this area. However, since bottlenose dolphins were seen on a number of occasions in North Welsh waters as well as in Liverpool Bay during the summers of 2011-13 (several identified as individuals previously occurring in Cardigan Bay), this may indicate a shift in dolphin presence from the SAC. Unfortunately, gaps in line-transect survey over a number of years (2002, 2004, 2008-10) due to lack of resources does not allow us a clear idea of the population status. To identify a statistically significant change in total population size through trend analysis requires a minimum of six consecutive years of data collection obtained over a consistent area.

The wider coverage between 2011-13 resulted in twelve sightings (4%) of bottlenose dolphins recorded outside of the two designated SACs. Four of these were recorded in the gap between the two SACs, two on the edge of Cardigan Bay SAC, one just outside the Pen Llŷn a'r Sarnau SAC, and five offshore outside the Pen Llŷn a'r Sarnau SAC. Despite offshore effort (aboard *Pedryn*) in 2011, particularly beyond the Pen Llŷn a'r Sarnau SAC, only one bottlenose dolphin sighting was spotted just outside the northern SAC that year. All other sightings were observed in 2012 and 2013 emphasising the difference in how the dolphins appear to have been using the Bay, and possibly serving as an additional explanation for the low estimates within Cardigan Bay SAC in 2012 and 2013. Aerial surveys conducted in 2007 had confirmed that bottlenose dolphins did indeed use the outer area of Cardigan Bay, at least in the winter months (Pesante *et al.*, 2008b). Here, we conclude that in some years, bottlenose dolphins may utilise the outer area of Cardigan Bay also in summer months. Further effort coverage should take place targeting those areas.

Spatial distribution of bottlenose dolphins in all three years revealed a high frequency of sightings in the coastal areas from Aberaeron to Cardigan, particularly off New Quay headland, Ynys Lochtyn, Mwnt, Pen Peles and Aberporth. Other centres of activity were found in the north of the Bay, and included Tremadog Bay and around the reefs and sandbanks of Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy. The encounter rates, however, showed yearly fluctuations again revealing some differences in how the dolphins use the area. In 2011 and 2012, sighting rates along the coastal area of Cardigan Bay SAC were higher than in 2013, with a few grid cells presenting very high sighting rates in offshore areas. However, data from offshore cells should be considered with caution as those may be biased, due to some cells with very low levels of effort yielding very high count rates. i.e if a transect line clips through a cell with 1 km of effort, yet encountered a group of dolphins in that kilometre stretch, then one would end up with this cell having one of the highest scores in the study area. Further analysis using larger grid cells may shed further light on the spatial distribution of the species.

Seasonal sighting frequencies (number of sightings per km per month) were calculated and showed a variation between years with strong peaks in July for 2011 and 2012 but a much lower value in 2013. A slight increase in sighting rates can be seen towards the end of the season in all years, most likely due to aggregations of pelagic prey, such as herring or mackerel, in the area (no sighting rates were possible for April-June 2011 due to a late start in line-transect surveys that year). Average group size was calculated for 2001-13 and revealed similar values for most years. A peak in average group size can be seen in 2006, correlating with a high abundance estimate for that year. A comparison of average group sizes between the two SAC's show lower group sizes in Cardigan Bay SAC. Relatively low average group sizes were calculated in 2007 and 2013, correlating with low absolute abundance estimates in Cardigan Bay SAC, and suggesting that group size may be a contributing factor influencing the recent decline in abundance estimates. Group sizes consisted mainly of 1-5 individuals with very few encounters of groups above ten individuals. Large groups are mainly seen at the beginning and end of the summer months.

6.2 Ad libitum surveys

Ad libitum surveys were conducted regularly throughout the season mainly within Cardigan Bay SAC, on board *Dunbar Castle II*, *Boat Gallois* and *Bay Explorer*. Some surveys also took place on board *Pedryn* in and around Pen Llŷn a'r Sarnau SAC. However, effort was concentrated upon line-transect surveys, thus reducing the number of *ad libitum* trips undertaken. *Boat Gallois* was used largely for recording bottlenose dolphin whistles and collecting grey seal photo ID data. Sightings of bottlenose dolphins and grey seals from *ad libitum* surveys were concentrated particularly between New Quay and Ynys Lochtyn, which is the route undertaken by the passenger vessels *Ermol V* and *Ermol VI*, and three surveys took place in 2011 on board the vessel *Bay Explorer*, leaving from Cardigan. Very few harbour porpoise sightings were recorded from these surveys throughout the study period (n=6 in 2011, n=22 in 2012, and in 2013). Previous studies have also shown that bottlenose dolphins exhibit a strong preference for the inshore waters in Cardigan Bay SAC, whereas harbour porpoise and grey seals are more widely distributed (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al.*, 2008b).

6.3 Activity budgets

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

A comparison of activity budgets in 2011-13 during line-transect and *ad libitum* surveys in Cardigan Bay SAC showed a large proportion of encounters involving 'foraging/feeding' activities (30% in 2011, 64% in 2012, and 56% in 2013), indicating the importance of the SAC as a foraging and feeding ground. A large proportion of the activity budget takes the form of 'travel' (74% in 2011, 55% in 2012, and 37% in 2013). However; it is likely that a significant portion of travel is in fact "forage-travel", where animals are searching for prey.

Similar to other studies (for example, Bearzi and Politi, 1999), years with a high percentage of feeding related activities (2012 and 2013) averaged smaller group sizes whereas years with a higher percentage of travel (2011) showed higher average group sizes. Resting and social behaviours were rarely observed, and it is possible that the high level of vessel activity in the area is affecting the frequency of these behaviours. Yearly comparisons of activity budgets between 2001 and 2013 in Cardigan Bay SAC confirm that 'travelling' was the predominant activity recorded in the SAC in 2003-11 followed by 'foraging/feeding' activities, while 'socialising' and 'resting' activities were the least recorded throughout these years.

'Foraging/feeding' activities were higher only in 2002, 2012 and 2013, suggesting that prey availability may have been lower in those years resulting in larger percentages of the activity budget spent on searching for food. In order to investigate whether this was unsuccessful foraging or successful feeding, further analysis of feeding and foraging activities were analysed separately for the years 2005-13. These indicated a peak in feeding activities (when definite feeding was observed) in 2012, suggesting that low availability of prey may not be the main reason for the low population estimates for this year. On the other hand, a general increase in 'suspected feeding' has been observed since 2006, suggesting that dolphins are spending more time foraging for food, although not necessarily consuming it.

'Definite feeding' was highest in April and lowest in October, whereas the opposite trend was observed in 'suspected feeding' activities, suggesting that local prey availability is lower in the latter part of the season. It may be that in recent years dolphins are generally spending more time searching for food, perhaps because it is less abundant in the SAC. This could explain the re-locating of some (identified) individuals during summer to other regions such as North Wales, although anthropogenic activities may also play a part.

A sufficient amount of data has now been collected within Pen Llŷn a'r Sarnau SAC that activity budgets could be analysed for this area as well. Sample sizes were much smaller than in Cardigan Bay SAC, and yet 'travelling' and 'foraging/feeding' still represented the majority of the activity budget. However, our data suggest that the northern part of Cardigan Bay is used rather differently by the dolphins, since consistently higher percentages of 'socializing' events were observed there (north vs south: 29% vs 20% in 2011; 21% vs 14% in 2012; and 25% vs 7% in 2013). Average group sizes were also higher in this SAC suggesting the northern part of the Bay may be used as a mating and socializing ground for the population whereas the southern areas are used more for feeding and as a nursery area.

6.4 Reproductive & Mortality Rates

Cardigan Bay SAC is recognised as an important nursery area for bottlenose dolphins (Veneruso and Evans, 2012a; Baylis, 2013; Feingold and Evans, 2013a, b). This continued to be the case during the period 2011-13, with 47% of groups encountered in 2011, and over 50% of encounters in 2012 and 2013 in the SAC including mother-calf/newborn pairs. A higher than average number of births, as seen in 2006 (13), 2010 (14), 2011 (15) and 2012 (13), may be a result of a number of females becoming reproductively mature at the same time, creating a "baby boom". This has been observed in other studies of bottlenose dolphin

(Bearzi *et al.,* 1997; Haase and Schneider, 2001), and also in Atlantic spotted dolphins (*Stenella frontalis*) (Herzing, 2007). Here, we present data indicating that the whole of Cardigan Bay is an important area for mothers and calves, with some females with calves being sighted only in the northern part of the Bay.

Table 21: Crude birth rates from studies of bottlenose dolphins around the world

Location	Crude birth rate	Source
Eastern Australia	1.2	Lear & Bryden, 1980
North Adriatic, Croatia	4.9	Bearzi *et al*., 1997
Cardigan Bay SAC (closed)	**5.3**	**This study (01-13)**
Sado Estuary, Portugal	5.4	Gaspar, 2003
Sarasota Bay, Florida	5.5	Wells & Scott, 1990
Moray Firth, Scotland	6.0	Wilson *et al*., 1999
Doubtful Sound, New Zealand	6.6	Haase & Schneider, 2001
Cardigan Bay, Wales (closed)	**6.6**	**This study (05-13)**
Southern California	7.2	Hansen, 1990
Cardigan Bay SAC, Wales (open)	**7.65**	**This study (01-13)**
Northern Gulf of Mexico	7.7	Leatherwood, 1977
Florida	8.2	Irvine *et al*., 1981
Cardigan Bay, Wales (open)	**8.9**	**This study (05-13)**
Argentina, South Atlantic Coast	9.6	Würsig, 1978
Tampa Bay, Florida	9.7	Weigle, 1990

Mean birth rates were calculated for Cardigan Bay SAC using both a closed and open model (5.3%, 7.65% respectively) and for the whole of Cardigan Bay (6.6% for a closed model and 8.9% for an open model). The estimated mean birth rate of the semi-resident population of UK bottlenose dolphins in the Moray Firth is 6.0% (Table 17; Wilson *et al.,* 1999; Grellier, 2000; Thompson *et al.*, 2004), a value situated in between those estimates for Cardigan Bay and its southern SAC, both calculated using the closed population estimate. Birth rates using the open population model estimate higher numbers, especially for Cardigan Bay as a whole (8.9%) due to a large number of females and newborns observed in Pen Llŷn a'r Sarnau SAC. Higher birth rates in the whole of the Bay indicate that additional individuals to those within the Cardigan Bay SAC are using only the northern part of the Bay as a calving ground, and that the entire Bay should therefore be viewed as an important site for mothers and calves. In addition, a recent project, which analysed female-calf sightings, showed no significant differences in calf sightings throughout the study area, strengthening the hypothesis that several locations, including some outside of Cardigan Bay, serve as calving grounds for this population (Feingold and Evans, 2013a). Another recent project selected twenty-two females for home range analysis. The results suggest that females use a smaller home range area and

core area when calf production rate is high, calf survival rate is high, and inter-birth interval is short (Baylis, 2013). These findings highlighted a clear correlation between home range and reproductive success, and should be taken into account as resident female dolphins inhabiting waters outside of the two SAC's receive less formal protection.

Table 22: Inter-birth intervals from studies of bottlenose dolphins around the world

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

Table 23: Juvenile mortality rates from studies of bottlenose dolphins around the world

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

The mean inter-birth interval in Cardigan Bay between 2001 and 2013 is estimated to be 3.3 years, similar to other studies of the species (Table 18), suggesting that the female population of Cardigan Bay is healthy and reproducing offspring regularly.

The calving season between 2001 and 2012 (corrected for the number of identified females per month) occurred mainly in the summer months, with the majority of newborns (76%) observed between July and September. Calf mortality rates between 2001 and 2012 were calculated as highest in the first two years (15% and 17% respectively), similar to records

from Sarasota Bay, Florida for the first year, and to Shark Bay, Australia for the second year (Table 19). Mortality rates then reduce to 7% in the third year, with a majority of calves (60%) surviving into their fourth year.

6.5 Photo ID & Home Ranges

The Photo ID catalogue of bottlenose dolphins in the Irish Sea contains a minimum of 378 dolphins. Thirteen new 'Marked' dolphins, 13 new 'Left' dolphins, and 16 new 'Right' dolphins were added to the catalogue during 2011-13. New dolphins tend to be juveniles that were previously unmarked; however, some dolphins added to the catalogue in recent years were those inhabiting North Welsh waters, specifically the Anglesey area. Our discovery curve, which has flattened off in the last few years, suggests that the catalogue may now represent the majority of dolphins regularly inhabiting Welsh waters.

From individual re-sightings of bottlenose dolphins in Cardigan Bay, the population can be described as a combination of residents (52-63%), occasional visitors (21-31%), and transients (16-19%). Residency patterns were calculated also for Cardigan Bay SAC alone, and showed lower percentages of resident individuals (37-43%) and higher percentages of transient dolphins (35-37%), suggesting that a larger proportion of the population is resident to the whole of the Bay but does not necessarily frequent the southern SAC. In addition, transient dolphins entering the Bay originate, most probably, from areas outside Cardigan Bay, although further analysis of the individual dolphins comprising each of these groups, is needed. Previous residency patterns in 2001-07 were calculated for Cardigan Bay SAC, and indicated a much higher figure with 58% residency for dolphins within the SAC (Pesante *et al.*, 2008b), suggesting there has been a change in recent years.

Population estimates for Cardigan Bay SAC reveal no apparent long-term trend, although the low numbers recorded recently from both photo ID and line-transect surveys are a cause for concern. High emigration rates and a high percentage of animals staying outside of the SAC were found in 2013, using a robust open model. A sharp decrease in survival rate (S) was also observed for that year (see Figure 39), and since no massive death and/or stranding reports of bottlenose dolphins in the area were reported, this is most probably a result of changes in emigration rates. This also reflects variation in usage of the area, suggesting that a larger proportion of the population has been occupying Cardigan Bay SAC on an irregular basis in recent years, most notably in 2013. Prey availability may be a cause for this, although our feeding activity budget analysis does not specially support this. It is also possible that local anthropogenic activities may be contributing (see section 7.9).

Population size estimates for bottlenose dolphins within Cardigan Bay as a whole have been made since 2005, when survey coverage was extended to Pen Llŷn a'r Sarnau SAC. Estimates derived from an open population model indicate a general increase from 128 individuals in 2005 to 222 individuals in 2007, with a lower estimate (181) in 2008. However, estimates in 2008, 2009 and 2010 should be viewed with caution, since, due to lack of funding, there was low effort in the northern part of the Bay. The population estimate in 2011 was also relatively low (193), almost the same value as in 2010 (192), with a low

number of sightings (Veneruso and Evans, 2012a). The Cardigan Bay population estimate for 2012 was 232 individuals (the highest estimate so far), but then reduced in 2013 to 167 individuals (joint second lowest estimate since 2005). This low estimate cannot be explained by low effort as the study area was well covered in 2013. Group sizes were smaller in both SAC's and the exceptionally good weather instigated more recreational activity in the area, which may have had an effect on sighting numbers as previously found (Pierpoint *et al*, 2009; Lohrengel *et al*, 2012). This highlights the need for consistent monitoring throughout the years, and a more in depth study of possible effects of anthropogenic activities in the area.

There are reasons why estimates derived from Photo ID (Mark-Recapture) and line-transect (Distance) analyses in 2012 (and any other year) may differ. Line-transect estimates present the average number of animals estimated to occur in the study area at the time of the surveys (a snapshot view) whereas Photo ID estimates the number of different individuals occurring in the study area over the particular study period (in this case usually April-October). If some individuals are visiting the SAC only briefly, they should still appear in the Mark-Recapture population estimate but by chance may not be reflected in the mean abundance estimate from the line-transect surveys. We believe the low estimate from the line-transects suggests a lower usage of the SAC in 2012, even though the number of dolphins visiting the SAC was not reduced. On the other hand, estimates for 2013 yield low population values from both Photo ID and line-transect analyses.

In 2007, survey coverage expanded to include the waters off NE Anglesey, and since then these have recorded significant numbers of bottlenose dolphins, particularly in winter. Many of the dolphins encountered in Cardigan Bay have now been identified off the Isle of Anglesey and some also around the Isle of Man and even into Liverpool Bay (Pesante *et al.*, 2008a, b; Veneruso and Evans, 2012b; Sea Watch, unpublished data). Nearly 40% of individuals have been identified in both SACs as well as north of the Llŷn Peninsula - around the Isle of Anglesey, Caernarfon Bay and the Isle of Man, indicating a large home range that most probably extends further into the northern Irish Sea. On the other hand, a small proportion of the population shows a much more local residency pattern with small home ranges. Seven percent of individuals were sighted only within Cardigan Bay SAC, 8% solely around the Isle of Anglesey and North Wales, and 3% within the Pen Llŷn a'r Sarnau SAC. Four percent of the population recorded between 2007 and 2013 were never seen in North Wales, suggesting that a small proportion of the population shows strong site fidelity, although the area which they frequent can be anywhere around the coast of West and North Wales. Further analyses of sightings along the North Welsh coast will be presented in a separate Bottlenose Dolphin Connectivity Report.

6.6 Body condition

Injured and/or underweight dolphins have been recorded in all three years of the study period. Five underweight individuals were recorded in 2011; two of these are known females and had dependent calves of approximately one year of age at the time. Both females were recorded in later years (2012 and/or 2013) along with their calves, and no longer appeared underweight. One underweight female accompanied by a calf, was recorded by Janet Baxter (Friends of

Cardigan Bay) in Cardigan Bay SAC, in 2012. However; this female was not spotted again in 2013. One dolphin of unknown sex and another underweight female were recorded in 2013, the latter also accompanied by a young calf. Bottlenose dolphins in the UK tend to have a thick layer of blubber, which makes these recent occurrences unusual. Of four underweight females recorded during the study period, three have been seen since 1990/1991 and one since 2003, with all of these recorded as having at least one previous calf. Although it is possible that a mother suckling her young may lose weight, this has never been evident in other mothers recorded in Cardigan Bay since 2001, nor in these mothers before 2011. Such unusual observations may suggest that currently there is low prey availability in the region, or that disease or parasite burdens are affecting them. Although neither of these explanations can be confirmed, the relatively low usage of the SAC in 2013, and the high percentages of foraging activities in 2012, accords with the first hypothesis.

Three injured individuals were recorded during the study period. One of these was a female well known to us since 2003. Her injury has been recorded previously, and has had no apparent effect on her, as she has been seen in both SACs as well as off Anglesey. She has also been recorded having two calves during the study period. The second individual was a very young calf, only one month old, recorded in Pen Llŷn a'r Sarnau SAC in 2012. The injury resembles a boat collision wound, and since this is the first calf recorded for this female, it is possible that her inexperience and the high boat traffic in the northern part of the Bay may have resulted in the injury. Both mother and calf were recorded again in 2013. The third injured individual was recorded in North Wales around the Isle of Anglesey in 2013. However, the identity of the individual could not be recognised. The wound resembles a propeller injury, which seems to have healed.

7. Review of Objectives and Conclusions

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

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

Estimates of population size have been assessed using two different methods: line-transect surveys and Photo ID. Line-transect analysis estimates the average number of animals in the study area during the surveys. Abundance estimates in Cardigan Bay SAC present similar numbers for 2003 and 2005, peaking at 214 individuals in 2006 and then declining to 109 individuals in 2007. Estimates rose again slightly to 133 individuals in 2011, before dropping considerably, to 70 and 90 individuals in 2012 and 2013 respectively. Unfortunately, funding ceased in 2008, and no line-transect surveys were undertaken until 2011, limiting our ability to assess long-term trends in abundance. 2011 was the first year when a large part of Cardigan Bay was surveyed by line-transect, and resulted in an overall abundance estimate of 309 individuals, followed by 330 in 2012 and 254 individuals in 2013. These results suggest that the species uses Cardigan Bay differently in different years with no obvious long-term

trend. However, the recent decline in Cardigan Bay SAC is reason for concern and should be investigated further.

Population estimates, calculated using the mark-recapture method based on Photo ID within Cardigan Bay SAC, show no clear trend when derived using an open population model. There is some indication of a general increase in population size since 2001 using the closed population model. However, a declining trend can be observed since 2009, reaching only 153 individuals in 2013. When examining population estimates for the entire Bay using the closed population model, a similar and more prominent decline is seen since 2009 reaching 205 individuals in 2013. The probability of dolphins leaving, and remaining outside the study area shows no apparent trend throughout the years though a sharp increase is seen in 2013 for both Cardigan Bay SAC and the entire Bay along with a sharp decrease in survival rates most probably as a result of fluctuations in emigration rates. This also reflects variation in usage of the area, suggesting that a larger proportion of the population has been using Cardigan Bay SAC on an irregular basis in recent years, particularly in 2013.

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

Bottlenose dolphins in Cardigan Bay have a predominantly inshore distribution. Evidence of much feeding in the area, and the frequent presence of mother-calf pairs suggests that prey availability is probably the leading factor for the observed distribution. Furthermore, the shallow nature of the Bay may make the area attractive for benthic feeding mothers with dependent young since it means the adults can forage without leaving the calf alone for more than a few minutes, whilst also enabling growing calves to learn to make shallow dives in order to capture prey for themselves. On the other hand, surveys conducted during 2011-2013, recorded twelve dolphin sightings outside of the SACs, five of those were recorded offshore outside Pen Llŷn a'r Sarnau SAC around the 20-40m isobath. Three of these dolphin groups also included calves, confirming the species as using the offshore waters of Cardigan Bay in summer months as well as in the winter. Offshore sightings have been reported on occasions in previous years although these have still been within c. 10 nm of the coast. Areas further offshore have only recently been surveyed in summer. Three of the five offshore sightings were recorded just over 10nm from the coast, and two were recorded just under 10nm. In addition, five sightings were recorded inshore in the gap between the two SAC's, and two more just on the outer edge of Cardigan Bay SAC. It is recommended that monitoring should be continued in these "unprotected" areas.

The overall distribution of the population may also be changing, with increased summer activity in North Wales observed in recent years. In 2011 and 2012, groups of dolphins were recorded in that region several times during the summer months, and included individuals that have previously shown a strong site fidelity to Cardigan Bay at this time of year. It may be the case that prey availability has improved off the waters off North Wales, and so dolphins do not make the journey into Cardigan Bay. Alternatively, there could be a prey shortage in Cardigan Bay, resulting in dolphins needing to travel more widely, including outside of the study area, in order to find food. The observations of undernourished adults

within Cardigan Bay over the last three years lend some support to the latter hypothesis. Information on the abundance of important prey species in Cardigan Bay and other parts of the Irish Sea would be useful in order to investigate this further. The decline in population estimates for the entire Bay suggests that the shift may be pronounced over the wider area and not only in Cardigan Bay SAC itself. Cardigan Bay SAC and the northeastern part of Pen Llŷn a'r Sarnau SAC are also considered a high-pressure area for boat traffic, with recreational boat activities increasing each year, which may thus be affecting bottlenose dolphin presence in the area (see section 5.9).

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

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

Reproductive rates in Cardigan Bay SAC present healthy crude birth rates of 5.26% and 7.65% using closed and open population models respectively, confirming that this region serves as an important nursery ground for females and their young calves. Birth rates calculated for the entire Bay are even higher, especially when using an open population model (8.92%), suggesting there are additional females nursing their young within other areas of the Bay including Pen Llŷn a'r Sarnau SAC. It is clear that the whole region, quite possibly extending beyond the Bay, serves as a regular calving ground. High intensity of vessel activity has been shown to cause stress particularly on mother-calf pairs, and improved application of current codes of conduct for recreational vessel activities is needed in the northern part of Cardigan Bay.

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

Calf mortality rates calculated for Cardigan Bay SAC were 15% for the first year and 17% for the second year, decreasing to 7% in the third year. The first year mortality rate seems to be average compared with other populations of the species. There are few studies that show the mortality rate of calves in the second and third years. Our calculation for year two is very similar to that obtained elsewhere, although somewhat higher for year three.

A total of 60% of calves survived into their fourth year. Bottlenose dolphin calves in Cardigan Bay tend to leave their mother by the fourth year. Unfortunately, once they leave the mother's side, they are no longer recognisable as individuals until they have acquired markings useful for Photo ID. For this reason, it is difficult to report on juvenile survival rates beyond the age of 3-4 years.

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

Our database currently holds records of 72 definite females and 19 definite males. However, at this stage, without moving into genetic sampling, it is not possible to provide an accurate assessment of sex ratios of this population. Animals can be positively sexed if the genital area of identifiable individuals is seen or, in the case of females, if a dolphin is recorded with a calf on several occasions (we use a minimum of three occasions as the criterion). Since there are many mother-calf pairs in the region, females can be identified much more easily and for this reason there is an under-representation of known males confirmed in the catalogue. Genetic sampling would allow us to sex individuals and also to identify related individuals both within and between groups. It would also provide information on population structure generally, enabling us to better differentiate sub-populations. If this aspect is to be addressed, genetic sampling of this population (by skin biopsy) will be necessary, as has been conducted with many other European populations, including those in Scotland and Ireland. Other recent methods that can be used for sex identification includes the use of underwater cameras while dolphins are bowriding. This was recently done using a GoPro camera mounted on a pole.

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

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

Recent analysis shows that nearly 40% of individuals have been identified in both SACs as well as north of the Llŷn Peninsula around the Isle of Anglesey, Caernarfon Bay, and Isle of Man, indicating large home ranges that most probably extend to the northern Irish Sea and possibly beyond. On the other hand, a proportion of the population exhibits a more local residency pattern, with relatively small home ranges: 7% of individuals were sighted only within Cardigan Bay SAC, 8% solely around the Isle of Anglesey, and 3% only in the Pen Llŷn ar Sarnau SAC (Figures 25-26).

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

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

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

Feeding and foraging along with travelling have been recorded as the primary activities within the bottlenose dolphin budget in 2011-13 in Cardigan Bay SAC, with a peak in feeding activities (those in which definite feeding was observed) in 2012, being the highest ever recorded since 2005, and relatively higher percentages also in 2013. Assuming prey availability is a major factor influencing dolphin presence, we would expect higher population estimates in 2012 and 2013. However, this is not the case, with abundance estimates (from line-transect surveys) from Cardigan Bay SAC being very low, with 2012 having the lowest estimate since 2001, suggesting other elements might be the cause for these low numbers.

Further monitoring in future years would show whether these recent low values are part of a natural fluctuation, or represent a longer-term trend, with a decline in prey availability in the SAC. Other evidence (underweight dolphins, and an apparent decline in numbers using Cardigan Bay SAC) suggests this may be at least partly responsible.

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

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

Leisure boat activity around the UK has generally increased in recent years, and dolphin watching activities in particular have risen markedly (O'Connor et al., 2009; Lambert and Evans, 2012). Boat traffic is now recognised as an important factor affecting distribution and behaviour of coastal cetaceans. Many studies present the negative effects upon bottlenose dolphins due to recreational activities, with behaviour responses ranging from moderate changes in behaviour to the avoidance of preferred habitats (see, for example, Gregory and Rowden, 2001; Hastie *et al.*, 2003; Lusseau, 2005; Mattson *et al.*, 2005; Lohrengel *et al.*, 2012; Thompson, 2012). Boat traffic, including the number and type of surrounding boats, was recorded at regular intervals during all our surveys in Cardigan Bay as part of our effort collection. Previous studies in the area have concluded that boat presence is negatively linked to bottlenose dolphin sighting frequencies, and one of the busiest sites, around the town of

New Quay within the Cardigan Bay SAC, has seen a steady decline in bottlenose dolphin occurrence since 1994, with the relative abundance of the species inversely related to the number of boats counted (Figure 55; Pierpoint *et al*, 2009).

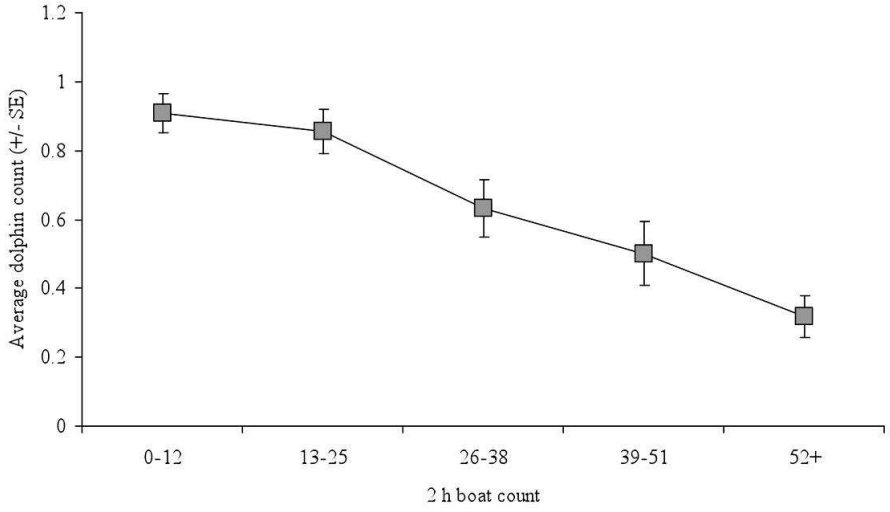


Figure 55: The Relative Abundance of Bottlenose Dolphins at different levels of Boat Traffic at New Quay, Cardigan Bay SAC
(Pierpoint *et al*., 2009)

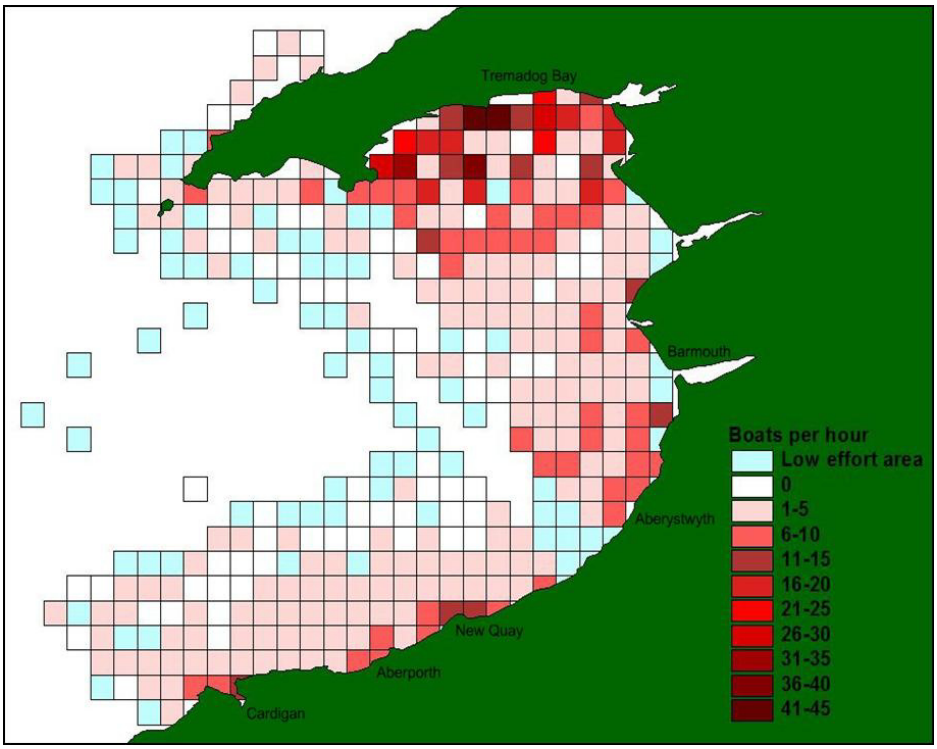


Figure 56: Vessel Activity in Cardigan Bay between 2006-11
(Lohrengel *et al*., 2012)

A recent study (Lohrengel *et al*., 2012) found that boat traffic, primarily motorised vessel levels, increased throughout Cardigan Bay from 2006 to 2011, with the highest rate of boat traffic in Tremadog Bay averaging at 11.5 boats per hour. Six sites within Cardigan Bay (Tremadog Bay, Barmouth, Aberystwyth, New Quay, Aberporth and Cardigan) had high levels of boat traffic (Figure 56).

Cardigan, Aberystwyth and New Quay all showed negative correlations between boat traffic levels and bottlenose dolphin sightings after 2007 (r^2 = -0.4 for all) but the strongest negative trend was observed around Barmouth (r^2=-0.94) (Figure 57). It is notable that in New Quay, the year with highest boat traffic, 2009, coincided with the lowest overall sighting rate for this area at just 0.72 sightings per hour. The relationship between sighting rate and boat traffic in Tremadog Bay was weaker (r^2=-0.2), however. Overall, motorised vessels such as motorboats, speedboats and fishing boats were the most prevalent, except for Tremadog Bay where yachts made up the largest proportion of boat traffic. Rowboats, jet skis, large ships and ferries made up less than 5% of total boats (Lohrengel, 2012). Studies elsewhere have found that bottlenose dolphins react more strongly to motorised vessels than non-motorised vessels (Mattson *et al*., 2005), and this may account for the weak relationship between sighting rate and boat traffic in Tremadog Bay.

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

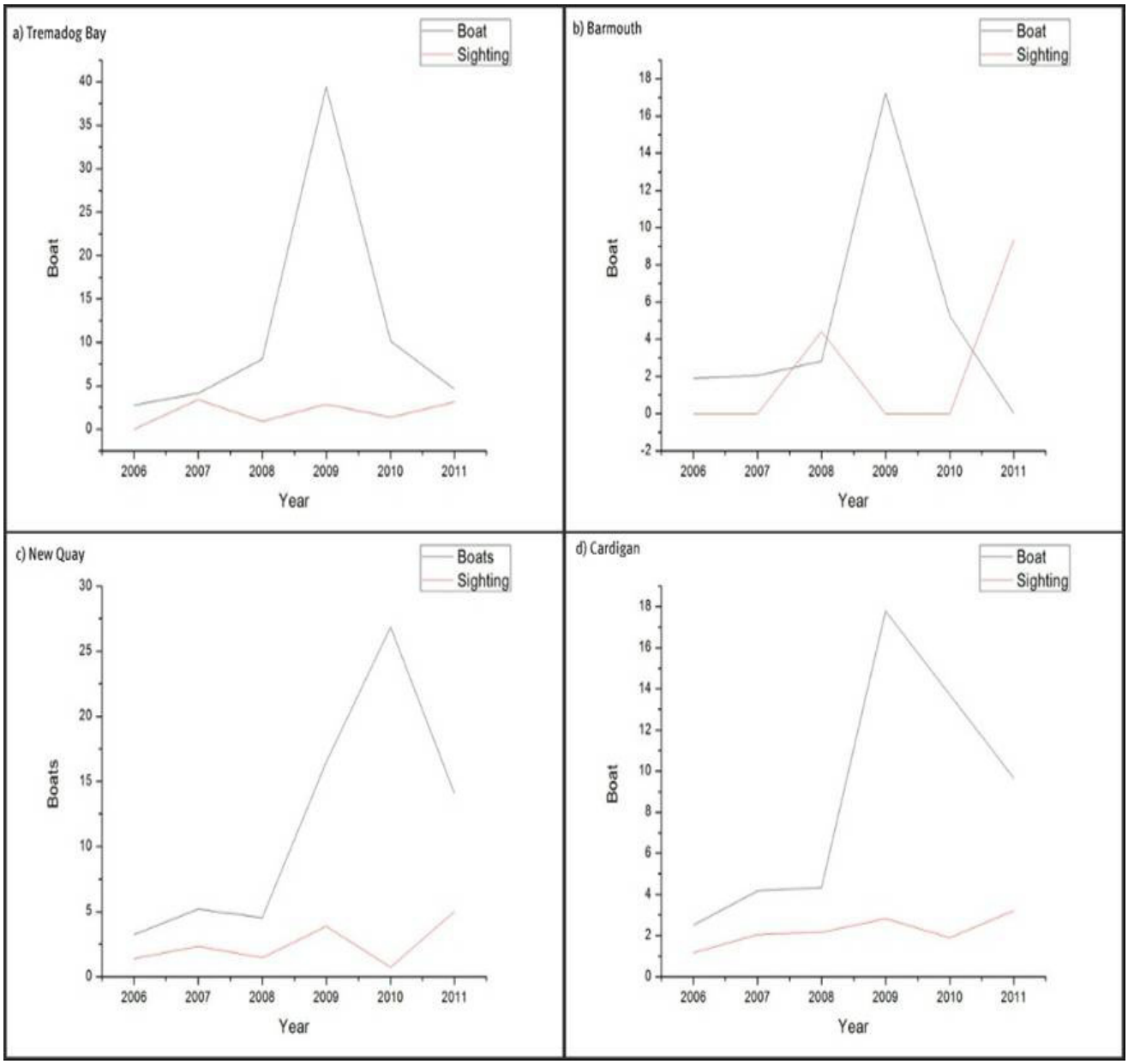


Figure 57: Trends in Sightings Rates *vs* Vessel Activity in Tremadog Bay (top left), Barmouth (top right), New Quay (bottom left) and Cardigan (bottom right) between 2006-2011
(Lohrengel *et al*., 2012)

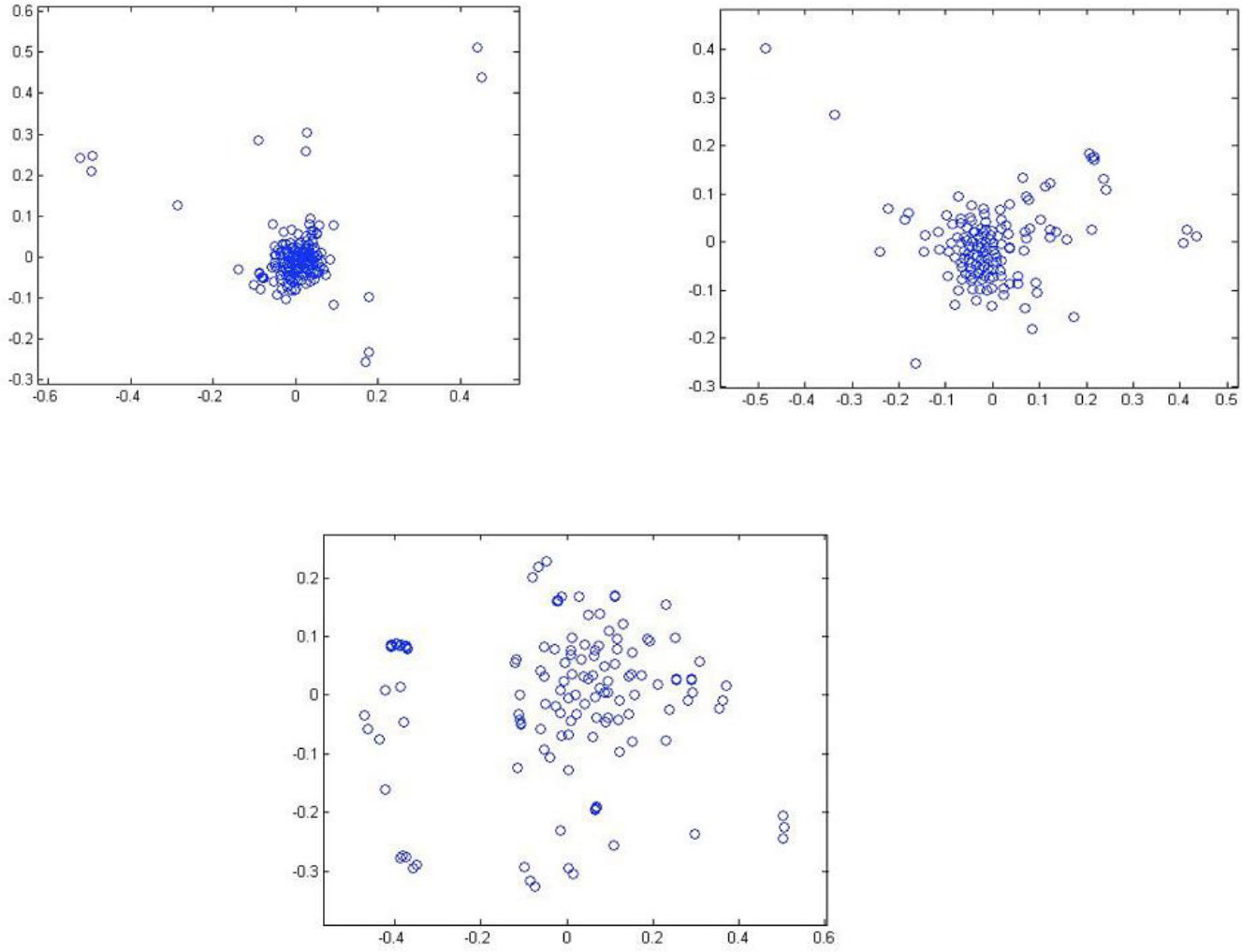


Figure 58: Representative Multi-dimensional Scaling Plots of bottlenose dolphin clusters in regulated high vessel traffic areas (top left); un-regulated high vessel traffic areas (top right); and low vessel traffic areas (bottom)
(Source: Richardson, 2012)

A further Masters project examined the effect of boat disturbance on the social structure of bottlenose dolphins in Cardigan Bay (see Appendix 1; Richardson, 2012). The results strongly indicated that vessel traffic impacts community structure. Group size was significantly smaller in areas of high vessel traffic, and results found that individuals in high vessel traffic areas formed moderately strong bonds with several other individuals, whereas those in areas of low vessel traffic formed very strong bonds with a smaller number of individuals. Very similar values between areas of regulated and unregulated vessel traffic indicated that dolphins modify their social behaviour when exposed to high levels of boat traffic, despite the regulating of boat behaviour (Figure 58).

These three studies (Lohrengel *et al*., 2012; Richardson, 2013; Thompson, 2013) along with previous research (Pierpoint *et al*., 2009) suggest that recent low population estimates for bottlenose dolphins derived from line-transect surveys in Cardigan Bay SAC may have been at least partly affected by high recreational vessel traffic within the area. High levels of vessel traffic are also observed in the northern part of Cardigan Bay, with Tremadog Bay having the highest rate, but here they comprise mainly sailboats. Since population estimates through line-transect surveys across the entire Bay have been lower in recent years than earlier, it is suggested that the effects may be widespread and not only localised to Cardigan Bay SAC.

Dolphins are recorded also in the outer parts of Cardigan Bay, an area that for the last few years has been subject to scallop dredging in winter months (see Figures 59 & 60). Further surveys of this region are necessary to assess the potential effects of this fishing activity upon the species.

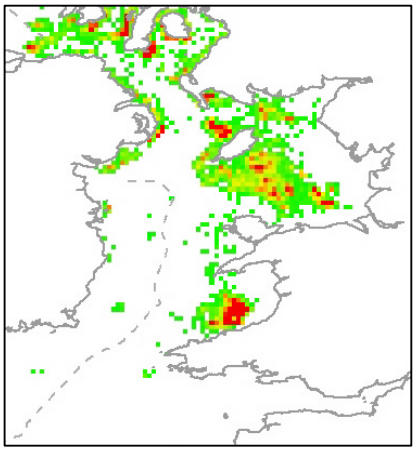


Figure 59: Distribution of dredging effort from VMS, 2007
(Lee *et al*., 2010)

Traditionally, scallop dredging in Welsh waters has concentrated upon scallop beds between Anglesey and the Isle of Man. A limited amount of effort also occurred off the coast in Cardigan Bay, although the inshore component of this fishery was subject to a seasonal closure between July and December. There was a noticeable decline in effort over the six-year period, 1998-2003 (Mills and Eastwood, 2005), but in 2007, vessels from Southwest England moved from Lyme Bay (Dorset) scalloping grounds into Cardigan Bay and started working this area (Figures 50, 51; see Evans and Hintner, 2010).

In 2009, the Welsh scallop fishery was due to open for the season 1st November 2009 to 31st May 2010 under the Scallop Fishing (Wales) Order 2005. However, a considerable increase in fishing effort in this fishery compared with the previous years (Figure 61) due to displacement from the closure of other UK scallop fisheries, led to its controversial closure until the end of February 2010 whilst new regulatory measures were drawn up. The Scallop Fishing (Wales) (No.2) Order 2010 came into force on 1st March 2010 and included both

spatial and technical restrictions to reduce the level of scallop fishing effort in Welsh waters. The technical restrictions set a maximum limit on engine power for scallop dredgers accessing the fishery and also set restrictions on the design and number of dredges deployed by vessels. In the main, the spatial restrictions prohibited scallop dredgers from designated areas in Welsh waters featuring vulnerable marine species and habitats although, as a result of survey work specifically undertaken to assess the impact of this fishery, scallop dredging was allowed in an offshore part of the Cardigan Bay Special Area of Conservation. The development of more sustainable management measures for the future of this fishery is ongoing (CCW, 2010; Evans and Hintner, 2010).

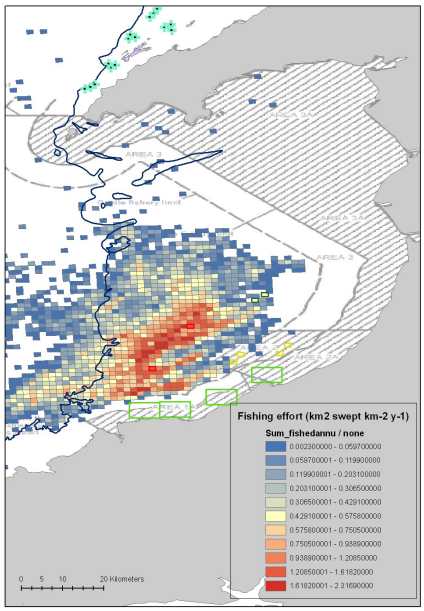


Figure 60: Distribution of scallop dredging effort in Cardigan Bay, 2008
(Source: School of Ocean Sciences, Bangor University)

The marked increase in scallop dredging effort throughout Wales from 2007 onwards (Figures 61, 62) has resulted in concerns expressed over possible long-term damage to seabed habitats, Scalloping effort in Cardigan Bay initially within sight of land (including its SACs) led to local disquiet about possible effects on the bottlenose dolphin population (Woolmer, 2009). At present, it is impossible to say whether scallop dredging has had any impact, although the marked increase in scalloping effort in 2007 was followed by very low birth rates for bottlenose dolphins within Cardigan Bay in 2008 and 2009, the lowest birth rates recorded throughout the 13-year study period.

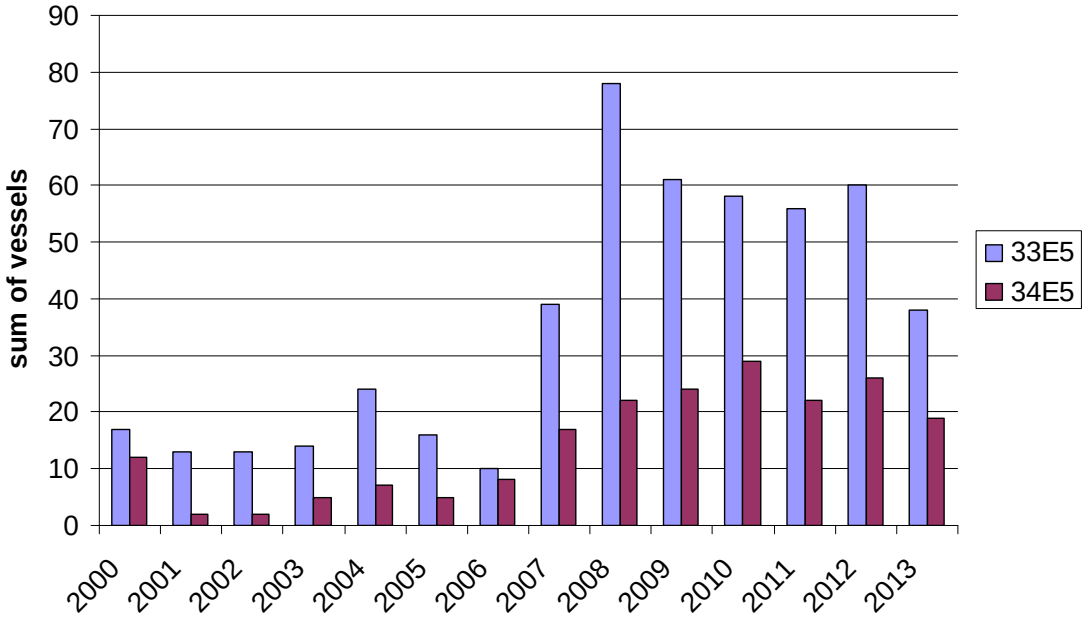


Figure 61: Number of all vessels taking part in scallop dredging in selected rectangles (33E5 – southern Cardigan Bay, and 34E5 – northern Cardigan Bay) in 2000-13 (Source: Marine Management Organisation)

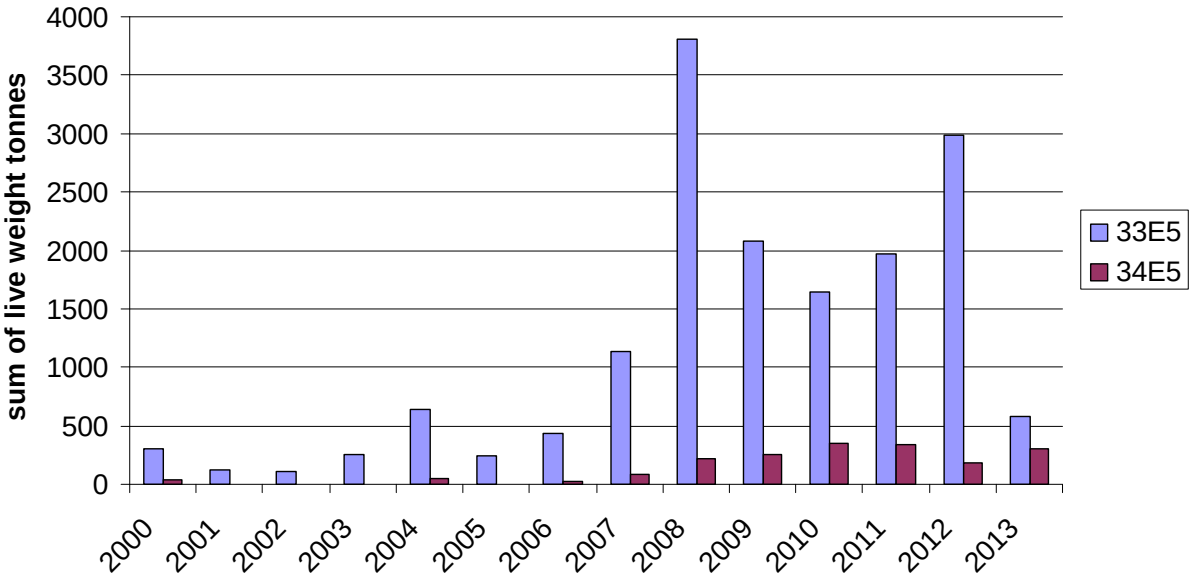


Figure 62: Amount of live weight tonnes of scallops obtained while dredging in selected rectangles (33E5 – southern Cardigan Bay, and 34E5 – northern Cardigan Bay) in 2000-13 (Source: Marine Management Organisation)

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

There were no observations by SWF of entanglement in anthropogenic debris between 2011 and 2013, nor any incidents reported to us. Commercial fishing is at a relatively low level in Cardigan Bay, with most of the industry focused upon potting and bottom fishing (Scalloping) (Evans and Hintner, 2010). To our knowledge, there are relatively few net fisheries operating in the area.

Significant fresh injuries commensurate with propeller or boat collision

Three injured dolphins were observed by Sea Watch Foundation researchers. One, which is a well known female (035-03W) observed since 2003, carries an injury thought to be a propeller cut that was first recorded in 2007. It appears that this injury has had little impact on the animal's mobility and reproductive ability since she has been seen accompanied by a calf and has been seen regularly throughout the study period, and in 2012 was observed in Cardigan Bay, off Anglesey, and the Isle of Man (Figures 48, 49).

The second individual was a very young calf, only one month old, accompanied by a dolphin assumed to be its mother (Figure 50). This is the first calf we have recorded for this female, which was first spotted in 2009. During our encounter with the two animals, they were observed bow-riding for long periods of time, an activity that is uncommon for such a young calf. The inexperienced mother, along with her young calf may therefore have been subject to this injury from one of the many vessels that occur in the northern part of Cardigan Bay during the summer months. On the other hand, one cannot discount the possibility that the calf was born with this disfiguration on its fin.

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

Underweight dolphins have been recorded in all three years of the study period. Two of these were spotted in 2011 and are known females with dependent calves of approximately one year of age at the time. Both females were recorded in later years (2012 and/or 2013) along with their calves and did not appear to be underweight then. One underweight female accompanied by a calf was also recorded by Janet Baxter (Friends of Cardigan Bay) in Cardigan Bay SAC in 2012 (Figures 46, 47). We have identified this individual to be 038-90W, a well-marked female seen in the area since 1990, and it was accompanied by a dependent calf at the time. Although she was spotted relatively early in the season (June), she was not seen again, so a further evaluation of body condition could not be assessed. One dolphin of unknown sex and another underweight female was recorded in 2013, also accompanied by a young calf.

Underweight dolphins have been recorded in Cardigan Bay a few times in recent years (Figures 44-47, 52-53), emphasising the need to further investigate prey availability in the area. A record of underweight dolphins should be kept in future surveys, and those individuals identified as underweight since 2011 should be monitored further.

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

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

Sea Watch Foundation has been monitoring bottlenose dolphins using standardised procedures for the past 13 years. However, in order to provide a robust assessment of the status of bottlenose dolphins in the SACs and in the wider Cardigan Bay, long-term monitoring with consistent effort and coverage is required. Due to lack of resources, there have been some years with little survey coverage and no overall abundance estimates could be calculated, thus providing some gaps in our knowledge. Furthermore, the focus in the earlier years was Cardigan Bay SAC and so we have a longer series of estimates than from Pen Llŷn a'r Sarnau SAC, whilst areas outside these SACs have only started to be surveyed in 2011 with this current contract. Despite this, some educated judgements can be made regarding abundance estimates for Cardigan Bay SAC and, at the present time, for the whole of Cardigan Bay. Examination of the longest dataset we have, which is for Cardigan Bay SAC, using both line-transect and photo ID data, suggest numbers have decreased since 2006.

The apparent contradiction between the numbers calculated in 2012 from line-transect surveys and those from Photo ID in Cardigan Bay SAC, may be due to the different measures they make. Line-transect surveys estimate the average densities and hence abundance of the area being systematically surveyed. Photo ID, applying mark-recapture, provides an estimate of the number of individuals using the study area during the period of data collection. Some individuals may use the area regularly whereas others may do so only infrequently. If some individuals use the area less, the line-transect abundance estimate may not be affected but the mark-recapture estimate could be. This may be what occurred during 2012, and some of the additional information from the Photo ID effort supports that. However, estimates for 2013 present a decline in population estimates from both Photo ID and line-transect analyses, suggesting this may reflect a true trend. Further monitoring efforts will elucidate whether or not this inference is correct.

When comparing estimates for the entire Bay, no real trend can be seen through the Mark-Recapture open population model analysis. However, the closed population model shows a clear decline since 2009, reaching a low estimate of 205 individuals in 2013. It is difficult to evaluate trends for the entire Bay from line-transect surveys as only three years of line-transects have taken place throughout the Bay, including Pen Llŷn a'r Sarnau SAC. In addition, line-transect surveys commenced late in the season in 2011, and did not include as full a spatial coverage of the region. However, the low population estimate in 2013 is reason for some concern. Taking all these aspects into consideration, it is clear that some movement of individuals between the SAC and other parts of the Bay is occurring, and some of these

appear to be longer lasting such that some animals may not be seen within the SAC in a particular year. This is supported further by very high emigration rates in 2013 along with high percentages of animals apparently staying outside of the SAC.

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

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

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

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

A further weakness is that in order to obtain precise abundance estimates with low CVs, unless the animals are very abundant a high volume of effort must be conducted. The Welsh weather conditions often leave fewer opportunities for surveys than recommended. Therefore, a full field season is necessary in order to achieve the required volume of effort. For this reason, for example, the recruitment of volunteers for the 2012 field season was extended to include most of April and all of October, in the hope that funding for line-transects would allow SWF to begin surveys in spring. However, 2012 was an exceptionally bad year in terms

of weather, and although we were able to cover all the inshore transects of the study area, there was lower effort offshore than we desired. There is also a limit to how much one can extend the field season because the majority of the Cardigan Bay bottlenose dolphin population usually only returns to the Bay sometime in April, and may then depart again in October. The summer of 2013 enabled excellent coverage of the area. This was mainly due to very good weather and the coverage of the extended transects in the offshore area of the Llŷn Peninsula on board *Pedryn*. The outer transects of Cardigan Bay SAC should be surveyed more, although a faster vessel is needed to cover this area.

As noted above, line-transect surveys are the standard method for calculating abundance of harbour porpoise, and indeed the only technique available to provide robust estimates for the species. We believe that the harbour porpoise estimates obtained here represent an accurate picture of the status of this species. We continue to work to minimise the CVs for a more precise abundance estimate, ideally to achieve CV values of 15-20%. For relatively small areas like Cardigan Bay, that is challenging. Nevertheless, the CV around the harbour porpoise abundance estimate from the SCANS II survey conducted across all NW European waters was in fact the same as ours in 2012 and 2013, at 20%.

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

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

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

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

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10. Appendices

Appendix 1: Student Projects – Thesis Abstracts

During the course of the last three years, Sea Watch has supervised a number of student projects to address various aspects of the biology and ecology of Welsh cetaceans, particularly bottlenose dolphin. The abstracts of these theses are presented below. The full theses are available through the library of the university at which the student was based, or can be provided on request from Sea Watch Foundation. They are organised here by year.

2011:

Coomber, F.G. (2011) An investigation into the environmental determinants of harbour porpoise (*Phocoena phocoena*) distribution using an inter-annual predictive habitat model within West Welsh waters: with respect to SAC implementation. MSc thesis, University of Bangor Wales

Marine mammals are highly mobile species with extensive geographical ranges, often cryptic and problematic to study. This presents inherent issues for their conservation and protection. Habitat niche models are being used progressively as a tool in the science of ecology and for conservation management, to infer a species' potential distribution and suitable habitat from the relationship between environmental variables and the species known distribution. This project utilised an existing dataset of cetacean sightings in the Irish Sea, to identify areas of high sighting rates and suitable habitat for the harbour porpoise (HP: *Phocoena phocoena*) within West Welsh waters, taking into consideration any spatial and temporal variations that were identified. The findings may be used to suggest possible areas for HP protection in order to fulfil the Natura 2000 agreement. Quality control measures were applied to the raw data to generate a comparable homogeneous dataset of effort and associated sighting which, could be used as the response variables within a model. A range of environmental predictor variables were sourced with known implications on HP distribution. Both sets of data were entered into a habitat niche model to create predictions of suitable habitat, taking into account temporal variations. It was found that throughout the entire survey area and temporal scale of the project that HP sighting rates were relatively uniform. However, the spatial distribution of HP within the survey area was not, with areas of high and low sighting rates. These areas coincided with the model predictions of suitable habitat probabilities. However, inter-annual variations in habitat predictions occurred, with some areas having continuous high probability between the years, whilst others varied dramatically. The important environmental variables found to be determining habitat suitability were Chlorophyll a, depth and tidal current. These determinants act as proxies for HP prey items and may work in unison to generate fine scale habitats that aggregate prey, improving HP foraging abilities. Areas found to be important, in respect to high sighting rates, continuous presence and habitat for the HP, were around the Llŷn Peninsula, Bardsey Island, Skoma Island, Cardigan and Newport. Much of this area is already protected by Special Areas of Conservation (SACs), except for the area around Newport estuary and it is therefore an ideal candidate for the implementation of a new SAC.

Salkeld, A. (2011) Environmental Determinants Effecting Minke Whale *Balaenoptera acutorostrata*, Short-beaked Common Dolphin *Delphinus delphis* and Risso's Dolphin *Grampus griseus* Distribution Patterns in the Irish Sea, St George's Channel and Celtic Deep. MSc thesis, University of Cumbria

The Irish Sea, St. George's Channel and Celtic Deep are important areas for cetacean populations in UK waters, particularly the common bottlenose dolphin *Tursiops truncatus* and the harbour porpoise *Phocoena phocoena*, however there has been significantly less research carried out on the short-beaked common dolphin *Delphinus delphis*, Risso's dolphin *Grampus griseus*, and the North Atlantic common minke whale *Balaenoptera acutorostrata acutorostrata*, which also occupy this area. In order to better conserve our cetaceans, we first must increase our knowledge of their basic habitat requirements and distributions and those factors influencing them. Geographic Information Systems were used to investigate a variety of environmental variables including depth, slope, aspect, sediment type, benthic community, sea surface temperature (SST) and chlorophyll concentration (CHL-a), which were then analysed for correlations and relationships between those and encounter frequencies for common dolphins, Risso's dolphins and minke whales within the study area. Significant relationships were found between some of the fixed environmental variables, however it was identified that it is not these variables alone that influence distributions and encounter frequencies of the species in question. Further studies should be carried out to identify the significance of prey availability on cetacean distributions in the area.

2012:

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

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

Sado Estuary. Future studies should focus on more conclusively determining the reasons behind the existing variation between these four populations of bottlenose dolphins.

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

Due to their coastal habitat and curious nature, grey seals (*Halichoerus grypus*) are often subject to anthropogenic disturbance from boat users and pedestrians. This can have many negative impacts upon the species, such as reducing the time they are able to spend resting and changing their haul-out patterns. Disturbance has been shown to be extremely detrimental during the breeding season, as it may interrupt lactation or cause separation of the mother and pup. This study examined the behaviour of grey seals whilst in the water and hauled-out, in order to gain a full picture of how the seals are impacted by boat disturbance. Observations were made at two sites on the Isle of Man, one that was subject to large amounts of boat disturbance, whilst the other received minimal disturbance. In--water surveys involved focal follows of individual seals in order to construct behavioural budgets, and to record the responses of focal seals to boat disturbance. Haul-out surveys were conducted to record general count data, levels of vigilance and response to disturbance. The proportion of time that seals in the water spent 'bottling,' (a form of rest at the surface of the water) was found to be significantly different between sites (U = 8.000, p = 0.04). On the other hand, the overall time spent resting was similar. A significant correlation was found between boat speed and the distance at which hauled seals showed alert behaviour ($X2$(14) = 0.55, p = 0.04). There also appeared to be a similar association between boat speed and movement and flushing response (entering the water), but this was not tested due to small sample size. The duration of the boat interaction was found to be important, with flushing occurring in all interactions lasting four minutes or longer. Due to unusually poor weather during the study, seals at the disturbance site were not subject to as high a level of boat traffic as is normal. However, boat disturbance would likely be much higher during good weather, and this location is close to a breeding site where seals are particularly vulnerable. Therefore stricter enforcement is needed to protect seals from the effects of disturbance.

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

The Lagrangian photo-identification technique has been used exclusively to monitor the Cardigan Bay *Tursiops truncatus* population since 1986. However, understanding of natural range and distribution of the population is limited. Improved spatiotemporal coverage via the unification of existing photo-ID catalogues was analysed in order to improve understanding and to determine the suitability of the current monitoring programme. Photographs were cross-matched by eye, with any probable matches confirmed or rejected by an experienced second reader. Individual recapture rates, defined as the number of years out of all years with survey effort that an individual was positively sighted, disappearance rate and mortality rate were calculated. A high matching success rate between Cardigan Bay catalogues and between these and the Isle of Man catalogue was found. No matches between the Cardigan Bay/Isle of Man and Hebridean catalogue were made. Certain individuals were found to exhibit 15 to 20

year site fidelity to southern Cardigan Bay. The effect of markedness on recapture rate was found to be significant, biasing results towards well-marked individuals. Photo quality was highly variable. A minimum average disappearance rate of 3.37% and a minimum average mortality rate of 2.44% was calculated. Mortality rates are concurrent with existing literature. The population is likely closed, and its range probably encompasses the entire Irish Sea. It is suggested that although southern Cardigan Bay, Anglesey and the Isle of Man do constitute seasonally important habitats, existing conclusions on range and distribution are likely artefacts of spatiotemporally limited survey effort and biased analyses. Future work must strive to improve coverage, employing a more multi-faceted monitoring approach where possible.

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

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

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

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

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

Razorbills *Alca torda* have experienced recent localised population declines with repeated breeding failure due to food shortage. An improved understanding of foraging behaviour would facilitate the implementation of appropriate at-sea protection measures. Using miniature GPS loggers, this study aimed to describe the foraging behaviour of breeding razorbills from two North Welsh colonies: Bardsey Island (2011) and Puffin Island (2011 and 2012). The study tested for inter-colony and inter-annual differences in maximum and total foraging trip distance and trip duration (using a GLM) and trip timing (using $\chi 2$-tests), and applied a fixed-kernel analysis to determine the 95% home-range and 50% core foraging areas, relating the latter to environmental parameters. Birds from Bardsey and Puffin Island travelled up to c. 40 and 60km from the colony, respectively. Overall, both colonies/years showed similar patterns with mean values of c. 13km maximum distance, 37km total distance

and 6h trip duration. However, when diurnal and nocturnal trips were analysed separately, a significant colony difference was found, with birds from Bardsey having longer distance diurnal trips, and shorter nocturnal trips. In both years/colonies, diurnal trips occurred between sunrise and sunset, whilst nocturnal trips revealed a significant diel pattern, probably representing crepuscular foraging. At Bardsey, the home-range extended in a south-western direction, with core foraging areas located c. 10-20km SW of the colony. At Puffin Island, the overall home-range extended NW of the colony, with core foraging areas located around Puffin Island and along the E/NE Anglesey coast. However, diurnal and nocturnal home-ranges and foraging areas differed substantially at both colonies, with diurnal foraging areas mainly over sandy substrates. In both years at Puffin Island, the diurnal foraging areas occurred in much shallower waters (<20m) than in nocturnal foraging areas (≤80m depth), whereas at Bardsey, both diurnal and nocturnal foraging areas occurred in waters of 50-100m deep.

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

The bottlenose dolphin is a widespread, iconic species and as such is protected by law throughout Europe. Cardigan Bay in Wales has two areas designated for the protection of the bottlenose dolphin. Legislation protecting the bottlenose dolphin requires Governments to ensure factors that may adversely affect populations are limited. With respect to the bottlenose dolphins of Cardigan Bay, this factor is likely to be disturbance. Boat disturbance within Cardigan Bay has been steadily increasing due to increases in the number of recreational boats used and wildlife watching trips taken. Studies show that boat disturbance can negatively impact bottlenose dolphins, with responses ranging from moderate changes in behavior to the avoidance of preferred habitats. This study focuses on the effect of disturbance on dolphin community structure, community structure being important to increasing an individuals' fitness. Additionally, it examined the effectiveness of current management plans in decreasing the possible effects of disturbance. Cardigan Bay was split into areas of regulated and unregulated high vessel traffic and areas of low vessel traffic. The results strongly indicate that vessel traffic does impact community structure. Group size was significantly smaller in areas of high vessel traffic and results suggested individuals in high vessel traffic areas form many moderately strong bonds with many other individuals, whereas those in areas of low vessel traffic formed very strong bonds with a small number of individuals. Very similar values between areas of regulated and unregulated vessel traffic indicate that the current management plan is not being effective in reducing all of the impacts of disturbance on the dolphin population. This study recommends the continued monitoring of Cardigan Bay to increase the understanding of how disturbance may affect the bottlenose dolphins and to allow an effective management plan to be put in place.

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

Knowledge of the spatial distribution of marine fish species is an important tool for the development of fisheries management plans. An example of the implementation of such management is the development of marine protected areas. Habitat suitability of species is a

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

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

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

2013:

Baylis, A. (2013) An investigation of the relationship between reproductive success and home range of the bottlenose dolphin (*Tursiops truncatus*) in Cardigan Bay, West Wales. MSc thesis, University of Bangor Wales

Although previous analysis of bottlenose dolphin (*Tursiops truncatus*) home range has been undertaken, few studies have investigated individual variation in home range patterns within a population. The aim of this study was to investigate the home ranges of individual bottlenose dolphins in relation to reproductive success to inform the management of Cardigan Bay, West Wales for the conservation of the species. This was done through the analysis of photo-identification data collected on boat-based surveys from 2001 to 2012. Minimum convex polygon and kernel density estimation maps of home range and core area were created for individuals and groups. Home range and core area results for the comparison of males and females (based on 2,200 sightings of 75 females and 608 sightings of 18 males) showed no statistically significant difference. Based on means, male range areas were slightly larger than females (16,420 km^2 versus 15,270 km^2). Based on data from 2001 to 2012, 22 females were selected for home range analysis of sightings of individual females with a calf compared with the same females in those years without a calf. Home range and core area comparisons between these two categories did not show statistically significant differences. The 22 selected females were then divided into subgroups for the following comparisons of reproductive success measurements: high versus low calf production, high versus low calf survival, and long versus short inter-birth interval. Based on these comparisons, the results suggest that females tend to use a smaller home range area and core area if characterised by one or more of the following attributes: a high calf production rate, a high calf survival rate, and a short inter-birth interval. These results indicate a correlation between home range and reproductive success. Change in home range and core area size was analysed for the overall population over the course of the study period, based on sightings of 75 identified females and 18 identified males. The three estimation techniques indicated a similar trend in area size, but in no clear-cut direction. The findings of this study should help inform management plans and research objectives for the Welsh bottlenose dolphin population and for the species as a whole.

Appendix 2: Primary Observer Sighting Form

Entered into PC   Checked by ____________

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

Sight #	**Time** (hh.mm)	**Lat** (min.sec)	**Long** (min.sec)	**Effort type**	**An. Ang** (deg)	**Boat course** (deg)	**Dist** (m)	**Species**		**Tot num**	**A**	**J**	**C**	**NB**	**Cue**	**Beh** / **Dir**	**Reac. to Boat**		**Seen by**
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	

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

Appendix 3: Independent Observer Sighting Form

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

IO #	**Time** (hh.mm)	**Lat** (min.sec)	**Long** (min.sec)	**An.Ang.** (deg)	**Boat course** (deg)	**Dist(m)**	**Species**		**Ind. #**	**Cue**	**Effort type**		**Seen by prim.platform?**		**If yes, sighting #**	**Seen by**	**Comments**
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			

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

Appendix 4: Effort Form

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

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

Time hh.mm	**Lat.** (min.sec)	**Long.** (min.sec)	**Transect**	**Leg num.**	**Tran. point**	**Boat act.**	**Speed** knots	**Course** Deg.	**Glare** degrees	**Effort type**		**Precipitation**				**Visibility** (km)	**Sea state**		**Sigh. ref.**	**Comments**
												Type		**Int.**			B	S		
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW LT	DS ID	N F	R	I C	L M H	<1 1-5 6-10 >10				

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

a. Data Archive Appendix

Data outputs associated with this project are archived as project 441, media 1481 on server–based storage at Natural Resources Wales.

The data archive contains:

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

[B] Photo ID images taken while conducting NRW funded surveys in .JPG format

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

[D] GPS tracks in .XLS format (projection WGS 84) for above

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://194.83.155.90/olibcgi by searching 'Dataset Titles'. The metadata is held as record no 115169

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