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Abundance and Life History Parameters of Bottlenose Dolphin in Cardigan Bay: Monitoring 2005-2007

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Crynodeb Gweithredol

Mae'r adroddiad hwn yn crynhoi'r gwaith ymchwil a wnaed gan y Sea Watch Foundation ym Mae Ceredigion yn ystod y cyfnod Ebrill 2005-Rhagfyr 2007, ar ran Cyngor Cefn Gwlad Cymru, er mwyn cyflawni contract monitor ar gyfer ymchwilio i baramedrau hanes bywyd ac amlder y dolffiniaid trwynbwl. Mae mwy na hanner cant o wirfoddolwyr tymor hir wedi gweithio gyda gweithwyr Sea Watch am dair blynedd erbyn hyn, ynghyd â thri ar ddeg o fyfyrwyr Gradd Meistr neu BSc. Yn ogystal â'r hyfforddiant uwch a gafodd pob un o'r rhain, mae hyn yn adnodd gyda gwerth ychwanegol o'r radd flaenaf i'r prosiect yr ydym yn ei gydnabod gyda diolch. Mae traethodau ymchwil y myfyrwyr wedi ymdrin ag amrywiaeth fawr o destunau na fyddai'r unigolyn a gyflogir yn Swyddog Monitro o dan y contract hwn wedi gallu ymdrin â hwy ar ei ben ei hun.

Prif nod y prosiect oedd amcangyfrif amlder y dolffiniaid trwynbwl, eu heldir a'u dosbarthiad, strwythur a deinameg eu poblogaeth, heldiroedd cartref, y modd y maent yn defnyddio eu cynefin a'r modd y mae gweithgareddau dyn yn aflonyddu arnynt, gan ddefnyddio arolygon ar gwch, ar dir, o'r awyr ac acwstig ac adnabod trwy dynnu lluniau; casglwyd data hefyd ar lamhidyddion yr harbwr a morloi llwyd, yn ogystal ag ar gyfer rhywogaethau morfilaidd eraill a ymwelodd yn achlysurol â'r Bae.

Ar hyn o bryd, mae'n rhy fuan i asesu a oes gan y dolffiniaid trwynbwl a llamhidyddion yr harbwr Statws Cadwraeth Ffafriol. Mae hyn yn gofyn mwy na chwe blynedd o fonitro a byddai o leiaf deng mlynedd yn well.

Mae adnabod dolffiniaid trwynbwl trwy dynnu lluniau ger arfordir Ynys Môn yn ystod 2007-08 wedi amlygu o leiaf 75 o unigolion y tynnwyd eu lluniau o'r blaen ym Mae Ceredigion. Mae'r canfyddiadau hyn yn cadarnhau nad yw Bae Ceredigion yn cynnwys heldir daearyddol cyfan y boblogaeth hon, ond ei fod yn cynnwys yn ôl pob tebyg holl arfordiroedd Gorllewin a Gogledd Cymru ac efallai holl Fôr Iwerddon.

Wedi gweld bod y dolffiniaid trwynbwl yn ymestyn yn llawer pellach na Bae Ceredigion, mae angen ystyried nawr y dylanwadau a allai fod mewn mannau eraill. Ger glannau Gogledd Cymru tuag at Fae Lerpwl yn y dwyrain, mae'n debygol bod difwynyddion yn llawer mwy pwysig, a bod chwaraeon dŵr yn llawer mwy cyffredin hefyd. Yn bellach o'r lan ym Môr Iwerddon, lle mae'r dystiolaeth ragarweiniol yn awgrymu bod dolffiniaid trwynbwl yno'n rheolaidd yn y gaeaf, mae gweithgareddau eraill fel pysgota gyda rhwydi a chwilio am olew a nwy wedi bod yn digwydd yn y blynyddoedd diweddar.

Mae'r datblygiadau a allai ddigwydd yn y dyfodol yn cynnwys arolygon seismig ac adeiladu safleoedd ar gyfer ynni adnewyddadwy oddi ar y lan, fel tyrbinau llanw a gwynt. Bydd angen monitro'n ofalus y modd y gallai'r rheini effeithio er mwyn gallu dilyn camau lliniaru lle bynnag y bydd eu hangen.

Cynhaliwyd saith deg chwech o arolygon drwy drawsraniadau llinell (a olygai deithio ychydig yn llai na 6,800 o gilometrau) yn ACA Bae Ceredigion yn ystod hafau 2005, 2006 a 2007, rhwng mis Ebrill a mis Hydref. O'r dadansoddiadau amlder, a waned gyda'r meddalwedd DISTANCE 5, cafwyd yr amcangyfrifon o 154, 206 a 109 o anifeiliaid ar gyfer dolffiniaid trwynbwl, a 107, 170, 214 ar gyfer llamhidyddion yr harbwr. Gwelwyd felly cynnydd ym maint poblogaeth y dolffiniaid trwynbwl yn y blynyddoedd 2005-07, o

gymharu ag amcangyfrifon blaenorol ar gyfer y cyfnod 2003-04 (140 o ddolffiniaid). Gwelwyd poblogaeth llamhidyddion yr harbwr yn lleihau ychydig bach o gymharu â'r blynyddoedd blaenorol (236 yn 2003 a 215 yn 2004), yna'n sefydlogi yn 2005-06, ac yn cynyddu yn 2007.

Gwnaed 438 o wibdeithiau *ad-libitum* trwy gyfnod yr astudiaeth. Trwy ddadansoddi dosbarthiad gofodol a dewisiadau cynefin y dolffiniaid, gwelwyd nad oedd yr anifeiliaid wedi eu dosbarthu ar hap, a bod yn well ganddynt i bob golwg ardaloedd penodol yn y Bae. Roedd y pellter o'r arfordir yn effeithio'n sylweddol ar y nifer a welwyd, a bod cynefin mor agos â 5 cilometr o'r arfordir yn well gan y dolffiniaid; roedd dŵr bas yn well ganddynt hefyd (dyfnder o 5-10 metr) a llethrau esmwyth. I bob golwg, mae'r ardal arfordirol gyfan, rhwng Aberaeron ac Aberteifi a ger Abergwaun, o bwys arbennig i'r dolffiniaid trwynbwl, yn enwedig trwyn Cei Newydd, Ynys Lochtyn, Mwnt, Pen Peles ac Aberporth. Gwelwyd gweithgarwch hefyd mewn mannau eraill fel Bae Tremadog ac o amgylch creigresi a banciau tywod Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn a bwi'r Patches. Fodd bynnag, amrywiodd y nifer a welwyd o flwyddyn i flwyddyn, yn enwedig yn 2006 a 2007 pan welwyd bod yr anifeiliaid yn ymestyn tros ardaloedd ehangach draw oddi wrth yr arfordir.

Mae arolygon trawsraniad llinell sy'n defnyddio'r fethodoleg DISTANCE yn cynnig amcangyfrif o nifer gyfartalog yr anifeiliaid sy'n defnyddio'r ardal a arolygir yn ystod cyfnod yr astudiaeth. Ar y llaw arall, mae Ffoto-Adnabod yn cynnig amcangyfrif o nifer yr anifeiliaid unigol gwahanol sy'n dod i mewn i ardal yr astudiaeth yn ystod y cyfnod. Mae'n cynnig felly amcangyfrif annibynnol a fydd ychydig yn fwy oherwydd ei bod yn debygol y bydd gwahanol anifeiliaid yn dod i mewn i'r ardal ar wahanol adegau.

Defnyddiwyd Ffoto-Adnabod lle bynnag yr oedd modd yn ystod y gwibdeithiau, a thrwy hynny daethpwyd o hyd i 189 o ddolffiniaid newydd, a chynyddu ein catalog i gyfanswm o 197 o anifeiliaid gyda marc arnynt, 103 o rai ochr dde a 100 o rai ochr chwith. Ac ystyried bod marciau ar gyfartaledd o 58% o boblogaeth y dolffiniaid trwynbwl, yr amcangyfrif cyffredinol felly ar gyfer Bae Ceredigion mewn unrhyw flwyddyn benodol yw 133 o anifeiliaid yn 2005, 179 yn 2006, a 198 yn 2007, ond 328 wrth ystyried y cyfnod cyfan 2001-07. Trwy ddefnyddio'r rhaglen MARK-CAPTURE a'r model poblogaeth gaeedig, mae'r amcangyfrifon amlder yn ystod y cyfnod 2001-07 yn dangos bod rhwng 121 a 210 o ddolffiniaid trwynbwl wedi defnyddio ACA Bae Ceredigion mewn unrhyw flwyddyn, a 379 yn ystod y cyfnod cyfan. Os defnyddir model poblogaeth agored gan ystyried Bae Ceredigion yn gyfan, mae'r amcangyfrifon mewn blwyddyn benodol yn amrywio rhwng 154 a 248. Mae pob un o'r tri dull o weithredu yn dangos mai hon yw'r boblogaeth fwyaf o ddolffiniaid trwynbwl yn Ynysoedd Prydain.

Mae'r nifer o weithiau y gwelwyd unigolion ar eu pen eu hunain a pha mor aml y gwelwyd hwy eto, ynghyd â thuedd y gromlin darganfod yn awgrymu mai dim ond rhan o boblogaeth y dolffiniaid sy'n aros yn y safle ac yn cael eu gweld dro ar ôl tro. Mae'n debyg y gellid disgrifio poblogaeth y Bae yn well fel cyfuniad o anifeiliaid dros dro, ymwelwyr achlysurol ac anifeiliaid preswyl.

Cynhaliwyd arolygon o'r awyr yn y gaeaf am y tro cyntaf ar hyd Bae Ceredigion (cyfanswm o dri). I bob golwg, roedd y gwibdeithiau hyn, er eu bod yn rhagarweiniol, yn cadarnhau bod dolffiniaid trwynbwl wedi eu dosbarthu draw oddi wrth y lan yn y gaeaf. Roedd data acwstig T-POD a gasglwyd o ddeg o safleoedd arfordirol yn dangos yn glir bod uchafbwynt tymhorol pendant yn yr haf ac nad oedd dolffiniaid i'w gweld yn aml yn

y gaeaf heblaw ger y ffatri bysgod yn y Cei Newydd, ond bod llamhidyddion yr harbwr i'w gweld gydol y flwyddyn gydag ychydig o uchafbwynt yn y gaeaf.

Cofnodwyd geni rhwng 13 ac 20 o loi dolffiniaid trwynbwl pob blwyddyn rhwng 2005-07 yn ACA Bae Ceredigion. O'r amcangyfrifon poblogaeth, mae hyn yn cynnig cyfradd enedigaethau gyda chyfartaledd bras o 0.104 ar gyfer y tair blynedd.

Ychydig o wybodaeth sydd eto am strwythur y boblogaeth, ac mae'n dibynnu ar hyn o bryd ar dystiolaeth ffoto-adnabod. Ni welwyd hyd yma unrhyw gydweddu gyda'r dolffiniaid trwynbwl y tynnwyd eu lluniau y tu allan i Fôr Iwerddon. Ym mhoblogaeth Bae Ceredigion, mae rhai unigolion i'w gweld yn cyflawni swyddogaethau canolog yn ei threfn gymdeithasol, gyda chysylltiadau perthynas gyda llawer o unigolion eraill, tra bod eraill sy'n ymwneud â nifer fach yn unig o unigolion eraill. Mae gan yr wybodaeth hon oblygiadau pwysig o ran rheoli cadwraeth oherwydd y gallai tynnu unigolion allweddol allan o'r boblogaeth greu goblygiadau pellgyrhaeddol ar gyfer ei strwythur cymdeithasol a rhannu gwybodaeth a phrofiad rhwng grwpiau.

Nid darganfod tueddiadau ym maint a dosbarthiad y boblogaeth yw unig swyddogaeth monitro, ond mae'n fodd hefyd i ddarganfod achosion unrhyw dueddiadau a welir, ac yna os yw effaith y rhain yn negyddol, sefydlu mesurau lliniaru priodol. Mae hyn yn gofyn monitro gofalus ar weithgareddau anthropogenig. Ym mae Ceredigion, y prif weithgaredd dynol y gwelir y gallai ei effeithiau fod yn negyddol yw aflonyddu gan chwaraeon dŵr a gweithgareddau adloniadol eraill. Gwelwyd mai un o ganlyniadau hyn yw osgoad ymddygiadol tymor byr gan ddolffiniaid, ond hyd yma, mae'n rhy gynnar i wybod beth fydd yr effeithiau yn y tymor hir, wedi chwe blynedd yn unig o fonitro.

Defnyddiwyd sawl dull yn olynol i fonitro'r dolffiniaid trwynbwl (a llamhidyddion yr harbwr) ym Mae Ceredigion. Maent yn cynnwys arolwg trawsraniad llinell o gychod ar dir, ffoto-adnabod, acwstig, ac arsylwi o'r tir. Dewiswyd y rhain oherwydd bod gan bob un ei gryfderau arbennig ond rhai cyfyngiadau hefyd, a thrwy eu defnyddio gyda'i gilydd yn unig y gellid rhoi sylw i bob nodwedd sy'n ymwneud â pharamedrau hanes bywyd ac amlder. Defnyddir dadansoddiad pŵer i gadarnhau beth fyddai'r ymdrech leiaf gyda thrawsraniad llinell a'r nifer o weithiau y byddai'n rhaid gweld dolffiniaid trwynbwl a llamhidyddion yr harbwr er mwyn cael amcangyfrifon amlder gyda CV oddeutu 0.20 neu lai.

Cynigir argymhellion ynglŷn â sut i wella effeithiolrwydd y monitro, ar gyfer y ddwy rywogaeth, yn ogystal â sut i gasglu rhagor o wybodaeth ynghylch ecoleg porthiant, strwythur poblogaeth a pharamedrau hanes bywyd, y mae pob un ohonynt yn hanfodol ar gyfer asesu Statws Cadwraeth Ffafriol a darganfod y modd y gallai gweithgarwch dyn effeithio. Mae'r ffaith bod dosbarthiad ac amlder y dolffiniaid yn gallu amrywio o flwyddyn i flwyddyn yn dangos bod rhaid hefyd i ansawdd y cynefin fod yn amrywiol. Hyd yma, nid ydym yn gallu dod i gasgliad ynghylch achos y newidiadau penodol hyn.

Executive Summary

This report summarises the research work carried out by the Sea Watch Foundation in Cardigan Bay during the period April 2005-December 2007, on behalf of the Countryside Council for Wales, in fulfilment of a monitoring contract to investigate abundance and life history parameters of bottlenose dolphins. More than fifty long-term volunteers have worked with Sea Watch staff over the last three years, along with eleven Masters and two BSc students. Besides the higher-level training that all of these received, this represents an enormous value added resource to the project which we gratefully acknowledge. The student theses have covered a wide range of topics that would not have been possible for the one person employed under this contract as Monitoring Officer, to conduct on their own.

The project's main aim was to estimate the bottlenose dolphin abundance, range and distribution, population structure and dynamics, home ranges, habitat use and disturbance from human activities, using boat, land, aerial and acoustic surveys and photo-identification; data were also collected on harbour porpoises and grey seals, as well as for any other cetacean species that occasionally visited the Bay.

At present, it is premature to assess whether bottlenose dolphin and harbour porpoise are at Favourable Conservation Status. This requires a period of monitoring exceeding six years and preferably at least ten years.

Photo-identification of bottlenose dolphins off the coast of Anglesey during 2007-08 revealed at least 75 individuals previously photographed in Cardigan Bay. These findings confirm that Cardigan Bay does not include the full geographic range of this population, but likely includes all of the West and North Wales coasts and possibly even the entire Irish Sea.

Now that it is clear that bottlenose dolphins range much further than Cardigan Bay, it is necessary to consider potential impacts elsewhere. Off the North Wales coast eastwards towards Liverpool Bay, pollutants are likely to be of much greater significance, whilst water sports also occur more intensively. Offshore in the Irish Sea, where preliminary evidence suggests that bottlenose dolphins occur regularly in winter, other activities such as net fisheries and oil & gas exploration have taken place in recent years.

Future potential developments include seismic surveys and the construction of installations for offshore renewable energy, such as tidal and wind turbines. The effects that those may have will need careful monitoring so that mitigation measures can be taken where necessary.

Seventy-six line transect surveys (amounting to just under 6,800 km travelled) were carried out in the Cardigan Bay SAC during the summers of 2005, 2006 and 2007, from April to October. The abundance analyses, performed with the software DISTANCE 5, provided the estimates of 154, 206 and 109 animals for bottlenose dolphins, and 107, 170, 214 for harbour porpoises. An increase in the population size for the bottlenose dolphins was thus observed in the years 2005-07, compared to previous estimates for the period 2003-04 (140 dolphins). The harbour porpoise population showed a slight decline when compared with previous years (236 in 2003 and 215 in 2004), then stabilised in 2005-06, and showed an increase in 2007.

A total of 438 *ad-libitum* trips were carried out over the study period. Analysis of the spatial distribution and habitat preferences of the dolphins showed that the animals were not randomly distributed, apparently preferring particular areas within the Bay. Distance from coast had a significant effect on encounter rates, with the dolphins favouring habitat as close as 5 km from the coast; they also showed a preference for shallow waters (5-10 metres deep) and gentle slopes. The entire coastal area from Aberaeron to Cardigan and around Fishguard seems to be of particular significance to bottlenose dolphins, in particular 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 Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy. The encounter rates, however, showed yearly fluctuations, particularly in 2006 and 2007 when the animals were found to range over wider areas away from the coast.

Line transect surveys using DISTANCE methodology provide an estimate of the average number of animals using the surveyed area over the study period. Photo-identification, on the other hand, gives an estimate of the number of different individual animals entering the study area over the period. It thus provides an independent estimate that will be slightly higher since different animals are likely to enter the area at different times.

Photo-identification was conducted wherever possible during trips, leading to the identification of 189 new dolphins, and increasing our catalogue to a total of 197 marked animals, 103 right and 100 left ones. Taking account of the fact that an average of 58% of the bottlenose dolphin population are marked, the overall estimate for Cardigan Bay in any one year is therefore 133 animals in 2005, 179 in 2006, and 198 in 2007, but 328 when considering the entire 2001-07 period. Using the MARK-CAPTURE program and closed population model, the abundance estimates over the period 2001-07 indicate that between 121 and 210 bottlenose dolphins have used the Cardigan Bay SAC in any one year, and 379 over the whole period. If an open population model is used and the entire Cardigan Bay is considered, the estimates in a particular year vary between 154 and 248. All three approaches indicate that it is the largest coastal bottlenose dolphin population in the British Isles.

The number of times that single individuals were seen, and the frequency of re-sightings, together with the trend of the discovery curve, suggest that only part of the dolphin population exhibits a high degree of site fidelity and high re-sighting rates, and that the population of the Bay might be better described as a combination of transients, occasional visitors and resident animals.

For the first time, winter aerial surveys were performed along Cardigan Bay (a total of three). These trips, although preliminary, appeared to confirm an offshore distribution of the bottlenose dolphins during the winter. T-POD acoustic data collected from ten coastal sites also highlighted a strong seasonal peak in summer with dolphins rarely occurring over the winter months except near the fish factory at New Quay, whereas harbour porpoise occurred year-round with a slight winter peak.

Between 13 and 20 bottlenose dolphin calves have been recorded born annually between 2005-07 in Cardigan Bay SAC. From the population estimates, this provides a mean crude birth rate of 0.104 for the three years.

The population structure remains little known, and presently relies upon photo-identification evidence. No matches have yet been found with bottlenose dolphins

photographed outside the Irish Sea. Within the Cardigan Bay population, some individuals appear to play central roles in its social organisation, having association links to many other individuals, whereas there are others that associate with only a small number of other individuals. This information has important implications for conservation management since the removal of key individuals from the population could have far reaching implications on its social structure and the sharing of information and experience among groups.

The function of monitoring is not simply to determine trends in population size and distribution but to identify causes of any trends observed, and then if these are having a negative effect, to establish appropriate mitigation measures. This requires careful monitoring of anthropogenic activities. In Cardigan Bay, the main human activity identified that currently may have negative effects is disturbance from water sports and other recreational activities. This has been shown to result in short-term behavioural avoidance by dolphins, but as yet, it is too early to determine long-term effects after only six years of monitoring.

A suite of methods has been used to monitor bottlenose dolphins (and harbour porpoise) in Cardigan Bay. They include line transect survey by vessel and land, photo-identification, acoustics, and land-based observations. These were chosen because each has its particular strengths but also some limitations, and it was only by using them in combination that one could address all the attributes relating to abundance and life history parameters. A power analysis is used to determine the minimum amount of line transect effort and number of encounters needed for bottlenose dolphin and harbour porpoise in order to have abundance estimates with CVs of around 0.20 or less.

Recommendations are made as to how to improve the effectiveness of monitoring, for both species, as well as how to collect further information on foraging ecology, population structure, and life history parameters, all of which are essential for assessing Favourable Conservation Status and identifying the effects of potential impacts of human activities. The fact that dolphin distribution and abundance can vary from year indicates that habitat quality must also be variable. As yet, we are unable to infer what is the cause of these particular changes.

Introduction

The bottlenose dolphin, *Tursiops truncatus*, is a protected species of nature conservation importance and a feature of both the Cardigan Bay and Pen Llyn a'r Sarnau SACs. Both these SACs are situated within Cardigan Bay, West Wales. This 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). There is also a resident population in the Shannon Estuary, Ireland (Ingram and Rogan, 2002, 2003). In addition, small groups have been recorded regularly elsewhere in UK waters, including along the coasts of Cornwall, Devon and Dorset, in the waters around the Hebrides, as well as in offshore waters of the North-east Atlantic, Irish Sea and St. George's Channel (Evans *et al.*, 2003). Bottlenose dolphins from Cardigan Bay probably interact with animals in waters of southwest UK and southern Ireland, and are likely to be moving and exchanging with more distant populations. Dolphins using both SACs will be contributing to this wider population. It is unclear at present whether there is an exchange of individuals or genes between resident populations in UK and Irish waters (Parsons *et al*., 2002). For the purpose of this project, the bottlenose dolphins in Cardigan Bay are considered an isolated population.

Conservation Objectives

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 activities on the population in the SACs, are made. The UK's Common Standards Monitoring (CSM) programme led by the Joint Nature Conservation Committee (JNCC) requires monitoring of mandatory attributes in the SACs across Britain. For bottlenose dolphins the mandatory attribute is 'numbers of bottlenose dolphins using the SAC'. The conservation objectives for Cardigan Bay and Pen Llyn a'r Sarnau SACs relate to:

1) Population size – absolute and relative abundance,
2) Reproductive success - calf production and survival,
3) Population structure – age distribution, sex ratio and stock structure,
4) Physiological health – reproductive capability, immunity/exposure to disease,
5) Range and distribution – distribution throughout the sites and beyond,
6) Extent and accessibility of habitat – feeding, calving, and nursery habitat,
7) Structure, function and quality of supporting habitat,
8) Prey availability and quality,
9) Management of human activities – undisturbed/unhindered use & ecosystem/quality effects.

The "bottlenose dolphin" feature will be considered to be in favourable conservation status when:

Population Dynamics

(i) The number of bottlenose dolphins within the SAC is stable or increasing
(ii) The number of bottlenose dolphin calves produced in the SAC and beyond is sufficient to sustain the population
(iii) There is a balance between the relative proportions of immature, mature, male and female bottlenose dolphins within the SAC and beyond
(iv) The physiological health of bottlenose dolphins within the SAC is good

Natural Range

(v) The range of the bottlenose dolphin within the SAC and their contribution to the SW UK and Ireland population is not constrained or hindered

Supporting Habitat

(vi) There are appropriate and adequate food sources for the bottlenose dolphins within the SAC and beyond.
(vii) The amount of supporting habitat for the bottlenose dolphins is stable or increasing

Security of the Feature in the Long-term

(viii) The management of activities or operations likely to damage or degrade the distribution, extent, structure, function or typical species populations of the feature, is appropriate for maintaining favourable conservation status and is secure in the long-term.

Monitoring and Research

This report summarises the research work undertaken by the Sea Watch Foundation in Cardigan Bay during the period April 2005 - December 2007, under the name of (CCW Contract FC 73-02-323) "Abundance and Life History Parameters of Bottlenose Dolphin in Cardigan Bay: Monitoring 2005-2007", and builds upon previous work undertaken by the Sea Watch Foundation in the area (Baines *et al*., 2002; Ugarte and Evans, 2006). The project's main aim was to fulfil the CSM requirements for the bottlenose dolphin population of the Bay, collecting information on their abundance, range and distribution, population structure and dynamics, home ranges, habitat use and disturbance from human activities, using boat, land, aerial and acoustic surveys and photo-identification.

The project also opportunistically monitored the other marine mammals that inhabit the study area, notably the harbour porpoise (*Phocoena phocoena*) and grey seal (*Halichoerus grypus*), as well as any other cetacean species that occasionally visited the Bay.

Measurement of the total population size, as opposed to some measure of abundance of dolphins within the SACs requires a long-term study using line transect techniques, combined with photo-identification and 'mark-recapture'. Identifying a statistically significant change in total population size is extremely difficult and will take several years. However, total population size should become a more viable attribute for use in the future with greater understanding of the population.

For greater understanding, photo-ID eventually will need to be linked to wider transects of the entire Bay and beyond, operated over an appropriate time period, to look at range and habitat use.

Calf production and survival provide measures of the size and health of the bottlenose dolphin population, and reproductive capability, immunity and exposure to disease are additional indicators of health. Data on population structure, supporting habitat and disturbance provide additional management information.

Background Information on the Bottlenose Dolphins of Cardigan Bay

Population size

The number of individual bottlenose dolphins using Cardigan Bay and Pen Llyn a'r Sarnau SACs is a Common Standards Monitoring attribute for this species. Both sites are contained within Cardigan Bay where various abundance estimates, based on mark-recapture using photo-ID and line transects, including DISTANCE sampling, have been made. Most recent estimates using photo-ID measured the size of the population using Cardigan Bay SAC during the study at 215 individuals (95% CI: 179-290); and from line transects the mean abundance of animals in the SAC at 135 (95% CI: 84-214). The overall population size was estimated at 213 animals, while the abundance in the Cardigan Bay SAC was estimated at 135 animals, (Evans *et al*, 2002). This is very close to the estimate of 138 animals (Ugarte and Evans, 2006).

Photo-ID techniques are considered to be the most appropriate method for estimating changes in dolphin abundance over a wide area such as Cardigan Bay. Any photo-ID study will need to apply sufficient effort in any one year in order to calculate an independent estimate for abundance for that year, as the ultimate aim of the estimation should be the assessment of trends and the status of the population. The long term commitment required in order to detect change has been demonstrated through power analysis, e.g. to detect a change of +/- 5% per annum in the Moray Firth bottlenose dolphin population would take 11 years of repeat surveys (Wilson *et al*., 1999a).

Reproductive success

Reproductive rate is low, females producing a single calf every 2 to 5 years, following a gestation period of about one year, and pregnancy rates do not appear to decrease with age (Kasuya, *et al*., 1997; Wells and Scott, 1999, 2002). The strongest social bonds are between mothers and young calves during the suckling and weaning periods. Calves are weaned after about 18-20 months, but continue to associate strongly with the mother for three to six years until they leave to join mixed groups of other juveniles. Calving is known to have taken place within Cardigan Bay and newborn and very young calves can be found from May to September, suggesting a seasonal pattern to calving.

Population structure

Both population structure and sex ratio are poorly known. Bottlenose dolphins are long-lived: females can live more than 50 years and some males have reached 40-45 years (Wells and Scott, 1999, 2002). The level of basic information on population dynamics is low for the species as a whole since even in the case of long-term studies, populations have only been studied for a proportion of an individual's likely life, i.e. c. 15-25 years. It is extremely difficult to determine the size, age or sex of free-swimming dolphins. Most accounts indicate a sex ratio of 1:1 although there appears to be higher male mortality amongst juveniles, which can skew the sex ratio in favour of females (Wells and Scott, 1999). Any population modelling assumes an overall 1:1 sex ratio and a stable population

structure that is unlikely to be realistic, highlighting a major gap in our understanding (Thompson *et al*., 2004).

Physiological health

Photo-ID studies also provide an opportunity to study the epidemiology of skin lesions (Thompson and Hammond, 1992). It is possible that visual signs such as changes in behaviour or skin lesions may be indicators of health but no clear links have yet been established. There is a possibility that incidence of skin lesions is linked to environmental factors (low water temperature and low salinity) and contamination (Wilson, *et al*., 1999b). These authors reviewed photographs of animals in Cardigan Bay and found the incidence of lesions was no higher than expected. There is a great deal yet to learn about bottlenose dolphin behaviour. It is not understood why dolphins in Cardigan Bay and the Moray Firth kill harbour porpoise. Bottlenose dolphin infanticide has also been recorded in the Moray Firth (Patterson *et al*., 1998).

Strandings provide data on the occurrence and distribution of stranded dolphins, and post-mortem analysis provides information on patterns of mortality, disease and diet. This is an important baseline for detecting unusual mortality events, and the monitoring programme continues to add to a collection of biological samples that can provide additional data on the life history characteristics and foraging ecology of the population.

Range and distribution

A number of areas have been identified as important for bottlenose dolphins in West Wales. They are most commonly seen in Cardigan Bay within 10 miles of the coast and particularly within two miles, e.g. at New Quay, Aberporth, Mwnt, Cemaes Head and around the Teifi estuary, from April to October. A second area, in Tremadog Bay, where animals are recorded less frequently, occurs from Barmouth out to Sarn Badrig northward to the western end of the Llyn Peninsula around Bardsey Island. They are also seen in North Wales and in northern Pembrokeshire.

There is evidence for periodic range shifts that suggest that distribution patterns are more flexible than previously believed (see, for example, Moray Firth population - Thompson *et al*., 2004). As yet, there is no evidence of exchange of individuals or gene flow via females between these areas. Genetic studies so far have been based on mitochondrial markers that are maternally inherited and work is required, based on microsatellite or other DNA markers, to determine whether male-based dispersal is occurring. At present, DNA material from stranded animals shows that dolphins in the Moray Firth are genetically more closely related to the Welsh population and those stranded along the southern coast of England than to individuals visiting the Scottish Western Isles (Parsons *et al*., 2002), indicating that there may be two or more ecotypes, with one occupying Atlantic waters, and one or more occurring in more coastal waters.

Extent and accessibility of habitat

There is anecdotal evidence that bottlenose dolphins are associated with sheltered conditions, taking advantage of the shallow coastal habitats of Cardigan Bay for calving, nursing and feeding. This observation may be due to improved sighting conditions compared with offshore or to a real change in the concentration of potential prey. Sea trout are concentrated in estuary mouths during settled weather, awaiting rivers levels to

rise after rainfall in order to make their way upriver. Shelter may be afforded to the bottlenose dolphins during stormy conditions in Cardigan Bay by small embayments such as New Quay, Ynys Lochtyn, Aberporth, Mwnt and in the Teifi Estuary.

Structure, function and quality of supporting habitat

Food resources appear to be a primary factor in determining movements and site fidelity in bottlenose dolphins. Several authors have noted that the species makes regular use of specific habitats within Cardigan Bay. Areas of strong tidal currents near headlands and estuaries are particularly favoured habitats, and behaviour interpreted as feeding is most frequently observed here. Prey is concentrated in these areas, and the local features may also play a role in aiding the capture of fish.

Prey availability and quality

Information on foraging ecology can be derived from behavioural studies and analysis of stomach contents of stranded individuals. Bottlenose dolphins are highly adaptable with respect to diet and feeding strategy and this has contributed to their success in diverse habitats. They are generalist and opportunistic feeders, and both observations and strandings records indicate they eat a wide range of fish, crustaceans and molluscs (Wells and Scott, 1999; Santos *et al.,* 2001). The animals forage widely and a decline in prey species in one area may not impact the population. In Cardigan Bay, bottlenose dolphin diet also appears to be varied and includes some commercially exploited species (Evans *et al*., 2000). The status of likely prey species and the degree to which the bottlenose dolphin population is limited by current prey availability, are generally unknown although there is no evidence to show that direct competition between marine mammal species and commercial fisheries has affected dolphin foraging rates (Grellier *et al*., 1995; CCC *et al*., 2001). On the other hand, stocks of particular fish species have been reduced significantly over the last 150 years as a result of commercial fishing operations.

Management of human activities

A summary of potential threats to the bottlenose dolphin population is given in Evans (1995) and Grellier *et al*. (1995), and factors that influence or may influence them are also described in the Cardigan Bay SAC Management Plan (CCC *et al.*, 2001). There are a wide variety of human activities taking place within and outside of the SACs that, depending on their location, timing and intensity and the way in which they are undertaken, may have the potential to cause disturbance and affect behaviour or survival of the features of the SAC and thereby affect the condition of the features and the favourable conservation status of the site. The areas of concern mostly relate to waterborne disturbance, artificial or toxic materials, and threat of vessel strikes.

Waterborne leisure, commercial and research activity boat traffic do cause disturbance. Bottlenose dolphins in Cardigan were observed to respond to approaching boats at a distance of 150-300 metres by making longer dives and moving away from the source of the sound, in a study using recordings of underwater sound (Evans *et al*., 1992). Although relatively quiet in terms of underwater noise, fast manoeuvrable craft such as jet skis were considered to have the potential to startle dolphins with their sudden approach, and place naïve young in some danger (Evans *et al*., 1992). Commercial wildlife-watching activities have increased in recent years, as have recreational activities. On the other hand, separation distances between bottlenose dolphins and passenger boats carrying visitors

were significantly greater after the introduction of a boat operator's code of conduct (Pierpoint and Allen, 2004). A code of conduct for researchers has also more recently been drawn up and should be adhered to, if disturbance to the animals is to be kept to a minimum.

The presence of artificial inert or toxic materials, e.g. synthetic plastics and fibres, hydrocarbons, etc, can cause not only pollution (through ingestion of toxic chemicals), but in a number of cases (notably discarded nets) can cause entanglement and incidental capture. There is little evidence to suggest that entanglement in fishing gear or the ingestion of marine debris is a major problem in Cardigan Bay, although isolated cases have occurred (e.g. the live minke whale that was found entangled in discarded fishing gear in summer 2003). Surveys conducted to assess the potential risk of marine mammal by-catch in Wales found no evidence to suggest that bottlenose dolphins are accidentally caught, although a number of harbour porpoises were reported, following the temporary introduction of tangle nets (Thomas, 1992, 2000). Collision is also a risk, although no cases have been reported, despite ferry routes between Holyhead and Dublin, and between Fishguard and Rosslare, using both traditional ferries and high-speed catamarans using water jet-drives. Physical damage to animals can also be caused by speed craft.

Aims and Objectives

1) To record, document, statistically analyse and report indicators of the condition of bottlenose dolphins in both the Cardigan Bay and Pen Llyn a'r Sarnau SACs.

2) To collect images and refer to those from established catalogues, at sites within and outside the key study areas, using photographic ID techniques, to evaluate dolphin movements, abundance estimates and distribution.

3) To monitor the number of bottlenose dolphins using the site and to assess the supporting habitat and estimate population structure (age and sex).

4) To gather evidence of any anthropogenic activities within the sites, while monitoring bottlenose dolphins.

A series of monitoring objectives have been set. Although some of these go beyond the scope of this particular contract, each will be considered and reviewed in this report. They are listed below under various subject headings:

Population Size & Trends

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

Population Structure

2) 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.
3) 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.

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

Population Distribution

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

Home Range Size and Use

6) Identify the home range sizes of individual identifiable animals, including determination of ranging movements and core areas.
7) 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.

Social Structure and Behaviour

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.

Anthropogenic Activities

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.
    - 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.

    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.

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.

Monitoring Methods

11) 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 above. Alternative sampling strategies should be explored.

The Study Area

Cardigan Bay is the biggest embayment in the British Isles, encompassing a total area of 4986.86 km^2 from the western tip of the Llyn Peninsula in the north (52° 47' 45'' N, 004° 46' 00'' W) to St David's Head in the south (51° 54' 10'' N, 005° 18' 54'' W, Fig. 1). It is a shallow bay, with waters nowhere deeper than 60 metres and very gentle slopes (Evans, 1995). The sea surface temperature fluctuates seasonally, ranging from a minimum of 5°C in February/March to a maximum of 16°C offshore and 20°C inshore in August/September (Evans, 1995; CCC *et al*., 2001). The salinity has seasonal fluctuations as well, which are related to freshwater inputs from rainfall, rivers and water masses from the Atlantic; it ranges from 34.2‰ in the summer to 33.3‰ in the winter (Evans, 1995). The Bay is exposed for 75% of the time to winds over Beaufort 3, coming largely from the west or southwest (Evans, 1995). The tides are semi-diurnal, the mean spring rate being around 4-5 metres. The tidal currents are generally lower than 3.3 km/h and flow northward during the flood phase, and south during the ebb phase. The substrate is strongly affected by the tidal current speed, consisting of gravel in the strong current zone, and mud where the water energy is low (Evans, 1995).

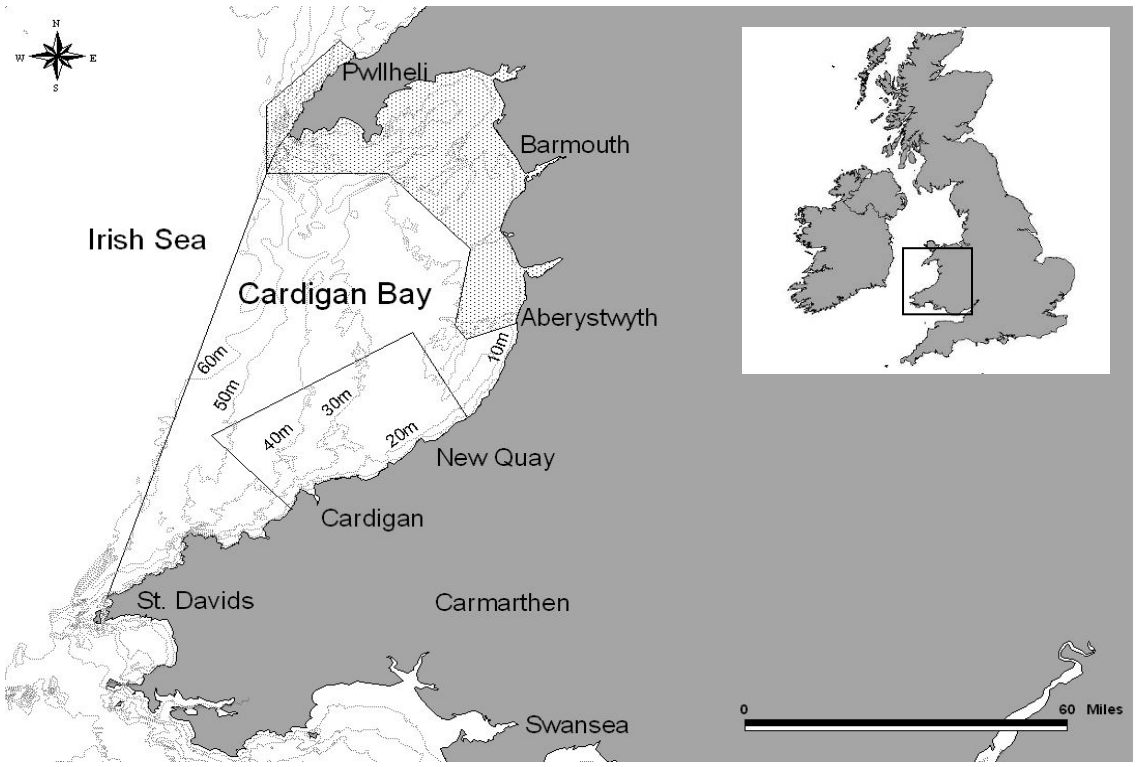


Figure 1. The study area: the diagonal line on the left delimits Cardigan Bay, the rectangle is the Cardigan Bay SAC, and the hatched polygon is the Pen Llyn a'r Sarnau SAC

In Wales, two Special Areas of Conservations (SACs) were proposed in 1996 for the protection of the bottlenose dolphin, an Annex II species (designated as candidates in 2001, with full status in 2004) under the 1992 EU Habitats and Species Directive. These were the Cardigan Bay SAC (CB SAC) and the Pen Llyn a'r Sarnau SAC (PL SAC). Research in 2005 was carried out mainly in the former, with only a few trips performed also in the latter SAC, but since 2006 the effort in the PL SAC has been much greater. Two surveys have also been undertaken south of the SACs in the southern end of the Bay. Absolute abundance estimates using line transect survey can only be applied to CB SAC since resources were not sufficient to use this approach in the PL SAC.

Part One: Boat based surveys

1) Distance-sampling line transect surveys in the Cardigan Bay Special Area of Conservation

Background

In order to estimate the number of bottlenose dolphins, harbour porpoises and grey seals inhabiting the Cardigan Bay SAC, distance-sampling line transect surveys were performed in the area. These types of surveys require a large effort in order to obtain reliable estimates. We calculated that at least 30 surveys each summer would be necessary for this purpose (Ugarte and Evans, 2006).

Methods

Research vessel The research vessel was a 9.7 metre long fibreglass motorboat, Dunbar Castle 2, which has an observer position eye height of 3.5 metres and a cruising speed of around 7-8 knots (Figure 2). In order to increase the survey effort, the trips were specifically dedicated to the research work and were totally independent of dolphin-watching tours, unlike most of the trips conducted on the motorboat Sulaire in the previous two years (2003-04).

Figure 2. Dunbar Castle 2, the boat used for the distance-sampling line transect surveys

Survey design In order to maximise sample size, a grid of systematically spaced lines was superimposed on the Cardigan Bay SAC. The SAC was also divided into two strata, inshore and offshore (Figure 3), since we already had information that the density of bottlenose dolphins in our study area is higher in near shore waters (Baines *et al.*, 2002). A line between the coordinates 52.15°N, 4.89°W and 52.33°N, 4.31°W delimited the boundary between strata. The outer limits of the inshore and offshore strata were at approximately 11 and 23 km from the coast, respectively.

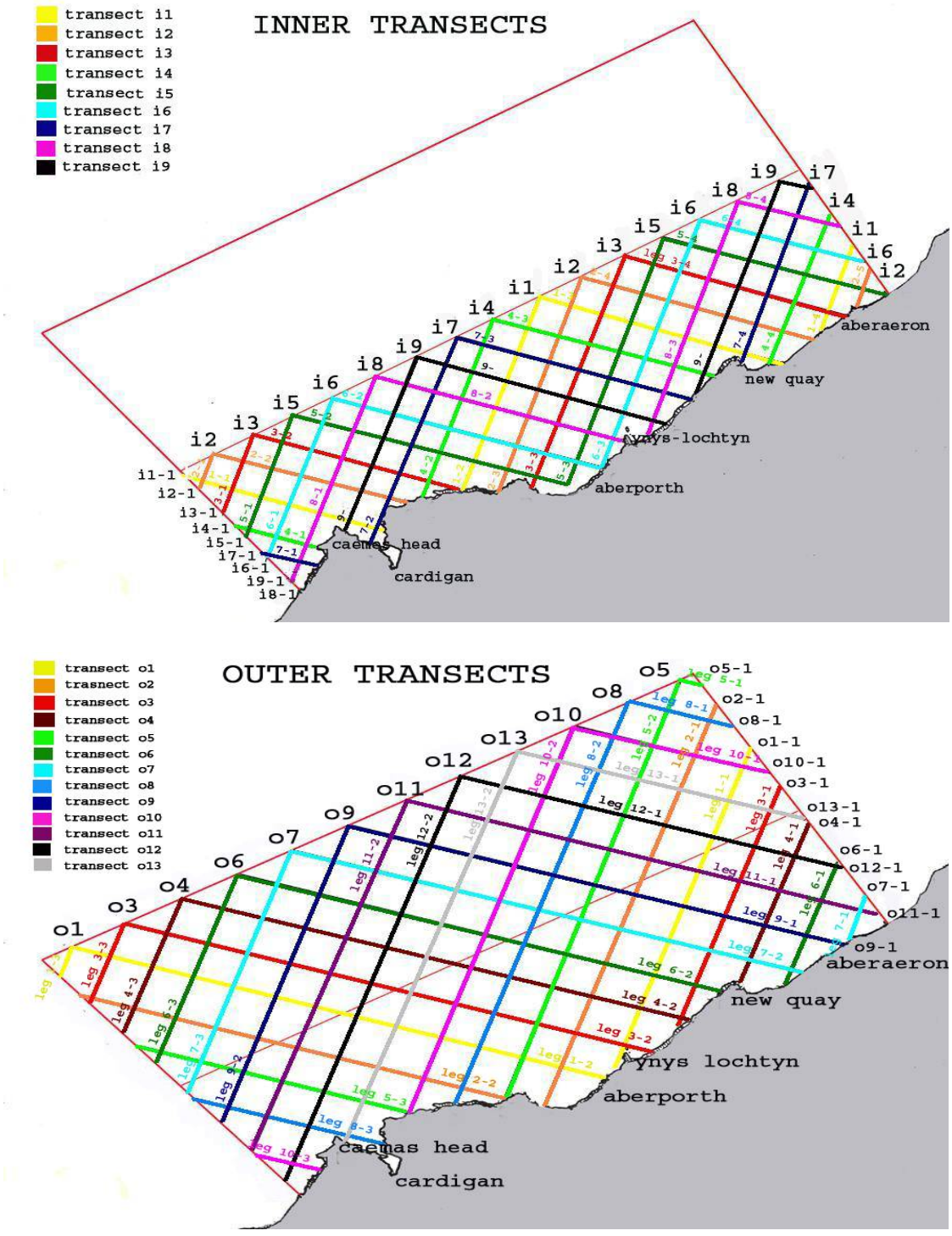


Figure 3. Inner and outer strata, with transect numbers, transect points and legs

Each stratum had some pre-defined routes called transects; each transect was divided into legs; each leg had a start and end point called "transect points".

Before leaving the harbour, a transect was selected at random, no matter whether it was an inner or an outer one. Once a transect had been chosen, it was put back into the hat so that, on each occasion, the transects were selected from the entire list (except for 2005, when the transects already covered were taken separately, in order to cover all the transects). This meant that some lines by chance were repeated more frequently than others. If time, weather or any other contingency did not allow us to complete the full extent of a transect during one day, this was interrupted halfway along the length, but it was resumed during the following survey.

Data collection The survey vessel traversed the pre-determined transect routes at a constant speed through the water of around 8 knots, resulting in a variable speed over ground, according to the strength and direction of the tidal flow. If for any reason, the vessel had to change course or speed, this was noted on the effort form, and the transect survey was temporarily suspended. Any movement off the transect line (for example to conduct photo-ID) was followed by a return to the point where the line was left, before resuming the transect.

The trips were conducted following a double platform method, with a minimum of five people onboard:

(a) Two primary observers (POs) positioned on a bench on the wheelhouse of Dunbar, who searched for animals from abeam (90°) on their side to 10°on the opposite side, changing sides (from port to starboard) every half an hour to help maintain concentration. Since the fundamental assumption of the line transect technique is that sightings on the track-line are not missed, the POs concentrated their effort along the track-line, rather then looking far away on either side. The POs looked with naked eye, and used binoculars only to check possible sightings or to identify the species. Their observations were recorded on a standardised "sighting form" (see Appendix 1).

(b) Two independent observers (IOs) stood at the back of Dunbar, constantly scanning the sea surface with binoculars. They concentrated their effort on the track line, looking from 45° on one side to 10° on the other. Unfortunately, the visibility directly along the track-line was reduced by Dunbar's wheelhouse, and so they were not able to view far ahead. The IOs recorded their sightings on an "independent observer form" (see Appendix 2), and sighting numbers were crossed linked with the POs ones. The IOs were trained not to inform the POs about any sighting they had and, in case of a group of mammals missed by the POs, to wait until the animals were abeam before informing the POs.

Both the POs and the IOs estimated and reported distance and angle to all groups of marine mammals observed, as well as other information. The distance was estimated by eye, but the observers had their estimations calibrated against objects of known range at regular intervals during the season. The angle to the sighting was calculated using an angle board, and rounding was avoided for both distance and angle.

At all times, at least one of the observers was an "experienced observer", meaning that he/she had previous experience observing and recognizing marine mammals and conducting line transect surveys. The experienced observer was responsible for estimating the distance to the animals.

(c) One person was responsible for recording the effort at 15-minute intervals or less on the "effort form" " (see Appendix 3). Any change in any of the variables collected (sea state, visibility, swell, transect point, end of leg, etc) was reported with a new line in the effort form even if 15 minutes had not passed. If nothing changed, then the effort was entered only every 15 minutes. During sightings, this person ensured that effort logs were maintained, switching to a photo-id mode. Four types of effort were considered and reported on the form: line transect, when following a predefined transect route with dedicated observers looking for marine mammals; dedicated search, with observers as in line transect mode, but the boat not following a transect route (e.g. in transit between transect tracks or to/from the home port); casual watch, with no dedicated observers looking for cetaceans (e.g. when sighting or weather conditions were bad or when the boat had to stop for any reason); photo-identification, when the boat followed bottlenose dolphin groups at close range.

When a dolphin encounter was made and conditions allowed photo-identification, the transect line was abandoned, the boat approached the animals and researchers concentrated upon photographing every member of the group, where possible from both left and right sides. Once confident that the group had been comprehensively photographed, but anyway not more then 40 minutes after the start of the sighting (following CCW's photo-identification licence guidelines, the boat returned to the point where the transect line was left, and resumed the transect (Figure 4).

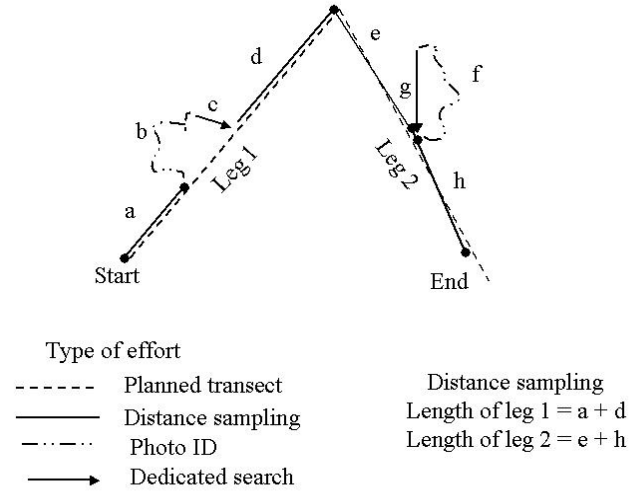


Figure 4. Schematic representation of two transect legs temporarily interrupted for photo-ID

Data analysis The effort and sightings were entered into the Sea Watch Foundation's national database (in Access). Perpendicular distances to the track line were estimated as the cosine of the angle multiplied by the distance from the boat to the animals sighted. The effort lines covered were plotted using ArcView 3.2, and the "CR tool" was used to measure the distance covered during each effort line. The length of each leg, together with the perpendicular distance, species and group size of each sighting associated with it, and the area of the corresponding stratum, were transferred into DISTANCE 4.1 software. Sightings further from the track-line than 500 metres in 2005-06 and 600 metres in 2007 for bottlenose dolphins, and 300 metres in all years for harbour porpoises, were considered outliers and truncated from further analyses. Abundance estimates were made using a half-normal model.

Results and Discussion

Seventy-six line transect surveys were conducted in the Cardigan Bay SAC during the summers of 2005-07, from April to October. Figure 5 shows the effort lines and Figure 6 the sightings position, for each year, while Tables 1 and 2 give effort and sightings details.

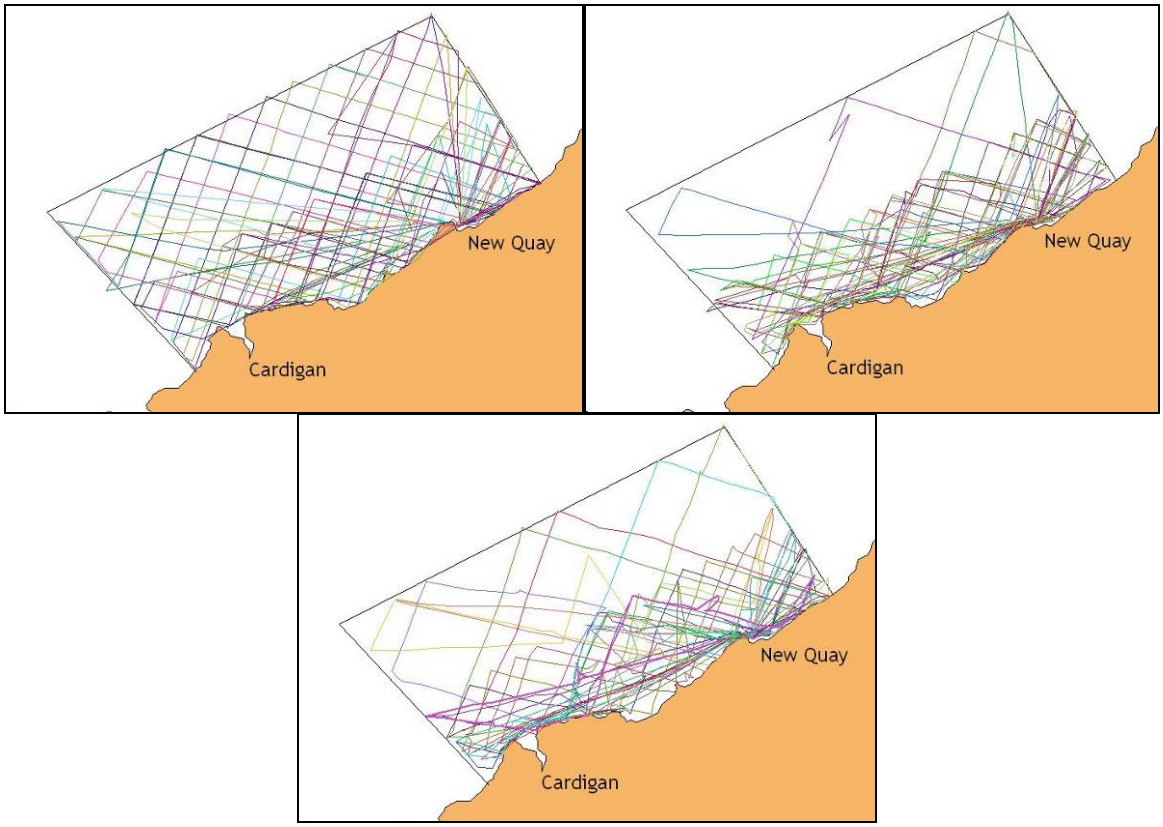
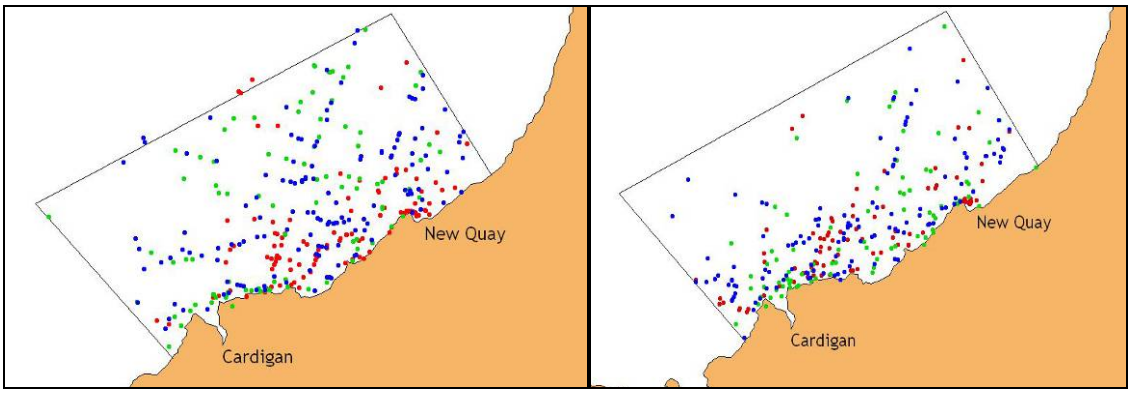


Figure 5. Effort lines covered during line transect surveys in 2005 (top left), 2006 (top right) and 2007 (bottom)



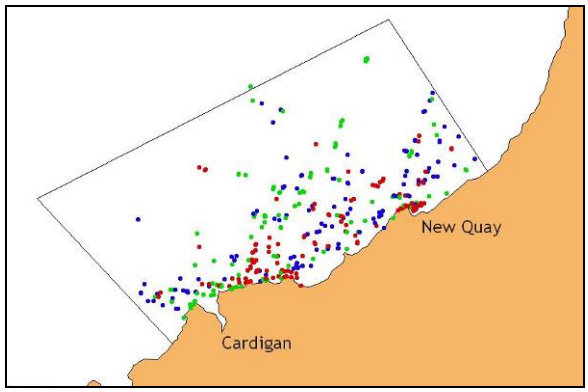


Figure 6. Sightings of bottlenose dolphins (red), harbour porpoises (blue) and grey seals (green) recorded during line transect surveys in 2005 (top left), 2006 (top right) and 2007 (bottom)

In 2005, the coverage of the SAC was more even, due to the different methodology applied when selecting transects, that aimed at covering all the transects available. However, since this distance-sampling theory requires that transects are chosen randomly and from the entire set of transects, the 2005 methodology was abandoned in the subsequent years, even if this meant uneven coverage of the area. In general, the outer stratum was surveyed with less effort then the inner one for two reasons, one intentional so as to cover the area with the highest sightings frequency for bottlenose dolphins (i.e. the inner stratum) in order to improve sample sizes and obtain more precise estimates; and the second, unintentional and caused by weather or time constraints.

It is clear that, at least during the summer, bottlenose dolphins have the tendency to inhabit more coastal waters, up to 8-9 km from the shore, while harbour porpoises and grey seals have a more even distribution and can be regularly found also farther offshore. The relatively small number of sightings of these two latter species in the outer strata in 2006 and 2007 is to be attributed to the uneven effort, which was more focused upon the inshore area.

Table 1. Line transect trips: effort, 2005-07

	2005	2006	2007	**Total**
No. of Surveys	25	25	26	**76**
No. of Legs	92	93	74	**259**
Km travelled	2498	2334	1952	**6784**
Km travelled in LT mode	1597	1163	985	**3745**
Km in inner transects	688.5	933	609	**2230.5**
Km in outer transects	908.5	230	376	**1514.5**

Table 2. Sightings of marine mammals during line transect trips, 2005-07

	2005	2006	2007	**Total**
Bottlenose dolphins	114	88	100	**302**
Harbour porpoises	144	133	105	**382**
Grey seals	94	91	94	**279**
Total	**352**	**311**	**299**	**963**

The number of trips conducted was similar throughout the three years, although the number of km travelled (in total and in LT mode only) was a little lower in 2007 due to the adverse weather conditions of that summer. The effort along the outer transects was higher in 2005, dropped to a minimum in 2006, and then increased in 2007.

The number of grey seal sightings was very consistent throughout the years, while bottlenose dolphin encounters showed a slight decline, although differences between 2005 and 2006-07 are to be attributed mainly to the slightly different way that the researchers defined a group. Harbour porpoises also showed a small decrease in the number of sightings. These data should be treated with caution and should not be used to show a decline of the number of animals using the SAC, because they depend on the amount of effort each year and on the way the groups are defined. Only effort related analysis (such as those that give the encounter rate of groups or individuals), or proper abundance estimates derived using the software DISTANCE or MARK, should be taken into consideration when estimating trends in the local populations.

The abundance analyses for bottlenose dolphin and harbour porpoise, performed with the software DISTANCE 5, provided the estimates shown in Table 3.

Table 3. Line transect trips: abundance estimates, 2005-07 in Cardigan Bay SAC

Year	definition	BND	HP
2005	abundance	**154**	**167**
	95% CI	90-264	121-230
	CV	27.81	16.46
	observations	45	73
2006	abundance	**206**	**170**
	95% CI	105-403	113-255
	CV	35.16	20.96
	observations	30	53
2007	abundance	**109**	**214**
	95% CI	49-239	145-314
	CV	41.70	19.80
	observations	24	46

An increase in population size for bottlenose dolphin was observed in the years 2005-07, when compared to the estimate from the 2003-04 period (140 dolphins). The low value for 2007 (109 dolphins) is believed to be due simply to the small number of observations and does not represent a true estimate; the 2007 summer was indeed characterised by bad weather and effort could not be as high as in previous years, leading to a small number of observations used for the analysis (24, compared with 45 and 30 in previous years). This is also evident from the CV for that year (41.7) which was the highest for the three years.

The harbour porpoise population appeared to be quite stable over the years 2005-06, and then showed an increase in 2007, with a total of 214 porpoises estimated in the SAC area. Although the number of observations was higher in 2005 (73), the CV was rather similar in the three years and relatively low, leading to quite precise estimations. Figures 7 and 8 show the detection functions for the three years for bottlenose dolphin and harbour porpoise, respectively.

Of the two cetacean species observed, the harbour porpoise was the most suited for abundance estimation using distance-sampling methodology. This is largely because they are sufficiently numerous to ensure the large sample size necessary for estimating detection probabilities as a function of distance. They are also suitable for distance-sampling because they tend to be spread throughout the area, rather than strongly

clumped; their group sizes are small and relatively homogeneous; and the probability of seeing a porpoise is usually not heavily affected by its behaviour.

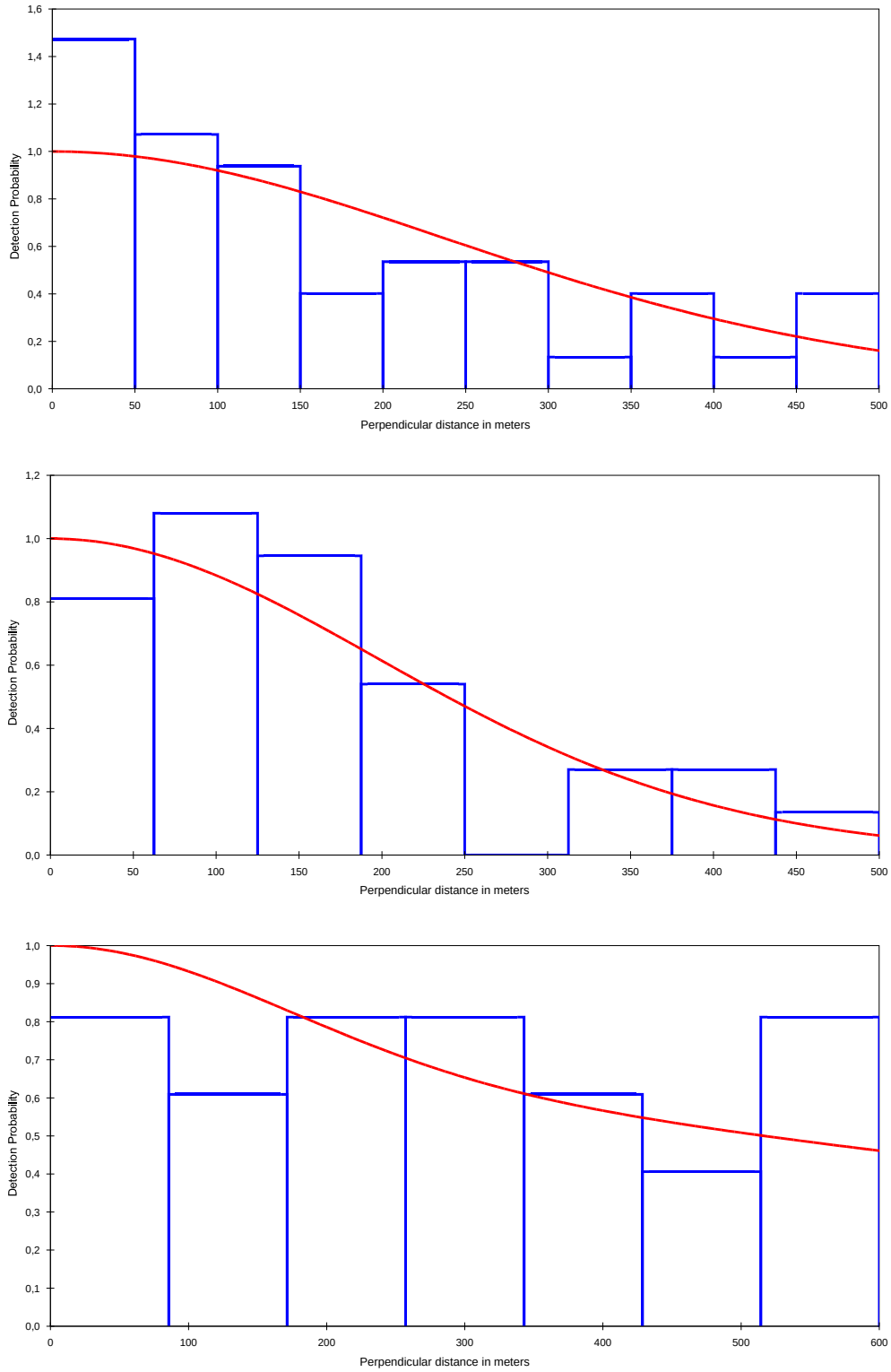


Figure 7. Detection functions for bottlenose dolphins in 2005 (top), 2006 (centre) and 2007 (bottom)

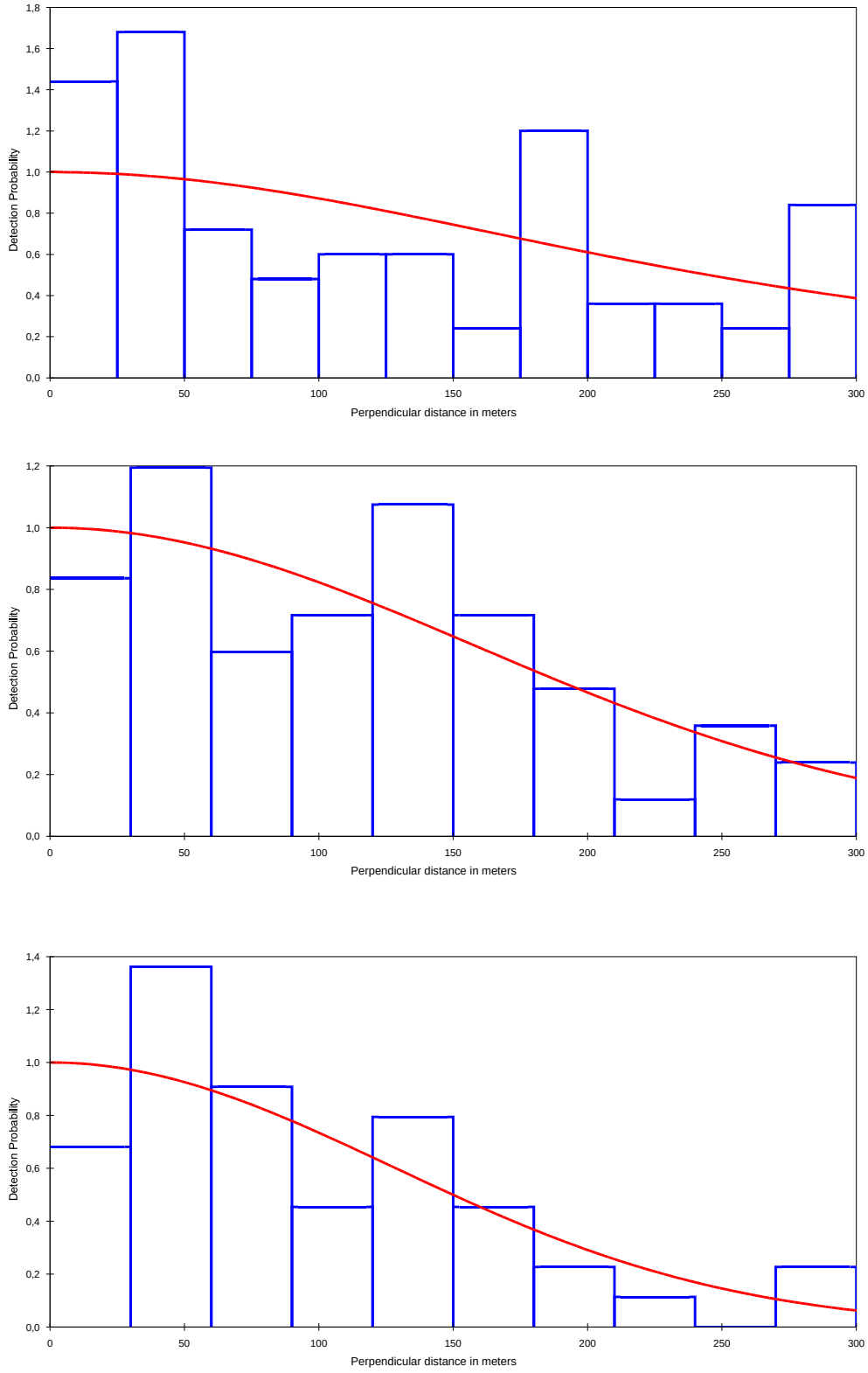


Figure 8. Detection functions for harbour porpoises in 2005 (top), 2006 (centre) and 2007 (bottom)

Line transect surveys provided estimates of the average number of animals of the two cetacean species within the SAC at any one time during the survey period. For a separate estimate of the total number of bottlenose dolphins using the SAC (including those individuals that might have come into the SAC only briefly), a mark-recapture method involving photo-identification was used, and will be described in the following pages.

2) Ad-libitum surveys throughout Cardigan Bay

Background

Although the bottlenose dolphins of Cardigan Bay are found with higher frequencies in certain preferred coastal locations (e.g. New Quay, Aberporth, Mwnt, Cemaes Head and around the Teifi estuary), they are known to occur also in Tremadog Bay (from Barmouth out to Sarn Badrig and northwards to the western end of the Llyn Peninsula around Bardsey Island), and in north Pembrokeshire. In order to better quantify the occurrence of the animals in these areas, as well as to understand the extent of their distribution and movements throughout Cardigan Bay, in the years 2005-07 the project was broadened to allow the research trips to cover a wider area, encompassing both Cardigan Bay and Pen Llyn a'r Sarnau SACs as well as the southern part of the Bay.

Table 4. The survey vessels used for the data collection, with details regarding the years in which they were used, length, eye height on the observers platform, mean cruising speed, type of engine, and total number of trips for which the boats were used.

Boat name	Years used	Length (m)	Eye height (m)	Speed (kn)	Engine type	Number of trips
Celine	2005-07	10.6	2.0	6.0	30hp diesel	41
Scorpius	2007	8.99	2.4	10.0	230hp diesel	2
Pedryn	2006-07	11.7	3.0	9.0	350hp diesel	4
Ermol VI	2004-07	10.9	2.5	6.0	twin 120hp diesel	530

Methods

Research vessel. We used various vessels, depending on the area surveyed and the type of trip performed. Most of the trips conducted in the PC SAC were onboard Celine, although a few were made onboard Pedryn (CCW research vessel), and in 2007, two exploratory trips were made in the south of the Bay on Scorpius. Ermol VI is a vessel used by a local wildlife tour operator for 1-2 hour long coastal trips along the Heritage coast, and some of our volunteers joined a number of those trips in order to collect photo-identification pictures and information on the presence and distribution of the marine mammals in that area. Table 4 gives the technical details for each research vessel.

Survey design. The trips were *ad-libitum* surveys, and therefore did not follow predetermined routes. Particular emphasis was given to surveying the areas around rocky reefs in the north of the Bay, since dolphins are known to occur there with higher frequencies. In the south, we tried to cover the area from the western boundary of the CB SAC to St David's Head (Pembs), which is the southern limit of Cardigan Bay.

Data collection. The protocols for data collection were very similar to those used for the line transect trips, with the main difference that we did not use a double platform methodology and therefore only two observers were scanning the sea surface at any given time, each one covering 180° (from the boat's bow to its stern), and using binoculars.

Data analysis. The effort and sightings were entered into the Sea Watch Foundation national database (in Access). The position of the sightings were plotted using ArcView

3.2, and the effort lines covered were obtained with the tool "Animal movements". The study area was divided into cells of 2'x2', and the information analysed using vector and raster formats. Effort and sightings in favourable sea and weather conditions were used to calculate the encounter rate per cell (ER), which is the number of sightings over the number of kilometres travelled in positive conditions. The encounter rate was weighted (ERW) for those cells that included also some land. Spatial interpolations were run to predict surfaces, and the relationship between dolphin presence and environmental variables was evaluated (Ingram and Rogan, 2002; Petroselli, 2006). Statistical analyses were carried out using the software SPSS 14.0. Residuals were checked for all parametric tests, and the response variables were transformed where appropriate. Uni- and multivariate analyses determined the quality of the data and the presence of any significant differences or relationships between the variables considered. Geostatistical methods were used to evaluate the precision of the predicted surfaces.

Results and Discussion

A total of 438 trips were carried out in the study period. Figures 9 and 10 show the effort lines and the sightings positions for each year, while Tables 5 and 6 give effort and sightings details.

Table 5. *Ad-libitum* surveys: effort 2005-07

Trip type	**Research trips**				**1-2 hrs along Heritage coast trips**			
	2005	2006	2007	**Total**	2005	2006	2007	**Total**
Surveys #	17	17	19	**53**	166	162	57	**385**
Km travelled	921	1326	2541	**4,788**	938	1564	585	**3,087**

Table 6. Sightings of marine mammals during *ad-libitum* surveys, 2005-07

	2005	2006	2007	**Total**
Bottlenose dolphin	58	21	43	**122**
Harbour porpoise	47	44	77	**168**
Grey seal	26	33	51	**110**
Risso's dolphin	-	-	5	**5**
Total	**131**	**98**	**176**	**405**

The analysis of the spatial distribution of bottlenose dolphins revealed a high frequency of sightings in several areas (Figure 11). The entire coastal area from Aberaeron to Cardigan and around Fishguard seems to be of particular significance to bottlenose dolphins, in particular 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 Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy. The encounter rates, however, showed yearly fluctuations, particularly in 2006 and 2007 when the animals were found to be much less concentrated in the coastal area.

Figure 9. Effort lines during *ad-libitum* surveys in 2005 (top), 2006 (centre) and 2007 (bottom)

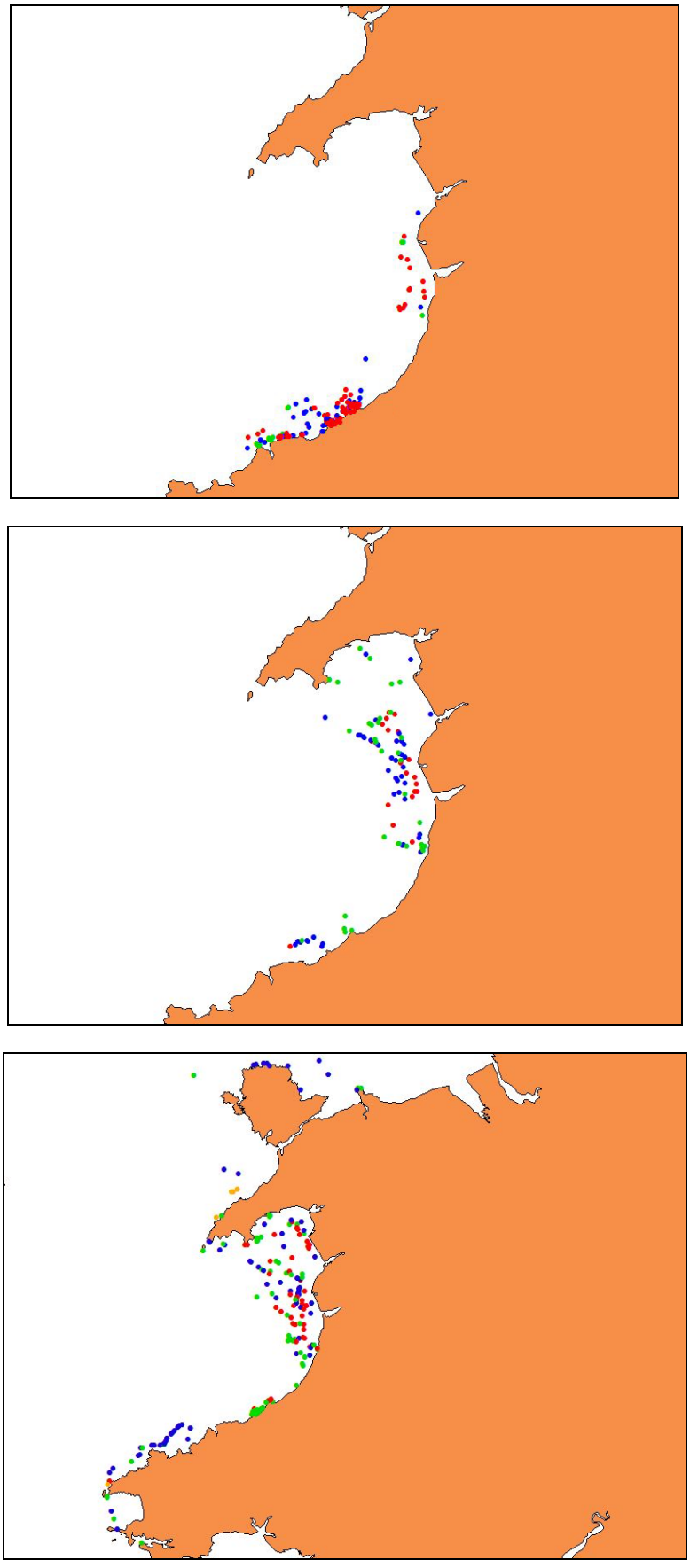


Figure 10. Sightings of bottlenose dolphin (red), harbour porpoise (blue), grey seal (green) and Risso's dolphin (orange) recorded during *ad-libitum* surveys in 2005 (top), 2006 (centre) and 2007 (bottom)

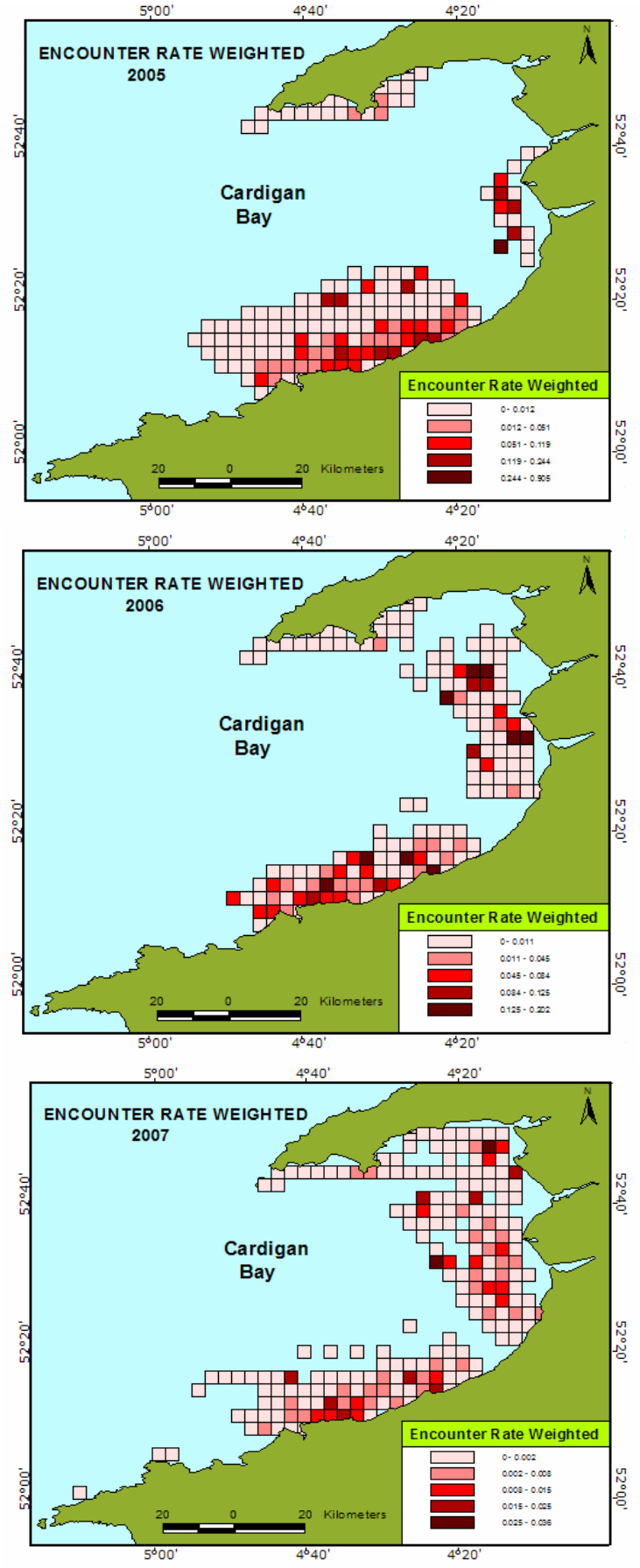


Figure 11. Encounter rates weighted for 2005 (top), 2006 (centre) and 2007 (bottom). The darker the cell, the higher the encounter rate

An analysis of bottlenose dolphin habitat preference from data collected over the period 2001-07 showed that the animals were non-randomly distributed, appearing to prefer particular areas within the Bay. Distance from coast (Figure 12) had a significant effect on encounter rates ($F=24.871$, $df=1$, $p<0.001$), with the dolphins preferring habitat as close as 5 km from the coast, but showing a tendency (not statistically significant) to favour waters more distant from the coast during the last three years.

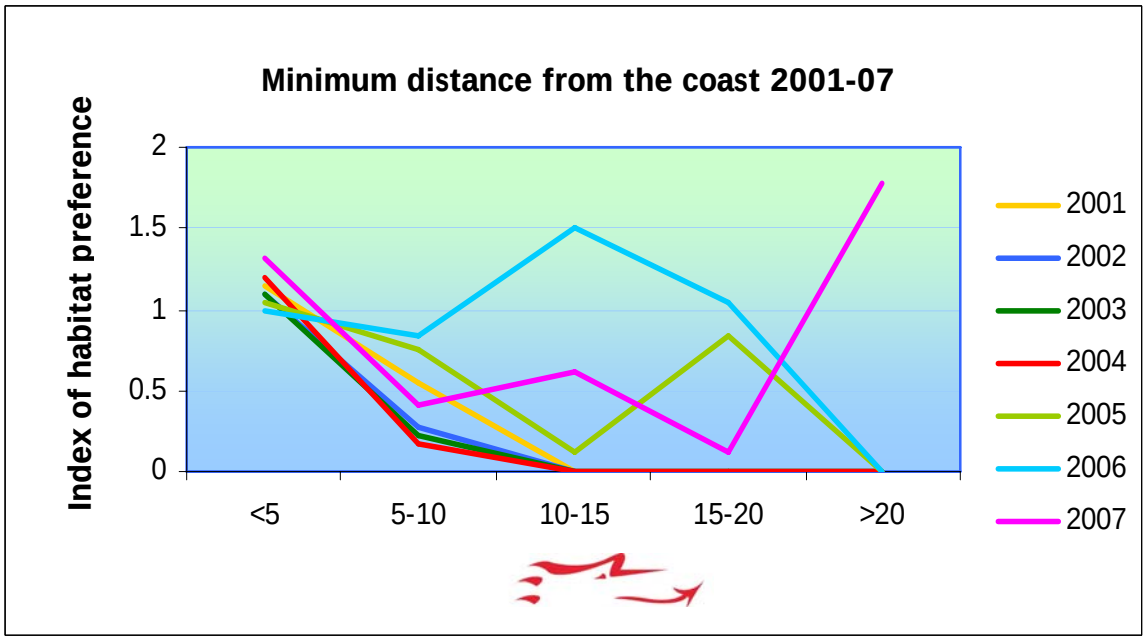


Figure 12. The index of habitat preference shows how far from the coast the bottlenose dolphins were found during the period 2001-07

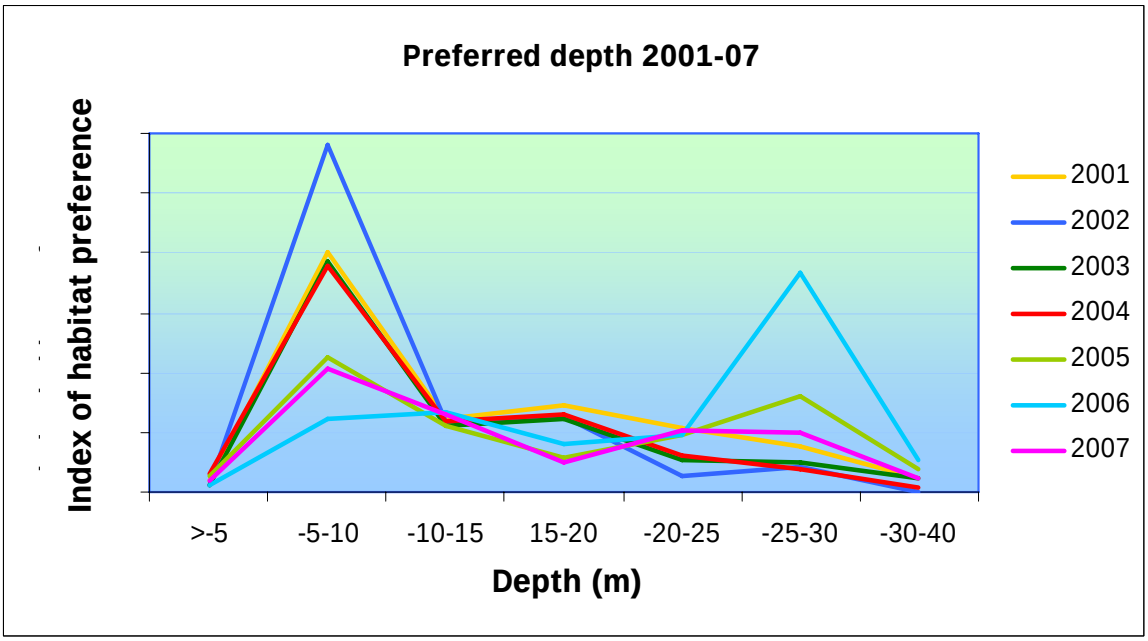


Figure 13. The index of habitat preference shows which depth category was preferred by the bottlenose dolphins during the period 2001-07

Dolphins showed a general preference for shallow waters (5-10 metres deep, $F=14,049$, $df=6$, $p<0.001$) throughout the period 2001-07 (Figure 13), but during the last three years, the animals were also found in deeper water (25-30 metres) and at a greater distance from the coast.

The mean slope was calculated from the depth predicted surface. Over 95% of Cardigan Bay had a slope of less than 1%. 99% of sightings were recorded over this slope range ($F=20.057$, $df=2$,$p<0.001$).

Part Two: Photo-Identification

Background

We collected photo-identification pictures in the Cardigan Bay SAC during line transect trips, dolphin-watch half-hour tours, and from the New Quay land site, as well as in the Pen Llyn a'r Sarnau SAC and the south of the Bay during *ad-libitum* surveys. Furthermore, we gathered and added to our catalogue pictures with those taken by other persons or organisations (e.g. Friends of Cardigan Bay and Janet Baxter during boat trips around Aberystwyth; from the land sites of Aberystwyth and Mwnt; and from MV "Shearwater" dolphin-watch trips around the Llyn Peninsula).

Methods

Data collection. Dolphin groups were approached to a distance of 20-50 metres following the guidelines outlined in the photo-identification licence granted to the Sea Watch Foundation by the Countryside Council for Wales. Once a group of dolphins was encountered, the boat attempted to match the speed and direction of the dolphins and gradually reduce the distance to them. If the dolphins were stationary in one area, the boat would either idle or stop the engine at approximately 100m from the animals, and drift among them with the tidal stream. We photographed the dolphins using either a digital Canon or Nikon camera equipped with 70-300mm or 28-300mm zoom lenses, using the shutter speed priority program with a speed of 1/1000. We tried to take at least one picture of the dorsal fin of each dolphin. Photo-identification sessions lasted until the dolphins either were lost from view, showed signs of distress, all the dolphins in the group were identified, or the maximum encounter length of 40 minutes allowed by the licence was reached. The photo-identification protocol followed Würsig and Jefferson (1990). A group of dolphins was defined as a cluster of animals separated by approximately 100m or less, moving in the same direction and engaged in a similar activity (Wells *et al.*, 1987). A new encounter started every time a different group of dolphins was approached and identification photographs were taken. During each encounter, we recorded the encounter number, date, time, position, group size and composition, photographer's name, as well as behaviours performed. Four age categories were used, based on the size of the animal relative to an adult, the swimming pattern, the skin coloration, presence of foetal folds and proximity to the mother. These were adult, juvenile, calf and newborn (Bearzi *et al.*, 1997). Group size was determined in the field, but if the photo-identification estimate led to a larger group size, this latter evaluation was used in the analysis.

Data analysis. The matching was performed using Adobe Photoshop 7.0 and/or ACDSee Pro, and followed the techniques described by Defran and colleagues (1990) and Würsig and Jefferson (1990). In order to avoid false positive or false negative mistakes, only high quality pictures were used to confirm the identity of a dolphin, and matches were confirmed by a second person (Hammond, 1986; Scott *et al*., 1990; Stevick *et al*., 2001).

The software programs MARK and CAPTURE were used for the mark-recapture analysis aimed at estimating the population size, using the Chao (Mth) model for closed populations (Chao *et al*., 1992).

Results and Discussion

The Catalogue. Following all these photo-identification sessions (Table 7), 189 new dolphins were identified over the period 2005-07, increasing our catalogue to a total of 197 marked dolphins (96 well-marked and 101 slightly-marked), with photographs of 103 right sides and 100 left sides (Table 8).

Table 7. Photo-identification effort for the years 2005-07

Year	2005	2006	2007	**Total**
Encounters	92	122	97	**311**
Encounters with identified animals	75	88	94	**257**
Pictures used	751	3283	3104	**7138**

Table 8. Overview of individuals identified in the 2005-07 period. Marked (M), left (L) and right (R) refer to the three categories of dolphin ID catalogues used in this study.

Year	2005	2006	2007	**Total**
Identifications	230 (175M+27L+28R)	358 (270M+42L+46R)	364 (297M+29L+38R)	**952 (742M+98L+112R)**
New dolphins identified	60 (28M+17L+15R)	79 (33M+24L+22R)	50 (16M+17L+17R)	**189 (77M+58L+54R)**
Encounter with calves or newborns	19	47	52	**118**
Calves seen	~13	~20	~20	**~53**

Considering just the number of marked individuals in the catalogue and the percentage of marked one in each encounter, the overall estimate for the bottlenose dolphin population for the "extended area" of Cardigan Bay is therefore 133 animals in 2005 (63% of the animals were marked), 179 in 2006 (62% were marked) and 198 in 2007 (60% were marked), or 328 when considering the 2001-07 period (some animals are seen in only one or two years, but they remain in the catalogue). In 2005 and 2006, the extended effort into the north of Cardigan Bay resulted in the identification of a relatively high number of new individuals), but in 2007 the discovery curve (Figure 14) was still showing an increase in the number of new dolphins identified, suggesting that not all the marked animals of Cardigan Bay have yet been identified.

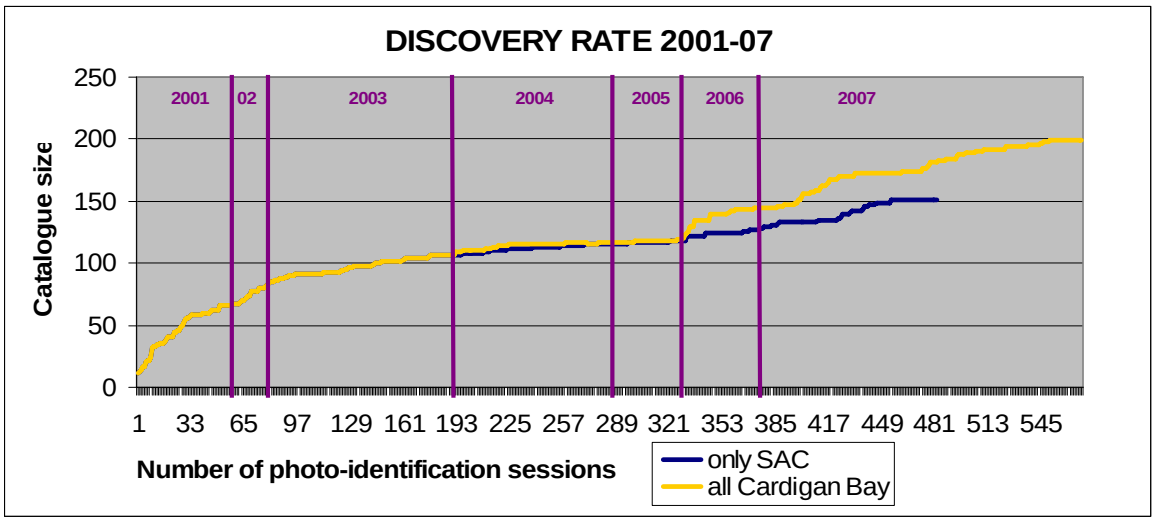


Figure 14. Discovery Curve for the bottlenose dolphin population. The dark blue line shows the results for the Cardigan Bay SAC only, while the yellow one represents the entire Cardigan Bay. Vertical bars separate single years. The curve does not start from 0 but from 11 because dolphins identified before 2001 were included in the catalogue

11.0% of the dolphins were seen once, 31.0% from 2 to 9 times, while the majority (58.0%) were seen more than 9 times (Figure 15), with two individuals seen as many as 45 times (ID No: 017-03W) and 48 (ID No: 051-91W), respectively. Frequencies of re-

sightings ranged from 1 to 26 (mean=4.13, SD=6.23; Figure 16). 25.0% of the dolphins were seen only in one of the seven years of data collection, 28% in two, and 47.0% in more than two. These data suggest that only a portion of the dolphin population exhibits a high degree of site fidelity and high re-sighting rates, and that the population of the Bay might be better described as a combination of transient, occasional visitors and resident animals.

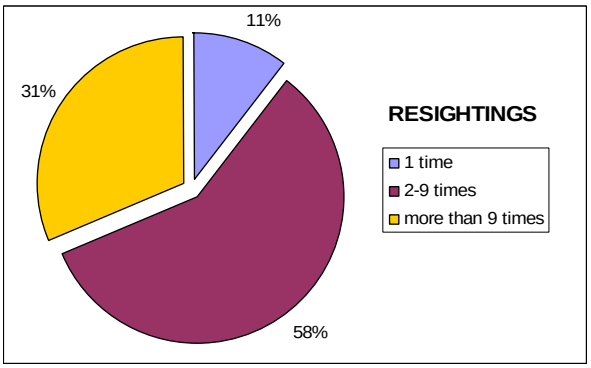


Figure 15. Percentage of animals seen 1, 2-9 or >9 times in Cardigan Bay in the 2001-07 period

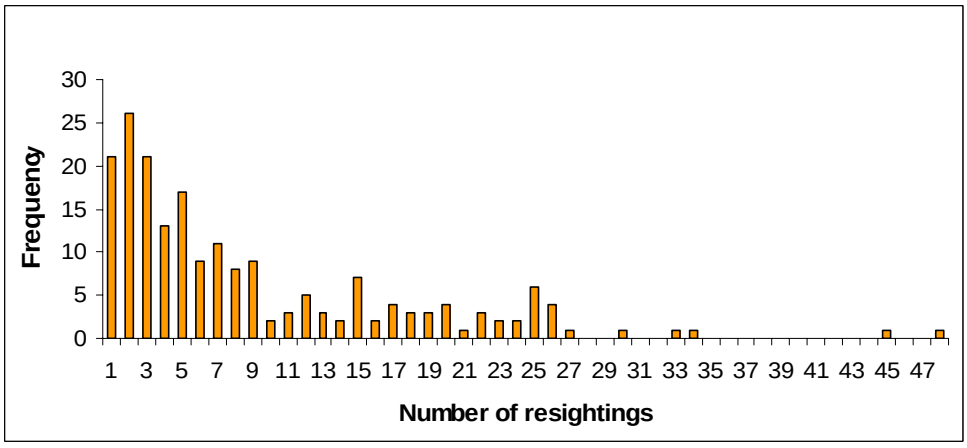


Figure 16. Frequency of re-sightings of the 197 marked animals during the 2001-07 period

Mark-recapture. Photo-identification data for the period 2001-07 in the Cardigan Bay SAC were analysed with the MARK-CAPTURE program using the Chao(mth) model for closed populations. Results are shown in Table 9.

Table 9. Population estimates for bottlenose dolphins showing identifiable markings occupying the Cardigan Bay SAC in the years 2001-07, obtained with the mark-recapture method and using a closed population model.. The minimum and maximum 95% confidence intervals and standard errors are shown

	2001	2002	2003	2004	2005	2006	2007	01-07
Population estimate	75	58	86	93	110	83	126	220
95% CI min	67	46	86	85	86	83	108	210
95% CI max	93	90	90	111	160	83	165	240
Standard error	6.32	10.56	1.00	6.39	18.05	0.00	13.94	7.39

These values represent the number of marked dolphins that have used the Cardigan Bay SAC in the study period. Since only a portion of the dolphin population is marked, in order to obtain the total number of dolphins (marked and non marked), these estimates

were obtaining by multiplying the mark-recapture estimates by the proportion of marked dolphins found in each group. Results are shown in Table 10.

Table 10. Population estimates for the bottlenose dolphins occupying the Cardigan Bay SAC in the years 2001-07, obtained with the mark-recapture method, using a closed population model, and considering the proportion of marked dolphins in each group. The minimum and maximum 95% confidence intervals are shown

	2001	2002	2003	2004	2005	2006	2007	01-07
Population estimate	156	121	143	163	175	134	210	379
95% CI min	140	96	143	149	137	134	180	362
95% CI max	194	188	150	195	254	134	275	414
Proportion of marked	0.48	0.48	0.60	0.57	0.63	0.62	0.60	0.58

As with the results of the line transect surveys, an overall increase in population size for the years 2005-07 was highlighted by this technique, although with some fluctuations. The 2007 estimate of 210 dolphins confirms that the low results from the line transect surveys in the same year are most likely due to the insufficient number of observations.

Photo-identification data for the period 2001-07 for the Cardigan Bay SAC and for the whole Bay were analysed with MARK-CAPTURE techniques also using the Pollock's robust model for open populations, that takes into account immigration, emigration, births and deaths. Results are shown in Table 11 (SAC only) and 12 (whole Bay).

Table 11. Population estimates for the bottlenose dolphins occupying the Cardigan Bay SAC in the years 2001-07, obtained using an open population model and considering the proportion of marked dolphins in each group

	2001	2002	2003	2004	2005	2006	2007
Population estimate	129	79	142	139	103	134	150
Proportion of marked	0.48	0.48	0.60	0.57	0.63	0.62	0.60

Table 12. Population estimates for the bottlenose dolphins occupying the whole of Cardigan Bay in the years 2001-07, obtained using an open population model and considering the proportion of marked dolphins in each group. The minimum and maximum 95% confidence intervals and standard errors are shown

	2001	2002	2003	2004	2005	2006	2007
Population estimate	156	154	157	168	183	224	248
95% CI min	138	109	147	149	162	208	231
95% CI max	209	268	191	221	219	254	277
Standard error	7.79	17.96	5.82	9.49	8.85	7.03	6.92
Proportion of marked	0.48	0.48	0.60	0.57	0.63	0.62	0.60

Even though the Cardigan Bay SAC is an important habitat for this population, some dolphins had much wider ranges, including at least the Llyn Peninsula in the north of the Bay. By contrast, some animals showed a preference for smaller areas and did not move through the whole Bay. These findings confirm previous indications that the Cardigan Bay

SAC by no means includes the full geographic range of this population, which probably encompasses the West and North Wales coasts or even perhaps the entire Irish Sea.

Table 13 provides an indication of the proportion of the total population that may be occupying Cardigan Bay in any one year. Estimates vary from 41% in the early years of the study to 66% in 2007.

Table 13. Proportion of the overall meta-population occupying Cardigan Bay

Year	Cardigan Bay meta-population	Proportion of overall population
2001	156	41%
2002	154	41%
2003	157	41%
2004	168	44%
2005	183	48%
2006	224	59%
2007	248	66%

Furthermore, in order to determine whether there is any exchange of dolphins between Cardigan Bay and other British and Irish populations, we compared our catalogue with pictures from other areas (see Table 14). In fact, no matches were found between the Cardigan Bay individuals and individuals from any of those of the above mentioned areas.

Table 14. Pictures compared to the Cardigan Bay photo-identification catalogue

	# of pictures analysed	Matches
South-East Ireland	46	0
Cornwall	17	0
South Devon	21	0
Dorset	106	0
Aberdeen	55	0
North Grampian coast	151	0
Moray Firth	412	0
Inner Hebrides	27	0
Shannon Estuary	328	0
Total	**1163**	**0**

Part Three: Aerial Surveys

Background

While the summer distribution of the bottlenose dolphins in Cardigan Bay is fairly well known, with most of the sightings occurring within 10 km of the shore, they are rarely seen close to the coast in the winter. The hypothesis is that during winter they distribute themselves much more offshore and that they may even leave Cardigan Bay to reach some surrounding seas, in order to find better feeding areas. In order to shed light on this matter, we ran some winter aerial surveys, leaving and returning to the local military airport of Aberporth. Boat surveys in the winter are indeed difficult because the sea is nearly always rough, and the weather is bad, so aerial surveys are a good way to take advantage of the few sunny and calm days we get in winter, and they allow one to cover, in a few hours, a large area of sea.

Figure 17. Seneca, the airplane used for the winter aerial surveys

Methods

Research platform. The ideal plane to be used for these types of aerial survey is a high-winged aircraft with bubble windows. However, such a plane was not available in Wales, and the only high-winged one we could have used was a Partenavia plane that could be hired from the airport of Liverpool. For logistic (the airport was too far away from our study area) and economic reasons (the hourly rental rate exceeded £500), we were unable to use that plane, and so opted for Seneca (Figure 17), a 6-seater Piper PA34-2005 with 200 hp turbocharged engines. This plane is low-winged, but the field of view from the last rows of seats was good and therefore it was considered suitable for the trips.

Survey design. A total of nine parallel, evenly spaced transects were designed running on a north-south axis across Cardigan Bay, at 5-mile intervals from one other (Figure 18). The trips started and ended from the airport of Aberporth, and included a stop halfway along the survey (in Aberporth) for refuelling and to change observers.

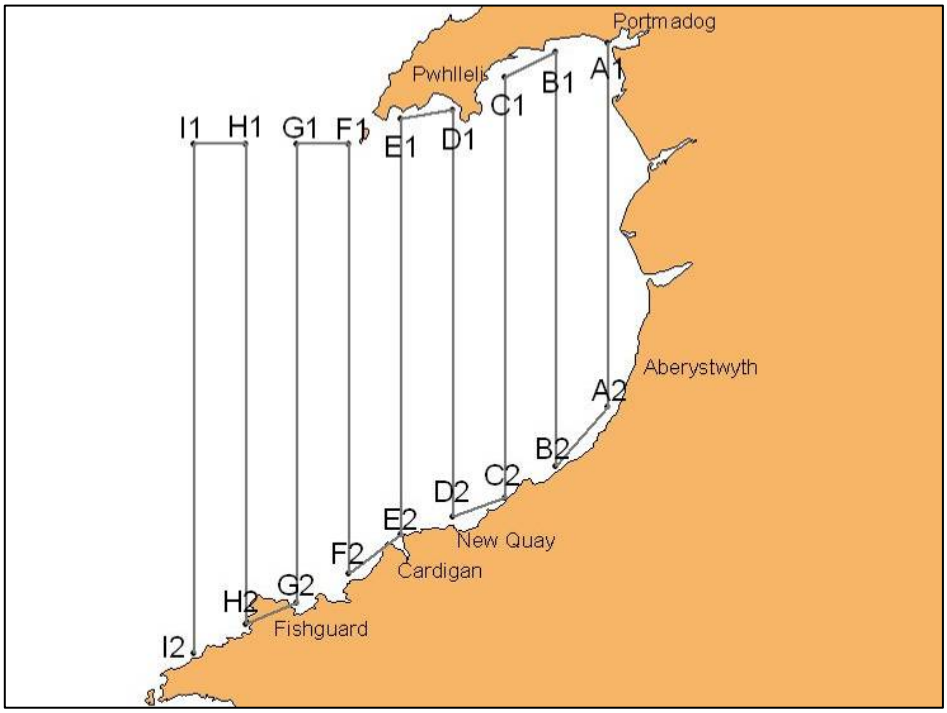


Figure 18. The transects followed during the winter aerial surveys

Data collection. The airplane flew at an altitude of around 150 metres and at a speed of 100 knots, as recommended for spotting small cetaceans. Three researchers were always onboard during the trips, one observer on each side of the plane and a person responsible for recording the effort, seated on the right side of the pilot, who was also scanning the sea surface ahead of the plane. Two hand-held Garmin GPS units were set to collect, every 30 seconds, information on the date, time, latitude, longitude, speed, course and altitude, while environmental variables (visibility, precipitation type and intensity, swell, sea state) and sightings details (sighting number, time, position, species, group size and composition, behaviour, direction of travel, distance) were manually reported on sighting and effort forms similar to the ones used for the boat trips.

Data analysis. The effort and sightings were entered into the Sea Watch Foundation national database (in Access). The positions of the sightings were plotted using ArcView 3.2, and the effort lines covered were obtained with the tool "Animal movements".

Results and Discussion

During the winter of 2006-07, we conducted three aerial surveys (in February, March and April). We had a total of 61 sightings, of which 12 were of bottlenose dolphins, 30 of harbour porpoises, and 19 of grey seals (see Table 15 for details).

Table 15. Sightings of marine mammals during the 2007 aerial surveys

	3/2/07	14/3/07	11/4/07	**Total**
Bottlenose dolphins	7	1	4	**12**
Harbour porpoises	6	0	24	**30**
Grey seals	3	4	12	**19**
Total	**16**	**5**	**40**	**61**

The track-lines that we followed and the distribution of sightings for the three aerial surveys are shown in Figure 19. Bottlenose dolphins showed a clear preference for offshore areas of the Bay. The only coastal sighting was from the February survey and was just in front of New Quay's headland, one of the few places where the dolphins are seen also during winter, probably due to the local abundance of food provided by the fish factory. The four sightings in the outer part of the Cardigan Bay SAC were from the April trip, a month when the dolphins start to be sighted closer to shore again, even if at lower frequencies than in the summer. Harbour porpoises were more evenly distributed, with sightings both in the offshore and inshore areas. Grey seals showed a similar distribution to harbour porpoises, but with a slightly higher preference for the eastern part of the Bay. These surveys, although preliminary, seem to confirm that bottlenose dolphins have an offshore distribution during the winter in Cardigan Bay. More trips are needed to confirm these results. It should also be considered that, since the track-lines were at a distance of 5 miles from one another, and the observers could not possibly scan as far as 2.5 miles on each side, it is likely that some sightings were missed during the trips. However, an alternative survey design, with closer track-lines, was not feasible because then it would not have been possible to cover the entire Bay in just one day.

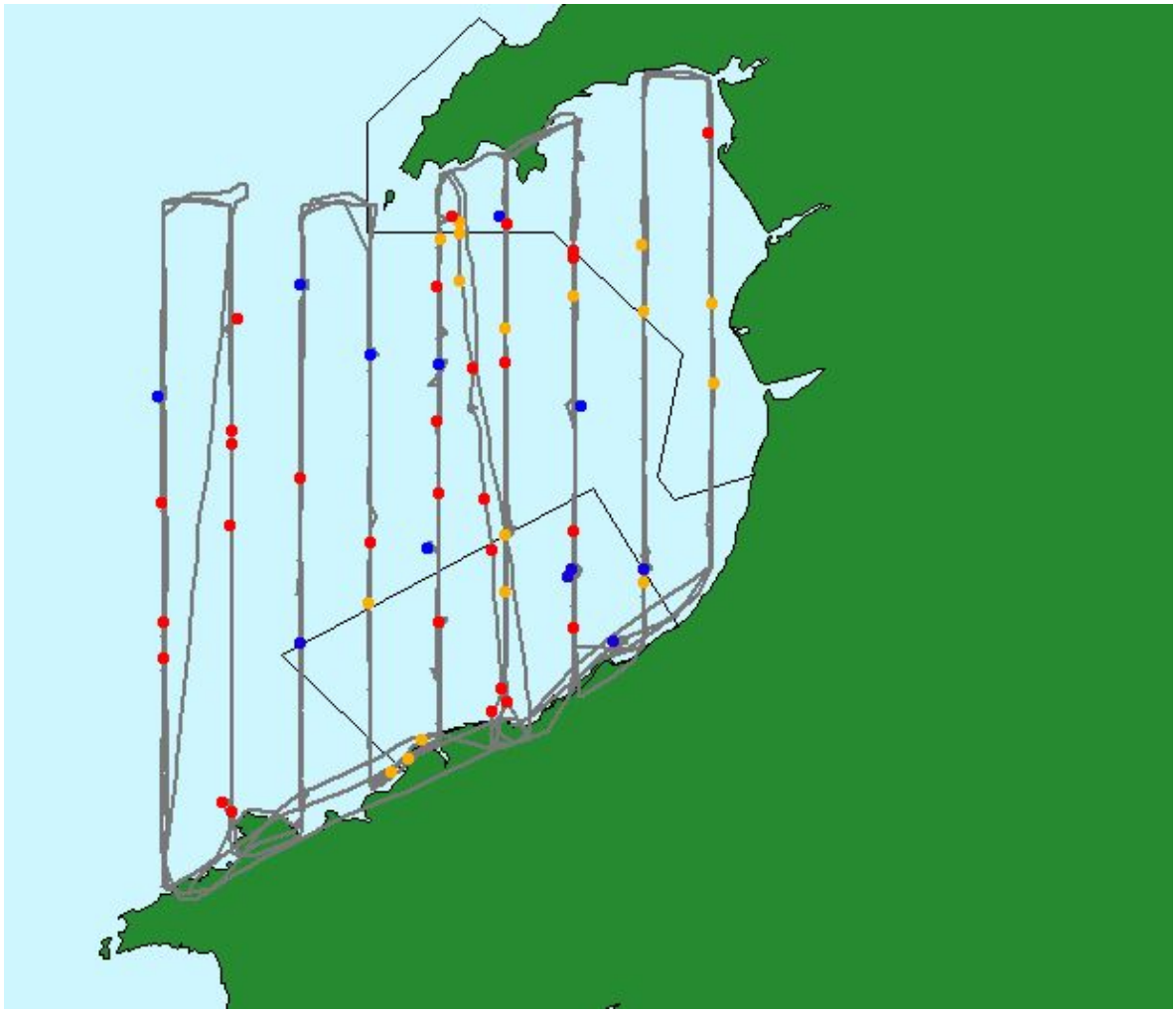


Figure 19. Track-lines and sightings for the three aerial surveys in the winter of 2006-07. Blue dots are bottlenose dolphins, red ones are harbour porpoises, and yellow ones are grey seals

Part Four: Student Projects

Background

It would be impossible for a single person, the monitoring officer employed under this contract, to address the large number of objectives set. Thus, to supplement those efforts in as cost-effective manner as possible, Sea Watch has taken advantage of a network of volunteers and students to provide necessary support. Besides the fifty or so volunteers that offered their assistance, a total of 13 students joined the Cardigan Bay Monitoring Project over the period 2005-07 in order to collect and/or analyze data for their MSc or BSc theses. The students have come from the Universities of Bangor (Wales), York (England), Central Lancashire (England), Jyväskylä (Finland) and Bogota' (Colombia). The subjects studied included abundance, range and distribution, behaviour, ecology and acoustics. The species mainly studied was the bottlenose dolphin, but some projects focused upon the harbour porpoise, and one was on grey seals. This section is a summary of the background, methods and results from each of the project theses, divided by subject.

Population Size & Trends

Study 1. Population size of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay (Special Area of Conservation), Wales (MSc thesis by Juliana Castrillon, November 2006)

The bottlenose dolphin (*Tursiops truncatus*) Cardigan Bay population has been protected since 1992, although the management plan was implemented only in 2001. Nonetheless, how the population size has responded to these strategies since then has not been evaluated. In order to achieve this goal, the population size was calculated from 2003 to 2005, and compared with information collected in the past. Data collected during Sea Watch Foundation surveys were used to estimate bottlenose dolphin abundance. The population size was estimated assuming a closed population, using photo-identification data and mark-recapture method using the Chao(mth) model. Most of the sampled individuals in the population were catalogued as frequent and common, showing that at least part of the population is likely to be resident, with 40% of the marked animals seen during two consecutive years (and with high capture frequency). No statistical difference was found in the estimated population size between 2003 and 2005, although there was an increase in the population size of 16% during that period.

Study 2. Estimation of g(0) for bottlenose dolphin, grey seal and harbour porpoise in the Cardigan Bay SAC (MSc thesis by Neal Reay, 2005)

With the current shift in management strategies towards the use of Marine Protected Areas (MPAs) to conserve species of marine mammals and their habitats, there comes the need for accurate annual abundance estimates of species within MPAs to gain insight as to the species status, and the effectiveness of particular management approaches. Line transect surveys used to estimate marine mammal abundance assume that detection on the track-line is unity ($g(0)$=l), which is rarely the case for marine mammals. If not accounted for, abundance estimates will be negatively biased by a factor proportional to the true value of $g(0)$. Dual platform, line transect surveys were conducted over three consecutive summers (2003-05) within Cardigan Bay SAC in order to estimate $g(0)$ for bottlenose dolphins, grey seals and harbour porpoises. Environmental covariates were recorded with each sighting to allow for the inclusion of covariates in the analysis and so reduce the effect of detection bias. Data from the 2003 and 2004 surveys were pooled due to low sample size.

Analysis using DISTANCE 5.0 revealed $g(0)$ (NB: significant covariates are given in brackets) for bottlenose dolphins to be 0.705 (group size) in the 2003-04 surveys, and 0.941 (group size, sea state, and observer experience) in the 2005 surveys. Estimates of $g(0)$ for grey seals were 0.815 (no significant covariates) for the 2003/04 surveys, and 0.934 (observer experience) for the 2005 surveys. Estimates of $g(0)$ for harbour porpoises were 0.728 (group size) for the 2003/04 surveys, and 0.811 (group size) for the 2005 surveys. The study revealed that $g(0)$ varied greatly between the three species, and between years, with variations in sample size and survey conditions greatly affecting estimates. In conclusion, researchers should always calculate $g(0)$ for each survey and incorporate as many covariates as possible to reduce detection bias.

Population Structure

Study 3. Comparison of whistle repertoire and characteristics between Cardigan Bay and Shannon Estuary populations of bottlenose dolphins (MSc thesis by Ronan Hickey, 2005)

In previous studies, comparisons of whistle characteristics between geographically isolated populations of delphinid species have revealed variation between locations. The waters of Britain and Ireland are home to three known resident populations of bottlenose dolphins: Cardigan Bay (Wales), the Shannon Estuary (Ireland) and the Moray Firth (Scotland). This study compared the rate, repertoires and characteristics of whistles of two of these populations: Shannon Estuary and Cardigan Bay.

Comparisons between years, groups and different group sizes were also carried out within the Shannon Estuary population. Cardigan Bay whistles were collected actively on-board Sea Watch survey vessels using a deployed hydrophone, while Shannon Estuary whistles were collected passively via a fixed hydrophone. Whistles were compared using a series of quantitative parameters and sorted into categories using contour shape. Overall, 1,882 whistles were analysed throughout the course of this study. The vast majority of whistles were collected in the Shannon Estuary. A total of 32 different whistle categories were described, of which 21 were observed in both populations, eight were exclusive to the Shannon Estuary, and one was exclusive to Cardigan Bay.

The average duration of whistles from the Shannon Estuary population was found to be longer than whistles from Cardigan Bay. The average starting, ending, maximum, minimum, and mean frequency of whistles from Cardigan Bay were significantly higher than Shannon Estuary whistles. However, there was no statistical difference in the whistle rate between the populations.

Variations in whistle parameters and frequency of occurrence of whistle categories were also observed in comparisons within the Shannon Estuary population. Whistle rates increased with increasing group size. On a side note, dolphins in the Shannon Estuary were observed to exhibit cyclic behaviour, which was influenced by tidal times. Dolphins were most commonly encountered during the mid ebb tide. The differences observed in the whistle characteristics between the two populations could be representative of behavioural, environmental, or morphological differences between the Cardigan Bay and Shannon Estuary populations. Further research is required to expand upon the results of this study before the variance in whistle characteristics of Cardigan Bay and the Shannon Estuary populations can be fully understood.

Population Distribution, Home Range Size & Habitat Use

Study 4. Fine-scale spatio-temporal variation and habitat partitioning in bottlenose dolphins and harbour porpoises (MSc thesis by Sarah Baulch, 2007)

Coastally distributed cetacean species face many threats from anthropogenic activities. However, owing to high temporal and spatial variability in the distribution of marine mammals, impacts can be difficult to detect, and long-term monitoring is required to detect changes in populations' distributions and habitat use. Understanding of these spatio-temporal changes in distribution and abundance of marine mammals is essential for successful conservation and management, as it allows mitigation measures to be targeted to critical times and habitats.

Fine-scale variation in the spatial and temporal distribution of bottlenose dolphins and harbour porpoises was examined in Cardigan Bay, West Wales, using acoustic monitoring. Static omni-directional hydrophones, known as T-PODs, were deployed at ten sites within the Bay, for two years, providing a continuous means of monitoring rates of occurrence of both species.

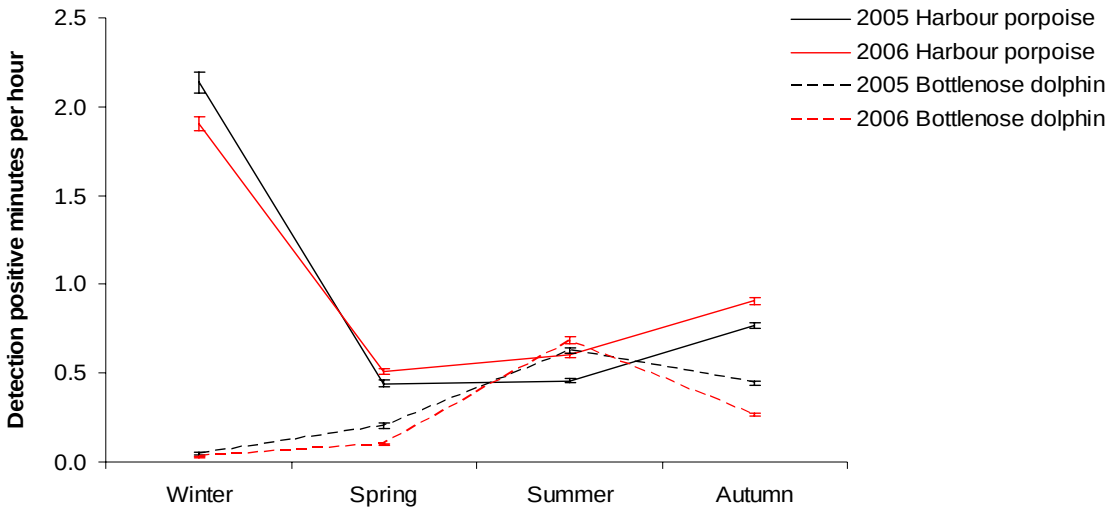


Figure 24. Mean number of detection positive minutes per hour of bottlenose dolphins and harbour porpoises in 2005 and 2006. Data represent means ± 1 standard error

Acoustic detections indicated large seasonal changes in the relative abundance of harbour porpoises and bottlenose dolphins in Cardigan Bay and revealed seasonal variation in habitat use within the Bay. Both species exhibited consistent seasonal changes in distribution from one year to the next (Figure 24), but relatively little variation in presence between diel periods, although finer-scale temporal variation was evident (Figure 25).

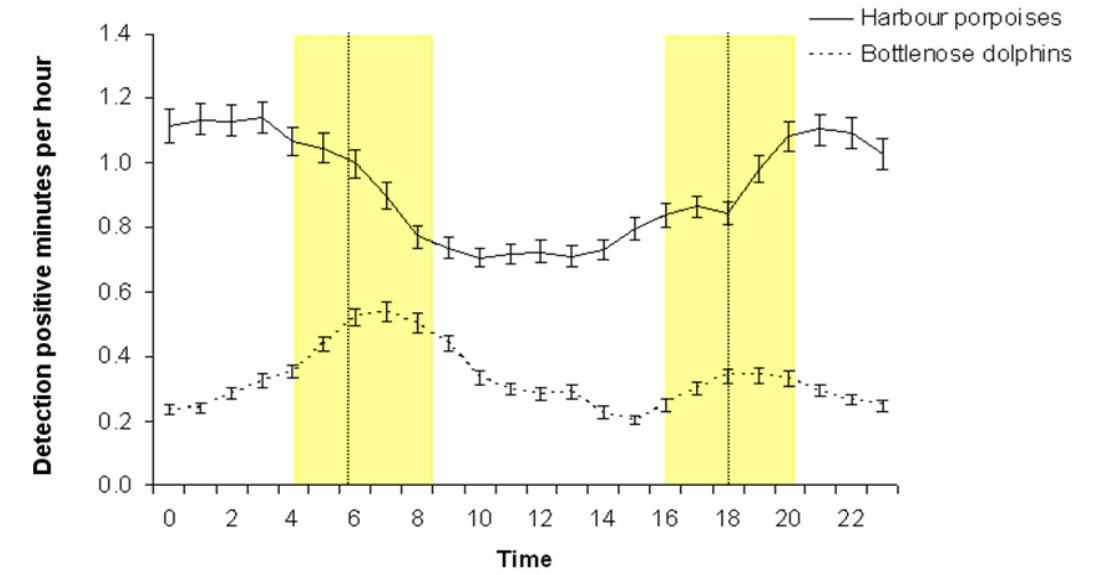


Figure 25. Mean number of detection positive minutes per hour of bottlenose dolphins and harbour porpoises at each hour of the day. Data represent means ± 1 standard error. Shaded areas represent range of sunrise and sunset times, with vertical dotted lines to show average sunrise and sunset times

In addition, both species displayed fine-scale fluctuations in occurrence over the tidal cycle, consistent across sites, seasons and years. Variation in harbour porpoise and bottlenose dolphin presence over the tidal cycle was strongly negatively correlated. This, in conjunction with differences in seasonal presence, and low rates of co-occurrence despite interspecific similarities in habitat preferences, provides evidence of fine-scale spatio-temporal habitat partitioning between harbour porpoises and bottlenose dolphins (Figure 26).

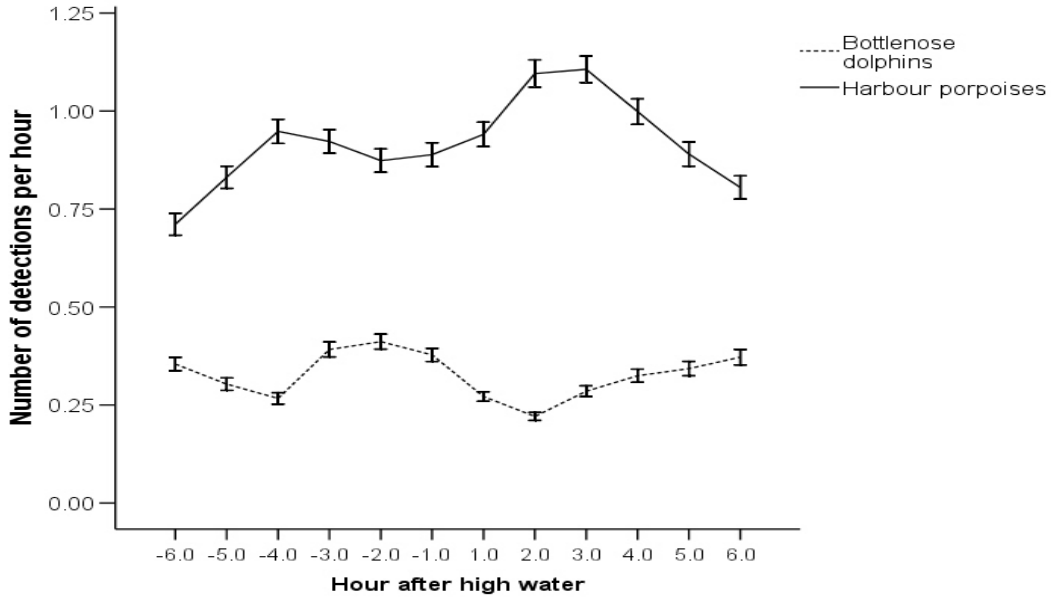


Figure 26. Mean number of detection positive minutes per hour of bottlenose dolphins and harbour porpoises at each hour of the tidal cycle. Data represent means ± 1 standard error

This is, to our knowledge, some of the first evidence of habitat partitioning between these two species. Not only does this mean that the two species may require different management actions but is particularly interesting considering the marked increase in

porpoise deaths as a result of bottlenose dolphin attacks in the last decade, which are suggestive of an increase in interspecific competition, whether as a result of changes in abundance or distribution of bottlenose dolphins or harbour porpoises, or increased competition for less prey.

Study 5. Fine-scale utilisation of New Quay Bay by bottlenose dolphins (MSc thesis by Eleanor Stone, November 2006)

This study is an investigation into the use of a small bay by a coastal bottlenose dolphin population. New Quay Bay is a shallow, sheltered bay, which has been frequented by dolphins since at least the 1920s. Using land-based observations, dolphin presence was recorded between May and September in 2004, 2005 and 2006. In addition, more detailed information about the numbers of animals, their behaviour and habitat use was collected in 2006. A digiscope system was also tested, during 2006, for the purpose of taking dolphin photo-identification images from land.

Dolphins were found to be present on an average of 29.6% of 15-minute observation intervals, although there was significant monthly variation, with an increased presence later in the year. This increase was due to greater numbers of animals in the area, coupled with an increase in group size at this time. Nevertheless, the majority of sightings were of single individuals, with a mean group size in all three years of only 1.8 animals. Tidal state was shown to have a strong influence on dolphin presence, with an increase during the ebb stage.

Dolphins were found to use the bay predominantly for feeding, with this behavioural state being observed 71.1% of the time. Feeding was shown to occur primarily in two areas at either side of the Bay, with the majority of travel behaviour being across the Bay between the two feeding spots. The digiscope was successfully used to take photo-identification images of dolphins, but the quality of images was highly dependent on the range and behaviour of animals and the sea conditions. New Quay Bay is thus an important area for the species, especially as a feeding hotspot, and continued monitoring of this area is necessary for the management of the Cardigan Bay bottlenose dolphin population.

Study 6. Coastal habitat use of harbour porpoise (*Phocoena phocoena*) in Cardigan Bay Special Area of Conservation, Wales (BSc thesis by Saana Isojunno, April 2007)

Small-scale habitat use of harbour porpoise was investigated using non-intrusive land-based watches in the southern part of Cardigan Special Area of Conservation, where relatively little such data had been previously collected. Past research has indicated that local porpoise abundance may respond to several oceanographic and bathymetric features, substrate type, and anthropogenic point sources.

Using Geographic Information System software, this study confirms that harbour porpoise habitat use can be site-specific even at a small scale. Two hypotheses were tested: 1) that sightings are distributed non-randomly in the study area, and 2) if sighting clusters exist, they can be related to environmental variables. To test the first hypothesis, the nearest neighbour-method was used in ArcGIS. Whereas sighting rates did not differ from one vantage point to another, the average observed distance between sightings was found to be significantly lower than expected, indicating clustering at a finer scale. Sighting densities were mapped and 467 individual sightings related to maps of sediment type and

bathymetry. Sighting rates, and average individual counts per 15-minute interval were treated as indices of abundance. Sighting rates increased towards the end of the two-month study period in July (Figure 20).

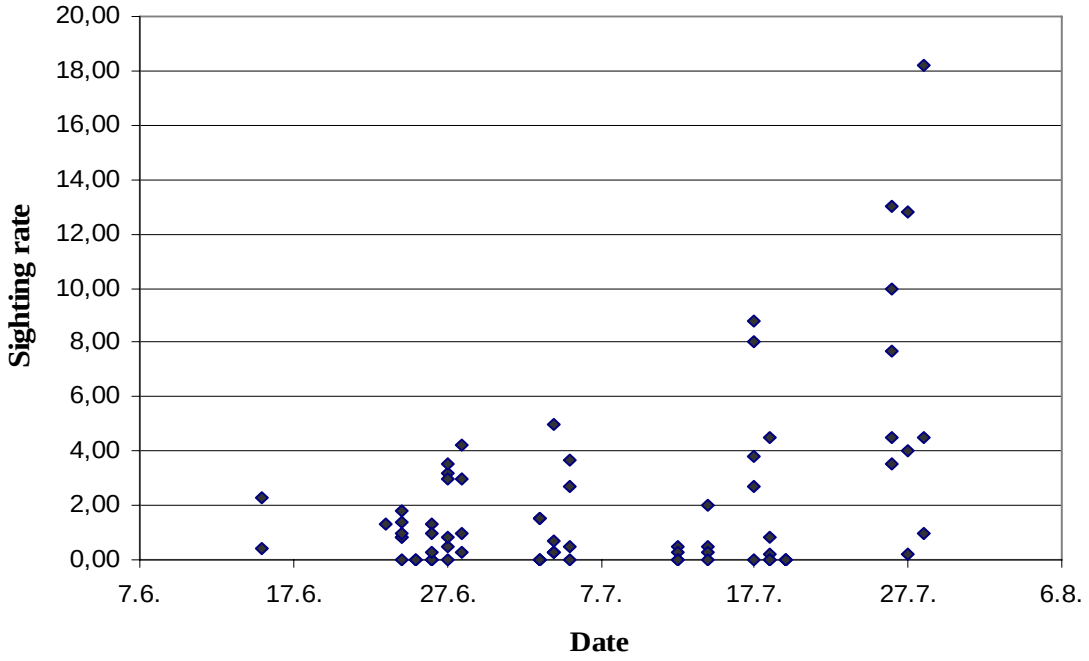


Figure 20. Sighting rates per 90 min watch period across the two-month study period in June-July 2006

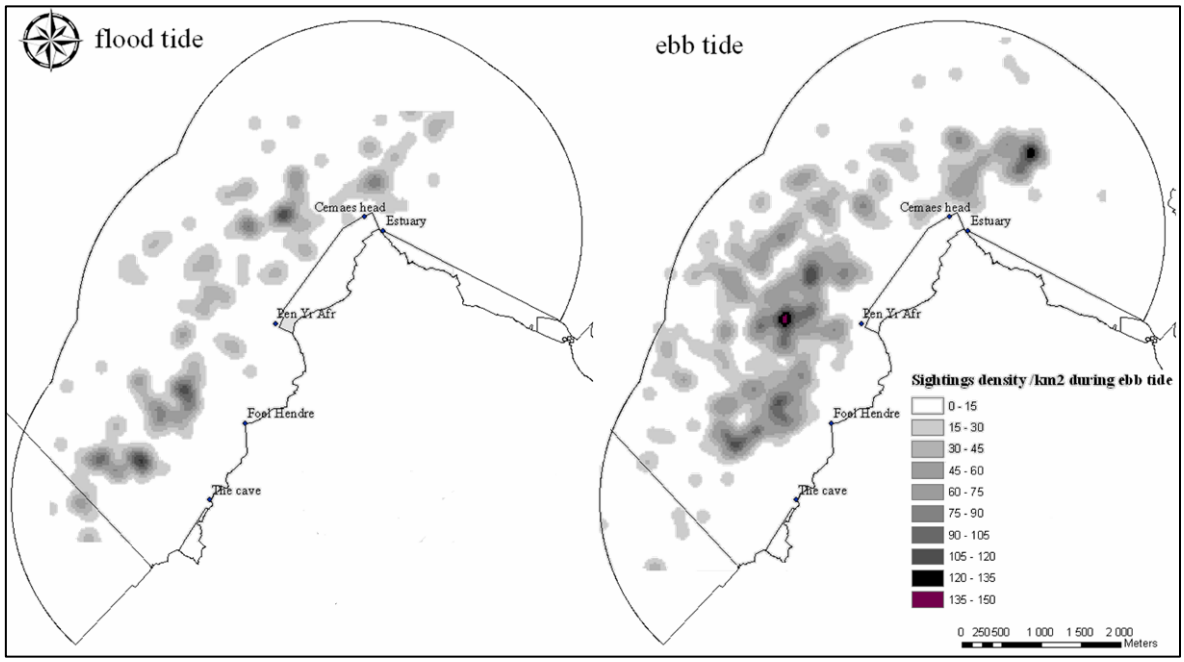


Figure 21. Sighting densities of all recorded harbour porpoises during flood and ebb tide.

Sighting rates were lower and transiting behaviour more frequent around the Teifi Estuary than at the other four studied sites. Of environmental variables, sighting rates and clustering tended to be higher during ebb tide (Figure 21) and in the afternoon.

Staying behaviour and associations with birds were also more frequent during ebb tide. The highest sightings frequency was found at depths of 16-20 m. Sightings also tended to be aggregated around steeper slopes. Most sightings were situated over cobbles with sand/silt and either sparse or moderate but short turf. These patterns are likely to relate to prey availability, which would be of interest for future study and management of the species' habitats.

Study 7. Habitat use, haul-out behaviour and site fidelity of grey seals along the Ceredigion Marine Heritage Coast (MSc thesis by Kate Lewis, December 2005)

Grey seals were sighted from visitor passenger boat trips within all ten zones of the Ceredigion Marine Heritage Coast between New Quay and Ynys Lochtyn in 2004 and 2005, demonstrating their presence along the coastline within the Cardigan Bay SAC. Environmental variables, collected via such trips, and direct observations from Bird's Rock, a designated Site of Special Scientific Interest, were analysed using univariate and multivariate methods, to investigate whether any particular factor influenced grey seal haul-out behaviour. Although tide, time of day, adjusted air temperature and disturbance primarily influenced haul-out behaviour at Bird's Rock, it is evident that a complex dynamic of intrinsic and extrinsic factors interact to determine haul-out behaviour.

Potential human-induced disturbance was investigated by logging grey seal-vessel interactions observed during direct visual surveys at Bird's Rock. Vessel traffic appeared not to induce short-term behavioural responses in the majority of seals present, suggesting that vessels which were abiding by the Ceredigion Marine Conservation Code of Conduct did not disturb seals in the short-term. Although infrequent, research vessels abiding by and canoes violating the Code of Conduct resulted in seals permanently modifying their behaviour and/or escaping Bird's Rock. Given that long-term effects of vessel disturbance are unknown, this study supports the need for further investigation.

Photo-identification of grey seals encountered along the Ceredigion coastline exhibited a degree of intra-seasonal and inter-annual site fidelity, particularly to Bird's Rock and Cwmtudu, a pupping beach. 52% of individuals were re-sighted at least twice within the initial season photographed. One bull (ID 015) was encountered in three successive years (2003-05), whereas a female (ID 007) known to have pupped at Cwmtudu in 2003 was re-sighted there in August 2005. Furthermore, grey seals at Bird's Rock exhibited a preference for specific haul-out rocks at Bird's Rock.

Finally, direct observation revealed that education of tourists remains paramount in maintaining the protection of grey seals along the Ceredigion Marine Heritage Coast. The continuation of a precautionary approach to management within this area is required.

Social Structure & Behaviour

Study 8. Social structure of bottlenose dolphins in Cardigan Bay (MSc thesis by Edita Magileviciute, November 2006)

The social structure of a population is a fundamental component of its biology and ecology. Mating strategies, foraging techniques, and the ability to explore the surrounding environment, are closely related to the network of relationships between individuals. The bottlenose dolphin population in Cardigan Bay is relatively small, broadly comparable in size to the Moray Firth and Shannon estuary populations.

Based on the association evidence, and comparing our findings to the patterns observed in other bottlenose dolphin communities, it is likely that this population could be regarded as having a fission-fusion social system with a large number of bonds, and many redundant paths for the transfer of information. Significantly frequent associations between individuals were used as a basis for the construction of a social network. In the present study, network analytical techniques, developed for the analysis of human sociality, were employed to construct and investigate bottlenose dolphin social networks in Cardigan Bay for the years 2001-06.

Density, the average shortest path length, and clustering coefficients were calculated to determine the average structure of a network. The variability of properties in annual networks indicated the dynamics of relationships. Divisions within networks were detected using the Girvan-Newman algorithm and modularity index, and could have been influenced by the degree of homophily of the preferred companionships, while the gender of individuals did not seem to play a significant role in association pattern. However, these findings were considered with caution due to the low number of individuals of known sex, age and kin relatedness in this population. Highly central individuals positioned on the boundaries of network components were identified (Figure 22). The presence of such individuals could be an important factor in spreading novelties in the community; in the case of a highly clustered network, as observed for Cardigan Bay in 2006, the spread of the innovation might be restricted within the component of the network where it has originated. In particular, the ego-network of dolphin #13 with its high centrality with regards to the degree and betweenness over the years, merits more detailed investigation in future studies.

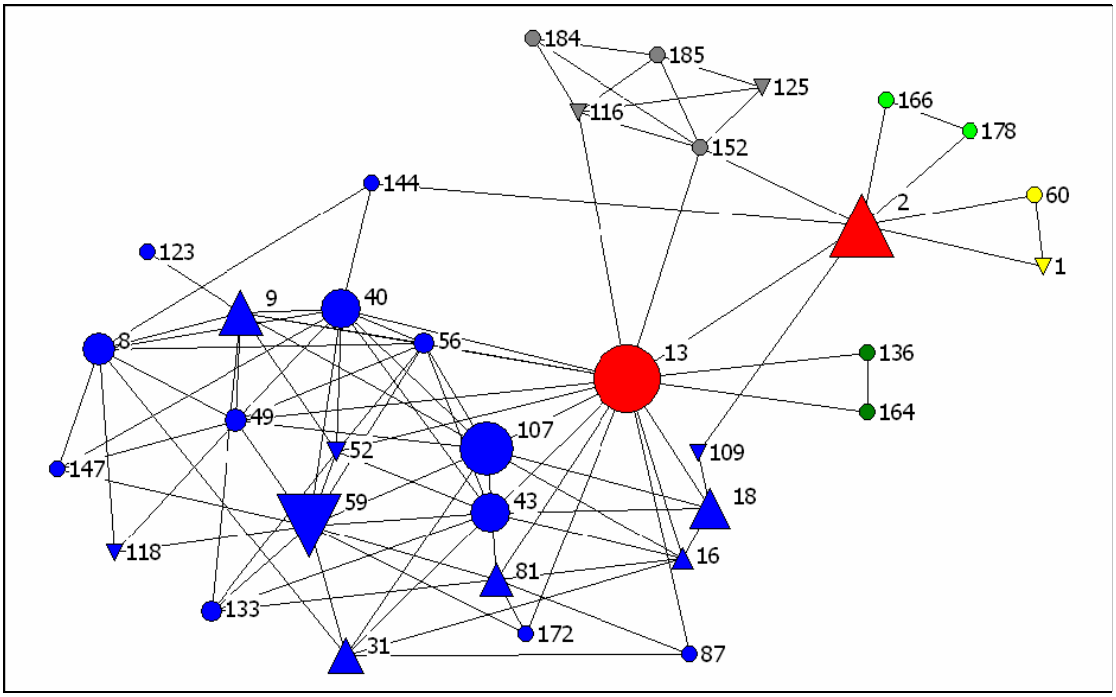


Figure 22. The division of the pooled data network 2001-06 into five components. Females are presented as up-triangles, males as down-triangles, and individuals of unknown sex as circles. Vertex number indicates dolphin ID, vertex colour- group membership. The size of each symbol shows the level of betweenness. Individuals #13 and #2 had the highest betweenness scores within the network and connected all five groups

Study 9. T-POD detection and acoustic behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay SAC: a comparison between T-POD recordings and visual observations (MSc thesis by Mercedes Reyes Zamudio, November 2005)

T-PODs are acoustic data loggers that detect echolocation clicks from harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Tursiops truncatuis*). In the past, T-POD research has focused mainly on harbour porpoises. This study aimed to investigate T-POD performance when studying bottlenose dolphins by measuring the detection range and detection probability in the presence of dolphins, and investigating the possibility of identifying particular dolphin behaviours from T-POD data. Two T-PODs were deployed for a period of six weeks (27th June – 8th August, 2005), at two different locations (Mwnt and New Quay, Cardigan Bay Special Area of Conservation, West Wales).

At each location, visual observations were undertaken using theodolites to calculate the distance between T-POD and dolphins, and to observe their behaviour. Comparisons between data obtained with T-PODs and simultaneous visual observations showed that the maximum T-POD detection range of bottlenose dolphin clicks was 650m. When the dolphins were present within this range, the T-PODs only detected them 11 percent of the time, and there was a significant negative correlation between distance and the T-POD detection probability, with a sharp decline in detection rate beyond 300m. In addition, the detection probability varied with dolphin behaviour so that dolphins that were feeding had a significantly higher probability of being detected by the T-POD than dolphins that were travelling T-POD data showed that dolphins that were feeding emitted click trans with significantly higher number of clicks, and had significantly lower inter-click intervals than travelling dolphins, suggesting that click trains with high numbers of clicks (>30) and low minimum inter-click intervals (<350μs) signify feeding behaviour in T-POD data. This could be a first step to using T-PODs to provide information on any spatio-temporal patterns of feeding. .

Study 10. The use of T-PODs to identify echolocation behaviour in bottlenose dolphins in New Quay Bay (MSc thesis by Sharon Bond, November 2006)

The odontocete echolocation system has evolved as a dynamic and specialized process for spatial orientation and the detection and localisation of prey, thus optimizing the chances of survival in an aquatic environment. This study was carried out primarily to explore the possibility of using T-POD acoustic data as a means of identifying the echolocation behaviour of bottlenose dolphins in New Quay Bay, West Wales. Dolphins were monitored through land-based visual surveys from May to September 2006, and observations were compared to corresponding click train parameter data collected with two T-POD units deployed in the study area. It was found that click trains produced by foraging dolphins had both significantly lower mean inter-click intervals and train durations, and a significantly higher number of clicks, than those emitted by dolphins observed in the behavioural states of travelling and foraging/travelling. These findings were applied to T-POD data collected in the study area throughout the year, revealing both significant diel and monthly variation in the number of foraging click trains acoustically detected.

The secondary aim of this investigation was to broadly determine the influence of directionality, group size, distance and behavioural state on T-POD detection rates. The collective evaluation of data obtained over the study period indicated that a combination

of these variables had an effect on T-POD detection rates. However, further work is required to determine the extent to which each of these factors influences acoustic detection rates, and how environmental variables may also contribute to the detection of echolocating dolphins with T-PODs. It was concluded that if the limitations of using T-PODs are accepted, the methodology employed in this study has the potential to monitor long-term changes in dolphin behaviour. Consequently, such monitoring could provide a method for monitoring fine-scale temporal changes in habitat use.

Study 11. The occurrence and foraging activity of bottlenose dolphins and harbour porpoises in Cardigan Bay SAC, Wales (MSc thesis by Lucy Alford, December 2006)

Ten cetacean click detectors (T-PODs) were deployed at set locations within the Cardigan Bay SAC. From sounds recorded between March 2005 and February 2006, bottlenose dolphin and harbour porpoise click trains were determined to allow for investigation into the occurrence and foraging activity of the two species. In doing so, the study would build on current knowledge of use of the SAC by these two species using both visual and acoustic methods.

Clear patterns in occurrence were determined, with bottlenose dolphin abundance reaching a maximum in September and October 2005, and harbour porpoises in December 2005. Spatial shifts between T-POD locations were not detected, however. Occurrence was further influenced by the spring/neap tidal cycle with bottlenose dolphins showing a trend of increased detection with increased tidal height and harbour porpoises a trend of decrease. It was assumed that changes in abundance were most likely related to prey availability.

Using click train characteristics to determine those trains involved specifically in foraging, two peaks in foraging activity were revealed. The first occurred during the late summer and early autumn, but was only observed at offshore Aberporth. A second peak occurred during winter months at the majority of T-POD locations and was believed to be a consequence of increased foraging requirements, declines in prey abundance or due to a reduction in boat activity. The analysis of foraging clicks did not distinguish between bottlenose dolphins and harbour porpoises, and so it was not possible to link foraging to a particular species.

Foraging was found to be unrelated to time of day at the majority of locations, although nocturnal foraging was revealed at Cardigan Island and offshore Aberporth. Tidal state was further found to affect foraging activity, with most foraging occurring during the first half of the ebb or first half of the flood. Velocity did not appear to affect foraging activity.

Study 12. Diurnal behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, West Wales (MSc thesis by Lauren Beddia, September 2007)

The behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, West Wales, was investigated to assess the daily behavioural budget and to identify differences due to years, months, group size and seasonality. The kernel ranges were also estimated using the Animal Movement extension in ArcView 3.3, so as to identify the 50% (core areas) and 95% (home ranges) Utilization Distribution (UD), within Cardigan Bay, and then compared between years and for presence of calves. Boat-based visual surveys were

conducted from 2001-07 during 435 survey days, resulting in 1,469 sightings of bottlenose dolphins exhibiting particular behavioural states. Focal animal follows were conducted during line transect and *ad-libitum* surveys. The following behaviours were considered: travelling, feeding, socializing, resting, and others - such as bow-riding or leaping. Groups were defined as an aggregation of dolphins within 100 metres, with the majority of the individuals engaged in similar activities.

During the study period, travelling and feeding comprised over 85% of the dolphins' diurnal budget, followed by 'others,' resting and socializing. No difference was found in the activity budgets of groups with calves present compared to those without calves. Single individuals spent more time feeding, while groups greater than 11 individuals spent more time travelling and socializing; more time was also spent feeding during the end of the study season compared with early in the season. The dolphins used the space within their home range non-uniformly, with core areas varying with behaviour types, stage of the season, and presence of calves. However, there was a significant overlap of the core areas for all behaviours and for the presence of calves. These findings provide important information concerning the spatial use of Cardigan Bay by this population of bottlenose dolphins.

Possible Impacts of Anthropogenic Activities

Study 13. Skin lesions of bottlenose dolphins in Cardigan Bay (MSc thesis by Edita Magileviciute, November 2006)

Epidermal skin abnormalities (lesions) for those bottlenose dolphins encountered in 2006, were identified and categorized in the present study. The purpose was to collect baseline information on the prevalence of these markings in the Cardigan Bay population. One or more lesions have been observed on the skin of 61% of the individuals. The most prevalent ones were found to be black-fringe spots (BFS). All the components in the network 2006 (see Study 10) had more than 50% of the individuals with epidermal markings. 66% of total cloudy lesions (CL) type were present in one particular group. Similarly, 69% of the total BFS were present in another component of the network. A Chi-squared test was employed in order to assess whether observed frequencies conform to a standard distribution. The results were found to be significant for all components ($p<0.01$), indicating that the distribution of epidermal lesions was not occurring at random. This high prevalence of cloudy lesions and black-fringe spots in two of the network components led us to examine the distribution of dolphins affected by these lesions. The results are illustrated in Fig. 23. Dolphins having BFS were mostly encountered in the north of Cardigan Bay, while dolphins with the prevalence of CL had centres of activity around Cemaes Head and Mwnt. In the New Quay sub-area, an overlap in the area utilization was observed.

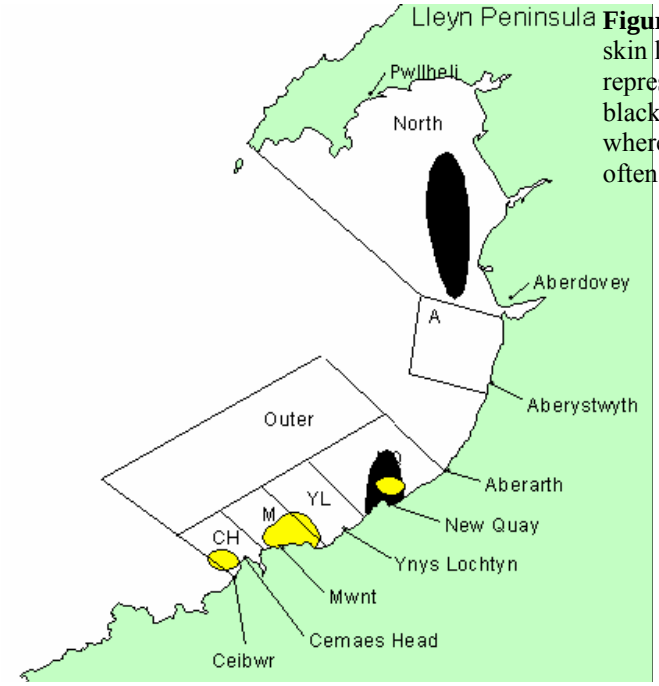


Figure 23. Distribution of individuals having skin lesions in the network 2006. Black kernels represent centres of activity for dolphins with black-fringe spots; yellow kernels show areas where dolphins with cloudy lesions were most often encountered

Study 14. Observations of bottlenose dolphins (*Tursiops truncatus*) behavioural changes in relation to boat presence in Cardigan Bay, Wales (BSc thesis by Nicola Ruston, 2007)

The bottlenose dolphins' habitat brings them into close contact with humans all over the world. There is growing concern over the effect of disturbance by boat traffic to dolphin behaviour and movement. This project investigated the changes in behaviour and movement patterns that took place when bottlenose dolphins came into close contact with various types of boats. The observation site was a 60 metre high headland, in New Quay (Cardigan Bay SAC, West Wales), to allow the best possible viewpoint for observations of both boat and dolphin behaviour. The study took place over a four-week period in June/July 2007, with 23 positive days for sightings. Behaviour of the dolphins in the absence of boats was recorded every three minutes after the first initial sighting until the dolphins disappeared. A similar procedure was followed during an encounter between a boat and dolphin(s).

The behaviours of the dolphins and boats were categorised before the investigation started to allow easy recognition of different behaviours. A theodolite was used to track and visually analyse any effect the boats may have had on the movement and behaviour of the dolphins and to allow the data to be graphically represented, using a Pythagoras cetacean tracking program. The results showed obvious relationships between the behaviour of the dolphins and the presence and behaviour of specific boats. Overall, there were 57 dolphin sightings and 49 dolphin-boat encounters; 89% of the dolphin-boat encounters showed a significant change in dolphin behaviour. Many of the encounters showed relationships that underline specific behaviours observed from the dolphins and how their behaviour changes depending on boat type and the manner in which they approach an individual. Observing the impact of how dolphins react to vessels will aid in the management of boats and the conservation of bottlenose dolphins within Cardigan Bay's designated SACs.

Part Five: Review of Objectives

Population Size & Trends

Estimates of population size have been derived using two research methods: line transect surveys and photo-identification. The former has been applied to both bottlenose dolphin and harbour porpoise, and the latter to bottlenose dolphin only. Line transect surveys provide an estimate of the average number of animals in the study area during the survey period (usually May-September), whereas photo-identification is used to calculate the total number of bottlenose dolphins using the study area over the survey period, which can be either a particular year (between May and September), or overall, combining successive years. In the case of line transects, the study area is the Cardigan Bay SAC; for photo-identification studies, the study area is either the Cardigan Bay SAC or the whole of Cardigan Bay (where *ad libitum* surveys have sampled a wider area and included Pen Llyn a'r Sarnau SAC). Even where the study area is the same for the two methods (i.e. Cardigan Bay SAC), photo-identification should always give a higher population size estimate because it is estimating the numbers of different animals that may come into the area over time as opposed to a snapshot estimate of the number at a particular time.

The abundance analyses from line transect surveys, performed with the software DISTANCE 5, provided estimates of 154, 206 and 109 animals for bottlenose dolphins and 107, 170, 214 for harbour porpoises in the Cardigan Bay SAC. A general increase in the population size for the bottlenose dolphins was thus observed in the years 2005-07, compared with the estimate for the period 2003-04 (140 dolphins). The harbour porpoise population showed a slight decline when compared with previous years (236 in 2003 and 215 in 2004), then stabilised in 2005-06, and showed an increase in 2007.

Using photo-identification, a total of 197 bottlenose dolphins with recognizable markings could be identified, and formed the Cardigan Bay catalogue. It was estimated from MARK-CAPTURE analysis that between 48% and 62% of the population in a particular year, were marked. Thus, the overall estimate for the bottlenose dolphin population for the entire Cardigan Bay in any one year is 133 animals in 2005, 179 in 2006, and 198 in 2007, but 328 when considering the entire 2001-07 period.

Gaps Since harbour porpoises are rarely marked sufficiently to be able to recognize individuals, line transect surveys are the only method available to determine population size for this species. Fortunately, sufficient numbers of encounters can be obtained by the current survey approach, resulting in precise estimates with coefficients of variation (CVs) between 15-20%, which is generally considered acceptable. The same does not apply to bottlenose dolphin population estimates using this method, which show CVs varying from 25-40%. For bottlenose dolphins, photo-identification is more suited for the determination of population size. However, since the Cardigan Bay population is clearly not a closed one, open population models should be applied, and geographic coverage widened further.

Population Structure

Information on population structure is some of the most difficult to obtain. Survival rate estimates require longitudinal data on as many animals as possible in order to monitor the proportion of the population still alive. However, this assumes the population is a closed one and there is negligible emigration. But the evidence indicates that this assumption probably does not hold true. This makes it very hard to calculate any proportions because some individuals may have moved out of the area either temporarily or permanently. Likewise, the recording of known deaths will almost certainly represent an underestimate of the true number of deaths given that probably only a small proportion of animals dying will be recovered.

It is also very difficult to determine gender of free-swimming dolphins, since for only a few will the genital area be viewable during encounters. And determination of age requires the counting of growth layers in the dentine of teeth, which means either capture of living animals, or the collection of teeth from stranded animals. The former is not viable in Cardigan Bay whilst the number of animals stranding is too small to provide a sufficient sample size to derive estimates of the proportion of different age cohorts.

From the photo-identification studies, an estimate of the number of calves born each year has been calculated. These are: 13 (2005), 20 (2006), and 20 (2007). From those estimates, crude birth rates (estimated number of newborn calves divided by the estimated total population) can be calculated. They give values of 0.098 (2005), 0.112 (2006), and 0.101 (2007), and a mean value for the three years of 0.104. These compare favourably with crude birth rate estimates calculated for other bottlenose dolphin populations, which range from 0.012 to 0.156, but in most cases are between 0.055 and 0.10 (Wells and Scott, 1999).

One aspect of population structure of particular relevance to conservation management is population discreteness – the extent to which there is a discrete Cardigan Bay bottlenose dolphin population or mixing with animals from elsewhere. At present, it is known that Cardigan Bay dolphins range as far as the north coast of Wales, and the fact that there are sightings of the species off the Isle of Man and north as far as the Solway Firth suggests the dolphins may range as far as there as well (Evans *et al*., 2003). However, to date there is no evidence of mixing with populations outside the Irish Sea, with no matches from other catalogues, whilst a comparison of whistle characteristics of dolphins from Cardigan Bay and the Shannon Estuary suggested differences indicating little or no mixing.

Gaps The major gaps in our knowledge of population structure come from insufficient information on gender. Too few individuals are of known gender. There are two approaches that could address this: the first is to conduct DNA studies (using skin/blubber biopsies) with sex-linked markers, which is the normal manner in which this information is collected from free-ranging animals; and the second is to employ an underwater polecam video system to film the external genital area of animals. The latter is less intrusive but relies upon animals coming close to the side of the vessel (as opposed to the bow), which may make it more difficult to obtain gender from more than a relatively small number of animals. DNA studies using biopsy samples will be needed if population discreteness is to be examined further since it requires sufficient genetic material for deriving markers.

Population Distribution

For seasonal trends in distribution, the best data come from the T-PODs deployed at ten locations along the coast within Cardigan Bay SAC. These show a summer peak in bottlenose dolphin activity in this coastal region with rather few in winter, whereas harbour porpoises occur year-round an actually show a winter peak. Preliminary aerial surveys presented here suggest that at least some dolphins move offshore in Cardigan Bay during the winter months, ranging over a much wider area, and from photo-ID surveys off Anglesey (Pesante *et al*., 2008), it is clear that a significant portion of the Cardigan Bay population spend time during winter off the North Welsh coast.

Analyses of spatial distribution patterns during summer show that within at least Cardigan Bay and Pen Llyn a'r Sarnau SACs, and probably beyond, bottlenose dolphins occur primarily within 5 km of the coast. Within these coastal areas are sites that appear to be favoured over others. The entire coastal area from Aberaeron to Cardigan and around Fishguard seems to be of particular significance to bottlenose dolphins, but in particular New Quay headland, Ynys Lochtyn, Mwnt, Pen Peles and Aberporth. Other centres of activity were found in Tremadog Bay and around the sandbanks Sarn Badrig, Sarn-y-Bwch, Sarn Cynfelyn and Patches buoy. However, dolphin distribution patterns varied between years, and in 2006 and 2007, the dolphins were found to be much less concentrated in the coastal area.

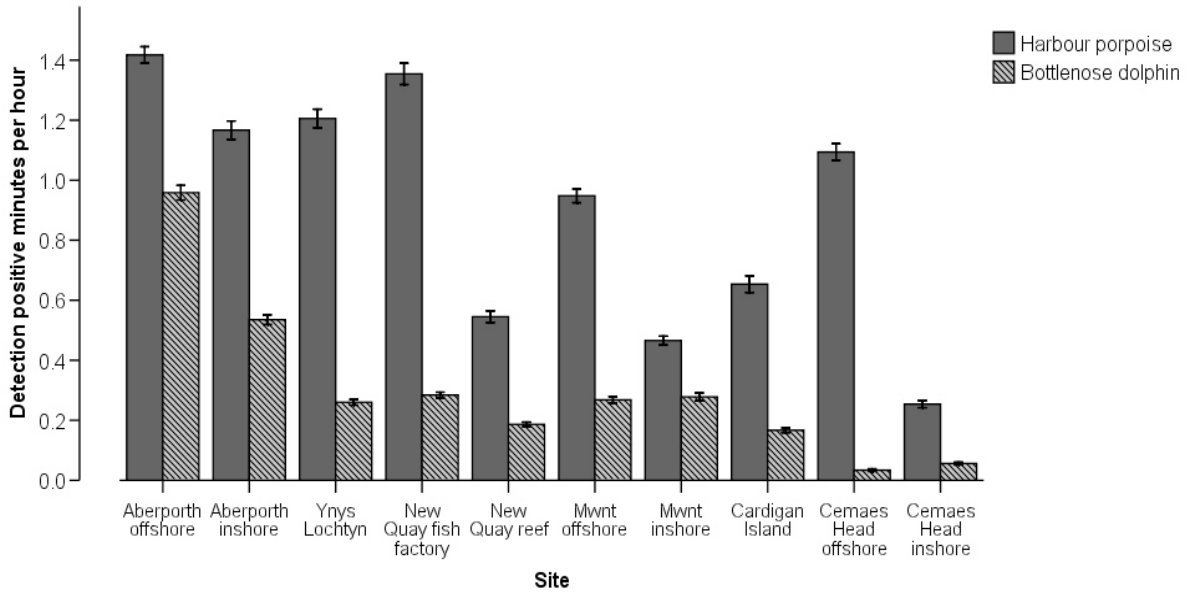


Figure 24. Number of detection positive minutes per hour of bottlenose dolphins and harbour porpoises at each site. Data represent means ± 1 standard error.

Harbour porpoises generally were much more widely distributed although they too appeared to have areas where they were more likely to occur. On the whole, densities were higher in the southern part of Cardigan Bay than further north, and land-based watches, vessel surveys and T-POD monitoring indicated a greater presence around the following sites: New Quay Head, Aberporth, Ynys Lochtyn, and between Cemaes Head and Ceibwr Bay (see Figures 11, 21 & 24).

Gaps Survey coverage of Cardigan Bay has concentrated upon Cardigan Bay SAC, with some effort also in Pen Llyn a'r Sarnau SAC, but limited coverage elsewhere in the Bay. T-PODs provide excellent temporal resolution (both diel and seasonal) for patterns of occurrence of both bottlenose dolphin and harbour porpoise, but their spatial resolution is poor because at present they are confined to the coastal area within the Cardigan Bay SAC. It would be useful to deploy T-PODs over a wider area of Cardigan Bay. Most information on spatial distribution comes from vessel surveys during the summer months and rarely extends far offshore. There has been a small amount of aerial surveys throughout the Bay between February and April. This could usefully be extended to every month of the year, and would provide a valuable snapshot of larger scale patterns of distribution that could also be calibrated against the smaller scale vessel surveys.

Home Range Size & Use

The ranging movements of several individual dolphins have now been investigated. Some animals showed a preference for relatively small areas and did not seem to range over the whole Bay whereas others were photographed at widespread locations that included Tremadog Bay, the Llyn Peninsula and even the North Welsh coast (Pesante *et al*., 2008). This confirms previous indications that the Cardigan Bay SAC by no means includes the full geographic range of this population, which may encompass the entire Irish Sea or even beyond. On the other hand, from comparisons with other photo-ID catalogues, there is no firm evidence as yet for any exchange of dolphins between Welsh and other British and Irish populations (NB a report by Wood (1998) of a match between Cardigan Bay and Cornwall has never been substantiated, and was not based on direct comparison of images from the two regions).

Photo-identification data collected over the period 2001-07 shows that the discovery rate is still increasing, although 92% of the animals had been photographed by the end of 2006. Individual dolphins were seen up to 48 times, although 11% of the dolphins were sighted only once and 31% less than ten times. 28% were seen in only one year, and 10% during all the years. The best fitting model that resulted from the mark-recapture analysis for 2001-07 indicated that the emigration rate between years within the Cardigan Bay SAC was 40% and the likelihood that emigrated animals stayed out of the SAC was 60% (Figure 25a). For the entire Bay, the emigration rate was 10%, and the likelihood that emigrated animals stayed out of the Bay the next year was as high as 80% (Figure 25b). These results suggest that we are dealing with a meta-population showing some level of residency and site fidelity but also with a consistent number of transients and infrequent individuals. This population is best described by an open model, and is probably drawn from a much larger one, encompassing part if not all of the Irish Sea.

A habitat analysis indicated that bottlenose dolphins in Cardigan Bay favour shallow areas with depths of 5-10 metres. However, during the last three years, the animals were also found in deeper water (25-30 metres). Over 95% of Cardigan Bay has a slope of less than 1%, and 99% of sightings were recorded over this slope range. Generalised additive modelling indicated a preference for substrates that include sand usually mixed with gravel or pebbles (Baines *et al*., 2005).

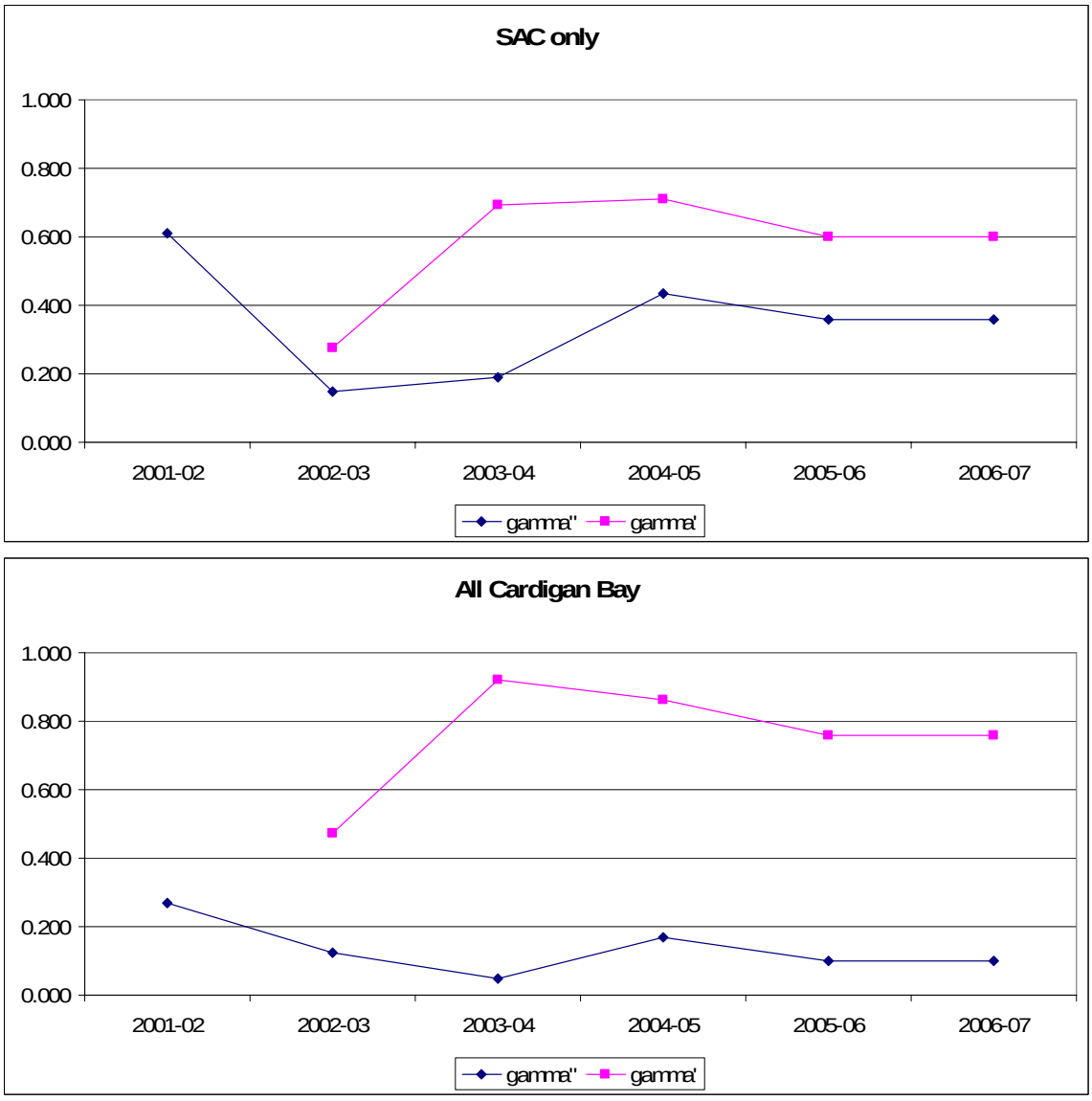


Figure 25. Bottlenose dolphin residency patterns for a) SAC only and b) All Cardigan Bay (gamma'' = probability of an animal emigrating from the study area; gamma' = probability of an animal staying outside the study area)

Gaps Although in the last two years, we have gained much new insight into the home range sizes and ranging movements of individual bottlenose dolphins, survey coverage remains concentrated largely upon Cardigan Bay SAC, and does not extend at all in the Irish Sea beyond Welsh waters. Surveys particularly in the northern Irish Sea would help to address this information gap.

Most physical environmental parameters typically used in habitat analysis, such as depth, slope, and aspect, exhibit little variation throughout Cardigan Bay. As yet, no detailed analysis has been conducted incorporating biological covariates such as chlorophyll "*b*" or densities of particular potential fish prey species. In the case of the latter, it is because the data do not readily exist. Observations have been made of dolphins with particular fish in their mouths (e.g. bass, garfish, conger eel, sandeel, salmon, sea trout, and herring), but the relative importance of different species in bottlenose dolphin diet is difficult to assess. Surface observations may not reflect overall dietary preferences. There are two ways in which one can elucidate what prey

are most important for the Cardigan Bay dolphins and how this might influence their habitat preferences. The first is by taking biopsy samples from free-ranging animals and then conducting fatty acid analysis to identify major prey species; the second is by spatio-temporal correlation analysis following scientific echo sounder surveys of the area. This latter method can provide density estimates for shoaling fish species (e.g. herring, mackerel, sandeel, sprat and other gadoids), but it has limited scope for solitary or benthic species. A combination of the two approaches would yield most information.

Social Structure & Behaviour

Using photo-identification and network analytical techniques initially developed for the analysis of human sociality, bottlenose dolphin social networks in Cardigan Bay were constructed for the years 2001-06. The results indicated that this population may be regarded as having a fission-fusion social system with a large number of bonds, and many redundant paths for the transfer of information. Similar findings have been obtained from studies of bottlenose dolphin social structure in other parts of the world (Wells and Scott, 1999; Connor *et al*., 1999).

Some individuals appeared to play central roles in the social organisation of this population, having association links to many other individuals, whereas there were others that associated with only a small number of other individuals. Without verification of gender for a greater proportion of the population, it is difficult to say whether alliances are stronger amongst males or females, or if one sex tends to play a more central role than the other. This information is important for conservation management since the removal of key individuals from the population could have far reaching implications on its social structure and the sharing of information and experience among groups.

During both vessel surveys and land-based watches, the main behavioural activities of animals have been recorded for each sighting. From these data, a daily behavioural budget can be derived, and compared both spatially and temporally. Boat-based visual surveys conducted from 2001-07 during 435 survey days, resulted in 1,469 sightings of bottlenose dolphins exhibiting particular behavioural states. The following behaviours were considered: travel, feeding, socializing, resting, and others - such as bow-riding or leaping. Groups were defined as an aggregation of dolphins within 100 metres, with the majority of the individuals engaged in similar activities. These studies found that travel and feeding comprised over 85% of the dolphins' diurnal budget, followed by 'others,' resting and socializing. No difference was found in the activity budgets of groups with calves present compared to those without calves. Single individuals spent more time feeding, while groups greater than 11 individuals spent more time travelling and socializing; more time was also spent feeding during the end of the summer compared with early in the summer. The dolphins used the space within their home range non-uniformly, with core areas varying with behaviour types, stage of the season, and presence of calves. Coastal areas tended to be used more for feeding and for small family groups with calves.

T-POD acoustic monitoring allows one also to identify when animals are foraging/feeding since during those activities, they have significantly shorter interclick intervals, emitting click pulses that sound like buzzes. Analyses of those data have revealed both higher foraging activity in the two hours after sunrise and two

hours before sunset for bottlenose dolphins, whereas they are highest during night-time for harbour porpoises.

Gaps Social network analyses depend upon a large quantity of photo-ID data involving groups of dolphins. The bigger the sample of re-sightings and the wider the geographic spread, the more confident one can be in the findings. Further photo-ID studies particularly over the entire Cardigan Bay addresses this issue, whilst accurate determination of gender requires either biopsy sampling with DNA analysis, or underwater video filming, as described above.

Describing behaviours and assembling activity budgets tend to rely upon surface observations. The only direct way to collect data on subsurface behaviour and during all weather and light conditions is to attach radio tags with time-depth recorders or if possible, D-tags, that also collect acoustic information. However, currently this would require capture of the animals for attachment, since remote deployment techniques have not been developed sufficiently as yet for safe and successful use on dolphins.

Anthropogenic Activities

The function of monitoring is not simply to determine trends in population size and distribution but to identify causes of any trends observed, and then if these are having a negative effect, to establish appropriate mitigation measures. This requires careful monitoring of anthropogenic activities. During surveys and land-based watches, any incident indicating disturbance or physical damage to dolphins (or other cetacean species) was recorded. Specific studies were also conducted on reactions by dolphins to various types of vessels and vessel behaviour so as to ascertain whether any disturbance was caused. Disturbance was generally assessed in term of changes in orientation, surfacing rates and aerial activity (breaches, tail slaps, etc), and, where possible, theodolite tracking of individual dolphins was conducted from land sites.

Photo-ID studies allow one to identify fresh injuries that could have been inflicted by propeller strikes or boat collisions, or entanglement in fishing gear, as well as the presence and prevalence of skin lesions that might be evidence of poor body condition or health problems.

As routine practice during offshore surveys, counts were made at regular intervals of different types of vessels observed in the area, in order to determine both spatial and temporal variation in their presence. This allowed one to determine whether there were particular areas or times at which vessel activity was high.

Together, these different sources of information provide a basis for assessing habitat quality for the species in Cardigan Bay, along with any trends that may suggest its deterioration.

Human activities likely to directly impact on the Cardigan Bay bottlenose dolphin population include: sound disturbance, vessel strikes, entanglement in fishing gear, pollution, and habitat loss. Although cetaceans in Cardigan Bay may occasionally become entangled (as for example occurred to a minke whale near New Quay in summer 2003), most fishing activities in the Bay involve only potting, and currently there are few net fisheries operating in the region.

The most obvious activity in the Bay that could have a negative impact is that of disturbance from recreational craft (speedboats, jet skis, yachts, and motorboats conducting sea angling trips or trips to see marine wildlife including the dolphins themselves).

Evidence for negative impacts from vessel activities comes from physical damage observed on dolphins in the form of propeller cuts, scars, and damaged vertebrae. However, it is rarely possible to be certain that physical signs result from a particular cause. Examples of possible cases are given in Figure 26. Most behavioural changes due to disturbance may be only short-term, resulting in vessel avoidance and changes to surfacing rates. At present, there is little evidence for animals shifting distributions away from areas of high boat activity such as New Quay, Aberporth, or Cardigan, but a longer time series is necessary before this can be properly assessed.

The effects of pollutants are difficult to establish. Even high levels of PCBs, pesticides, or heavy metals such as mercury or zinc, may not necessarily result in health problems for the animals, although there is growing evidence of a link for PCBs with disease (Jepson *et al*., 2005; Hall *et al*., 2006). Levels of pollutants in two stranded bottlenose dolphins from Cardigan Bay were amongst the highest ever recorded in the UK, although the source was unlikely to have been local (Morris *et al*., 1989; Law *et al*., 1995). Skin lesions have been found in several bottlenose dolphin populations (Wilson *et al*, 1999b), and it has been speculated that these may be caused by fungal or virus infections perhaps from untreated sewage. Animals in the Cardigan Bay dolphin population also exhibit a variety of skin lesions which appear to vary in prevalence, the most common being black-fringe spots and cloudy lesions. One or more lesions were observed on the skin of 61% of individuals photographed. However, the distribution of lesions was non-random, with dolphins having black-fringe spots were mostly encountered in the north of Cardigan Bay, while dolphins with a prevalence of cloudy lesions had centres of activity around Cemaes Head and Mwnt, in the south of the Bay. As yet, it is still not known whether these lesions have any health implications.

Gaps The major gaps in our knowledge are whether any human activities in Cardigan Bay are actually having long-term negative impacts upon the bottlenose dolphin population. This requires extended population monitoring over a number of years, a better understanding of range sizes and movements of individual dolphins, and comparisons between localities where a particular activity occurs and control areas where it does not. This will be difficult for the assessment of the effects of pollutants which are unlikely to be confined to discrete areas, but should be feasible with respect to vessel disturbance, as has been demonstrated by recent studies in Australia (Bejder and Samuels, 2003; Bejder, 2005; Bejder *et al*., 2006a, b) and New Zealand (Lusseau, 2003, 2004; Lusseau and Highman, 2004).

Future potential developments include seismic surveys and the construction of installations for offshore renewable energy, such as tidal and wind turbines. The effects that those may have will need careful monitoring so that mitigation measures can be taken where necessary.

Figure 26. Examples of physical damage or deformities potentially caused by vessel strikes, top and bottom pictures) or entanglement in nets or debris (middle).

Favourable Conservation Status Assessment

In order to provide a reasoned opinion on the status of bottlenose dolphins in the two SACs and Cardigan Bay in general, it is necessary to have annual estimates of population size over a period of at least ten years. Thus any conclusions at this stage must be considered preliminary. With that caveat in mind, there is no evidence to indicate that the population is not in Favourable Conservation Status – from both line transect surveys using Distance analysis and photo-ID studies using Mark-Capture

models, the population appears to be either stable or slightly increasing over the period 2001-07 (Figure 27). There are no comparable estimates for previous periods, but the evidence indicates no substantial change in abundance or distribution. Measures of reproductive rates compare favourably with those for bottlenose dolphin populations elsewhere.

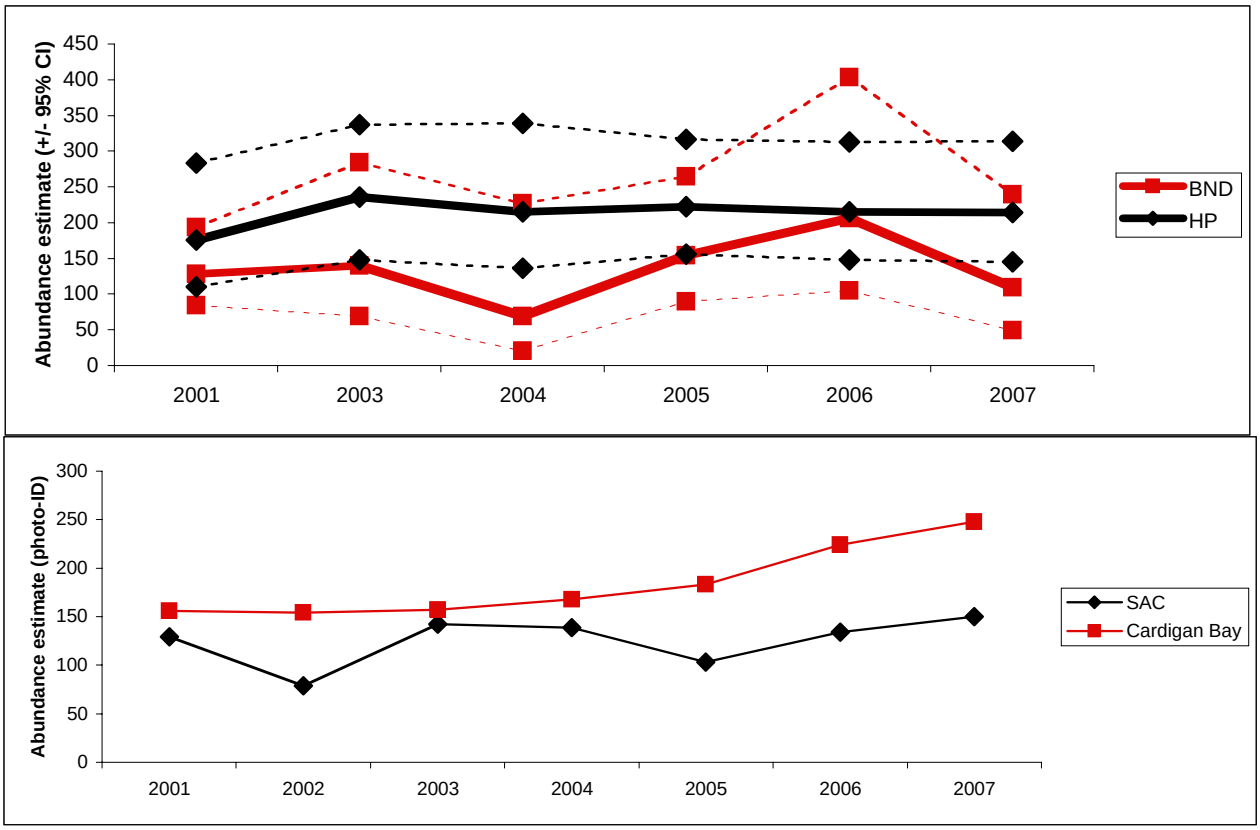


Fig. 27. (top) Trend in abundance estimates of bottlenose dolphin & harbour porpoise, from line transect surveys with Cardigan Bay SAC, 2001-07
(bottom) Trend in abundance estimates of bottlenose dolphin, from Photo-ID (Open Population Model) within the SAC & entire Cardigan Bay, 2001-07

On the other hand, the number of animals using the area can vary by around 50% from one summer to the next, and this may reflect variation in habitat quality between years. Furthermore, recent studies show clearly that bottlenose dolphins from Cardigan Bay may regularly range far from there. Seventy-five individual dolphins photographed off the North Welsh coast have been found to be a match with the Cardigan Bay catalogue (Pesante *et al.*, 2008). Sightings in this area peak in winter, with a mean group size of 18 individuals, which is three times larger than summer sightings in Cardigan Bay. The North Wales coast has much greater recreational activity occurring in its waters, and together with a much more industrialised area adjacent in the form of Liverpool Bay and Cheshire coast with its chemical works, these pose significant threats to the Cardigan Bay population. Conservation management of this population must therefore take into account human activities occurring more than 100 km away.

Gaps The most important gap in our knowledge for a full assessment of Favourable Conservation Status is obviously the lack of a sufficiently long series of annual

population estimate. Besides this, there is a need to obtain a more comprehensive picture of the long-term ranging movements of individual dolphins and the extent to which there is exchange between this population and others.

Monitoring Methods

A suite of methods was used to monitor bottlenose dolphins in Cardigan Bay. These were chosen because each has its particular strengths but also limitations, and it was only by using them in combination that one could address all the attributes relating to abundance and life history parameters.

Vessel surveys using line transects are the only method available to provide abundance estimates for harbour porpoise whilst they also give an independent estimate of bottlenose dolphin abundance. Systematic coverage of the area with the employment of distance measures allow one to derive population densities for both species, and to identify hotspots where concentrations occur. Line transects provide good spatial resolution but relatively poor temporal resolution. Vessels surveys are most effective in calm conditions, and therefore are best conducted during summer months, although the deployment of a towed hydrophone can increase survey efficiency. For winter survey coverage, and to survey large geographical areas so as to better determine distribution patterns, aerial surveys are more appropriate.

Photo-identification is the most cost effective method for determining population size in bottlenose dolphins. At the same time, it is the only method that provides information on life history parameters of free-ranging dolphins – birth rates, rates of immigration and emigration, and individual home range sizes and use. Where populations are open and there is migration, it is a greater challenge to determine population size.

The deployment of static acoustic devices such as T-PODs provides high resolution temporal monitoring of the presence of both bottlenose dolphin and harbour porpoise at specific sites. This allows intensive coverage of tidal, diel, and seasonal patterns of occurrence. Their detection ranges are usually relatively small - less than one kilometre and so spatial coverage is limited.

Gaps More precise bottlenose dolphin abundance estimates from line transect surveys would be obtained by increasing the survey effort and thence the encounter rate. This becomes clear from a crude power analysis, plotting both effort (Figure 28) and numbers of encounters (Figure 29) for bottlenose dolphin and harbour porpoise against the Coefficients of Variation (CVs) of the resultant annual population estimates. For bottlenose dolphin, CVs only become reduced to an acceptable level (c. 0.20 or less) when effort is >1500 km and there have been around 40 sightings. Increasing the number of sightings beyond that (equivalent to 1,500 km of effort) does not make any appreciable difference to the CVs obtained. For the harbour porpoise, CVs are at 0.20 or less when effort is >1000 km and there have been around 50 sightings. Increasing the number of sightings beyond 75 sightings (and 1,500 km of effort) makes no difference to the resultant CVs, which remain at a very reasonable level of around 0.175, given the relatively small area surveyed.

Broadening the geographical area of *ad libitum* surveys, concentrating along a coastal strip 5 km wide, would maximise the likelihood of encounters at least in summer, for photo-ID. However, if separate offshore populations also exist, then surveys would

need to cover those areas as well. Aerial surveys over a wide area, preferably conducted once a month, would clarify this. For sites thought to be of particular importance to dolphins (and/or porpoises), T-PODs provide the best means of monitoring temporal changes. At present, their deployment is confined to Cardigan Bay SAC. This should be extended to other key sites in Cardigan Bay.

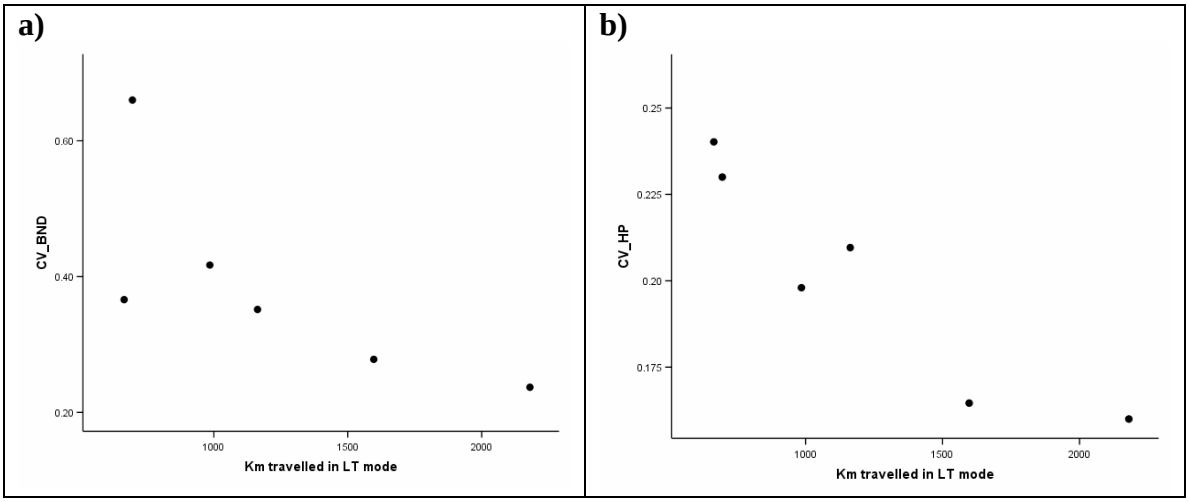


Figure 28 Power Analysis showing variation in CVs of Abundance Estimates (from Distance sampling) for a) Bottlenose Dolphin and b) Harbour Porpoise as a function of effort (distance travelled in km whilst on line transect)

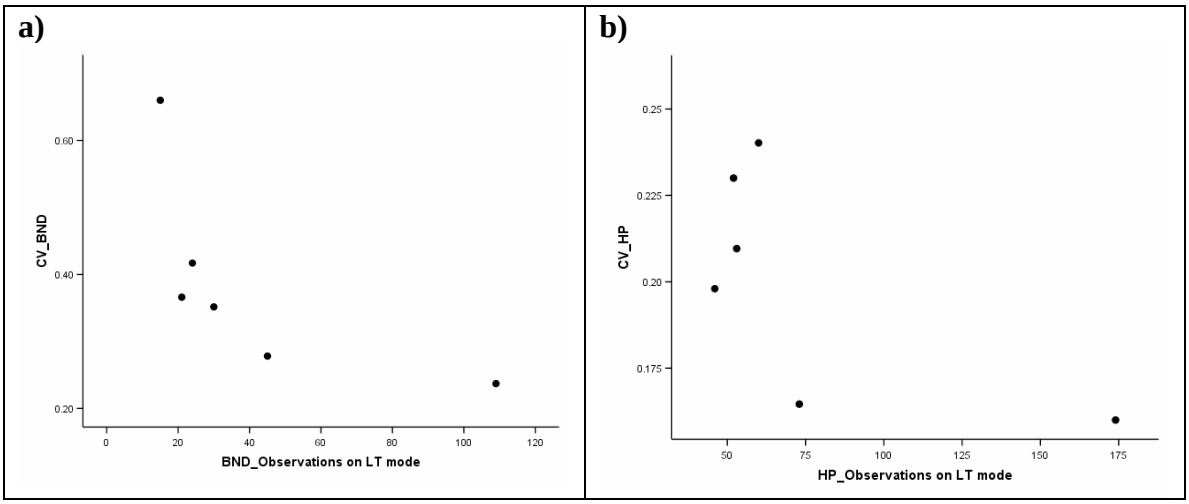


Figure 29 Power Analysis showing variation in CVs of Abundance Estimates (from Distance sampling) for a) Bottlenose Dolphin and b) Harbour Porpoise as a function of the number of sighting encounters

For collecting information on other attributes such as sex ratios and social structure, population discreteness, and dietary preferences, more specialised research approaches will be needed, such as biopsy sampling, underwater video, telemetry, and echo sounder surveys of fish densities.

Part Six: Recommendations for Future Work

- Maintain a continuous monitoring programme. In order to be able to detect trends in the abundance of marine mammals, it is recommended that any mark-recapture or distance-sampling monitoring programme lasts for a significant number of years with no interruptions. For bottlenose dolphins, Wilson and colleagues (1999) estimated that the detection of any trend can only occur following >8 years of research effort. Furthermore, reproductive and life histories of the individuals of the population can only be properly recorded if photo-identification surveys are run every year and preferably throughout the entire year, rather than being concentrated just in the summer months.

- Conduct aerial surveys both in summer and winter. The aerial surveys have proved to be a very powerful tool for providing a snapshot of the distribution of the marine mammals throughout the Bay at any one point in time. The running of the surveys during summer (possibly once a month or once every two months) would allow to properly compare the distribution of the animals between seasons, and to confirm that the bottlenose dolphins are not found in offshore areas during the summer months.

- Conduct some photo-identification sessions also during the winter, possibly in conjunction with the aerial surveys. Indeed, it would be very important to see which animals are found in the Bay during the winter to better understand the level of site fidelity and the population dynamics of the Cardigan Bay population. A boat could be ready to leave the harbour during any aerial survey, in order to reach any group of dolphins sighted from the plane and take pictures for the photo-identification.

- Improve the suitability of boats used for the surveys. Boats that can travel faster (i.e. 9-12 knots cruising speed) and with a higher observation platform are required for the various types of trips performed in the Bay. This is particularly true for the surveys run in the northern part, where a faster boat would allow the coverage of a wider area, whilst a higher observation platform would prevent from missing to spot any group of mammals. Effort should be made to have platforms where observers can operate independently of one another on the same vessel, with clear view of the track-line.

- Perform trips outside Cardigan Bay, both in the north and in the south, and towards Ireland, in order to evaluate the level of emigration and immigration in the population of bottlenose dolphins of Cardigan Bay, and to better establish their true home range. This is particularly important in order to verify whether the conservation management plan presently in place is appropriate to protect the species.

- Improve the design of the distance-sampling line transect surveys. The actual transects followed during the distance-sampling trips are designed in a way that does not take into consideration the fact that during the summer, the majority of the dolphins are found very close to the coast. This results in most of the sightings being recorded when not in line transect mode, and therefore not being used for

the abundance estimates, giving values that in some years do not represent the real dimension of the population and that have very wide confidence limits.

- Conduct simultaneous acoustic surveys. The use of a towed hydrophone during surveys (both line transects *& ad libitum* surveys) could enhance their value and efficiency, by providing an independent assessment of dolphin distribution and give advance warning of dolphins in the area.

- Identify feeding activity. A hydrophone could be deployed at strategic locations to record characteristic calls associated with the capture of prey (see, for example, Janik, 2000), used in combination with T-POD studies and underwater video recording.

- Deploy T-PODs over a wider area of Cardigan Bay. The monitoring of potentially important sites for bottlenose dolphins (and harbour porpoise) should be extended beyond the Cardigan Bay SACs to include other locations within the Bay, particularly around Aberystwyth, the Sarns, and Tremadog Bay.

- Estimate the number of calves born annually in the population throughout Cardigan Bay. Measure birth rates, calf and juvenile survival rates, calving intervals, and preferred calving periods. This requires data collected over a continuous series of years.

- Examine the possible long-term effects of vessel disturbance. Compare behavioural budgets, activity patterns, and calving rates for known individuals occupying locations experiencing long-term disturbance with those where disturbance is minimal.

- Collect skin & blubber biopsies, for DNA analysis for gender determination and population genetics studies, and for stable isotope and fatty acid studies of diet and population structure.

Acknowledgements

First of all, we would like to thank the Countryside Council for Wales for funding and support.

At sea, on land and in the office, a small army of volunteers have donated thousands of hours of work. Without their input, the project would not have been possible. Besides helping to carry out the studies described in this report, our volunteers collected and entered data for our database of cetacean sightings and effort, and for the long-term land-based monitoring of bottlenose dolphins carried out by the Ceredigion County Council, co-ordinated in New Quay by Sea Watch. Lucy Buckingham (06-07), Tom Felce (05-06), Laura Barba Villaescusa and Pavan Chodka (07) were responsible for coordinating the volunteers and for supervising the input of all the sightings and effort data into computer, which was in itself a considerable task. We profusely thank all the volunteers and their coordinators and we hope that, while

helping us, they also gained new skills and knowledge that will help them in the development of their careers.

Many students joined the project as a part of their MSc and BSc studies. We are grateful to all of them for their valuable contributions to our work.

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Appendix 1: The Sighting Form, used during line-transect trips

SIGHTING FORM   Entered into PC □ Checked by ____________

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

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

Type of trip LT = line transect surveys, NLT = other than line transect surveys GMT=Greenwich Mean Time, BST=British Summer Time Effort type LT, DS, CW, ID Species BND=bottlenose dolphin, HP=harbour porpoise, GS=grey seal A=adult, J=juvenile, C=calf, NB=newborn Cue HE=head, F=fin/fluke, L=leaping, S=splash, B=blow, BA=back, BI=bird, R=reflection, O=other, U=unknown. Behaviour For BND and 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 2: The Independent Observer Form, used during line-transect trips

INDEPENDENT OBSERVER FORM Entered into PC ☐ Checked by ____________

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

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

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 3: The Effort Form, used during line-transect trips

EFFORT FORM

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

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

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

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

Appendix 4: Data archive details

Raw Photo-ID images are stored in……

Images of individual bottlenose dolphins are catalogued and stored in a Word Document/Access database? in…… and converted into an Adobe Portable Document Format (PDF) file and stored on optical media (Media Asset number: MSFG Media) as CCW Marine Monitoring Report No. 66.

Sightings data is input into the SWF database and will be incorporated with outputs from the Marine Mammal Distribution and Abundance Mapping Project SL32 – AO26 to be produced by December 2008.