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Cetacean monitoring effort carried out by voluntary NGOs in UK waters

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Contents

1 Introduction

There is an obligation under Article 11 of the Habitats Directive to undertake surveillance on the conservation status of all cetacean species occurring in UK waters and to report on this every six years. The purpose of the Habitats Directive is that species and habitats achieve and maintain a Favourable Conservation Status (FCS). Monitoring trends in abundance and distribution of species is one of the main ways to undertake surveillance.

The FCS as defined by the Habitats Directive is measured mainly by assessing changes in the three following parameters: 1) natural range, 2) population size, and 3) habitat. Monitoring must therefore lead to a clear picture of the actual conservation status of species and trends on various levels, with coordination to better detect changes in the distribution or abundance of these species that could reflect a failure to achieve FCS.

Since the Joint Cetacean Database (JCD) was established in the late 1990s, leading to the publication of the Atlas of Cetacean Distribution in North-West European Waters (Reid *et al.*, 2003), a wide range of non-governmental organizations (NGOs) from the voluntary sector have started projects that collect information on cetacean distribution and abundance in the waters around the British Isles.

The Joint Cetacean Protocol (JCP) has been established recently, as a follow up to the JCD and Atlas, and aims to update the JCD project and customise its output in order to better enable the assessment of the FCS of cetacean species in UK and adjacent North-West European waters. Its valuable input to the FCS assessments can be further developed if new partners join the protocol and contribute with their data. Knowledge of which organisations undertake surveying and monitoring of cetaceans, of the spatio-temporal coverage in effort, of the quality of their data and of the potential for data *standardisation* for the purposes of its use under the JCP is essential in the development of a surveillance strategy.

2 Aims & Objectives

This report reviews planned monitoring effort on cetacean distribution and abundance in UK waters carried out by the voluntary NGOs up to 2007, with the aim of identifying areas with good monitoring effort, gaps in coverage, and data quality issues. This report serves to contribute to the development of a UK Surveillance Strategy for cetaceans.

For the purpose of this review, the waters around the British Isles and Ireland are divided regionally using ICES Sea Areas (see Fig. 1, Table 1). Within each area, information is summarized through a questionnaire to NGOs, on the following aspects:

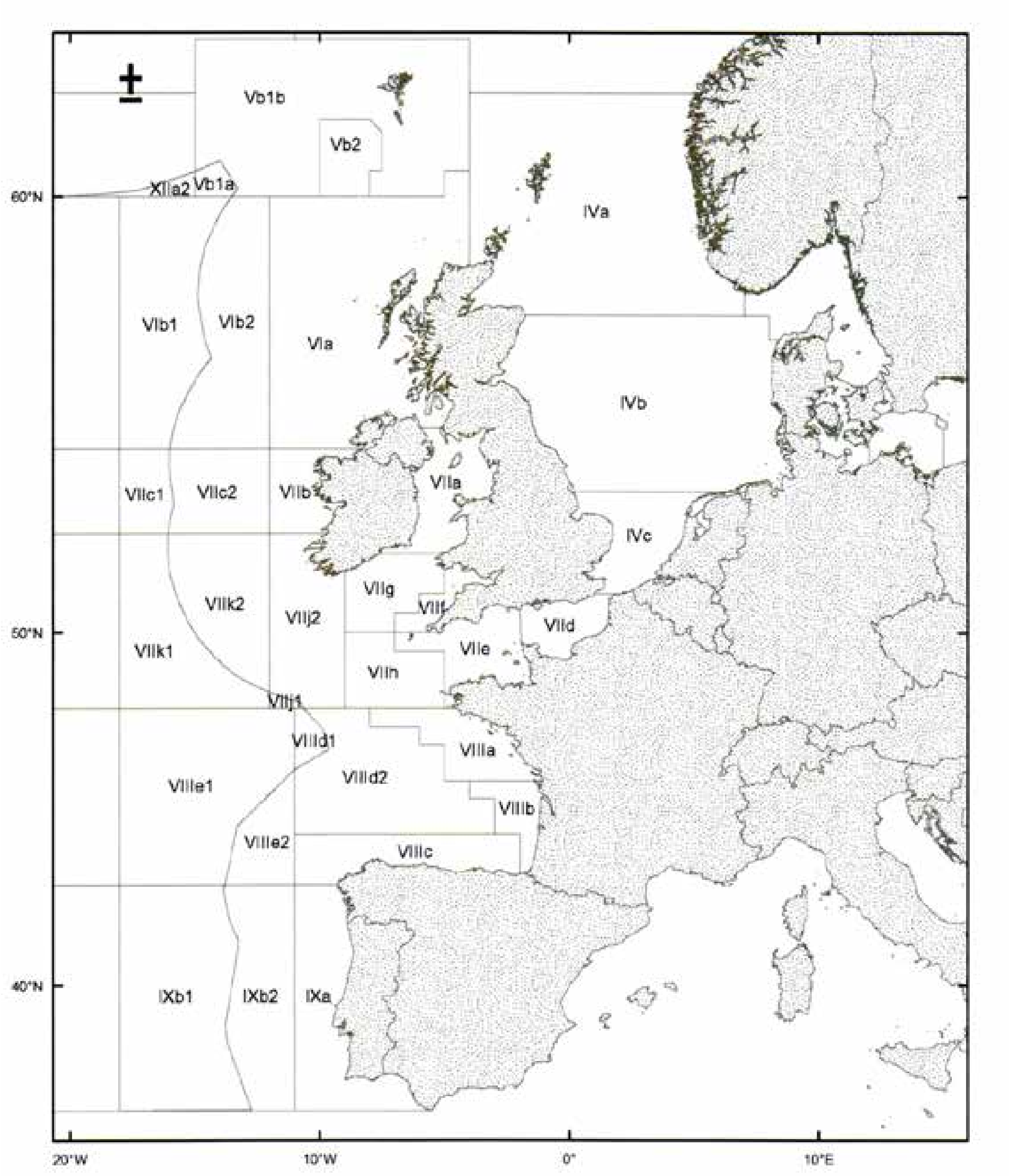


Figure 1. Map of ICES Sea Areas used in review of effort distribution.

1) the main purpose of surveying/monitoring;
2) the cetacean species investigated;
3) overall temporal coverage, including some measure of the frequency and intensity of coverage;
4) spatial coverage, including the extent of area surveyed/monitored and how representative the area is of the range of the species targeted;
5) methodologies used: type of observation platform, surveying method (acoustic, visual, photo-identification);
6) data type and resolution;
7) measures for data quality control; and
8) recommendations on the potential for data standardization, with a view to inclusion within the JCP.

Table 1. ICES Sea Areas used in effort summaries.

Sea Area	Description
IVa	NE Scotland & Northern Isles; Northern N Sea
IVb	E Scotland & E England; Central N Sea
IVc	SE England; Southern N Sea
VIId	Eastern Channel
VIIe	Western Channel
VIIf	N Cornwall & Devon, Bristol Channel, S Wales, S Ireland
VIIg	Celtic Sea
VIIh	South-west Channel Approaches
VIIa south	Southern Irish Sea (to 53° N)
VIIa north	Northern Irish Sea (from 53° N)
VIIj$_2$	South-west Ireland
VIIb	Western Ireland
VIa	Western Scotland & Hebrides
Vb1b, Vb$_2$	Faroe Islands
VIIIa, VIIId$_2$, VIIIc	Bay of Biscay

This information will be summarized in the form of a series of tables with associated annotated text organized by ICES Sea Area. An important consideration in assessing the utility of data sets for integration within a JCP, is the nature of observation effort. For the purpose of this review, we have classified data sets into seven main categories (see Table 2). We distinguish “experienced” from “inexperienced” observers on the basis of whether they have either received some external training in cetacean survey techniques and species identification, or have been self trained but then assessed externally in some way. Inevitably, this has to be a value judgment, and in this case is made by the first author of this report (Evans,P.G.H.). It should be noted that the categories used here are merely guidelines. The more refined methods for conducting surveys such as line transects by DISTANCE sampling do not necessarily involve experienced observers, but on the whole one can expect them to have had a greater element of formal training prior to survey than those recording cetaceans during watches conducted for other target groups.

When interpreting the tables documenting regional effort, it should be noted that there is likely to have been some double counting since some groups incorporate data from other groups, and this has not necessarily been identified in their questionnaire responses. In the case of Sea Watch, any integration of large data sets from other groups has been flagged up, and the quantities identified to avoid double counting. Another consideration to bear in mind is that some groups have been operating prior to 1998, and have not actually specified how much data apply specifically to the last ten years but instead have given a total figure for the amount of sightings and effort in their databases. And, finally, some groups have specified effort in the form of the number of hours of observation or kilometers traveled, but others have simply recorded the number of lines of effort data. Without more information, it is not possible to convert this into a temporal or spatial unit of effort. Nevertheless, the tables should give a broad overview of how effort is distributed. This will be elaborated further in the regional reviews.

Table 2. Effort Intensity Categories

Category	Effort Intensity
CW	Casual watching (generally applied to wardens, etc, of small island observatories who are present over particular time periods but are not actually conducting dedicated sea watches)
DWNC	Dedicated watching of the sea (applies mainly to ferry operators, yachtsmen, persons on watch of merchant or naval vessels, weather ships, etc) by persons inexperienced at observing cetaceans
IDNC	Dedicated watching of the sea for non-cetacean marine wildlife (seabirds, sharks, etc) by persons inexperienced at observing cetaceans
EDNC	Dedicated watching of the sea for non-cetacean marine wildlife (seabirds, sharks, etc) by persons experienced at observing cetaceans
IDFC	Dedicated watching for cetaceans by inexperienced observers
EDFC	Dedicated watching for cetaceans by experienced observers
LTFC	Dedicated watching for cetaceans by experienced observers using line transect distance methodology

3 Regional Reviews

Reviews of survey effort are provided for sixteen North-west European Sea Areas, including all the waters that surround the British Isles and Ireland.

3.1 NE Scotland, Shetland & Orkney and northern North Sea (ICES Sea Area 1Va)

(See Table 3.)

Casual recording of cetacean sightings is common and widespread through the region, involving a relatively large network of observers. Effort-based observations are conducted from ferries between Aberdeen and Lerwick (Shetland), Aberdeen and Kirkwall (Orkney) and between Lerwick and Kirkwall. Further effort-based observations are made opportunistically from Shetland Island ferries, notably the one that runs between Grutness in South Shetland and Fair Isle. Land-based watches from Shetland and Orkney occur mainly around Sea Watch Foundation’s (SWF) annual National Whale & Dolphin Watch week sometime between June and August, and which was started in 2002. A few dedicated offshore surveys in the region of the Northern Isles have been conducted.

Along the coasts of Caithness and around the Black Isle, a number of land-based watches have been conducted, with some sites (notably Lybster Point, Chanonry Point and Fort George) receiving attention on a regular basis. The waters of the inner Moray Firth are the subject of photo-ID studies by Aberdeen University’s Lighthouse Field Station in Cromarty, and have been so since 1989.

Along the south side of the Moray Firth, regular land-based watches were undertaken during the 1990s from a number of sites, but these have gradually been replaced by offshore surveys, largely within 12nm of the coast, and operating out of Lossiemouth, Buckie, Findochty and Fraserburgh. During summer months, since 2001, CRRU (Conservation Rescue & Research Unit) has been undertaking transects parallel to the coast using a RIB at four different distances (a coastal transect and then three others approximately 1.5km apart out to c. 5m from the coast) along an 83km stretch between Fraserburgh and Lossiemouth. In addition, WDCS has started surveys from a larger fishing vessel in the western part of the area mainly between Burghead and Portknockie. Additionally, SWF has undertaken a small number of vessel surveys across the entire region, though rarely beyond 12nm.

Coverage offshore in the northern North Sea has been sparse. NORCET ferry surveys go through this area but, except in high summer, tend to be during hours of darkness.

Table 3. Survey effort in ICES Sea Area IVa, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, WBD, MW since most common)	2,099 hrs	Jan-Dec but main effort Apr-Sept, 1998-2007	Shetland-Fair Isle ferry, coastal waters of S. Moray Firth; various land sites mainly in Caithness, Black Isle & North Grampian	Mainly EDFC visual & photo-ID; small vessel & ferry surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep.. of 1st	√
SWF / Norcet	All	c. 400 hrs (2004-06), 2007 not yet processed	Aug 2004; Apr-May, July 2005; May-Sept 2006 & 2007	Aberdeen – Shetland & to Orkney ferries	Mainly EDFC, some IDFC	Si/h + si/km; Access, Excel & paper	Double validation	√
Shetland Biological Records Centre / SSMG	All	Incorporated within SWF database	Mainly Apr-Oct, 1994-2007	Shetland waters (mainly coastal)	Mainly casual sightings, but some EDFC	Mainly si/h; Recorder & paper	Double validation	√
CRRU	All (but mainly MW, HP & BND)	600+ records	May-Oct 1997-2007	South-east Moray Firth	Mainly EDFC, some IDFC	Si/h + si/km; Access & Excel	Species validation	x
WDCS	All (but mainly BND)	Prob. hundreds of hours	c. May-Oct 2004-2007	South-west Moray Firth	EDFC & IDFC	Si/h + si/km; Excel & paper	Species validation	x

3.2 East Scotland, Eastern England; and the central North Sea (ICES Sea Area IVb)

(See Table 4.)

In East Scotland, there has been relatively intensive effort by SWF observers in coastal waters along the Aberdeenshire coast over the entire period 1998 to the 2007. Land-based watches have been conducted at a range of sites, but with regular effort particularly at Peterhead, Aberdeen Harbour, Girdleness, and Souter Head at Cove. In addition, there have been vessel surveys mainly within 12nm and between Stonehaven and Aberdeen. These have been conducted primarily between April and September. NORCET ferry surveys have also taken place between Aberdeen and Shetland & Orkney, passing through waters between Aberdeen and the outer Moray Firth (generally to & from around 58° N, 01°30'W) in daylight hours.

Further south, there are land-based watches conducted by Sea Watch observers on an opportunistic basis from the Fife coast (e.g. Fife Ness), at North Berwick and along the coasts of Northumberland (e.g. around the Farnes), Tyne & Wear (e.g. Souter Head), and Yorkshire (e.g. Bempton), with some offshore effort, for example, around the Firth of Forth, and recent photo-ID surveys by the Sea Mammal Research Unit (St Andrews University) within St Andrews Bay. Coverage in the middle of the North Sea is poor, with the exception of some ferry surveys across to Scandinavia out of Newcastle-upon-Tyne, and sightings collected during Centre for Environment, Fisheries & Acquaculture Science (CEFAS) fisheries surveys. In the eastern North Sea, there has been recent intensive effort involving aerial surveys (targeting porpoises, but all species recorded), vessel surveys (mainly targeting seabirds), and T-POD acoustic deployments, particularly in connection with offshore wind farm developments in German North Sea waters (Schleswig-Holstein District). There have also been Dutch observations both from aerial surveys and from fisheries research vessels in the central (and northern) North Sea, although these have largely targeted seabirds and should have been submitted to the European Seabirds at Sea (ESAS) database.

Table 4. Survey effort in ICES Sea Area IVb, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, WBD, MW)	1,977 hrs	Jan-Dec but main effort Apr-Sept, except Aberdeen where land-based is year-round, 1998-2007	Coastal waters from Stonehaven to Aberdeen; various land sites mainly in South Grampian, Northumberland, Tyne & Wear	Mainly EDFC visual & photo-ID; small vessel & ferry surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
SWF / Norcet	All (but mainly HP, BND, WBD)	c. 40 hrs (2004-06), 2007 to be processed	Aug 2004; Apr-May, July 2005; May-Sept 2006 & 2007	Aberdeen – Shetland & Orkney ferries	Mainly EDFC, some IDFC, visual; ferry surveys	Si/h + si/km; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
ORCA	All	c. 680 effort records	Jan-Dec but main effort Apr-Sept, 2006 & 2007	Ferries across North Sea (may also include data in Sea Area IVc)	Mainly EDFC, visual; ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Species validation	x

3.3 South-eastern England and the southern North Sea (ICES Sea Area IVc)

(See Table 5.)

Offshore surveys in the southern North Sea from UK bodies have largely been using platforms of opportunity – ferries, fisheries research and protection vessels, and rarely on a regular basis. More routine observations have been made in coastal waters from a number of land sites, e.g. Dunwich in Suffolk and Dungeness in east Kent. In addition, the Essex Wildlife Trust has deployed some T-PODs to monitor porpoises, and casual observations are submitted to Sea Watch by the county trusts as well as the Institute of Zoology, which is co-ordinating a Thames Marine Mammal Survey. At present, these involve very little effort-based monitoring, although there are plans to develop this further from 2008 onwards. Further offshore effort has come from continental Europe, with some Dutch and Belgian based surveys, usually targeting either seabirds or fisheries.

In this sea area, only the harbour porpoise is seen at all regularly, with both systematic and casual observations indicating a strong seasonal peak in spring.

3.4 Eastern Channel (ICES Sea Area VIId)

(See Table 6.)

Most offshore effort comes from platforms of opportunity - either ferry routes or fisheries protection vessels. Additionally, there has been some coverage from small vessels, whilst both casual and systematic effort-related observations have been made from a number of land-based sites, mainly in the vicinity of Brighton in East Sussex. Records of cetaceans are relatively rare in this sea area, and mainly involve bottlenose dolphin during summer months (plus 1-2 solitary social bottlenose dolphins that have roamed over more extended periods between Kent and Hampshire).

Table 5. Survey effort in ICES Sea Area IVc, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND)	228 hrs	Jan-Dec but main effort Apr-Sept, 1998-2007	Some offshore effort; various land sites mainly around Thames Estuary	Mainly EDFC visual; large vessel & ferry surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
Essex Wildlife Trust	HP	To be determined	To be determined	Essex coast	Acoustic deployments (T-PODs) in Essex	Porpoise positive minutes & detections per min/day	To be analysed	x

Table 6. Survey effort in ICES Sea Area VIId, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly BND)	250 hrs	All months except Jan, 1998-2007	Some offshore effort; land sites mainly in East Sussex	Mainly EDFC; some IDNC & EDNC; visual; small vessel surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√

3.5 Western Channel (ICES Sea Area VIIe)

(See Table 7.)

A number of groups are active in coastal waters of Dorset, Devon and Cornwall. In Dorset, there has been a long-standing land-based monitoring programme at Durlston Head by the Durlston Marine Project (DMP), which has been running since the 1990s. This has involved local people, most of whom have had some training in conducting watches and species identification. In the past, Sea Watch has undertaken training courses for these observers at its Centre in New Quay, West Wales. The future of this programme is currently unclear. In the late 1990s – early 2000s, some offshore survey effort by DMP was concentrated around Poole Bay in connection with oil & gas activities, and for a number of years they had a T-POD deployed outside Poole Harbour, monitoring the bottlenose dolphins that tend to make seasonal appearances there in late spring. Observations have also been conducted regularly from ferries leaving Portsmouth for Bilbao in Northern Spain, and from Poole to Cherbourg.

Further west, since 2005, the Devon Wildlife Trust has been active in collecting casual sightings and undertaking systematic land-based watches from a number of headlands, and complementing these has been regular watching since 2005 by the Berry Head Wildlife Centre (and before that, the neighbouring Sea Shore Centre at Goodrington, Paignton), and these have revealed seasonal peaks in porpoises during late winter.

Sea Watch has conducted some offshore large vessel surveys in conjunction with Earthkind between the south coast and the Channel Islands, and Marinelife/BDRP, ORCA, and the Santander ferry survey have been undertaking regular watches from those ferries which cross the western English Channel from Portsmouth, Poole and Plymouth to the NW French and North Spanish coasts. These have been particularly between April and September, although some have been year-round.

Sea Watch Charter, operating out of Falmouth in Cornwall has conducted surveys (targeting sharks but recording all cetacean species) in the western English Channel as far as the Isles of Scilly, during summer.

Between 2006 and 2007, Exeter University conducted aerial surveys for turtles in the western Channel, recording also cetaceans, as well as participating in some ferry surveys. In future, they plan some vessel surveys and acoustic monitoring in relation to an offshore wind farm proposal. Finally, the north-western part of the English Channel has been surveyed by combined WDCS & Greenpeace teams in the form of line transects during November 2002, January to March 2004 and February to March 2005. Their aim was to obtain winter estimates of absolute abundance for short-beaked common dolphins in relation to fisheries activities, to record spatio-temporal variation in encounter rates, and to map the distribution of sightings.

Table 7. Survey effort in ICES Sea Area VIIe, 1998-2007

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, CD)	958 hrs	All months, 1998-2007	Offshore effort; some land sites including Start Point & Prawle Point	Mainly EDFC visual from both small & large vessels; land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
Durlston Marine Programme (DMP)	All (but mainly BND)	Probably hundreds of hours	Mainly Apr-Sept, 1998-2006	Mainly watches from Durlston Head, Dorset; some offshore small vessel surveys	EDFC & IDFC visual; land-based, some small vessel survey & acoustics	Mainly si/h; Excel; some data still on paper	Species validation	Earlier data received but awaiting recent years
Devon Wildlife Trust	All (but mainly HP & BND)	All but 2007 within SWF database (531 hrs of land watches in all Devon since Oct 2005)	All months, 2005-2007	Mainly watches from Start Point & Prawle Point	Mainly EDFC visual; land-based watches, some small vessel surveys	si/h for land & sea; si/km for sea; Excel & paper	Double validation, 2nd indep. of 1st	√
Berry Head Wildlife Centre, S. Devon	All (but mainly HP)	Probably low hundreds of hours	All months, 2005-2007	Land-based watches from Berry Head	EDFC & IDFC visual; land-based watches	si/h	Species validation	x
Exeter University	All (but mainly HP, BND)	<100 effort records overall	Jan-Oct 2006-07 (aerial) Apr-Oct 2006-07 (ferry)	Cornish waters	EDFC & IDFC visual ferry & EDNC aerial	si/h & si/km can be derived; Excel & paper	Species validation	x
WDCS / Greenpeace	All (but mainly targeting CD)	c. 200 hours	Nov 2002, Jan-Mar 2004, Feb-Mar 2005	Western end of Channel	EDFC & IDFC visual	si/h & si/km can be derived	Species validation	x

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
BDRP / Marinelife	All (but mainly CD, HP, BND, LFPW)	Prob. low hundreds of hours	Jan-Dec 1998-2007	Offshore effort on ferries to Biscay and NW France	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Excel & paper	Species validation	x
Sea Watch Charter	All (but mainly HP, BND)	c. 200 effort records	Apr-Sept, 1998-2007	West from Plymouth to Lands End and then northwards to Irish Sea	EDNC visual; small vessel surveys	Can derive Si/h & si/km; paper	Species validation; Double validation for data to SWF	√ (earlier years; rest still to be tran-scribed)
Santander Ferry Surveys	All (but mainly CD, SD, FW, LFPW, CBW)	849 hours (spread between areas VIIe, VIIh, VIIIa, $VIIId_2$ & VIIIc)	Jan-Dec, 1998-2007	Offshore effort from Plymouth to Santander	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Double validation, 2nd indep. of 1st (once data received by SWF)	√ (2007 to come)
ORCA	All (but mainly CD, SD, FW, LFPW, CBW)	c. 1,900 effort records (spread between areas VIIe, VIIh, VIIIa, $VIIId_2$ & VIIIc)	Jan-Dec, 1998-2003, 2005-2007	Offshore effort from Portsmouth to Bilbao	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Species validation	x

3.6 South-west Channel Approaches (ICES Sea Area VIIh)

(See Table 8.)

This largely offshore area has received coverage mainly from either dedicated large vessel surveys or those involving ferries that cross the region on fixed routes. A systematic line transect survey was conducted by WDCS & Greenpeace in October 2002 that crossed part of this sea area, but most effort has involved platforms of opportunity.

3.7 North Cornwall, North Devon, the Bristol Channel and South Wales (ICES Sea Area VIIf)

(See Table 9.)

As with sea area VIIe, the country wildlife trusts of Devon and Cornwall have a large network of observers who submit casual sightings to SWF. In addition, there are systematic land watches conducted regularly by Sea Watch/Devon Wildlife Trust observers from north Devon (notably Baggy Point and Harland Point). SWF has conducted large vessel offshore transects in the Outer Bristol Channel, as has WDCS/Greenpeace. Exeter University has carried out some aerial surveys for turtles in Cornish waters (exact area unspecified), recording also cetaceans.

In South Wales, there have been land-based observations by the Gower Marine Mammal Project from the Gower Peninsula (mainly Worms Head and Burry Holm), and in summer 2007, they started offshore porpoise surveys in the Bristol Channel.

Eurydice has been contracted in recent years to undertake long-term acoustic surveillance (by T-PODs) along with some vessel surveys in Swansea Bay in connection with an offshore wind farm proposal.

Sea Watch Charter has collected effort-related sightings data whilst transiting from Cornwall to the Irish Sea en route to the Firth of Clyde & Hebrides in late spring, returning again in the autumn. These have been conducted annually from 1998 to 2007. Although targeting sharks, all cetacean species are recorded.

Table 8. Survey effort in ICES Sea Area VIIh, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, CD)	168 hrs	Jan-Dec but main effort Apr-Sept, 1998-2007	Mainly offshore effort	Mainly EDFC visual; large vessel & ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
WDCS / Greenpeace	All (but mainly targeting CD)	Tens of hours	Oct 2002	Offshore effort	EDFC & IDFC visual; large vessel survey	Can derive Si/h & si/km	Species validation	x
BDRP / Marinelife	All (but mainly CD, BND, MW, LFPW)	Prob. low hundreds of hours	Jan-Dec 1998-2007	Offshore effort	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Excel & paper	Species validation	x

Table 9. Survey effort in ICES Sea Area VIIf, 1998-2007

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND)	868 hrs	May-June, Sep-Oct 1998-2007	Offshore effort in the Outer Bristol Channel; land sites e.g. Baggy & Harland Points, Gower Peninsula	Mainly EDFC visual; large vessel & ferry surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
Devon Wildlife Trust	All (but mainly HP, BND)	531 hrs of land watches in all Devon since Oct 2005	All months, 1998-2007, but mainly 2005-2007	Mainly watches from Baggy Point & Harland Point	EDFC & IDFC visual; land-based	si/h for land & sea; si/km for sea; Excel & paper	Double validation, 2nd indep. of 1st	√ (2007 not yet rec'd)
Exeter University	All (but mainly HP, BND)	<100 effort records overall	Jan-Oct, 2006-07 (aerial) Apr-Oct, 2006-07 (ferry)	Cornish waters	EDFC & IDFC visual ferry & aerial	Si/h & si/km can be derived; Excel & paper	Species validation	x
Gower Marine Mammal Project	All (but mainly HP)	>1,000 effort records	Jan-Dec, 1998-2007 (land-based); July-Sept 2007 (offshore); acoustics (T-PODs), 2002-05	Various sites on Gower Peninsula; some offshore effort in Bristol Channel	EDFC visual land-based; EDFC & IDFC offshore in small vessels; some acoustics	Si/h for land; si/h & si/km for sea; Excel & paper	Double validation, 2nd indep. of 1st	√ visual (2007 not yet rec'd) x (acoustics)
Eurydice	All (but mainly HP)	>1,000 effort records	Jan-Dec, 2004-06	Swansea Bay	EDFC visual offshore in small vessels; acoustics	Si/h & si/km can be derived; Excel & paper	Species validation	x (not yet rec'd)

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
WDCS / Greenpeace	All (but mainly HP, CD)	Tens of hours	Oct 2002	Outer Bristol Channel	LTFC, EDFC & IDFC visual, large vessel survey	Si/h & si/km can be derived; Excel & paper	Species validation	x
Sea Watch Charter	All (but mainly HP, BND)	c. 150 effort records	Apr-Sept, 1998-2007	Northwards from West Cornwall into Irish Sea	EDNC visual; small vessel surveys	Can derive Si/h & si/km; paper	Species validation; Double validation for data to SWF	√ (earlier years; rest still to be transcribed electronically)

3.8 Celtic Sea (ICES Sea Area VIIg)

(See Table 10.)

Since 2004, there has been good coverage of the northern part of the Celtic Sea through regular systematic line transect surveys sampling an area of about 3,100km^2, undertaken by Sea Watch, and observations made regularly aboard ferries crossing the St George's Channel by observers from IWDG and Sea Trust SW Wales. In addition to this, during summer 2007, routine surveys of coastal waters around the islands of Skomer, Skokholm and Grassholm have been conducted as part of a porpoise Masters project. Opportunistic land-based watches have been undertaken at a few sites in west Pembrokeshire, notably Skomer Island, Strumble Head and Ramsey Sound, and for a period during the 1990s, acoustic monitoring (using early PODs) was carried out at sites along the north Pembrokeshire coast (Newport Bay, Ramsey Sound and Strumble Head).

As in the previous sea area, Sea Watch Charter has collected effort-related sightings data whilst transiting from Cornwall into the Irish Sea en route to the Firth of Clyde & Hebrides in late spring, returning again in the autumn. These have been conducted annually from 1998 to 2007. Although targeting sharks, all cetacean species have been recorded.

Further south and west in the area, SWF conducted large vessel surveys during June-July 1998, and surveys targeting large baleen whales have been undertaken by IWDG in recent years.

Table 10. Survey effort in ICES Sea Area VIIg, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, CD, RD, MW, FW)	c. 200 hrs offshore (c. 3,500 km of effort) + c. 300 hrs coastal waters	June-July, 1998; May-Nov, 2004-2007	Mainly offshore effort, but also coastal waters of West Pembs	Mainly EDFC visual; large vessel & ferry surveys	Can derive si/h & si/km; Access & Excel	Double validation, 2nd indep. of 1st	√
IWDG ferry surveys	All (but mainly HP, CD, RD, BND)	Prob. high tens to low hundreds of hours	Jan-Dec but main effort Apr-Sept, 2004-2007	East coast of Ireland; Rosslare to Pembroke ferry	EDFC & IDFC visual ferry surveys	Si/h & si/km poss; Excel & paper	Species validation	x
Sea Trust SW Wales	All (but mainly CD, HP)	??	Jan-Dec but main effort Apr-Sept, 1998-2007, but mainly 2004-2007	Mainly west coast Pembs, and ferry route from Fishguard to Rosslare	EDFC & IDFC visual; small vessel & ferry surveys; some land watches	??	??	x
Eurydice	Targeting HP, but visually recorded other species	Visual sightings incorporated in SWF database	July 2001	West & north of Pembs	EDFC visual & acoustic; large vessel survey	Can derive si/h & si/km; Access	Species validation	√
Sea Watch Charter	All (but mainly HP, CD, BND)	c. 150 effort records	Apr-Sept, 1998-2007	Northwards from West Cornwall into Irish Sea	EDNC visual; small vessel surveys	Can derive Si/h & si/km; paper	Species validation; Double validation for data to SWF	√ (earlier years; rest still to be transcribed electronically)

3.9 Southern Irish Sea (ICES Sea Area VIIa south)

(See Table 11.)

Southern Irish Sea is defined here as ICES Sea Area VIIa north to 53°N. This is probably one of the most intensively surveyed areas in the UK, although most regular effort is concentrated within 20nm of the Welsh coast. This derives from the establishment of Special Areas of Conservation (SAC) for the bottlenose dolphin in Cardigan Bay, and line transect abundance surveys have been carried out regularly between April and September in 2001 and 2003-2007 by SWF within Cardigan Bay SAC, with extra effort in northern Cardigan Bay, Tremadog Bay and around the Lleyn Peninsula. These have been complemented in winter by aerial surveys over all of Cardigan Bay, along with photo-ID studies. In addition, there have been regular opportunistic surveys from a commercial dolphin watching operation (West Wales Chartering Company(WWCC)/Cardigan Bay Marine Wildlife Centre(CNMWC)) mainly in the coastal section of Cardigan Bay SAC between April and September. West and north of Pembrokeshire, a combined visual and acoustic survey using a towed hydrophone was undertaken by Eurydice & IFAW (International Fund for Animal Welfare) during July 2001.

SWF, in collaboration with CBMWC, has undertaken regular land-based watches from New Quay (as well as supervised a series of Masters projects involving headland watches). A very extensive land-based monitoring programme has been running throughout the last ten years, coordinated by the Ceredigion County Council, in collaboration with Eurydice. Acoustic monitoring involving ten T-PODs deployed at regular intervals along the coastal section of Cardigan Bay SAC has also been undertaken by SWF since 2005.

Further north, Friends of Cardigan Bay (FoCB) have undertaken vessel surveys between Aberystwyth and the Dyfi Estuary during the summers from 1998 to 2007. And around the western end of the Lleyn Peninsula and Bardsey Island, FoCB and, subsequently, Whale and Dolphin Conservation (WDCS) have been conducting land-based watches and some small vessel surveys during late summers from 2001 to 2007.

A number of ferry surveys across the Irish Sea between Fishguard and Rosslare have been undertaken since 2004 mainly by the Irish Wales and Dophin Group (IWDG) and Sea Trust SW Wales, with a few also by SWF observers.

Along the east coast of Ireland, IWDG have observers conducting land watches at a variety of headland sites. In addition, Cork Ecology has been undertaking intensive vessel surveys on the Arklow Bank, Co. Wicklow during summer months from 2000 to the 2007, as part of an offshore wind farm development.

Sea Watch Charter has collected effort-related sightings data whilst transiting up and down the Irish Sea between Cornwall and the Firth of Clyde & Hebrides in late spring, returning again in the autumn. These were conducted annually from 1998 to 2007. Although targeting sharks, all cetacean species have been recorded.

Finally, although outside the period under consideration, it is probably worth noting an Irish Sea wide line-transect survey that was conducted by SWF in conjunction with Earthwatch between July-August 1995.

Table 11. Survey effort in ICES Sea Area VIIa south, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, CD, RD, MW, FW)	4,490 hrs (excl. CCC data)	Jan-Dec but main effort Apr-Sept, 1998-2007	Mainly offshore effort from small vessels; land sites mainly between New Quay & Cemaes Head , Ceredigion	Mainly LTFC & EDFC visual; small vessel surveys, photo-ID, acoustics (T-PODs & towed hydrophones), land watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
CCC / Eurydice	All (but mainly HP, BND)	8,075 hrs (to 2005)	June-Sept 1998-2007	Several sites between Aberystwyth & Mwnt	Mainly IDFC; land watches	Si/h; Access, paper; 2006/07 to be analysed	Double validation for data to SWF	√ (data for specific sites)
CBMWC	All (but mainly BND, HP)	>1,000 effort records (c. 2/3 in SWF database)	Apr-Oct. 2001-2007	Mainly Cardigan Bay SAC	EDFC & IDFC, photo-ID	Si/h & si/km poss; Access & paper	Species validation	√ (except 2005-07)
FoCB	All (but mainly BND, HP)	Prob low hundreds of hours	Jan-Dec but main effort Apr-Sept, 1998-2007	Aberystwyth to Dyfi Estuary	EDFC & IDFC visual; small vessel surveys, some land watches	Si/h & si/km poss; Excel & paper	Species validation; double validation for data to SWF	√ (1998-2003) x (2004-2007)
IWDG	All (but mainly HP, CD, RD, BND)	Prob. hundreds of hours	Jan-Dec but main effort Apr-Sept, 2004-2007	East coast of Ireland; Rosslare to Pembroke, Dublin to Cherbourg ferries	EDFC & IDFC visual ferry surveys	Si/h & si/km poss; Excel, Access & paper	Species validation	x

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
Sea Trust SW Wales	All (but mainly CD, HP)	??	Jan-Dec but main effort Apr-Sept, 1998-2007, but mainly 2004-2007	Mainly west coast Pembs, and ferry route from Fishguard to Rosslare	EDFC & IDFC visual; small vessel & ferry surveys; some land watches	??	??	x
WDCS	All (but RD & HP target species)	Prob. hundreds of hours	Jul-Sept, 2001-2007	Bardsey Island & western end of Lleyn Peninsula	EDFC & IDFC visual, land watches, small vessel surveys, acoustics (T-POD)	Si/h for land & sea; si/km for sea; Excel	Species validation	x
Cork Ecology	All (but mainly HP)	19,078 km to Sept 2007	Jan-Dec but main effort Apr-Sept, 2000-2007	Arklow Bank, Co. Wicklow	EDNC visual; vessel surveys	Si/h & si/km; Paradox in SAST format	Species validation	x
Eurydice	Targeting HP, but visually recorded other species	Visual sightings incorporated in SWF database	July 2001	West & north of Pembs	EDFC visual & acoustic; large vessel survey	Can derive si/h & si/km; Access	Species validation	√
Sea Watch Charter	All (but mainly HP, BND, MW)	c. 200 effort records	Apr-Sept, 1998-2007	Northwards up Irish Sea	EDNC visual; small vessel surveys	Can derive Si/h & si/km; paper	Species validation; Double validation for data to SWF	√ (earlier years; rest still to be transcribed electronically)

3.10 Northern Irish Sea (ICES Sea Area VIIa north)

(See Table 12.)

The Northern Irish Sea is defined as that area from 53°N to the northern boundary of ICES Sea Area VIIa. Effort is not as great as in the Southern Irish Sea, although some localities have received particular attention. Most SWF effort has been from vessel surveys off Anglesey and the Lleyn Peninsula, whilst, as noted in the previous area, an Irish Sea wide line-transect survey was conducted by SWF in collaboration with Earthwatch between July-August 1995.

Marine Awareness North Wales has been conducting porpoise small vessel surveys along the north coast of Anglesey but also east to Great Orme Head since 2001, and land-based watches have been regularly undertaken, particularly from Point Lynas, Middle Mouse and West Mouse in North Anglesey.

Further north, the Manx Whale & Dolphin Watch, established in summer 2005 in collaboration with SWF, has been collating casual sightings and conducting regular land-based watches along the coast of the Isle of Man. In summer 2007, it also started offshore vessel surveys in waters surrounding the Island.

Along the east and north-east coasts of Ireland, IWDG observers have been conducting land watches at a variety of headland sites. And offshore, since 2005, they have participated in a number of ferry surveys along fixed routes from Cairnryan to Larne, Holyhead to Dublin, Liverpool/Mostyn to Dublin, and Dublin to Cherbourg. These have been conducted mainly between the months of April and September.

Sea Watch Charter has collected effort-related sightings data whilst transiting up and down the Irish Sea between Cornwall and the Firth of Clyde & Hebrides in late spring, returning again in the autumn. These have been conducted annually from 1998 to 2007, with all cetacean species recorded despite sharks being the target group.

Since 2004, some acoustic T-POD deployments have also been made by John Goold in the vicinity of the North Hoyle Wind Farm site off the coast of North Wales. These have provided information on seasonal presence of harbour porpoises.

Table 12. Survey effort in ICES Sea Area VIIa north, 1998-2007

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND)	1,507 hrs	Jan-Dec but main effort Apr-Sept, 1998-2007	Some offshore effort off Anglesey & Lleyn Peninsula, and around Isle of Man; land sites in Anglesey & Isle of Man	Mainly EDFC, also LTFC visual; land-based watches and some small vessel surveys	Can derive si/h for land & sea; si/km for sea; Access & Excel	Double validation, 2nd indep. of 1st	√
Marine Awareness North Wales (MANW)	All (but HP is target)	Prob. hundreds of hours (2,400 effort records)	Jan-Dec but main effort Apr-Sept, 2001-2007	Mainly north coast of Anglesey; some additional recording from Gt Orme's Head in east to Lleyn Peninsula in west	LTFC, EDFC & IDFC visual from land-based and small boats, some acoustics (T-POD)	Si/h for land & sea; si/km for sea; Excel	Species validation	x
Manx Whale & Dolphin Watch	All (but mainly HP, CD, RD & MW; also FW, KW)	c. 200 effort records included within SWF database (some of 2007 still to come)	Jan-Dec but main effort Apr-Sept, 2005-2007	Some offshore effort; various land sites mainly in Isle of Man	Mainly CW, also EDFC & IDFC visual; land-based watches & from 2007, small vessel surveys	Si/h for land & sea; si/km for sea; Excel & paper	Double validation, 2nd indep. of 1st	√
IWDG	All (but mainly HP, CD & MW)	Prob. hundreds of hours	Jan-Dec but main effort Apr-Sept, 2002-2007; 2002-03 (Dublin to Cherbourg), 2006-2007 (Cairnryan to Larne)	Ferry routes from Cairnryan to Larne, Holyhead to Dublin, Liverpool/Mostyn to Dublin, Dublin to Cherbourg; some land watches along East coast Ireland	EDFC & IDFC visual ferry surveys; land watches	Si/h for land & sea; si/km for sea; Excel, Access & paper	Species validation	x
Sea Watch Charter	All (but mainly HP, BND, MW)	c. 200 effort records	Apr-Sept, 1998-2007	Northwards up Irish Sea	EDNC visual; small vessel surveys	Can derive Si/h & si/km; paper	Species validation; Double validation for data to SWF	√ (earlier years; rest still to be transcribed electronically)

3.11 South-west Ireland (ICES Sea Area VIIj$_2$)

(See Table 13.)

Survey effort in South-west Ireland has been undertaken by IWDG and by University College Cork. The latter have conducted line-transect surveys in association with oil and gas exploration west of Ireland, during the summers of 2000 and 2001 (SIAR Survey) and again in summer 2003 from Counties Kerry to Mayo, as part of the Petroleum Infrastructure Programme (PIP). These data have been submitted to the ESAS database and so are not detailed here. They also involved acoustic recording from a towed hydrophone.

A small amount of large vessel survey effort was also carried out by SWF in collaboration with Earthkind in June-July 1998. And, platform of opportunity data have been collected during research cruises of the Irish marine research vessels, R.V. Celtic Explorer and R.V. Celtic Voyager since 2005, as well as with vessels of the Irish Navy.

Since the late 1990s, small vessel surveys, photo-ID and acoustic (T-PODs) have been employed in the Shannon Estuary in studies of the bottlenose dolphin population that is resident there. These have formed a PhD from University College Cork, as well as studies by the Shannon Dolphin & Wildlife Foundation (SDWF).

There have been some land-based watches by IWDG observers, although coverage outside the Shannon Estuary is relatively low.

Finally, small vessel surveys have recently been started by IWDG around the Blasket Islands, Co. Kerry, following its proposal as an SAC for the harbour porpoise.

3.12 Western Ireland (ICES Sea Area VIIb)

(See Table 14.)

As with the previous sea area, recent survey effort in Western Ireland has mainly been undertaken by IWDG and by University College Cork. The latter have conducted line-transect surveys in association with oil and gas exploration west of Ireland, during the summers of 2000 and 2001 (SIAR Survey), and again in summer 2003 from Counties Kerry to Mayo, as part of the Petroleum Infrastructure Programme (PIP). These data have been submitted to the ESAS database and therefore are not detailed here. They have involved also acoustic recording from a towed hydrophone.

In Broadhaven Bay, Co. Mayo, visual surveys and acoustic monitoring using T-PODs were conducted in 2002 by University College Cork, in relation to plans to construct a marine pipeline. And at the same time, a T-POD study was initiated by UCC in Connemara, Co. Galway to detect both harbour porpoise and bottlenose dolphin.

Additionally, there have been some land-based watches at various sites along the west coast by IWDG observers.

Table 13. Survey effort in ICES Sea Area VIIj$_2$, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND)	37 hrs	June-July 1998	Offshore effort in waters of Counties Cork & Kerry	Mainly EDFC visual; large vessel surveys	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
IWDG / SDWF	All (but mainly HP, BND, CD, AWSD, MW)	Prob. low hundreds of hours	Jan-Dec but main effort Apr-Sept, 1998-2007	Land sites in Counties Cork, Kerry & Clare; small vessel surveys in Shannon Estuary & around Blasket Islands	EDFC & IDFC visual; small vessel surveys & land-based watches	Can derive Si/h for land & sea; si/km for sea; Access, Excel & paper	Species validation	x

Table 14. Survey effort in ICES Sea Area VIIb, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, BND, CD, AWSD, MW)	30 hrs	Jun-Aug, 1998-2007	Mainly offshore effort	mainly EDFC visual; small vessel surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
IWDG	All (but mainly HP, BND, CD, AWSD, MW)	High tens or low hundreds of hours	Jan-Dec but main effort Apr-Sept, 1998-2007	Land sites in Counties Galway & Donegal; some offshore effort	EDFC & IDFC visual; mainly land watches; some vessel surveys	Si/h for land & sea; si/km for sea;	Species validation	x

3.13 Western Scotland and the Hebrides (ICES Sea Area VIa)

(See Table 15.)

Besides the southern Irish Sea and North-east Scotland, the other sea area where there has been intensive survey effort is Western Scotland and the Hebrides.

Most effort has centred upon particular regions – the waters around Mull, Coll & Tiree by Sea Life Surveys, later joined by the Hebridean Whale & Dolphin Trust; the Small Isles of Rum, Eigg, Muck and Canna and adjacent Sounds as well as Sound of Sleat by Sea Watch Foundation, Arisaig Marine (MV “Sheerwater”), and Sea Life Surveys (MV “Alpha Beta”), and the waters of Inner Sound and Gairloch by Sail Gairloch. Between 1992 and 2000, wider surveys were conducted by SWF in collaboration with Western Isles Sailing Company across the Minches and Sea of Hebrides between the months of June and September. A survey was also undertaken by SWF with HWDT in June 2003 to the Northern Irish coast.

From 2002 to 2007, HWDT has possessed a vessel “Silurian” for research and education, and this has been used to conduct systematic surveys during summer mainly in the Argyll region, but also with occasional forays further afield across to the Outer Hebrides and even to St Kilda. Also from 2002, Aberdeen University started regular observations along some of the fixed routes undertaken by Calmac ferries across the Minches and Sea of Hebrides.

Sea Watch Charter has surveyed waters in the Firth of Clyde & Hebrides during each summer from 1998 to 2007. In recent years, these surveys have been conducted in conjunction with Earthwatch, but there are no plans to continue these beyond 2007.

West of the Outer Hebrides, there have been a number of surveys mainly related to oil and gas exploration. These have generally been submitted either to the ESAS database or directly to JNCC as part of its seismic MMO programme.

Along the west coast of Scotland and Inner Hebrides, a number of land-based watches have been undertaken from particular headlands, for example Ardnamurchan Point, Mallaig, Gairloch, and Stoer Head (Highland Region), and Calliach Point (Isle of Mull).

3.14 Faroese Waters (ICES Sea Area Vb1b Vb2)

(See Table 16.)

Most survey effort in Faroese waters has been conducted in relation to oil and gas exploration, with results mainly submitted directly to JNCC, although a number of Danish surveys have also been undertaken, with data included in the ESAS database. In addition, there have been a few ferry surveys between northern Scotland and the Faroes, whilst acoustic monitoring has been conducted by Aberdeen University in the Faroe-Shetland Channel using low-frequency omni-directional sonobuoys to record fin and blue whales. These were deployed in May, October & December 2000, May & October 2001, October 2002, and May and October 2003.

Table 15. Survey effort in ICES Sea Area VIa, 1998-2007

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly HP, MW, also RD, CD, WBD, AWSD, KW)	1,013 hrs	Jan-Dec but main effort Apr-Sept, 1998-2007	Mainly waters around Skye & Small Isles; extra surveys throughout Hebrides	Mainly EDFC visual; large vessel & ferry surveys & land-based watches	Can derive si/h for land & sea; si/km for sea; Access & Excel	Double validation, 2nd indep. of 1st	√
Arisaig Marine	All (but mainly HP, MW)	c. 3,000 hrs (not yet integrated with SWF database)	Apr-Oct, 2004-2007	Waters around Small Isles (Eigg, Muck, Canna, Rum, Soay)	EDFC visual; medium vessel along fixed routes	Si/h & si/km	Double validation, 2nd indep. of 1st	√
Sea Life Surveys	All (but mainly MW, HP, & CD)	Prob. some thousands of hours	Apr-Oct, 1998-2007	Waters around Mull, Coll & Tiree	Mainly EDFC visual; small vessel surveys	Si/h & si/km can be derived; Excel	Species validation	√ (recent years still to come)
HWDT	All (but mainly HP, MW, CD; also BND, RD, KW)	Prob. some thousands of hours	Apr-Oct, 1998-2007	Maiinly waters around Mull; extra surveys throughout Hebrides	Mainly EDFC visual; small vessel surveys; land watches on Mull & Ardnamurchan Point	Si/h & si/km can be derived; Access, Excel & paper	Species validation	√ (except most Silurian surveys)
Sail Gairloch	All (but mainly HP, MW)	High tens of hours	Mar-Oct, 1998-2003	Inner Sound & Minch around Gairloch	Mainly EDFC visual; small vessel surveys; land watches around Gairloch	Si/h for land & sea; si/km for sea; Lotus Approach	Double validation, 2nd indep. of 1st	√
Aberdeen University	All (but mainly HP, MW, CD, RD)	Prob. hundreds of hours	May-Sept, 2002-2007	Minches & Sea of Hebrides	Mainly EDFC visual; ferry surveys along fixed routes	Si/h & si/km can be derived; Excel	Species validation	x

Table 16. Survey effort in ICES Sea Area Vb1b, Vb2, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly AWSD, WBD, LFPW, MW, FW)	143 hrs	Sept-Oct, 2007	Offshore effort around Faroes	EDFC visual; large vessel surveys	Can derive si/h & si/km; Access,& paper	Double validation, 2nd indep. of 1st	√

3.15 Bay of Biscay (ICES Sea Areas VIIIa, VIIId$_2$ & VIIIc)

(See Table 17.)

Since 1995, regular observations have been conducted aboard the “Pride of Bilbao” ferry that runs from Portsmouth to Bilbao (Northern Spain), mainly by Biscay Dolphin Research Programme (BDRP), now referred to as Marinelife, and by ORCA. Around the same time, surveys were also started from the ferry that runs between Plymouth and Santander (Northern Spain).

In addition, systematic surveys have been conducted in recent years, mainly targeting beaked whales, in the Cap Breton Canyon and along the Galician coast of Spain, by BDRP, ORCA, AMBAR and SWF.

Table 17. Survey effort in ICES Sea Area VIIIa, VIIId$_2$ & VIIIc, 1998-2007.

Research Group	Species	No. Effort Records	Main Temporal Coverage	Main Spatial Coverage	Type of Survey	Data Type	Quality Control	Data to SWF
SWF	All (but mainly CD, SD, BND, FW, LFPW, CBW)	149 hrs (+ 849 hrs from Santander Ferries, c. 200 hrs from BDRP, c. 100 hrs from Company of Whales)	July 2007 + Bilbao Ferry, Jan-Dec 2004, Santander Ferry Surveys, Jan-Dec, 1998-2007	Offshore effort in S Bay of Biscay + north coast of Spain	EDFC & IDFC visual; ferry & small vessel surveys	Can derive si/h & si/km; Access, Excel & paper	Double validation, 2nd indep. of 1st	√
Santander Ferry Surveys	All (but mainly CD, SD, FW, LFPW, CBW)	849 hours	Jan-Dec, 1998-2007	Offshore effort from Plymouth to Santander	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Double validation, 2nd indep. of 1st (once data received by SWF)	√
BDRP / Marinelife	All (but mainly CD, SD, FW, LFPW, CBW)	Prob. several hundred hours	Jan-Dec, 1998-2007	Offshore effort from Portsmouth to Bilbao	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Excel & paper	Species validation	√ (1995-98) x (1999-2007)
ORCA	All (but mainly CD, SD, FW, LFPW, CBW)	c. 1,900 effort records (spread between areas VIIe, VIIh, VIIIa, VIIId$_2$ & VIIIc)	Jan-Dec, 1998-2003, 2005-2007	Offshore effort from Portsmouth to Bilbao	EDFC & IDFC visual; ferry surveys	Can derive si/h & si/km; Access, Excel & paper	Species validation	x
AMBAR	All (but mainly CD, SD, BND, FW LFPW, CBW)	>10,000 effort records	Jan-Dec, 2001-2007	Waters off north coast of Spain	EDFC visual; small vessel surveys, photo-ID, land watches, acoustics	Can derive si/h & si/km; Access, Excel & paper	Species validation	x

4 Survey Conclusions

NGO survey effort in the waters around the British Isles and Ireland has been variable both in space and time, although effort has grown in recent years. Coverage has been greatest in the southern Irish Sea, followed by the waters off West Scotland and then parts of Eastern Scotland. It has been poorest offshore in the North Sea.

Rarely do surveys target a particular species, and, even then, generally all cetacean species spotted are recorded. In the tables above, the species most likely to be encountered are summarized for information. As for whether coverage currently applies to a large part of the range of a species, this is difficult to assess given the spatio-temporal variability that often occurs. Some cetacean species, like the short-beaked common dolphin and long-finned pilot whale, have distributions that extend far beyond UK waters. Coastal populations (which in some cases, e.g. bottlenose dolphin, may be distinct from offshore populations) are generally well recorded by current survey effort. Those with largely offshore distributions, e.g. beaked whales, long-finned pilot whale, and Atlantic white-sided dolphin, are not so well recorded. For those, it is recommended that regular surveys are designed to adequately sample their favoured habitats.

Systematic surveys along routes pre-determined to adequately sample an area are relatively few, and usually the result of a specific grant-aided research programme. In this context, complementary methods such as passive acoustics and photo-ID have also often been employed. A significant amount of survey effort offshore has involved platforms of opportunity – either ferries or vessels undertaking surveys for other purposes (e.g. oceanography or fisheries). This is not surprising when NGOs have low budgets. They can allow some assessment of trends over time but are difficult to interpret if not supplemented by surveys providing wider spatial coverage, since the fact that routes are fixed means that small changes in distribution can yield markedly different estimates of abundance.

Visual surveys tend to be concentrated between the months of April to September, largely because sea conditions are generally better in summer. T-PODs have been deployed for year-round coverage in a number of coastal locations, mainly targeting harbour porpoise and/or bottlenose dolphin, but for visual surveys in winter, aerial surveys may be the most cost-effective method.

A variety of survey and monitoring approaches recommended for future long-term surveillance are reviewed in Chapter 5, with some case examples. For each of these, the methodology used, some sample results, and a summary of strengths and weaknesses are given. Finally, the costs of each method are outlined.

5 Case Study of Survey & Monitoring Approaches

5.1 Introduction

Methods for detecting trends in abundance, range and habitat use need to be adapted to suit the target cetacean species. The choice of approach will depend upon anticipated encounter rates, how the study population is dispersed, and whether particular techniques (such as photo-ID and acoustics) are appropriate. In this case study, we will use Sea Watch data to illustrate the suitability of particular methods that we feel are most cost effective for a variety of species. In UK and adjacent waters, 14 out of 28 cetacean species may be regarded as regular. However, these vary not only in their abundance and accessibility for survey and monitoring, but also with respect to the ease with which they can be detected by methods such as photo-ID or acoustics (see Table 18; also Evans & Hammond, 2004).

The suitability of a particular method has been assessed here on the basis of the status of the species in the UK. For some cetacean species, in regions where they are more abundant, a particular method rejected here may be more suitable. Photo-ID (using mark-recapture) is assessed on the frequency with which individuals within the population can be uniquely recognized from year to year, bearing in mind the total size of that population within likely study areas. Acoustics (using PAM or Passive Acoustic Monitoring methods either deployed statically or from a moving vessel) is assessed by nature of the sounds emitted by the species – how vocal they are year-round, and whether the sounds can be readily distinguished by the equipment, from those made by other species. For absolute abundance measures to be particularly suitable, requires one to be able to correct for violations of the various assumptions of Distance sampling (recognizing that they cannot be entirely accounted for). Examples of problem species are those that respond to vessels either positively or negatively (particularly if beyond observer detection ranges), those with clumped distributions and large group sizes that are difficult to count accurately, and less common species where encounter rates may be too low to obtain estimates with low coefficients of variation. Sampling error when sample sizes are low also provides the major obstacle to using measures of relative abundance.

Table 18. Major UK cetacean species & most appropriate methods for survey or monitoring.

(+++ = most suitable, (+) = least suitable, - = unsuitable)

Species	Photo-ID	Acoustics	Relative Abundance	Absolute Abundance
*Common **(at least locally)***				
Harbour Porpoise	(+)	+++	+++	+++
Bottlenose Dolphin	+++	++	+++	++
Short-beaked Common Dolphin	+	++	+++	++
White-beaked Dolphin	+	++	+++	++
Minke Whale	+	+	++	++
Rare				
Atlantic White-sided Dolphin	(+)	++	++	+
Risso's Dolphin	+	++	++	+
Long-finned Pilot Whale	+	++	++	+
Killer Whale	++	++	++	+
Northern Bottlenose Whale	+	+	+	-
Sperm Whale	+++	+++	+	-
Fin Whale	++	+	+	(+)
Sei Whale	+	+	+	-
Humpback Whale	+++	+	+	-

Four different approaches for detecting trends in abundance and distribution, as well as habitat use, will be illustrated using data collected by Sea Watch in West Wales. Each has its own advantages and limitations but together are considered the most cost-effective for answering different questions and for different cetacean species with particular characteristics.

5.2 Trends in abundance & distribution, as well as habitat use for harbour porpoise and bottlenose dolphin

5.2.1 Study Area

Cardigan Bay Special Area of Conservation (c. 1,000km^2), occupies a large (largest in the UK), shallow (<60m depth) bay in West Wales, open to the Irish Sea (Fig. 2).

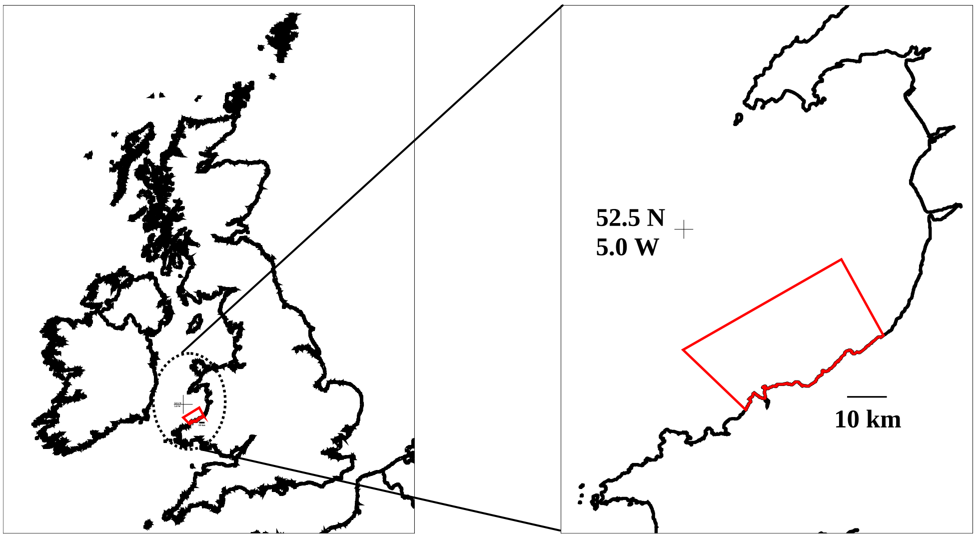


Figure 2. Cardigan Bay Special Area of Conservation, West Wales.

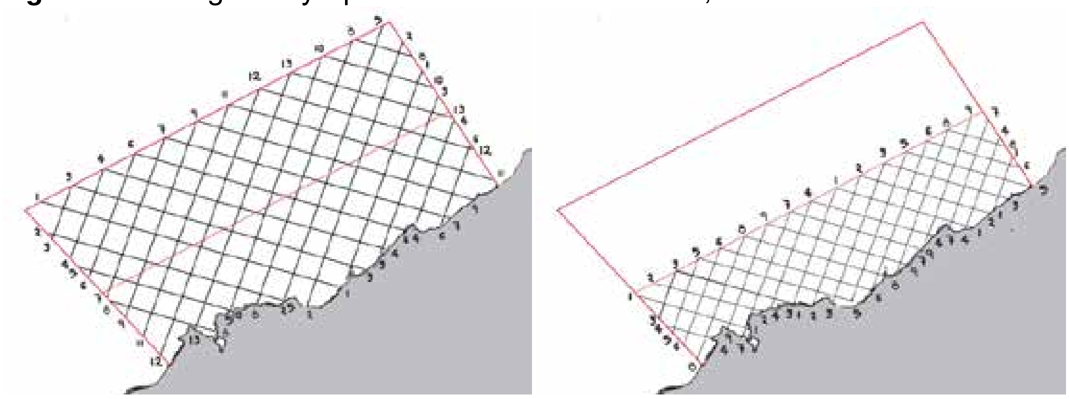


Figure 3. Left: the 13 possible transect routes used to sample the inshore and offshore strata. Right: the 9 possible transect routes used to sample the inshore strata.

5.2.2 Methods

An average of 25 line-transect surveys were carried out in the Cardigan Bay SAC each summer (from April to October 2001, and 2003-06), in order to estimate the abundance of bottlenose dolphins and harbour porpoises in this area (see Figure 1 for map of study area,

Figure 2 for survey design, and Tables 19 and 20 for effort and sightings details for years 2005 and 2006). Three small research vessels were used for the purpose, between 2001 and 2006: in 2001, the 9m motor boat “Ocean Breeze”; in 2003-04, the 10m motor boat “Sulaire, and between 2005-06, the 9.7m motor boat “Dunbar Castle II” (Baines *et al*., 2001; Ugarte & Evans, 2006; Pesante *et al*., 2007). The observer position eye height on all three was between 3.0 and 3.5m, and cruising speeds were c. 7 knots on “Ocean Breeze”, c. 8 knots on “Sulaire”, and c. 7 knots on “Dunbar Castle II”. The trips were performed following a double platform method, when the sea state was ≤3 Beaufort and the visibility was good (no rain or fog). A digital compass or an angle board were used to record angles to sighting, and distances were estimated by eye, but calibrated for each observer against known ranges using radar or GPS (see example in Figure 4).

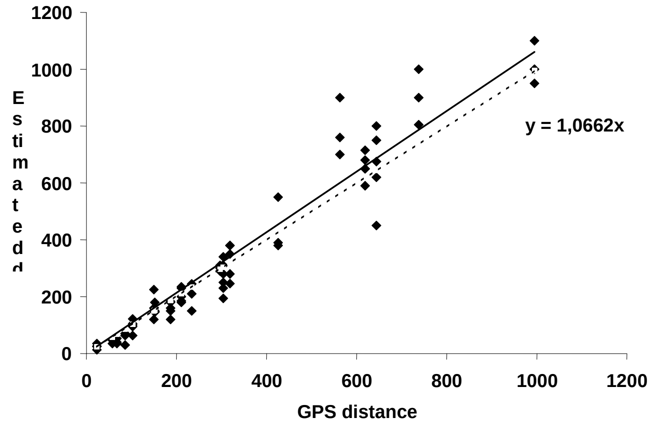


Figure 4. The distances to a buoy estimated with a GPS (x axis) and by the observers (y axis). Dashed line would be the slope if y = x.

5.2.3 Analyses

The study area was divided into inshore and offshore halves; because no sightings of bottlenose dolphin were made in the offshore half, only data from the inshore half were used in the Distance analyses for both species. Estimated distances for each sighting were first adjusted using a correction factor derived from the distance calibration experiment. Data were analysed in program DISTANCE v.5 using the multiple covariates distance sampling (MCDS) engine, with sea state as a covariate. Model selection was based on minimising both Akaike’s information criterion (AIC) and the coefficient of variation (CV). Best fit was obtained using a half-normal model with cosine series expansion, and data truncated to 500m in the case of bottlenose dolphin, and 400m for Harbour Porpoise.

5.2.4 Results

a) Abundance & Density Estimates

Sample summaries of survey effort and sightings are shown for, 2005-06 (Tables 19-21). From these can be derived encounter rates corrected for effort, and these indicate that, during summer in Cardigan Bay SAC, bottlenose dolphins are at between 1.5 and 2 times the abundance of harbour porpoises. The DISTANCE analyses provided absolute abundance estimates varying between 140 and 240 bottlenose dolphins (excluding the estimate in 2004 which was unrealistically low due to low sample size and a skewed detection curve), and between 176 and 236 harbour porpoises. An increase in population size for bottlenose dolphins was observed in 2006, when compared with previous estimates (Table 22). On the other hand, harbour porpoise numbers levelled off at around 220 animals, showing only minor yearly fluctuations (Table 23). Densities of bottlenose dolphins varied between 0.15 animals/km^2 and 0.37 animals/km^2 (Table 22), whereas those for harbour porpoise varied between 0.20 animals/km^2 and 0.53 animals/km^2 (Table 23).

Table 19. Line-transect trips: effort, 2005-2006.

	2005	2006	**Total**
Surveys #	25	25	**50**
Legs #	92	93	**185**
Km travelled	2498	2334	**4832**
Km travelled in LT mode	1597	1163	**2760**
Km in inner transects	688.5	933	**1621.5**
Km in outer transects	908.5	230	**1138.5**

Table 20. Cetacean sightings during line-transect trips, 2005-2006.

	2005	2006	**Total**
Bottlenose dolphins	114	88	**202**
Harbour porpoises	144	133	**277**
Total	**258**	**221**	**479**

Table 21. Encounter rates during line-transect trips 2005-2006 (indivs/100km).

	2005	2006
Bottlenose dolphins	13.57	17.99
Harbour porpoises	9.77	8.53

Table 22. Abundance estimates for the bottlenose dolphin in the Cardigan Bay SAC for the years 2001 and 2003-06, from line-transect surveys using DISTANCE sampling. (The minimum and maximum 95% confidence intervals, CVs and mean densities are shown)

	2001	**2003**	**2004**	**2005**	**2006**
Abundance estimate	128	140	69*	150	240
95% CI min	84	69	21	80	123
95% CI max	194	284	227	280	240
CV	0.21	0.37	0.66	0.33	0.35
Mean Density/km^2	0.25	0.32	0.07	0.15	0.24

Table 23. Abundance estimates for the harbour porpoise in the Cardigan Bay SAC for the years 2001 and 2003-06, from line-transect surveys using DISTANCE sampling. (The minimum and maximum 95% confidence intervals, CVs and mean densities are shown).

	2001	**2003**	**2004**	**2005**	**2006**
Abundance estimate	176	236	215	222	215
95% CI min	110	148	136	156	148
95% CI max	283	337	339	316	313
CV	0.15	0.24	0.23	0.18	0.19
Mean Density/km^2	0.20	0.53	0.49	0.23	0.22

b) Distribution & Habitat Usage

One advantage of vessel surveys is that they can provide distributional information and, in some cases, data also on a variety of environmental variables.

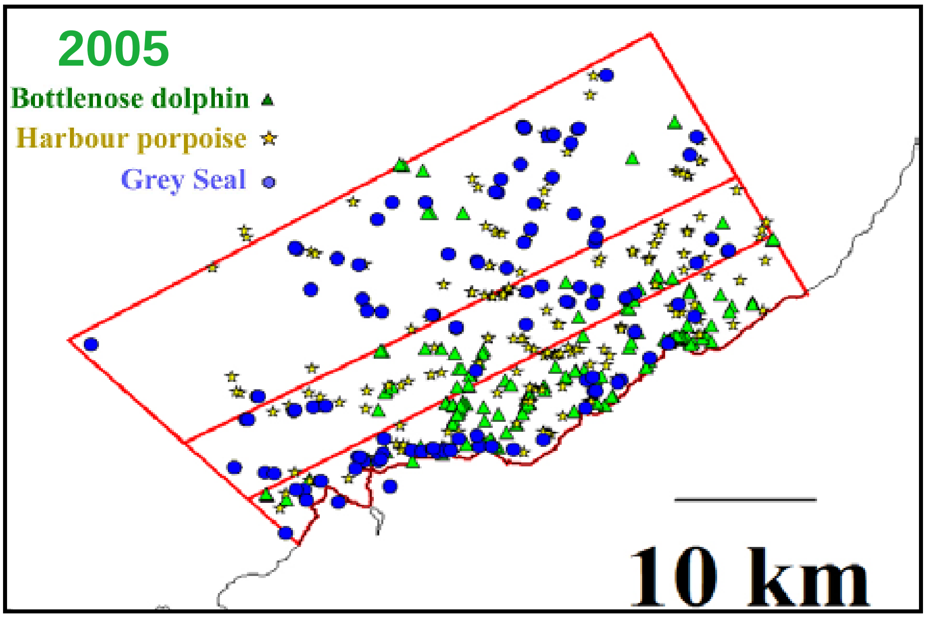
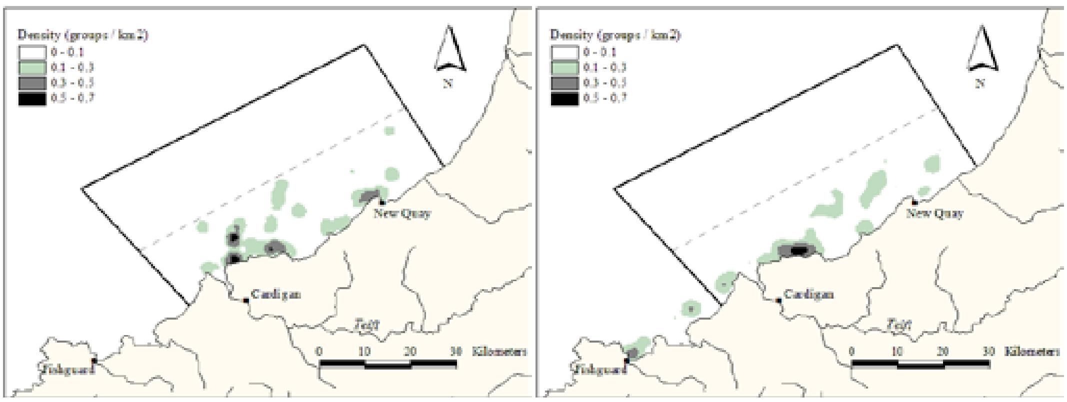


Figure 5. Sample distribution patterns of bottlenose dolphin, harbour porpoise and grey seal from line-transect surveys conducted between April and September 2005.

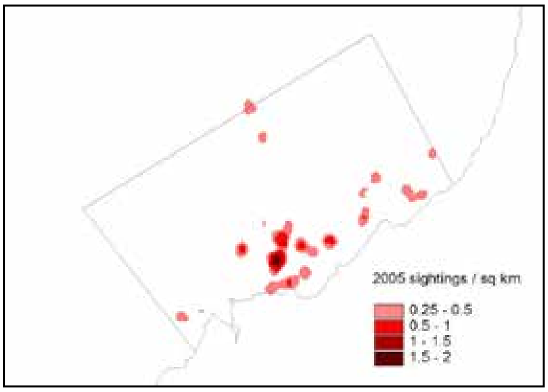
An example of distribution patterns for different species is shown in Figure 5, where sightings of bottlenose dolphin, harbour porpoise and Atlantic grey seal are plotted from a single season's survey. They clearly show that whereas bottlenose dolphin sightings are concentrated near the coast, porpoises are more widely distributed, and grey seals to an even greater extent.



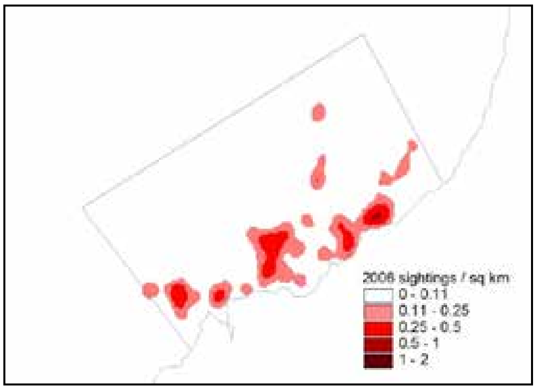
a) May – July b) Aug - Sep

Figure 6. Density of sightings of bottlenose dolphin groups between early and late summer periods in 2001, plotted as groups per km^2, using a neighbourhood mean function.

The centre of highest density of bottlenose dolphin sightings was located between the Teifi estuary and Aberporth Head, both during the period May – July 2005 (Figure 5a) and August – September 2006 (Figure 5b). In the earlier period, a secondary centre of moderately high density was located close to New Quay, but later in the season the importance of this area diminished. Instead, areas to the west of the Teifi estuary, extending outside the SAC boundary became more important, especially Fishguard Bay.



a) Summer 2005



b) Summer 2006

Figure 7. Annual variation in the density of sightings of bottlenose dolphin groups between 2005 and 2006, plotted as groups per km^2, using a neighbourhood mean function.

Density surfaces may also vary over a longer time period. Comparisons between the summers of 2005 and 2006 indicated heavier usage of Cardigan Bay SAC by bottlenose dolphins in 2006 than in 2005, and this was borne out by the higher encounter rates in terms of numbers of individuals, and overall abundance estimates in 2006 (see Tables 21-22). Despite these differences, however, there appear to be core areas used by the species from one year to the next (e.g. between the Teifi Estuary and Aberporth). Continued sampling over a period of several years will establish how long-lasting are these hotspots, and whether they represent critical summer habitat for the species.

The identification of environmental parameters influencing cetacean distribution can best be done by taking existing sightings and associated ecological features, and using predictive models (generalized additive, generalized linear, and mixed models). Variables frequently used include locational ones (latitude, longitude, distance from shore, etc), substrate type, bathymetry (depth and slope), sea surface temperature, salinity, and chlorophyll 'a'.

A GAM(generalized additive model) uses a link function to establish a relationship between a response variable (e.g. animal abundance) and a smoothed function of the explanatory variables. Continuous variables (e.g. depth) and categorical variables (e.g. substrate type) can be combined in a model. As an example of how this can be used, we overlaid the SAC study area by a grid and then associated the data with grid cells. The grid resolution selected was 2 minutes longitude by 2 minutes latitude. The analysis here is based on data from 2001.

The following variables were used:

- **Absolute location**:
  Latitude
  Longitude

- **Relative location**:
  Distance from the coast
  Distance from New Quay
  Distance from the Teifi estuary

- **Bathymetry**:
  Mean depth
  Slope

- **Substrate**:
  Dominant substrate type
  Substrate diversity index

The substrate of the area had already been surveyed in detail by Roxann acoustic methods, with some ground truthing (Baines *et al., 2000*). Substrate categories included:

A. Dense cobbles with sparse turf.
B. Cobbles with sand/silt and either sparse or moderate but short turf.
C. Cobbles with frequent larger stones. Turf mainly on stones.
D. Sand.
E. Mixed sediment; cobbles with gravel and pebbles, sparse turf.
F. Gravelly, shelly sand, probably megaripples.
G. Flat gravelly, pebbly sand.
H. Rocky shore

Methods

On-effort transects were divided into short segments (n = 3255, mean length = 0.8km, mean duration = 4.4 minutes). Each segment was then assigned to a grid cell, based on the location of the mid point of the effort segment. Data associated with each segment included: date, length, duration, sea state, and sightings (species, group size, angle & distance). Effort was summed for each grid cell. Cells with less than 1 nm effort were discarded to avoid problems caused by low effort.

DISTANCE software was used to estimate the detection function for each species. Data were truncated at perpendicular distances of 500m (BND) or 400m (HP). The response variable used in the GAMs was the estimated number of groups (*N*) derived from the Horvitz-Thompson estimator, rather than the actual counts.

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{1}{\hat{P}_{ij}}$$

where n_i is the number of detected groups in the i^{th} segment and P_{ij} is the estimated probability of the j^{th} detected group in segment *i*, obtained from the detection function.

Models were fitted using package “mgcv” for R. Combinations of potential explanatory variables were tested for best fit. Objective criteria used in decisions to drop terms from the model. Model selection was based on three criteria:

- Minimising the General Cross Validation score (GCV) - an approximation to Akaike's Information Criterion (AIC).
- The percentage of deviance explained.
- A visual comparison of spatial displays of the original data with that predicted by the model.

Results

The formula used for bottlenose dolphin groups was:

offset(log(Area searched)) + s(Latitude) + s(Longitude) + s(Distance from Teifi) + s(Depth) + Substrate type + Substrate diversity

Parametric coefficients were:

	Estimate	SE	t ratio	Pr(>|t|)
Sub_type C	0.52657	0.4807	1.095	0.27679
Sub_type D	-0.21024	0.2752	-0.764	0.4472
Sub_type E	0.72548	0.4361	1.663	0.10033
Sub_type F	7.343	45.56	0.161	0.87239
Sub_type G	**-1.6467**	**0.4817**	**-3.418**	**0.0010153**
Sub_type H	0.27747	0.5433	0.511	0.611
Sub_diversity	-0.16255	0.1181	1.376	0.17274

Approximate significance of smooth terms were:

	edf	Chi. Sq.	p-value
s(Latitude)		4.522	43.151
s(Longitude)	4.5269	52.324	0.00000007
s(Distance from Teifi)	5.05	24.187	0.0007
s(Depth)	6.786	79.959	0.0000000007

R-sq.(adj) = 0.874 **Deviance explained = 81.8%**
GCV score = 0.42986 Scale est. = 0.31159 n = 105

5.2.5 Bottlenose dolphin group size model

Groupsize ~ P + s(Distance from Coast) + s(Depth) + s(Slope) + Substrate type

Parametric coefficients were:

	Estimate	SE	t ratio	Pr(>|t|)
Sub_type C	-0.24643	0.4538	-0.543	0.5897
Sub_type D	-0.24496	0.2624	-0.9335	0.35533
Sub_type E	0.4626	0.581	0.7962	0.42995
Sub_type G	-1.3839	1.046	-1.323	0.19235
Sub_type H	0.62849	0.765	0.8216	0.41547

Approximate significance of smooth terms were:

	edf	Chi. Sq	p-value
s(Distance from Coast)	2.559	3.6974	0.24431
s(Depth)	2.63	7.4371	0.055228
s(Slope)	1.898	3.6014	0.16314

R-sq.(adj) = 0.279 Deviance explained = 42.4%
GCV score = 2.6509 Scale est. = 2.0387 n = 61

The formula used for harbour porpoise groups was:

offset(log(Area searched)) + s(Latitude) + s(Longitude) + s(Slope) + s(distance from coast) + s(distance from Teifi) + Substrate type + Substrate diversity

Parametric coefficients were:

	Estimate	SE	t ratio	Pr(>|t|)
Sub_type C	0.2947	0.5367	0.5491	0.58452
Sub_type D	-0.10521	0.2942	-0.3576	0.7216
Sub_type E	-0.073392	0.4088	-0.1795	0.85801
Sub_type F	-4.073	26.78	-0.1521	0.8795
Sub_type G	**1.6349**	**0.7226**	**2.263**	**0.026522**
Sub_type H	**1.2609**	**0.6**	**2.101**	**0.038922**
Sub_diversity	0.09012	0.1113	0.8099	0.42053

Approximate significance of smooth terms was:

	edf	Chi. Sq	p-value
s(Latitude)	2.506	6.8614	0.058908
s(Longitude)	1	6.2923	0.014262
s(Slope)	2.416	6.8762	0.054343
s(Distance from Coast)	4.229	17.448	0.003802
s(Distance from Teifi)	1	6.3917	0.013544

R-sq.(adj) = 0.599 **Deviance explained = 40.3%**
GCV score = 1.8476 Scale est. = 1.4752 n = 95

The results of the GAM provided a plot of spatial distribution of predicted densities for the bottlenose dolphin, which emphasized the likely importance of the coastal region between the Teifi Estuary and Aberporth as well as slightly offshore from Cardigan Island eastwards to New Quay Head (Fig. 7). Bottlenose dolphins were not recorded in the offshore sector during the period (summer 2001) on which this analysis is based.

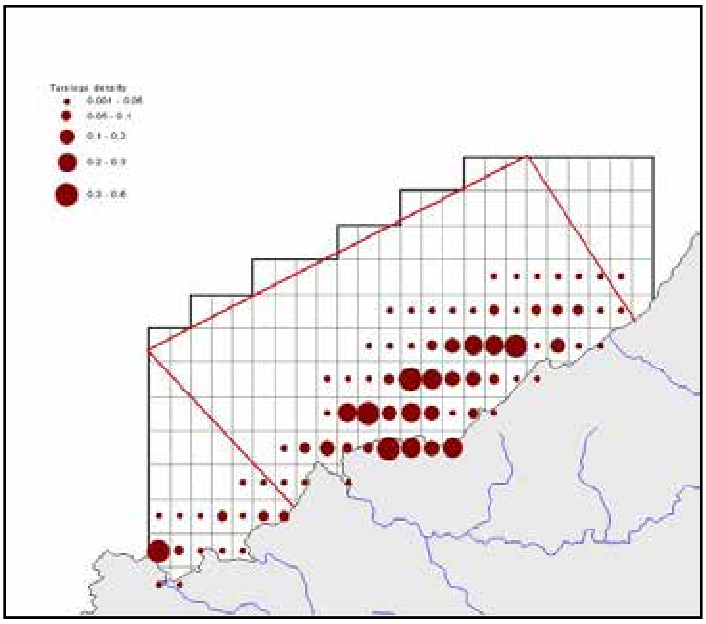


Figure 8. Spatial distribution of predicted densities of bottlenose dolphin.

5.2.6 Harbour Porpoise group abundance model

The formula: for Harbour Porpoise groups was:

offset(log(Area searched)) + s(Latitude) + s(Longitude) + s(Slope) + s(Distance from Coast) + s(Distance from Teifi) + Substrate type + Substrate diversity

Parametric coefficients were:

	Estimate	SE	t ratio	Pr(>|t|)
Sub_type C	0.2947	0.5367	0.5491	0.58452
Sub_type D	-0.10521	0.2942	-0.3576	0.7216
Sub_type E	-0.073392	0.4088	-0.1795	0.85801
Sub_type F	-4.073	26.78	-0.1521	0.8795
Sub_type G	**1.6349**	**0.7226**	**2.263**	**0.026522**
Sub_type H	**1.2609**	**0.6**	**2.101**	**0.038922**
Sub_diversity	0.09012	0.1113	0.8099	0.42053

Approximate significance of smooth terms was:

	edf	Chi. Sq	p-value
s(Latitude)	2.506	6.8614	0.058908
s(Longitude)	1	6.2923	0.014262
s(Slope)	2.416	6.8762	0.054343
s(Distance from Coast)	4.229	17.448	0.003802
s(Distance from Teifi)	1	6.3917	0.013544

R-sq.(adj) = 0.599 **Deviance explained = 40.3%**
GCV score = 1.8476 Scale est. = 1.4752 n = 95

5.2.7 Harbour Porpoise model with term for bottlenose dolphin density

The formula used for Harbour Porpoise groups was:

offset(log(Area searched)) + s(Latitude) + s(Longitude) + s(Slope) + s(Distance from coast) + s(Distance from Teifi) +**s(bottlenose dolphin density)** + Substrate type + Substrate diversity

Approximate significance of smooth terms was:

	edf	Chi. Sq	p-value
s(Latitude)	1.525	5.0189	0.055547
s(Lonitude)	1	6.5153	0.012794
s(Slope)	1.937	6.0499	0.051542
s(Distance from Coast)	5.688	20.015	0.0047586
s(Distance from Teifi)	1	9.8611	0.0024403
s(Tursiops density)	**3.153**	**6.0163**	**0.13297**

R-sq.(adj) = 0.658 **Deviance explained = 45.7%**
GCV score = 1.9484 Scale est. = 1.4916 n = 95

5.2.8 Harbour Porpoise group size model

The formula used was:

Groupsize ~ P + s(Latitude) + s(Longitude) + s(Depth) + s(distance from Teifi)

Approximate significance of smooth terms was:

	edf	Chi.Sq	p-value
s(Latitude)	2.369	2.5909	0.34663
s(Longitude)	1	0.79606	0.37450
s(Depth)	4.953	6.9705	0.22898
s(Distance from Teifi)	4.703	7.7791	0.15716

R-sq.(adj) = 0.0959 **Deviance explained = 24%**
GCV score = 0.42013 Scale est. = 0.36326 n = 111

The GAM model produced a much more even spread of predicted densities for the harbour porpoise, with highest values in the inner sector of the SAC with the exception of the area immediately adjacent to the Teifi Estuary and east of New Quay (Fig. 9).

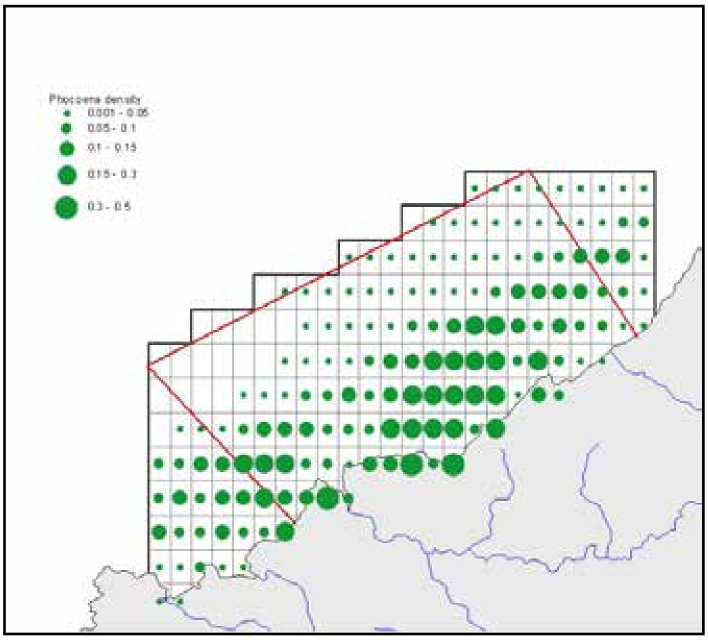


Figure 9. Spatial distribution of predicted densities of Harbour Porpoise.

The two examples (for bottlenose dolphin and harbour porpoise) shown here are used simply to illustrate the type of information that can be gained from this approach, making further use of systematic surveys using small vessels. Obviously the more data that are collected, the better, and although the environmental variables used here were primarily physical ones that are stable over time, fluctuating variables such as SST, chlorophyll ‘a’, current strength, and ideally information on abundance of different fish species would likely better explain spatio-temporal variation in cetacean densities. Unfortunately, precise information on some of these is largely lacking.

5.2.9 Potential of line transect approach using small vessels

Using a systematic survey design and applying Distance methodology allows one to derive estimates of both relative and absolute abundance, along with density estimates and information on distribution and habitat use. If a number of the assumptions that apply for absolute abundance estimation are strongly violated, then nonetheless one can use the data for measures of relative abundance. Small vessels make it economic to collect a lot of data. In this particular study, charter of motor vessels cost £40-60 per hour. For absolute abundance estimates with CVs of 25% or less, it was found that at least thirty encounters with cetacean groups were required. In Cardigan Bay SAC, this equated to between 25 and 30 days of survey or between 1,000km and 2,000km of line transect effort (variation in estimates is caused by differences in encounter rates between years). A typical day’s survey would be for 8-10 hours. Thus, total annual boat costs for this amount to c. £12,500-15,000. In fact, this includes c. 2 hours per day for photo-ID around suitable encounters (see section 2.3).

5.2.10 Limitations and recommendations for improvement

A small vessel has certain constraints for line transect surveys – notably relatively low platform height, more restricted offshore capabilities, and the difficulty to establish truly independent observer platforms. Of these, the latter is probably the most important. Low platform height may simply lessen the effective strip width surveyed, and although this could potentially result in animals reacting to the vessel before being sighted, this is likely to be offset by the lower noise generated by the smaller engines. The precise relationship between the two for different platforms has yet to be established but would be a useful exercise. In the region, there were no vessels available with a flying bridge, which undoubtedly would be an advantage. Offshore capabilities were not required for the Cardigan Bay study, but elsewhere, may well be important. This issue is addressed in section 2.5.

In Cardigan Bay, other logistic constraints apply: 1) all of the boats available for long-term hire had relatively low maximum cruising speeds (6-8 knots). A vessel that could readily cruise at c. 10 knots (optimal for most surveys), and also attain speeds of 15+ knots would have been an advantage for covering more ground and making more use of windows of good weather; and 2) there are rather few safe harbours and most of these are tidal. This can limit the times at which vessels can go out or return, although in most cases it is possible to moor the boat and come ashore by dinghy. The berthing conditions mean that for many harbours in West Wales, vessels are usually taken out of the water in winter, so surveys outside April-October can be more difficult.

The conditions in winter rarely allow boat surveys to be undertaken since windows of good weather are frequently narrow, and it is difficult to conduct surveys on a regular basis. In order to cater for this, it is recommended that aerial surveys be adopted instead, which we have started doing with some success. Plane charter costs vary. For a high-winged twin-engined Partenavia with a bubble window, the costs are currently around £500 per hour. No such plane exists in Wales, the nearest location being Manchester airport, and this was beyond our budget. Instead, we have been using a twin-engined Cessna at a charter cost of £360 per hour. This is not a high-winged plane and does not have a bubble window but for general surveying of cetacean distribution, it has proved very good.

5.3 Trends in population size of bottlenose dolphins in Cardigan Bay by application of Photo-ID methods with Mark-Capture programs

5.3.1 Introduction

Whereas line-transect surveys provide estimates of the average number of bottlenose dolphin within Cardigan Bay 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 has been used.

5.3.2 Methods

Dolphin groups were photographed from a boat that was either chartered for dedicated marine mammal surveys (see Chapter 5.2), or used as a platform of opportunity during dolphin-watching trips. Once a group of dolphins was encountered, the boat would attempt 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.

In 2001, and from 2003-04, an analogue single lens reflex camera was used (either Nikon or Canon) equipped with 70-300 mm zoom lens or fixed 300mm telephoto. From 2004 to the 2007, digital Canon EOS 60D and then 20D were used, with 28-300mm or 75-300mm zoom lenses. Where possible, dolphins were photographed at distances of less than 50m, and attempts were made to take at least one picture of the dorsal fin of each dolphin (and preferably both sides). During dedicated surveys when the weather conditions were optimal for distance sampling (sea state 0-2, visibility >1.5km and no precipitation), time spent photographing a single group of dolphins was limited to 20 minutes or less. Encounters with dolphins were longer during dolphin-watching trips and when the weather was not optimal for visual surveys.

A group of dolphins was defined as a cluster of animals separated by approximately less than 100m and engaged in a similar activity. An encounter was an event in which identification photographs of one group of dolphins were taken. A new encounter started every time a different group of dolphins was approached and identification photographs were taken. A new encounter started also if the group composition changed because of animals leaving or joining.

Analyses: Slides were analysed over a light table using either a magnifying lens or a dissection microscope. Digital pictures were downloaded into a computer and viewed on the screen. Individual dolphins were recognised from irregularities in their dorsal fins and/or pigmentation marks. A unique alphanumeric code was given to each dolphin. This code consisted of a three-digit number, followed by the year when the dolphin was first identified and a letter (e.g. 001-03W). Dolphin pictures were classified into one of three categories/catalogues:

1) <u>Marked:</u> pictures of dolphins with irregularities in the dorsal fin that allowed for identification from either side of the animal (Fig. 10).[1]
2) <u>Right:</u> pictures taken from the right side of dolphins without irregularities in their dorsal fins (Fig. 11). [2]
3) <u>Left:</u> pictures taken from the left side of dolphins without irregularities in their dorsal fins (Fig. 11).[3]

The best images of each dolphin, and at least one image from each encounter, were digitally stored. Slides were scanned using the highest available resolution (4000 dpi, Nikon Super CoolScan LS4000 Film Scanner).

Data associated with each identified dolphin included the encounters when the dolphin was seen, the age/sex category of the dolphin, and suspected mother/offspring relationships (see Ugarte & Evans, 2006, for full details).

Photo-identification data for the years 2001 and 2003-06 were analysed with the MARK-CAPTURE programme using the Chao (mth) model for closed populations.

[1] The alphanumeric code for the dolphins in this catalogue ended with the letter W if the animal was marked with features large enough to allow for identification from distant or un-sharp pictures (W stands for “well marked”). If the identification features were only discernible from sharp pictures taken at close range, the code ended with an S (for “small nicks”). Examples of dolphin “names” from this catalogue are: 013-01W, 014-01S, 015-03W

[2] Alphanumeric codes in the right and left catalogues ended with the letters R and L, respectively.

[3] The running numbers from each catalogue were independent of the numbers in the other two catalogues. For instance, dolphins 003-01W, 003-03L and 003-03R were three different individuals. If we knew that a left and a right side belonged to the same dolphin, the database was cross-referenced but the dolphin remained with two different names. For instance, dolphin 019-03L from the left catalogue was the same individual as dolphin 021-03R from the right catalogue.

Figure 10. Dolphins 115-01W (left) and 010-01W (right), from the “Marked” catalogue.

Figure 11. Dolphins 012-03L, from the “Left” catalogue (left) and 043-03R, from the “Right” catalogue (right).

5.3.3 Results

Results are shown in Table 24. These data are preliminary, since the dataset used has not been completely analysed, and a variety of different models are currently being applied.

Table 24. Population estimates for the bottlenose dolphins of the Cardigan Bay SAC in the years 2001 and 2003-06, obtained with the mark-recapture method. The minimum and maximum 95% confidence intervals and standard errors are shown.

	2001	2003	2004	2005	2006
Population estimate	213	153	169	205	197
95% CI min	183	144	150	165	165
95% CI max	279	176	214	287	259
Standard error	23.65	7.75	15.90	29.85	23.41

The annual estimate for the bottlenose dolphin population occupying Cardigan Bay SAC in summer 2001-06 has varied between 153 and 213 animals. During the 2003-06 period, a total of 314 animals have occurred here (some animals are seen in only one or two years, but they remain in the catalogue).

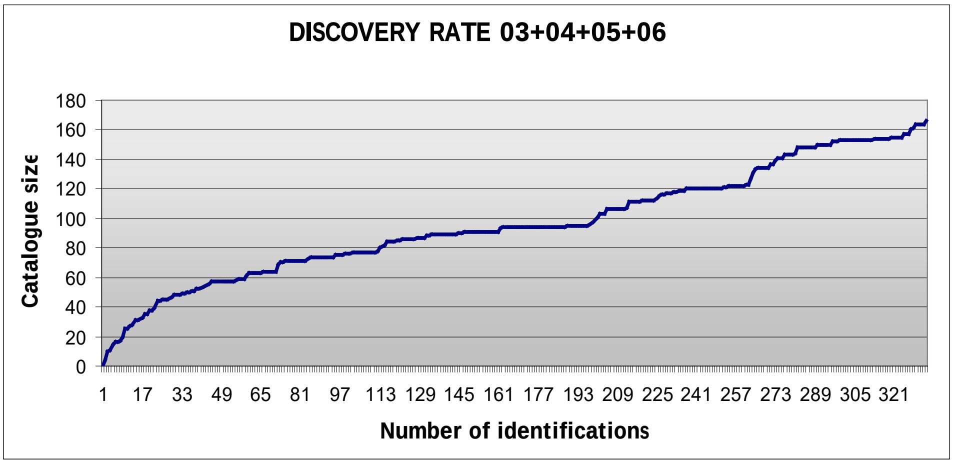


Figure 12. Discovery Curve for the bottlenose dolphin population Cardigan Bay SAC.

The discovery curve is still showing an increase in the number of new dolphins identified, suggesting that not all the marked animals of Cardigan Bay have been identified, and that there is some turnover from year to year (Fig. 12).

Most of the marked dolphins (80%) were seen more than once during this study (Fig. 13), with two individuals seen as many as 37 (ID No: 051-91W) and 39 times (ID No: 017-03W) respectively (Fig. 14). This high number of re-sightings is a strong indication that although new animals enter the population each year, at least a significant portion of the population is resident in Cardigan Bay during the summer months.

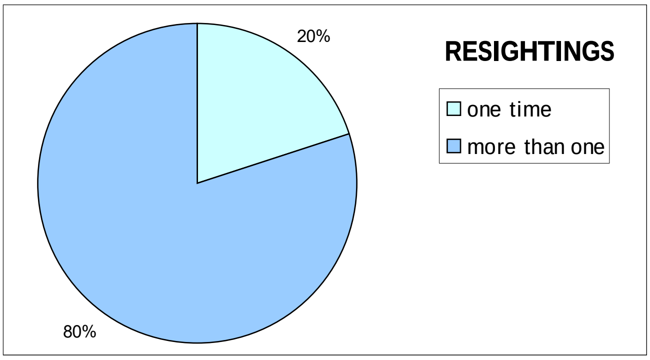


Figure 13. Percentage of animals seen more than once in Cardigan Bay during the 2003-06 period.

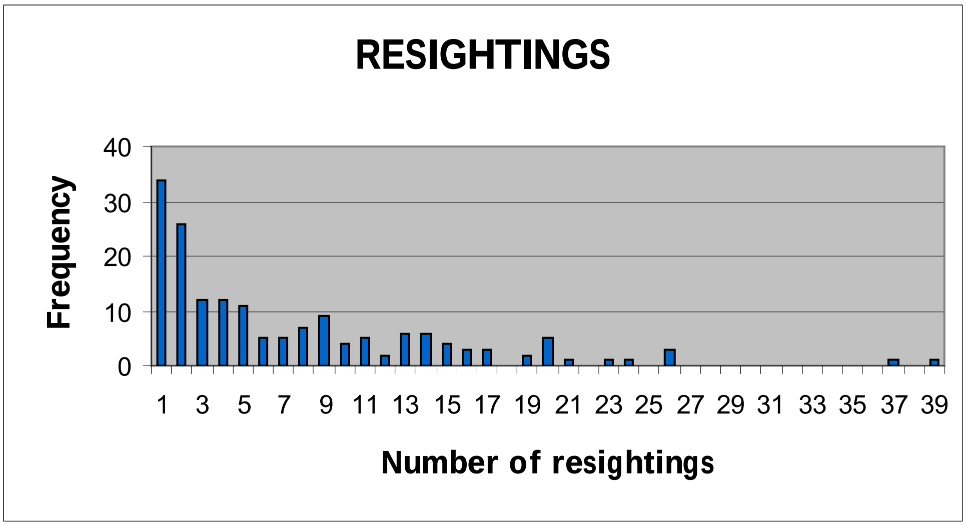


Figure 14. Frequency of re-sightings of the marked animals during the 2003-06 period.

5.3.4 Potential of Photo-ID for monitoring trends

The technique of Photo-ID is well established for determining population size in a variety of cetacean species that have unique individual markings (Hammond *et al*., 1990). It additionally provides information on home ranges, movements, and demographic parameters such as birth rates, along with aspects such as social structure and individual associations.

The costs of collecting sufficient photo-ID data for a robust population size estimate obviously depends upon encounter rates and the area to be covered. In the case of the Cardigan Bay SAC, the boat charter costs were integrated with line-transects, whilst additional photo-ID effort made use of commercial dolphin watch boat operators at no extra cost. If these had to be costed separately, then estimated number of days of boat charter would be c. 30 per season (April-October), which at c. £450 per day amounts to a total of £13,500.

5.3.5 Limitations and recommendations for improvement

The most obvious limitation of the technique is that it applies only to certain cetacean species. Even those species where some individuals are well marked, photo-ID may not necessarily be appropriate either because they form too small a portion of the population (e.g. in some short-beaked common dolphin populations) or the markings are not reliable and may change significantly over time (e.g. in some Risso's dolphin populations).

Other potential issues relate to various assumptions of MARK-CAPTURE which may be violated, for example that animals photographed will always be recognized if seen again, and that animals are sampled in an unbiased manner (i.e. that there is no significant heterogeneity of capture probabilities). Animals should also be recognizable over time. Other difficulties to overcome include accurately determining group size, and thus the proportion that have been photographed.

In Cardigan Bay, it is clear that widening the study area will increase the population estimate, since some individuals occur mainly outside the Cardigan Bay SAC, ranging into the area only briefly. Thus it would benefit the study if greater effort could be placed over a larger geographical area. That is what is now being attempted, funding permitted.

5.4 Passive Acoustic Monitoring at specified locations to determine trends in Occupancy

5.4.1 Introduction

The T-POD is a self-contained omni-directional echo-location click logger with signal processing software, designed to detect porpoise or dolphin tonal signals at 30-170 kHz (Tregenza, 2007). It comprises a metal tube of 70cm length, 88mm diameter, weighing 4.5kg, and contains a battery pack of 12 alkaline D cells, which can log for c. 60 days, and a cylindrical piezo-electric ceramic transducer. T-POD hardware configuration changes through 6 settings/min., so that clicks centred at 50, 70, 90 kHz, etc, can be logged for 10 secs/minute. The time of occurrence and duration of all clicks received are logged to 10μsec resolution. All T-PODs were calibrated against each other under controlled conditions (see Fig. 15 for set-up).

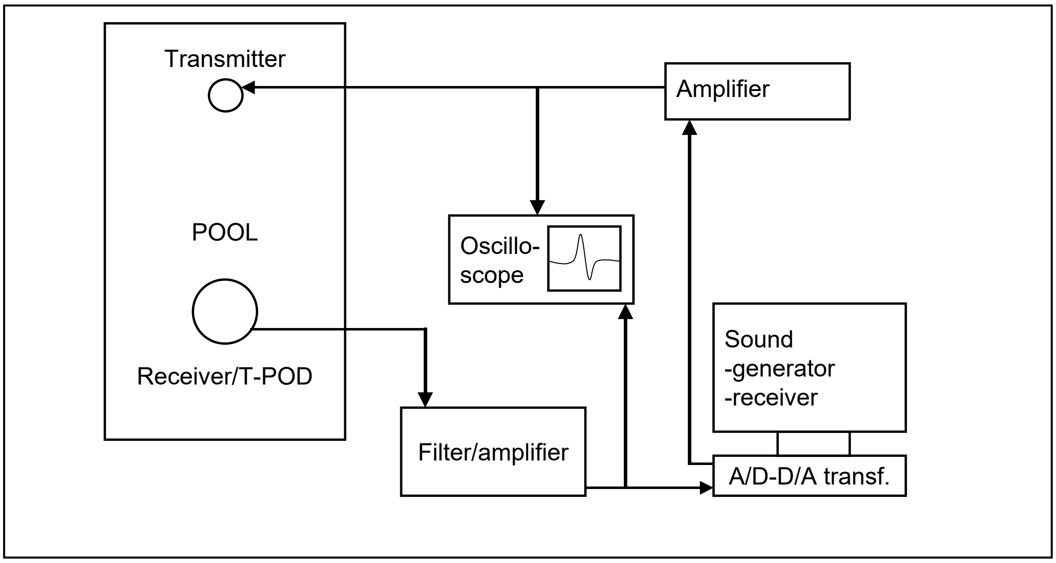


Figure 15. Illustration of the controlled experimental setup for T-POD calibration.

For secure deployment, the arrangement shown in Fig. 15 was used, and to date has not resulted in the loss of any POD.

5.4.2 Methods

From April 2005 to 2007, local fishing boats have been used to deploy ten passive acoustic data loggers, referred to as T-PODs, along the coast of the Cardigan Bay SAC (Fig. 16). At seven locations, T-PODs were placed 500m from shore, and at three locations (Aberporth, Mwnt and Cemaes Head), an additional “offshore” T-POD was deployed 1.5km from shore (i.e. 1km away from the closest inshore T-POD). All PODs were deployed at depths ranging from 12-25 metres. Two versions (V4 & V5) of T-PODs were deployed, Although exhibiting slightly different characteristics, these were calibrated against each other to standardize detections.

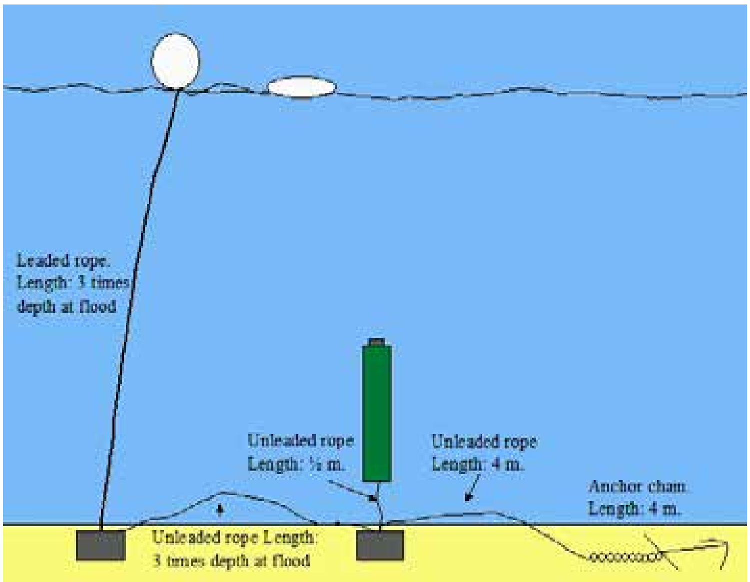


Figure 16. T-POD mooring set up.

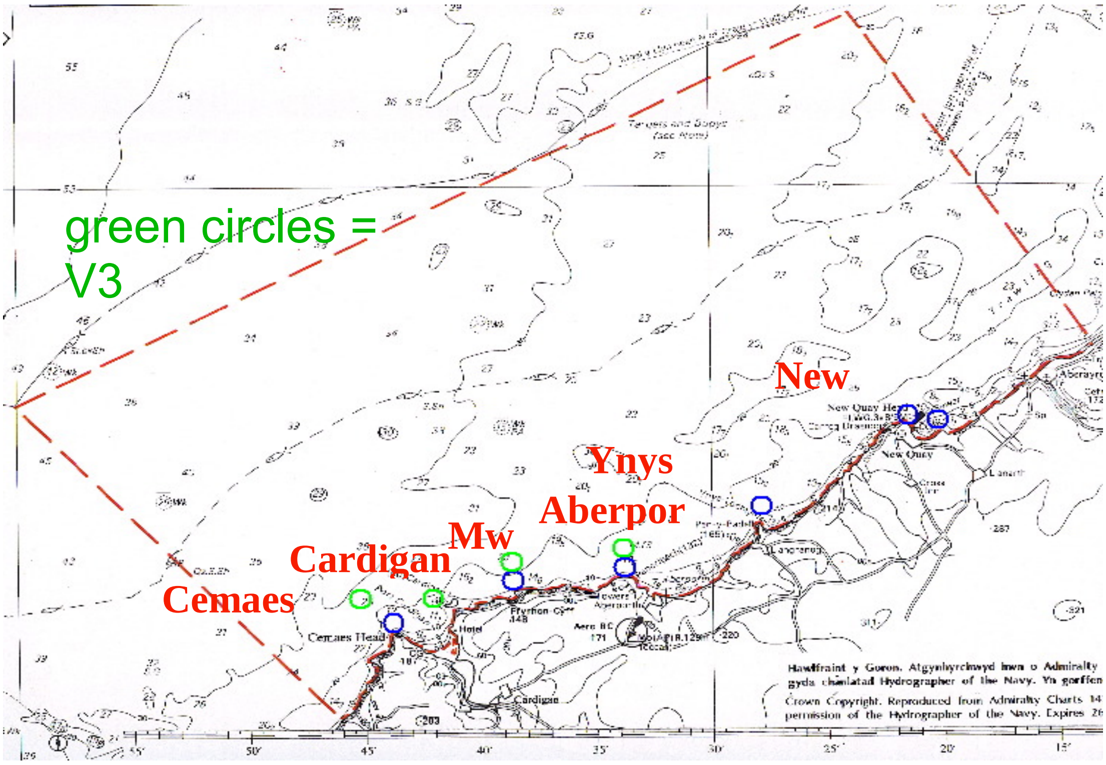


Figure 17. Deployment sites for ten T-PODs within Cardigan Bay SAC.

The T-PODs automatically log the time and duration of clicks that resemble those of the target species, scanning through six frequency channels per minute. Three channels are set to detect bottlenose dolphin clicks and three for detection of harbour porpoise. Whereas bottlenose dolphin echolocation signals have a peak frequency of 60-140 kHz, harbour porpoises produce clicks between 120-150 kHz (Au *et al.*, 2000). Although there is some overlap in the frequencies used by bottlenose dolphins and harbour porpoises, by comparing the output of two filters on each channel it is possible to differentiate the two species. For bottlenose dolphins, the target filter was set to 50 kHz with a reference filter set to 70 kHz, resulting in a peak sensitivity at 50 kHz, which falls to zero beyond 60 kHz. Therefore, only frequencies falling below 60 kHz are logged, eliminating any false positive detections of harbour porpoises on bottlenose dolphin channels. Harbour porpoise channels have a target filter frequency of 130 kHz and a reference filter of 92 kHz, so all frequencies falling below 110 kHz are filtered out. Although there is a chance of false positive detections of harbour porpoises due to occasional high frequency echolocation by bottlenose dolphins, use of a narrow bandwidth setting eliminates the vast majority of bottlenose dolphin clicks. T-POD hydrophones were calibrated to a sensitivity of ± 2 dB (*re* 1µPa) before being deployed, and settings were later validated with a field calibration. Data are logged continuously for 5-6 weeks before being downloaded and the T-POD re-deployed.

T-PODs have a detection range of up to 1250m (possibly greater under certain conditions), but the majority of acoustic detections occur within 500m, with detection rate decreasing with increasing distance from the T-PODs, (Reyes Zamudio, 2005; Tougaard *et al*. 2006; Philpott *et al*. 2007).

5.4.3 Analyses

Acoustic data are analysed with the software T-POD.exe (version 8.17; Chelonia Ltd. Cornwall, UK) which classifies click trains as having a ‘high’, ‘low’ or ‘doubtful’ probability of being of cetacean origin according to the regularity of the click train, since variation in inter-click intervals within cetacean click trains is more constrained than in click trains arising from other sources such as boat sonar, propellers or other biological sources (Tregenza, 2007). Both ‘high’ and ‘low’ probability classified trains are typically considered as being of cetacean origin, therefore both can be used for analysis, with doubtful ones excluded. T-POD software imports data on the time and duration of click trains, the number of clicks within a train, the maximum and minimum inter-click interval, and the pulse repetition frequency, all into a text format. In addition, the number of minutes within a 10-minute interval, an hour or a day in which there was a positive detection can be calculated, and these are usually referred to as detection positive minutes (DPM).

5.4.4 Results

Acoustic data loggers are able to operate throughout 24 hours and in all weathers. They can produce large quantities of information on the occurrence of echolocation clicks for comparisons between sites and examination of trends with time of day, tidal cycle, season, and from year to year. Examples of trends with each of these are shown in Figures 18-20b)

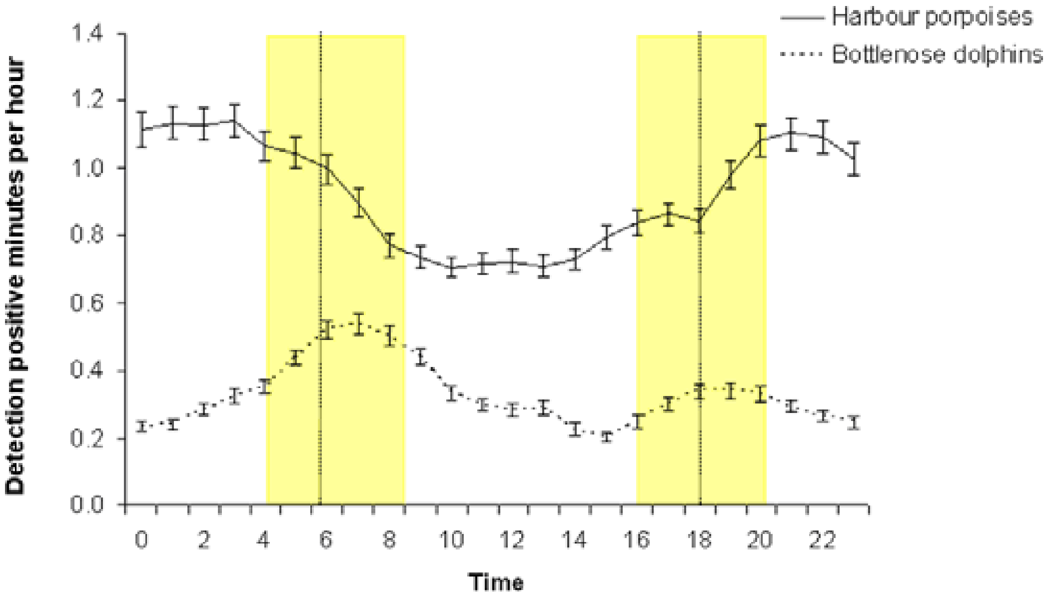


Figure 18. Mean number of detections per hour of bottlenose dolphins and harbour porpoises at each hour before and after sunrise. Data represent means ± 1 SE. Shaded areas represent range of sunrise and sunset times, with vertical dotted lines to show average sunrise and sunset times.

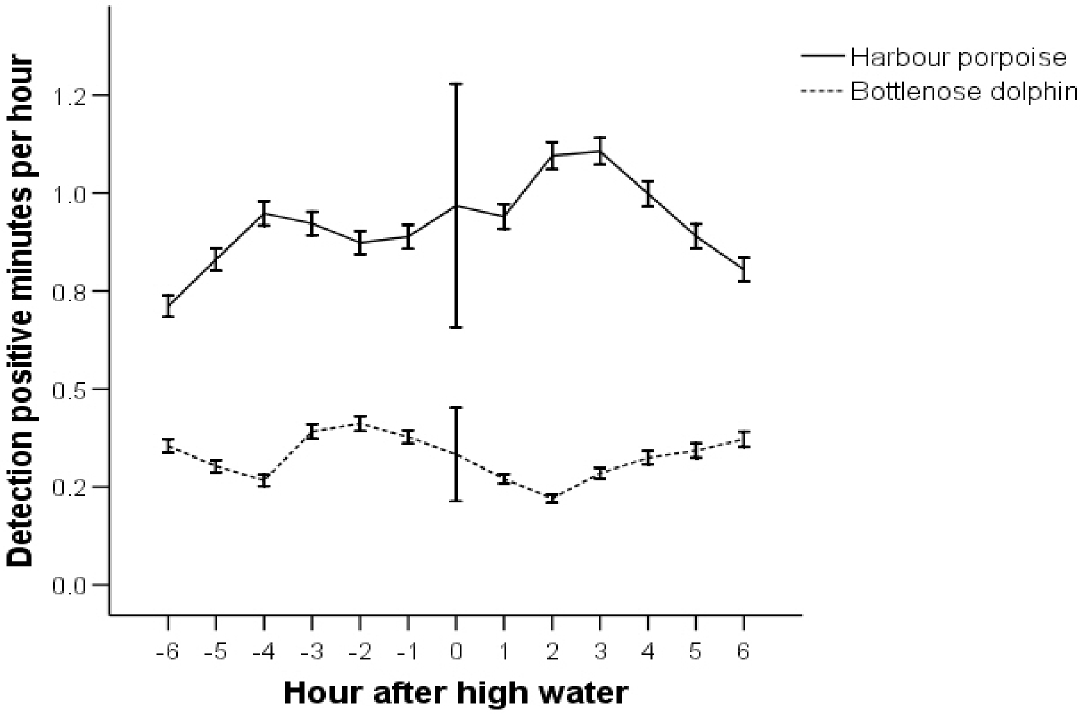


Figure 19. Mean number of detection positive minutes per hour of bottlenose dolphins and harbour porposes at each hour of the tidal cycle. Data represent means ± 1 SE.

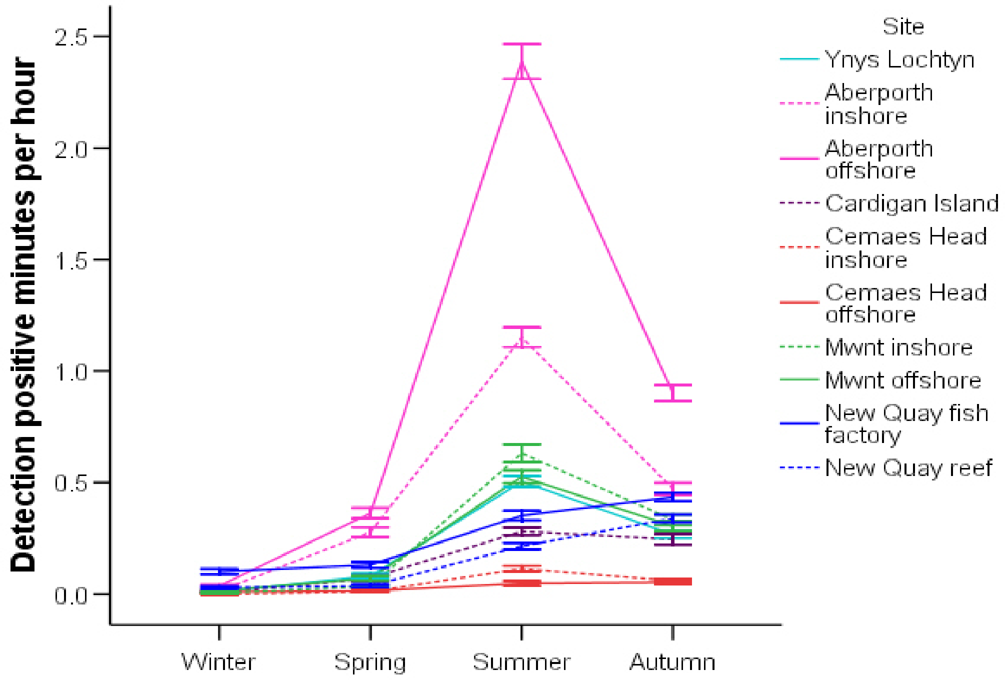


Figure 20a. Mean number detection positive minutes per hour of bottlenose dolphins at each site in winter, spring, summer and autumn. Data represent means ± 1 SE.

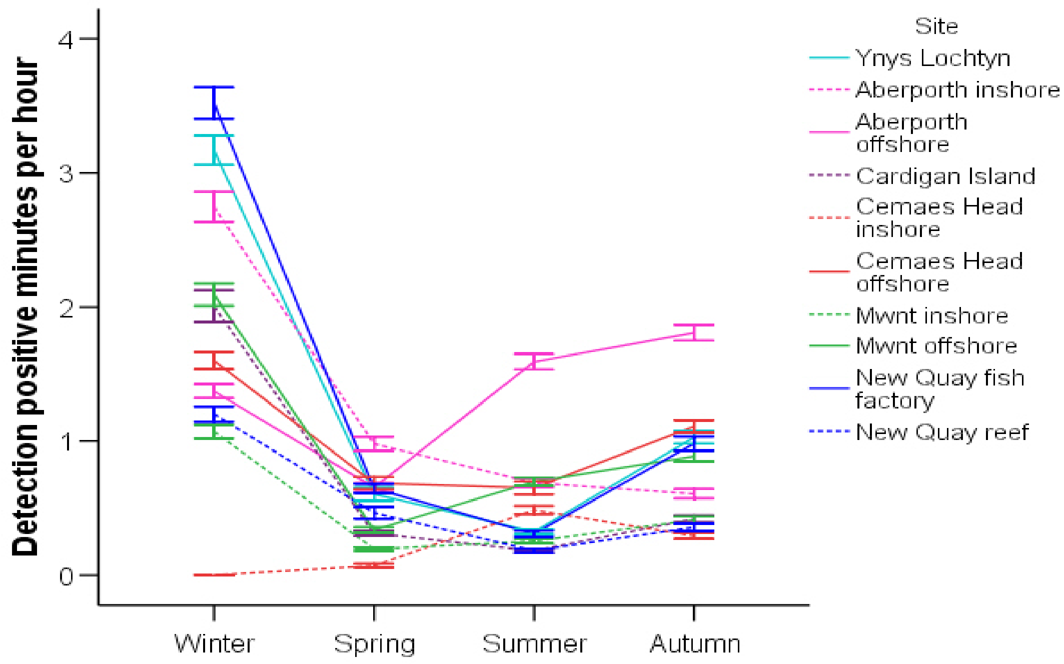


Figure 20b. Mean number of detection positive minutes per hour of harbour porpoises at each site in winter, spring, summer and autumn. Data represent means ± 1 SE.

Many studies have used T-PODs without calibrating them against each other. Since they can vary in their sensitivity, particularly between versions, it is essential that calibration tests are performed first. Other factors may affect detection rates – the precise orientation and depth of deployment, sound transmission characteristics, and, not least, the behaviour and activity of the species under study. Recent versions are able to distinguish between harbour porpoise and bottlenose dolphin although other delphinid species can be more difficult.

Visual and theodolite studies from cliff-tops overlooking T-PODs indicate that porpoises are much more readily detected than bottlenose dolphins, with a greater frequency of clicks, possibly related to their specific foraging behaviour (Reyes Zamudio, 2005).

Harbour porpoise detections changed significantly throughout the 24-hour cycle (Kruskal-Wallis: H=171.3, df=18, P<0.0001), with peak detections occurring after midnight, and large decreases in occurrence at five hours before sunrise and at sunrise itself (Fig. 18). Detections remained low throughout the day until c. 19:00h, the average time of sunset, when it increased again Bottlenose dolphins also showed significant changes throughout a 24-hour period (Kruskal-Wallis: H=727.3, df=26, P<0.0001). However, by contrast to the harbour porpoise, detections were relatively low throughout the night but increased prior to dawn, and continued to rise after sunrise, increasing by 37% in the first hour after dawn and reaching a peak 2-3 hours after sunrise. Throughout the rest of the day, detection rates decreased progressively until 16:00h when there was a slight increase, coinciding with sunset (Fig. 18).

Detection rates of bottlenose dolphins and harbour porpoises varied significantly over the tidal cycle (Kruskal-Wallis, bottlenose dolphins: H=87.5, df=11, P<0.0001; harbour porpoises: H=148.3, df=11, P<0.0001). For harbour porpoises, detection rates were significantly higher during the ebb phase of the tidal cycle (Mann-Whitney: U=1227258214.5, P=0.001), whereas bottlenose dolphins were significantly higher during the flood (Mann-Whitney: U=1217371873.0, P<0.0001). In addition, occurrence rates fluctuated within the flood and ebb phases (Fig. 19). Occurrence of bottlenose dolphins peaked at low water and 2-3 hours before high water, falling to a minimum 2 hours after high water, and then increasing as low water was approached, 3-5 hours after high water (Fig. 19). There was also a significant negative correlation between the relative occurrence of bottlenose dolphins and harbour porpoises over the tidal cycle (Spearman's rank correlation: r=-0.629, n=12, P=0.028), with 40% of the variation in occurrence of one species explained by that of the other.

Relative abundance of bottlenose dolphins differed significantly between all seasons (Scheirer-Ray-Hare: $H_{3,116273}$=453.8, P<0.0001), with a significantly higher number of detection positive minutes per hour in summer than in any other season (0.66 DPM per hour). Detection rates increased from April, peaking in July and then falling throughout the following months, with relative occurrence 83% lower in autumn (0.36 DPM per hour), though this exceeded occurrence in spring (0.12 DPM per hour) and winter (0.03 DPM per hour; Fig. 20a). Relative abundance of harbour porpoises also differed significantly between all seasons (Scheirer-Ray-Hare: $H_{3,116273}$=572.9, P<0.0001), but with a significantly higher number of detections in winter, with more than double the number of positive detections per hour of any other season (Fig. 20b). Relative occurrence was progressively lower in autumn (0.83 DPM per hour), summer (0.54 DPM per hour) and spring (0.50 DPM per hour), respectively.

These examples show the value of maintaining T-PODs in particular locations over the long-term, for monitoring cetacean activity; in this case, data are based on deployments over a 30-month period.

5.4.5 Potential for use of static passive acoustics in monitoring

As noted earlier, the fact that T-PODs can monitor the presence of animals day and night and in all weathers, providing opportunities for longitudinal studies and the collection of large quantities of data. Currently, T-PODs cost about £1,250 each, whilst batteries and materials for deployment cost about £100 per POD per annum. Additional costs for boat charter for uplifting each T-POD, replacing the battery, downloading data and re-deployment. For ten T-PODs deployed in Cardigan Bay SAC, this amounts to ten trips, two each dealing with five

PODs every 10 weeks (the duration for which batteries last in the current versions) @ £450/trip, or a total of £4,500. Some safety margin should be allowed around these costs in case more frequent visits to the T-PODs are needed.

5.4.6 Limitations and recommendations for improvement

Besides the capital outlay costs, which are relatively high, static passive acoustics has two other limitations. The first is that, as with all acoustic methods, it relies upon animals making sounds. If there is no direct relationship between vocal activity and animal abundance, it may not measure population trends or even variation in usage of particular sites. Research is underway to evaluate ways to determine if a relationship can be established. This will need to be repeated for different cetacean species and in a variety of locations. In the examples given from Cardigan Bay SAC, the greater number of clicks per hour at night in porpoises may be the result of greater numbers of animals at that location during night time or to more echolocation activity. At present, it is not possible to readily distinguish between the two.

The second limitation relates to the typical detection range of a T-POD. Because it is usually less than one kilometre radius, and can be much less, cetacean activity around the POD may not reflect the situation in a wider context. This may be overcome by a network of PODs, but then the overall costs increase proportionately.

One final potential limitation concerns the correct assignment of clicks to a particular species. Much effort has been made to improve identification capabilities, and the new D-POD (or digital POD) has potential to make further refinements, needed if other delphinid species are to be differentiated.

5.5 Offshore visual & acoustic line-transects using small vessels

5.5.1 Introduction

In Chapter 5.2, small vessel line-transect surveys were used to provide estimates of absolute and relative abundance of bottlenose dolphin and harbour porpoise in a coastal area - that of Cardigan Bay SAC. For surveying wider areas further offshore, targeting a variety of species, a similar approach is used but with slightly larger, more ocean-going vessels, supplemented by operating a towed hydrophone to record cetacean vocalisations. The study area is the northern sector of the Celtic Deep in the St George's Channel between Pembrokeshire and Ireland, southwards into the Celtic Sea (Fig. 21).

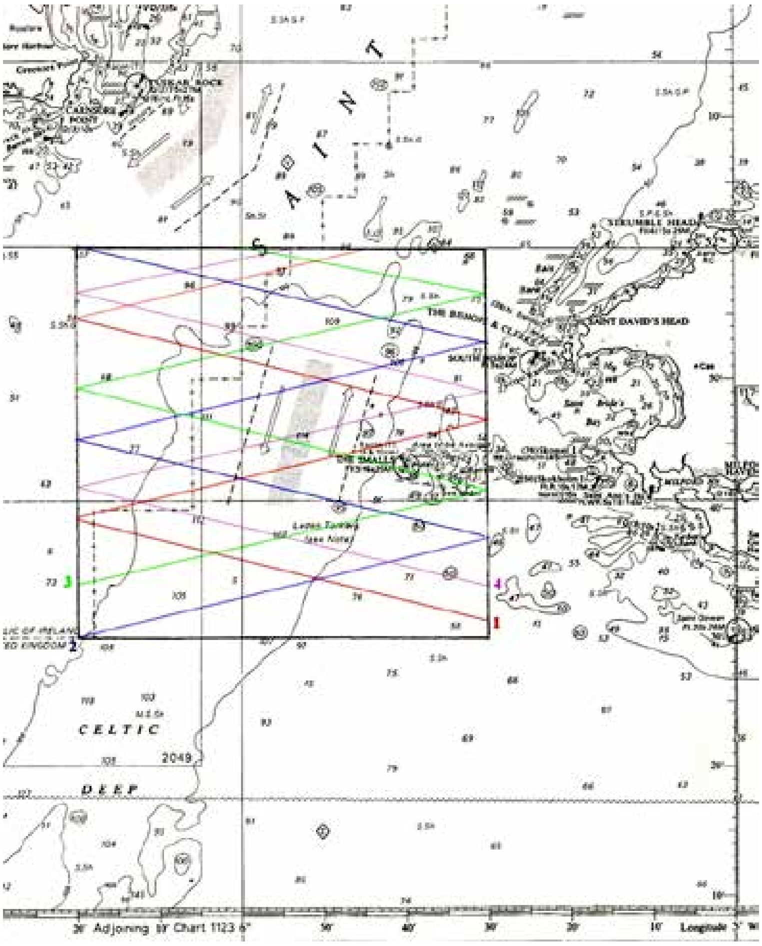


Figure 21. Nautical map of the survey area with transect lines. Different colours indicate the different survey track-lines: (Admiralty Chart, Hydrographic Office).

The survey area spans a rectangular block between latitudes 51°30'N and 52°00'N and longitudes 005°30'W and 006°20'W. Depths vary between about 30 and 120 metres.

5.5.2 Methods

An area of c. 3,134km^2 was surveyed between Wales and Ireland (see Fig. 21), with 2-day surveys approximately every six weeks between May and November, 2004-06. Three different vessels were used for the purpose: the 15m M/V Llanstadwell, based in Milford Haven, Pembrokeshire (survey speed: 7-9 knots; platform height: 5m), the 11m M/V

Predator, based in Neyland (survey speed: 9-11 knots, platform height: 3m), and the 12m M/V Liberty of Wight, also based in Neyland (survey speed: 9-11 knots; platform height: 4m). Most surveys used the latter boat, Liberty of Wight.

The survey routes were randomly chosen from a pre-designed grid superimposed over the study area (Fig. 21). During surveys, two observers, equipped with a hand held GPS, an angle board and sighting forms were placed on the highest suitable point (generally a flying bridge). These observers recorded the angle, distance, species and group size of every cetacean observed, as well as the time and the position of the boat when the observation was made, and information about the behaviour and swimming direction of the animal. An additional observer was placed either in the cockpit of the boat or on the foredeck, and logged the environmental conditions and relevant information, such as boat speed, direction, position and type of effort. This latter observer also recorded independent observations of cetaceans to test if the assumption of all groups close to the track line being detected was true. Photo-ID was conducted when suitable opportunities arose but, generally, line-transects were conducted in “passing” rather than “closing” mode, in accordance with the majority of conventional line-transect surveys.

The target species for absolute abundance estimation was the short-beaked common dolphin, but all cetacean species were routinely recorded.

Acoustic recordings were made continuously throughout a number of the surveys, using hydrophones based upon the Benthos AQ-4 transducer towed at either 130m or 230m behind the vessel, travelling at a speed of around 7-11 knots. The hydrophones were connected to a 3 kHz high pass filter, and then to a Sony TCD-D8 digital audio tape (DAT) recorder with a flat frequency response from 20 Hz to 22 kHz (see Ansmann, 2005 for full details).

5.5.3 Analyses

a) Visual

For estimation of absolute abundance using Distance 4.1 software, information on leg length and associated group sizes and distances to common dolphins from the legs made during line-transect effort mode, with good visibility and no white caps. (i.e. sea state 2 or less).

The data were analysed using the MCDS engine with sea state as a covariate, and post stratified by month to take into account heterogeneity in the seasonal distribution of effort between years. The post stratification was carried out using pooled data for the whole year to estimate the detection function, as there were insufficient data in some months to yield a useful result if the detection function was estimated for each month. The global density estimate was calculated as the mean of stratum estimates, weighted by the total amount of effort in each stratum. No allowance has been made in these results for g(0)<>1 or attraction to the vessel, but this is planned.

Measures of relative abundance are derived by calculating encounter rates and numbers of individuals for each species, corrected for effort (by distance traveled). Further refinements can be applied, such as corrections for the effects of sea state. For this, all dedicated watch data are used whether or not in line-transect mode.

b) Acoustic

The recordings of whistles were digitally downloaded at a sample rate of 48 kHz and 16 bit resolution, using the program Adobe Audition version 1.5 (Adobe Systems Incorporated). The continuous recordings of each survey day were broken down into 10-minute-intervals, and the number of whistles in each of these 10-minute-files counted visually, using the spectral view function in Adobe Audition (spectrogram settings: Hanning window, 512 point spectral resolution). Whistle density (number of whistles per minute) was then calculated by averaging the counted number of whistles over the duration of the file. Whistle intensity was noted as *clear* (if at least 50% of whistles stood out clearly from background noise) or *faint* (if at least 50% of whistles could only be seen faintly, and their entire contours could not be made out clearly).

c) Visual vs Acoustic comparisons

To correlate the visual and acoustic recordings, data were compiled for each 10-minute-file, quantifying whether there was a sighting during this period, as well as details such as number of animals, behaviour, and start and end distance of the animals to the boat. The 10-minute-periods were then categorised into cases where there was (1) no acoustic contact and no sighting, (2) both acoustic contact and sighting, (3) acoustic contact but no sighting or (4) a sighting but no acoustic contact.
.
The relationship between group size (number of animals) and whistle density (number of whistles/minute) was examined, using correlation and regression analyses to develop an equation from which group size could be predicted based on whistle density. Other possible factors that could influence whistle density such as the mean distance of the animals from the vessel and the behaviour of the animals were analysed by looking for significant correlations/regressions. Multiple regression analysis was carried out to determine which of the possible factors had the most important influence on whistle density.

5.5.4 Results

a) Visual

The number of encounters and number of individuals for each cetacean species is calculated for the years 2004, 2005 and 2006 (Table 25). These include all sightings during time engaged in dedicated search, whether or not on line-transect. A total of eight species were recorded: three baleen whales and five odontocetes. The commonest species encountered by far was the short-beaked common dolphin with group sizes varying from 1 to 120, followed by harbour porpoise with group sizes varying from 1 to 15, and then minke whale with group sizes varying from 1 to 5.

Table 25. Summary of the number of encounters and individuals recorded in the Celtic Deep for different species during surveys, 2004-06.

Species	2004 Enc.	2004 Indiv.	2005 Enc.	2005 Indiv.	2006 Enc.	2006 Indiv.
Common dolphin	46	344	139	1,492	160	997
Harbour porpoise	21	34	52	106	58	100
Minke whale	2	5	17	24	14	16
Fin whale	0	0	2	7	3	8
Humpback whale	0	0	0	0	2	2
Risso’s dolphin	1	2	2	2	0	0
Killer whale	0	0	2	4	0	0
Bottlenose dolphin	0	0	1	2	0	0
Unidentified cetaceans	0	0	3	3	2	2

An example of sighting and individual rates for the years 2004 and 2005 is given in Table 26. These allow direct comparison between species and where data have been collected for a series of years, it is then possible to test statistically for trends.

Table 26. Comparison of sightings and individual rates for 2004 & 2005.

Rates: Number/hr of effort

Species	2004 Sighting	2004 Individual	2005 Sighting	2005 Individual
Common dolphin	0.91	6.82	1.39	15.12
Harbour porpoise	0.38	0.63	0.53	1.08
Minke whale	0.04	0.10	0.17	0.24
Risso's dolphin	0.02	0.04	0.02	0.02
Humpback whale	0	0	0.02	0.04
Killer whale	0	0	0.02	0.07
Fin whale	0	0	0.01	0.02
Bottlenose dolphin	0.91		1.39	15.12

The distribution of sightings for the same two years is given in Figure 22. Common dolphin sightings occur widely across the Celtic Deep. Greatest concentrations occur in the eastern sector of the Deep, where the largest group sizes have also been recorded (Fig. 22). Of other cetacean species, the second most frequently recorded species, the harbour porpoise, showed a preponderance of sightings in depths of 50m or less in the eastern portion of the study area (Fig. 23).

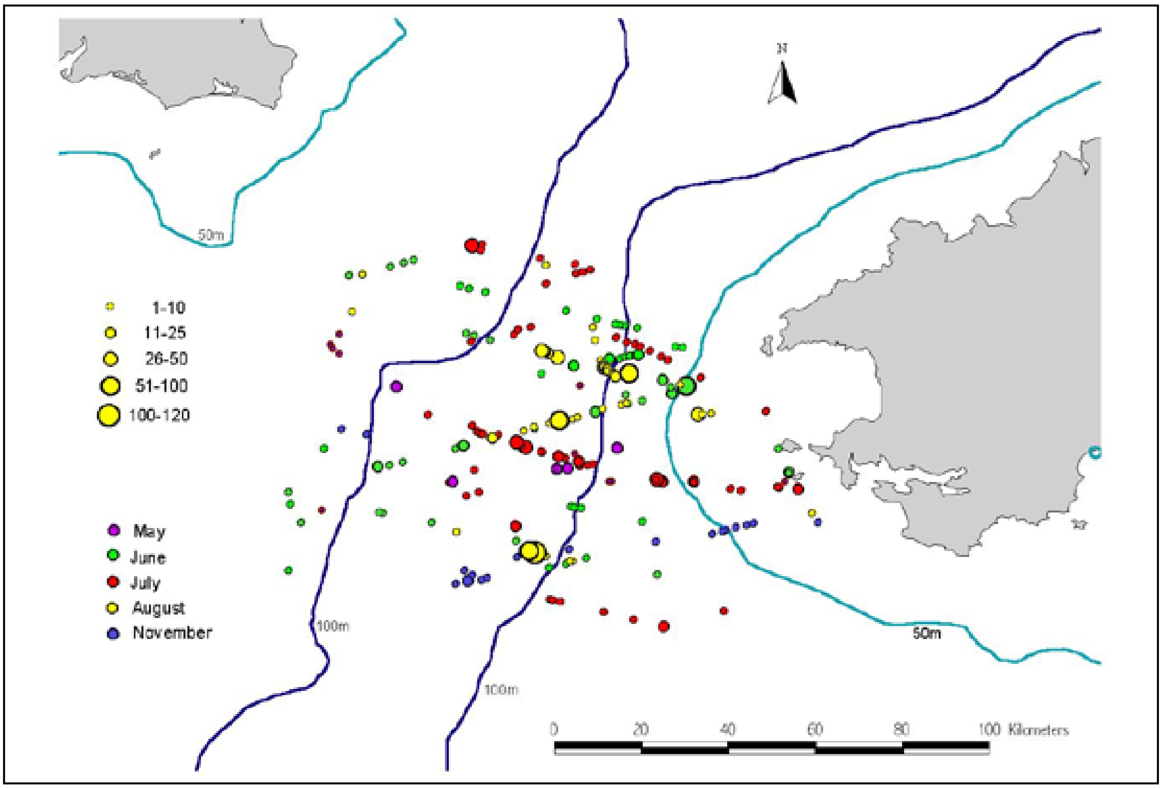


Figure 22. Distribution of common dolphin sightings according to group size and month.

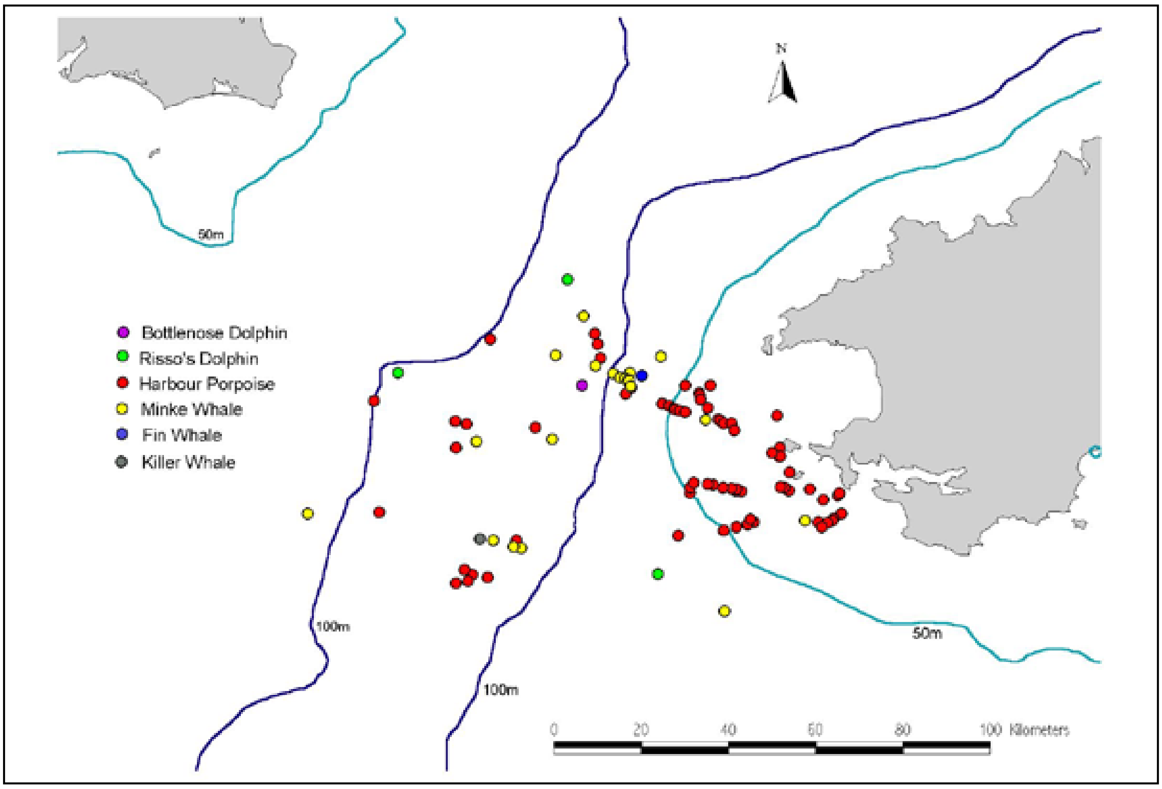


Figure 23. Distribution of sightings of other cetacean species according to group size.

Absolute abundance estimates were calculated for common dolphins in each of the three years. Best fit was obtained using a half-normal model with cosine series expansion, and data truncated to 800m for each of the years 2004-06.

Table 27. Summary of Effort and Abundance Estimates from line-transect surveys, using DISTANCE sampling, for short-beaked common dolphins in the Celtic Deep.

Year	Effort (km)	Observations	Density	Abundance	%CV	Lower 95% CI	Upper 95% CI
2004	723	30	0.38	1186	40.6	520	2709
2005	866	73	0.52	1644	26.8	968	2792
2006	1309	119	0.69	2166	17.42	1541	3045

The results provided abundance estimates of between 1,186 and 2,188 common dolphins, with an increasing trend from 2004 to 2006 (Table 27). Density estimates increased from 0.38/km^2 to 0.69/km^2.

5.5.5 Responsive movement and g(0)

These are two separate issues that can affect the particular abundance estimates obtained here. Both the primary and independent platforms were relatively low, such that it was unlikely that the independent observer could detect animals sufficiently further ahead than the primary observer to see them before they responded to the approach of the vessel. Strong attraction to the vessel is suggested by the detection function plot obtained (Fig. 24), using the MCDS engine, with sea state as a covariate. A scaling factor therefore needs to be derived to take account of this responsive movement towards the vessel, which would otherwise bias density and population estimates upwards.

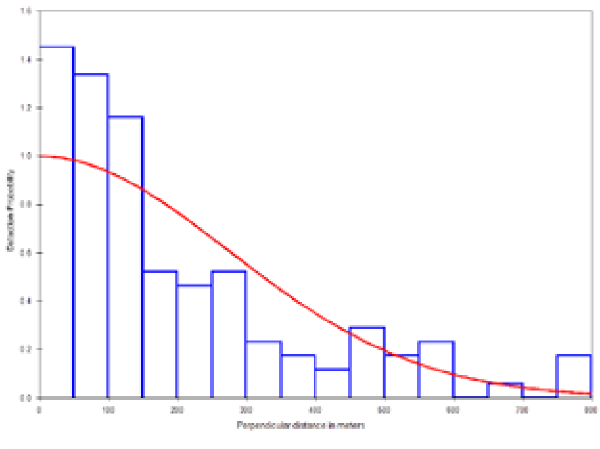


Figure 24. Plot of detection function from the 2006 data, truncated to 800m.

On the other hand, animals on the track-line, whether or not attracted there in response to the vessel, could be missed by the primary observer, resulting in g(0) < 1. Therefore g(0) was estimated for the 2006 data using the MRDS engine in the trial observer configuration, assuming point independence. Sea state and group size were used as covariates. This gave a result of g(0) = 0.79 (SE = 0.067, CV = 0.08).

5.5.6 Acoustic and Visual Detection Rates

The continuous acoustic recordings were broken down into 366, 10-minute-periods. Out of those, 163 (44.5%) had no acoustic contact and no sighting, 86 (23.5%) had both acoustic contact and one or more sightings, 110 (30.1%) had acoustic contact but no sighting, and only 7 (1.9%) had a sighting but no acoustic contact (Fig. 25).

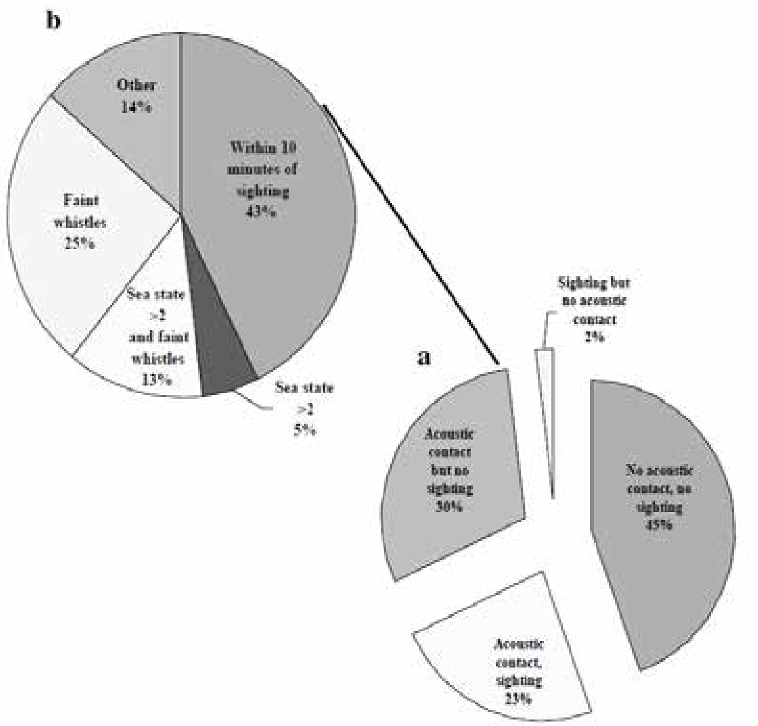


Figure 25. Pie charts showing a) all 10-minute-recordings broken down into 4 groups depending on whether acoustic contact and/or sightings were recorded during that period and b) the group in which there was acoustic contact but no sighting, broken down into cases in which certain factors were present that could explain why no sighting was recorded.

Looking more closely at the 30% of all 10-minute-files during which whistles were recorded even though no dolphins were seen, out of those 110 cases, 47 (42.7%) were within 10 mins of a sighting. This implies that those sightings were not missed completely but rather that the dolphins were heard before they were seen or still heard some time after they were last seen. Out of the remaining cases where sightings were missed, six were recorded during sea states greater than 2 (5.5% of the total 110 cases), in 28 (25.5%) the majority of whistles were faint, and in 14 (12.7%) both of these criteria were met (sea states were greater than 2 and whistles were faint). In the remaining 15 cases (13.6%), none of the above criteria were met (Figure 26).

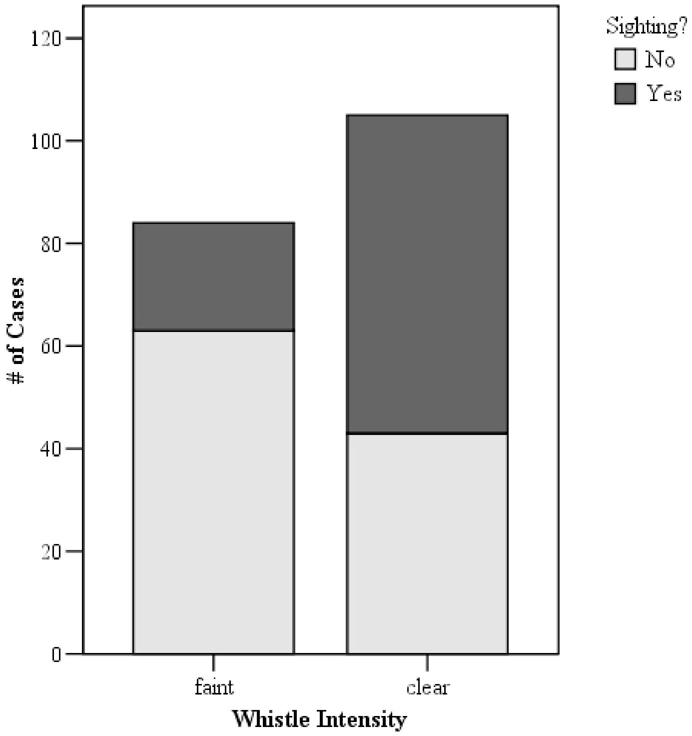


Figure 26. Effect of whistle intensity on whether a sighting was recorded or not.

These situations, in which acoustic contact confirmed the presence of dolphins but sightings were missed (disregarding the cases of acoustic contact within 10 minutes of a sighting), were further analysed statistically by looking at all 10-minute-intervals during which there was an acoustic contact, both with and without a sighting. Cases with a sighting were compared to those where the sighting was missed, even though acoustic contact showed that animals were in the area. Three factors were identified as possible reasons why a sighting could have been missed. These were sea state, group size of the dolphins, and distance of the animals from the vessel. Since no sightings were recorded for the cases in question, no observational data about the group size and distance of the dolphins was available. Thus, whistle density was taken as an expression of the group size (assuming that more whistles per unit time are recorded from a larger group of dolphins), and whistle intensity was used as an expression of the distance (assuming that whistles are clearer if the animals are closer to the vessel and hydrophone).

No significant correlation between sea state and whether or not a sighting was recorded was found (Spearman's rho=-0.089; Kendall's tau=-0.082; N=189; $p>0.05$). However, both whistle intensity as well as whistle density were significantly correlated with whether there was a sighting (whistle density: Spearman's rho=0.379; Kendall's tau=0.312; N=189; $p<0.001$; whistle intensity: Spearman's rho=0.341; Kendall's tau=0.341; N=189; $p<0.001$). Cross tabulation showed that the sighting was missed in 75% of cases where whistles were faint, but only in 41% of the periods with clear whistles (Figure 26), and a significant relationship between whistle intensity and sighting record was found (Pearson r^2=21.964; df=1; p<0.001) with a Cramer's V value of 0.341, indicating that although significant, whistle intensity had a relatively weak effect on sighting record. Whistle density had a mean value of 7.99 whistles/minute (SD=18.39; 95% CI=4.45-11.54) when no sighting was recorded compared to a mean of 30.39 whistles/minute (SD=48.58; 95% CI=19.78-41.00) when there was a sighting. A significant mean difference of 22.39 whistles/minute (95% CI=11.24-33.55) between mean whistle densities for the two categories (sighting: yes/no) was found (t=-3.982; df=100.442; p<0.001) (Figure 27). The significant result was also confirmed by a non-parametric Mann-Whitney test (U=2460.5; N=189; p<0.001).

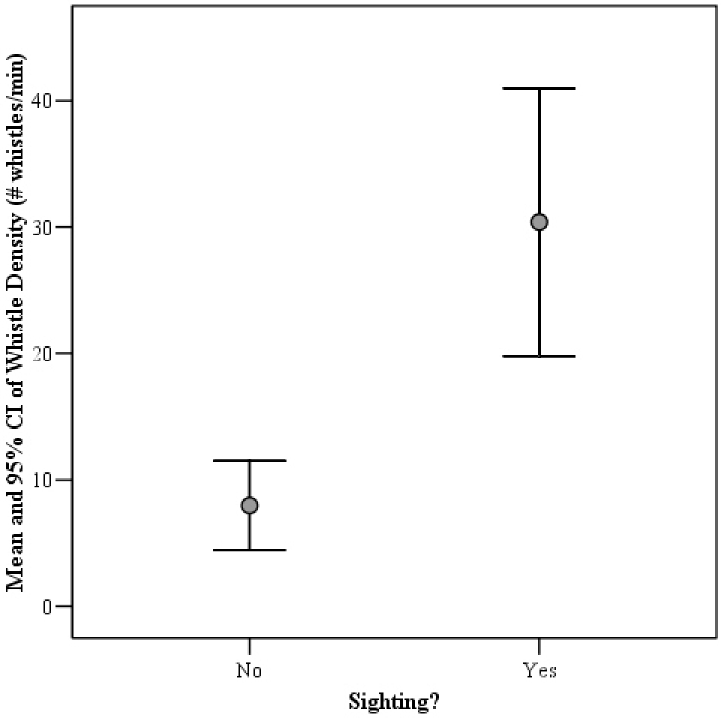


Figure 27. Whistle densities (whistles/min) when a sighting was or was not recorded.

5.5.7 Relationship between Whistle Density and Group Size

Using the cases where an acoustic contact as well as a sighting, were recorded, the relationship between whistle density and group size was analysed. A scatter plot indicated a moderately strong positive relationship although a large spread of the data around the line of best fit was observed. Group size explained 22.6% of the variation in whistle density (r^2=0.226) and a significant correlation of moderate strength between whistle density and group size was found (Pearson Correlation: r=0.475; N=43; p=0.001). A regression analysis was then carried out to examine the form of the correlation. This yielded a significant regression (b=0.634; t=3.456; n=43; p=0.001) and the equation for the regression line (line of best fit):

Predicted whistle density (#/min) = 18.501 + 0.634 x group size
[Eqn. 1]

This indicates that for every unit increase in group size (i.e. for every 1 extra animal), there is a predicted increase in whistle density of 0.634 whistle per minute. Rearranging this equation allows a prediction of group size based on whistle density:

Predicted group size = 1.577 x whistle density (#/min) – 29.181
[Eqn. 2]

However, testing the assumption of normality showed that the residuals of the whistle density data were slightly skewed and not normally distributed. Thus whistle density was transformed using the natural logarithm (LN(whistle density +1)) which yielded an approximately normal distribution. Repeating the correlation test with the LN transformed whistle density data gave similar results as before (Pearson Correlation: $r=0.479$; $N=43$; $p=0.001$). Repeating the regression analysis resulted in a new equation:

Predicted LN transformed whistle density (#/min) = 1.955 + 0.025 x group size
[Eqn. 3]

Thus, using these data, for every increase in group size by 1, an increase in LN(whistle density +1) of 0.025 is predicted.

An analysis was then conducted to determine whether any other factors also influence whistle density, such as the mean distance of the animals to the vessel (determined as the mean between recorded minimum and maximum distances) and/or the behaviour of the dolphins. The mean distance showed no significant correlation with the untransformed whistle density (Pearson Correlation: $r=-0.153$; $N=43$; $p>0.05$) but a weak significant negative correlation with LN transformed whistle density (Pearson Correlation: $r=-0.315$; $N=43$; $p<0.05$) (Figure 6). Regression analysis of mean distance and LN transformed whistle density ($b=-0.001$; $t=-2.125$; $n=43$; $p<0.05$) yielded the following regression equation:

Predicted LN transformed whistle density (#/min) = 3.207 – 0.001 x mean distance (m)
[Eqn. 4]

Since significant correlations were found between LN transformed whistle density and group size as well as mean distance but not behaviour, a multiple regression analysis was carried out for the two significantly correlated predictors (group size and mean distance). Both predictors were significantly correlated with LN transformed whistle density, as shown before, but not significantly correlated to each other. The multiple regression analysis yielded the following regression equation:

Predicted LN transformed whistle density = 2.624 + 0.025 x group size – 0.001 x mean distance
[Eqn. 5]

The standardised regression coefficients showed that group size was the more important predictor of whistle density (Beta = 0.480 versus 0.317 for mean distance). This model could explain 33% of the variation in LN transformed whistle density ($r^2=0.330$). The relationship found in the sample was strong enough to also imply a relationship in the whole population (the sample R was found to be significant using an ANOVA ($F(2,40)=9.843$; $p<0.001$)).

In this study, there were only seven cases (out of 366 ten-minute-intervals) where common dolphins were detected visually but not acoustically. In four of those, the animals were seen at an estimated distance of over 1km from the vessel. In two out of the remaining three, only a solitary animal was seen, and in the third case it was a pair of two individuals. Conversely, the case of visual sightings being missed when dolphins were detected acoustically, was far more frequent, and made up 30% of all 10-minute-intervals. Surprisingly, perhaps, sea state did not have a significant effect on whether sightings were missed, although since surveys were conducted primarily in sea states of 2 and less, this might account for that. The chance of missing a sighting was, however, significantly correlated with whistle density (number of whistles per minute) as well as whistle intensity (‘clear’ versus ‘faint’) in the recording. This indicates that the chances of detecting common dolphins visually are higher for larger groups of animals (assumed to be implied in higher whistle density) and for smaller distance of animals from the vessel (assumed to be implied in clearer whistle intensity). Those results are rather as one might predict, that the detectability of cetaceans decreases with increasing distance from the transect line, and is positively related to school size.

A major problem with acoustic surveying of cetaceans is that it is very difficult to reliably estimate numbers of individuals from vocalisation rates, especially when the animals occur in large groups, or show complex behaviour and long dive durations. The present study did find a significant regression between whistle density and group size, which yielded an equation that allows predicting group size from whistle density. However, this was only a moderately strong relationship, and group size could only explain 22.6% of the variation in whistle density. Whistle density is also influenced by confounding factors such as the distance of the animals. The multiple regression which included the factor mean distance in addition to group size as predictors could explain 33% of the variation in whistle density, more than the regression with group size alone, even though group size was the more important predictor variable. However, this multiple regression is not useful in real life applications. The purpose of developing this kind of regression equation is to estimate group size from passive acoustic survey data where no visual records are available. Thus, data on ranges of the animals would not be available either, and could not be included in an equation.

5.5.8 Potential for use of small vessel line-transects with towed hydrophones for offshore monitoring

In this study, small vessels with a cruising speed of 9-11 knots and which could attain maximum speeds of around 20 knots were found to be excellent platforms for offshore surveys of this nature. They had the flexibility to travel to distant locations, and indeed, an average full day of survey (including down-time at some encounters) would cover distances of between 100 and 160 nautical miles. The extra speed capability is of particular value when attempting to maximize use of windows of good weather that so often prevail in the waters around the British Isles.

A flying bridge was an important asset since it provided a higher platform and was more suited to observation by two observers alongside one another with a reasonable amount of protection from the weather. The deployment of a towed hydrophone is a valuable complementary monitoring tool at least for those species that vocalize on a regular basis, which is usually the social odontocetes. The vessel provided space for a team of six observers (with overnight accommodation), plus two crew. It is important that the skipper has an offshore ticket allowing him/her to operate beyond 40 miles of the coast.

The cost of running surveys of this nature was around £50 per hour so that in a typical 12-hour day, this would amount to £600. Each line-transect survey, sampling the entire box, took two days, thus yielding a boat charter cost of £1,200. Diesel costs have sharply increased in recent years so one should anticipate these amounts rising somewhat. The hydrophone equipment (and recording instruments) represents the only major capital outlay. Those costs can vary greatly depending upon the type of equipment used, but are generally between £2,000 and £6,000. If recordings are made directly to a laptop or desktop with sound card, then there is an additional cost of around £1,000.

5.5.9 Limitations and recommendations for improvement

As with near-shore surveys, the main constraint for absolute abundance estimation is the difficulty in most conventional small motor vessels of 10-15m length to operate an independent observer platform. This is an advantage for absolute abundance estimation to determine the proportion of animals missed from the track-line ($G_{(0)}$) and assess the effects of responsive movement. A high platform also aids the latter, although larger vessels with larger, noisier engines may elicit responses from animals at greater ranges. The balance between a faster, smaller and therefore cheaper vessel and a slower, larger more expensive one has yet to be fully explored for longitudinal monitoring.

Some of the above practical limitations could be overcome by customizing the features on the survey vessel, and this is actually what we are planning to do now for offshore surveys in the future.

At this stage, we conclude that acoustic surveying techniques cannot fully replace traditional visual methods, mostly because group sizes of social cetaceans cannot be accurately estimated from recordings alone. However, acoustic surveying does greatly increase the chance of detecting cetaceans, especially in cases where they are at greater distances from the vessel or in smaller group sizes and thus more likely to be missed by visual observers. Thus it forms a useful complementary monitoring technique at least for particular species.

6 Conclusions

There is no panacea to routine monitoring of cetaceans. The methodology used needs to be adapted to the circumstances and the questions being addressed. However, there is a suite of techniques available that can be used effectively at relatively low cost for surveillance of cetacean populations at various spatial and temporal scales. The major constraint to assessing trends is often sampling error resulting from a paucity of data. Thus methods that will maximize this are to be encouraged. A number of cost-effective approaches are described here. There remain limitations to overcome, some of which are being addressed currently through research. A further constraint that has dogged most studies, particularly within the voluntary sector, is that of consistency – maintaining surveys over long periods of time using standardized methodologies. That has been largely because long-term funding for this has not been available, most projects having a life span of 3-5 years.

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