The Inshore Distribution and Abundance of Small Cetaceans on the West Coast of Ireland: Site Assessment for SAC Designation and an Evaluation of Monitoring Techniques

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“It is increasingly recognized that our understanding of cetacean biology and population dynamics is going to remain inadequate in the foreseeable future. Thus following the precautionary principle, we need to be prepared to act”

Hal Whitehead, 2000

TABLE OF CONTENTS

	Page no.
OVERALL INTRODUCTION	i

CHAPTER 1

CETACEANS IN IRISH WATERS: A REVIEW OF RECENT RESEARCH

Abstract	2
Introduction	3
Legislation	3
Historical records	4
Methods used to survey cetaceans in Irish waters	6
Other survey techniques	16
Biology and ecology of cetaceans in Irish waters	17
Threats: Actual and perceived	25
Future cetacean research in Ireland: Recommendations	29
References	34
Appendix 1	47

CHAPTER 2

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN GALWAY BAY: AN EVALUATION OF MONITORING TECHNIQUES AND ASSESSMENT OF SITE SUITABILITY FOR FUTURE SAC DESIGNATION

Abstract	53
Introduction	54
Materials and Methodology	57
Results	65
Discussion	73
Conclusions	78
References	79
Appendix 2. Tables	84
Appendix 3. Figures	90

CHAPTER 3

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN CLEW BAY: AN EVALUATION OF MONITORING TECHNIQUES AND ASSESSMENT OF SITE SUITABILITY FOR FUTURE SAC DESIGNATION

Abstract 96
Introduction 97
Materials and Methodology 99
Results 103
Discussion 105
Conclusions 107
References 109
Appendix 4. Tables 112
Appendix 5. Figures 114

CHAPTER 4

STATIC ACOUSTIC MONITORING OF HARBOUR PORPOISES (PHOCOENA PHOCOENA) AND BOTTLENOSE DOLPHINS (TURSIOPS TRUNCATUS) ON THE WEST COAST OF IRELAND USING T-PODS

Abstract 118
Introduction 120
Materials and Methodology 124
Results 131
Discussion 138
Conclusions 144
References 146

CHAPTER 5

EVIDENCE FOR LONG-DISTANCE MOVEMENTS OF BOTTLENOSE DOLPHINS (TURSIOPS TRUNCATUS) AROUND THE IRISH COAST USING PHOTO-IDENTIFICATION

Abstract 153
Introduction 154
Materials and Methodology 156
Results 157
Discussion 166
References 169
Appendix 6. Tables and Figure 173

<u>CHAPTER 6</u>

EXPLORING THE SOURCES OF VARIABILITY ASSOCIATED WITH VISUAL MONITORING OF SMALL CETACEANS

Introduction 177

<u>Part I</u>. Examination of inter-observer variability 182
Materials and Methodology 182
Results 185

<u>Part II</u> . Observer Questionnaire 187
Introduction and Methodology 187
Results 187

<u>Part III</u>. Deriving and absolute abundance estimate of bottlenose dolphins in the Shannon Estuary 189
Materials and Methodology 189
Results 192

<u>Part IV</u>. Cost analyses of survey techniques and the assessment of the efficacy of 100 minutes watch duration as required by the IWDG 194

<u>Cost analyses</u> 195
Results 195

<u>Land-based effort watching</u> 196
Results 196

Discussion 197
Recommendations 201
References 207

APPENDIX 7. ACKNOWLEDGEMENTS 210

APPENDIX 8. Notes published in the *Irish Naturalists' Journal* based on results generated during the present study 213

OVERALL INTRODUCTION

To date, 24 cetacean species have been recorded in Irish waters. These are protected by a range of legislation, including national (The Whale Fisheries Act 1937 and The Wildlife Acts 1976, 2000) and European legislation (EU Habitats Directive 43/1992). Ireland is party to other conventions beyond Europe, including the United Nations sponsored global agreement, the Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention) and, since 1985, the International Whaling Commission, which currently bans commercial whaling. A conservation approach to whales and dolphins in Ireland was established with the Wildlife Act (39/1976) and Amendment (38/2000), which prohibited the hunting, injury, wilful interference and destruction of breeding places of cetaceans, within the Exclusive Economic Zone. The protection of cetaceans was further extended through the EU Habitats Directive, which was transposed into Irish law with the European Communities (Natural Habitats) Regulations (S.I. 94/1997) and Amendment (S.I. 378/2005). These legislative instruments oblige Ireland to designate Special Areas of Conservation (SAC) for harbour porpoise and bottlenose dolphin (listed under Annex II), and provide strict protection to all cetacean species (all listed under Annex IV) within the entire EEZ. Currently two SACs have been designated for harbour porpoises (Blasket Islands and Roaringwater Bay and Islands) and one for bottlenose dolphins (Lower River Shannon). The Habitats Directive requires Ireland to undertake surveillance, to form management plans, and ensure that all populations of whale and dolphin species are maintained at “Favourable Conservation Status”. FCS is the desired status of a habitat or species, at any geographical scale from its entire geographical range to a defined area within a site.

In 2004, the National Parks and Wildlife Service (NPWS) of the Department of the Environment, Heritage and Local Government invited tenders for research to estimate the habitat use of small cetaceans along the western seaboard, between Counties Clare and Donegal. This research was limited to already designated SACs, where bottlenose dolphins and harbour porpoises were not included on their remits. This research was aimed at providing information that could facilitate site designation and management in compliance with the EU Habitats Directive. The Galway-Mayo Institute of Technology (GMIT), in partnership with the Shannon Dolphin and Wildlife Foundation (SDWF) were successful in tendering for this programme, and hence was the beginning of the current study. As a number of suitable study sites existed along the western seaboard, GMIT and SDWF used three criteria as part of their site selection process. These included:

i) Evidence of use of site by harbour porpoise and bottlenose dolphin

ii) Designation of all, or some of the site as a candidate marine SAC

iii) Accessibility of the research site, allowing for the exploitation of transient weather windows.

A review of the literature, including (Berrow, S.D., Whooley, P. and Ferris, S. 2002. Irish Whale and Dolphin Group Cetacean Sighting Review (1991-2001), Reid, J.B., Evans, P.G.H. and Northridge, S.P. 2003. Atlas of cetacean distribution in North-west European waters. JNCC) showed that the only site between Loop Head and Donegal with a concentration of harbour porpoise sightings was Galway Bay. Bottlenose dolphin sightings were more widespread with concentrations in Galway Bay, Clew Bay, Achill Island, Broadhaven Bay and Donegal Bay. These sites were consistent with those sites proposed for designation by Dwyer (2000), who in consultation with the IWDG, devised a shadow list of proposed SACs (pSACs) around the Irish coast. As parts of Galway Bay (Galway and Ballyvaughan Bays (Site Code 00268), around Inishmór (Site Code 00213) and Kilkieran Bay (Site Code 02111)), and Clew Bay (Clew Bay and Islands (Site Code 001482) and around Achill Island (Site Code 2268)) are already designated as marine cSACs, this further influenced the selection of these sites. In terms of accessibility of research, Galway Bay provided the most accessible of all sites. It is relatively sheltered from westerly swells by the Aran Islands to the west and there are many access points by boat. As the region is well serviced by ferry routes to the Aran Islands from Rossaveal, Doolin and Galway docks, this made provision for a number of vessels' to be used as "platforms of opportunity". As GMIT is also adjacent to Galway Bay, this allowed for the optimisation of favourable weather windows as well as minimising travel time and expenses.

The present study commenced in March 2005. In Galway Bay (primary study site), fieldwork consisted of a combination of dedicated boat transects, dedicated quantified effort shore watches, use of platforms of opportunity (POPs) and acoustic monitoring in order to assess its potential. Systematic surveys were carried out during monthly dedicated boat-based transects, while bi-monthly land-based watches were carried out at seven sites, with an eventual reduction to once a month at four sites. Photo-identification was carried out where the opportunity arose. POPs were carried out twice monthly where possible, as this method allowed for an increase in survey effort and allowed seasonal variation to be determined. In Clew Bay (secondary study site), fieldwork was restricted to the months

May to September 2005 to 2007. Monthly, land-based quantified effort watches were carried out at five sites in Clew Bay, while systematic boat surveys were also carried out on a monthly basis. Casual sightings were recorded at both locations, as they provided an additional source of information on the occurrence of cetaceans outside survey routes. Long-term static acoustic monitoring was also carried out at both locations, with the use of devices called T-PODs. All data, both visual and acoustic were analysed to determine if the criteria for SAC selection could be met. As an end product, a number of recommendations were made as part of the present study as to whether sites warranted the status of SAC designation. Galway Bay was identified as an area requiring conservation through SAC designation as it supports a widespread population of harbour porpoises regularly recorded in all seasons. Bottlenose dolphin occurrence in Galway Bay was rare and therefore the data do not support the designation of the site for this species. Harbour porpoise were found to use Clew Bay year round as determined from acoustic data, but further research will be needed to gain information on density and abundance of the species in the area. Clew Bay was also identified as important for bottlenose dolphins, but the data was not robust enough to carry out capture-recapture analysis.

This thesis is set out in six chapters. The first chapter reviews all Irish cetacean literature, from historical to present times. This chapter was aimed at drawing together all literature in a readily accessible format and to identify information gaps and issues that should be addressed in the future, while contributing to the preparation of research and management plans. Chapter one was published in the Irish scientific journal, Biology and Environment, Proceedings of the Royal Irish Academy in 2009. In chapters two and three, the results from visual and some acoustic fieldwork carried out in Galway Bay and Clew Bay are presented. Chapter four consists of detailed analyses of acoustic data from Galway and Clew Bay, in respect of seasonal, diel and tidal factors. In chapter five, results are presented from photo-identification fieldwork carried out as part of the present study and combined with additional data from the IWDG, while the implications of long distance movements undertaken by bottlenose dolphins around the Irish coast are discussed. This chapter was submitted to the Journal of Cetacean Research and Management in early 2009 and was accepted for publication as a note. The final chapter explores the sources of potential bias that affect visual datasets and a number of approaches are recommended in order to reduce these variables and to standardise data collection.

CHAPTER 1

CETACEANS IN IRISH WATERS: A REVIEW OF RECENT RESEARCH

(O'Brien, J., Berrow, S., McGrath, D. and Evans, P. 2009 Cetaceans in Irish waters: A review of recent research. Biology and Environment: Proceedings of the Royal Irish Academy, 109B, 63-88).

Pilot whales stranded at Cloghane, Co. Kerry in 1965, from Fairley (1981).

ABSTRACT

To date, 24 cetacean species have been recorded in Irish waters. These are protected by a range of legislation, including the Whale Fisheries Act, the Wildlife Acts and the EU Habitats Directive, which oblige Ireland to maintain cetacean populations and their habitat at a favourable conservation status. Policies aiming to maintain conservation objectives must be underpinned by scientific research. In this chapter, historical and recent research on cetaceans in Irish waters (within the EEZ) is reviewed in order to evaluate present knowledge and identify gaps in research. This information includes historical (pre-1976) records, targeted and incidental land, vessel and aerial based observations, acoustic surveys and monitoring as well as information from strandings. The habitat requirements of most cetacean species are not fully understood but some important habitats have been identified. A number of threats to the welfare of cetaceans in Irish waters have also been identified, including fisheries interactions, pollution, climate change and disturbance. Future research required to fill gaps in knowledge highlighted by this manuscript is considered and discussed.

INTRODUCTION

Irish coastal and offshore waters are some of the most important for cetaceans in Europe (Berrow 2001). Over the last two decades, there has been a rapid growth in our knowledge of the ecology of many cetacean species, due to an increase in research effort and the publication of literature. Cetacean related publications have been consistently increasing since 1976 (Figure 1). There has been an increase in national and international legal obligations for the protection of cetaceans and their habitats. Ireland has recently submitted its first conservation assessment of cetaceans under the EU Habitats Directive (NPWS 2008). For the 18 species (not including vagrants), which required an assessment, information on 12 of these species was reported as unknown, thus their conservation status could not be assessed. Ireland will be required to obtain sufficient information before the next reporting round of the Directive in 2013. In this chapter, the current knowledge of cetacean ecology and research carried out to date in Irish waters is reviewed. The overall aim of this review was to draw together all literature in a readily accessible format to identify information gaps and issues that should be addressed in the future, while contributing to the preparation of research and management plans. However, a detailed review and analysis of specific topics was beyond the scope of this manuscript.

LEGISLATION

There is a range of legislative instruments in Ireland which seek to protect and manage cetaceans and their habitats. The first cetacean related legislation enacted was the Whale Fisheries Act (1937) and associated Statutory Instruments, which required the licensing of all Irish-registered vessels engaged in whaling, and banned the taking of (i) immature baleen whales (ii) female baleen whales accompanied by a calf, (iii) and all right whales. A conservation approach to whale and dolphin species was established with the Wildlife Act (1976) and Amendment (2000), which prohibited the hunting, injury, wilful interference and destruction of breeding places of cetaceans, within the Exclusive Economic Zone (EEZ). The Government also issued guidelines to all boat operators in Ireland (Marine Notice 15 of 2005), under a Statutory Instrument for correct procedures when encountering whales and dolphins, dictating *inter alia* that boats should not get closer than 100m and should maintain a speed less than 7 knots.

Ireland ratified the Bern Convention on the Conservation of European Wildlife and Natural Habitats (1979), which offers protection to cetacean species. However, this legally binding agreement did not extend the legal protection beyond that afforded by the Wildlife

Act, although it acted as a forerunner to more wide-ranging legislation. The protection of cetaceans was further extended through the EU Habitats Directive (1992), which was transposed into Irish law with the European Communities (Natural Habitats) Regulations (94/1997) and Amendment (378/2005). These legislative instruments oblige Ireland to designate Special Areas of Conservation (SAC) for harbour porpoise *Phocoena phocoena* Linnaeus 1758 and bottlenose dolphin *Tursiops truncatus* Montagu 1821 and provide strict protection to all cetacean species (listed under Annex IV) within the entire EEZ. Currently two candidate SACs have been designated for harbour porpoises (Blasket Islands and Roaringwater Bay and Islands) and one for bottlenose dolphins (Lower River Shannon) (Figure 2). This legislation also requires Ireland to undertake surveillance, to form management plans, and ensure that all populations of whale and dolphin species are maintained at a "Favourable Conservation Status" (EEC 1992).

Ireland is also party to international conventions that extend beyond the European Union. One of the most notable is the Convention on Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention). This United Nations sponsored global agreement currently has 99 signatory countries. One of its outcomes has been the formation of Regional Agreements, including ASCOBANS (Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas). The area covered by ASCOBANS includes all Irish waters although Ireland is not yet a signatory. Other international agreements offering protection to cetaceans include the OSPAR Convention (The Convention for the Protection of the Marine Environment of the North-East Atlantic), which seeks to protect the marine environment and establish Marine Protected Areas for threatened species, and CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora), which forbids the trade of cetacean species or their products beyond international borders. Ireland has also been a participant at the International Whaling Commission since 1985, which currently bans commercial whaling. Ireland has recently ratified the EU By-catch Resolution (814/2004), which requires the use of pingers on gill-nets by certain vessels in some areas and to monitor by-catch rate in a range of gill-net and trawl fisheries.

HISTORICAL RECORDS

Prior to the enacting of the Wildlife Act (1976), much of the historical information on cetaceans in Irish waters was sparse and not collated. Reviews by Fairley (1981) and Evans and Scanlan (1989; 1990) sought to address these deficits. Records of stranded cetaceans in Ireland date back to at least AD 752 (Fairley 1981). Stranded whales were a source of protein for coastal communities and occasionally great efforts were made to kill those cetaceans that stranded alive (Anon 1995a), or to drive them ashore (O'Crohan 1934; O'Riordan 1975). Between 1913 and 1974, cetacean strandings in Ireland were recorded as part of the Whale Stranding Scheme run by the Natural History Museum in London (Harmer 1914-1927; Fraser 1934–1974). O'Riordan (1972) published a provisional list of stranded and captured cetaceans and sea turtles. Since 1983 records have been published as *Cetacean Notes* in the Irish Naturalists' Journal, while a comprehensive review of stranding records between 1901 and 1995 was published by Berrow and Rogan (1997). Commercial whaling in Ireland dates back to at least the 18th Century. The presence of fin whales, *Balaenoptera physalus* (Linnaeus 1758) or "huge herring hogs" each spring in Donegal Bay led to the Congested Districts Board encouraging a fishery as early as 1736 (Henry 1739), but only a few whales were ever caught (Fairley 1981). Many of these early whaling efforts were also sustained by hunting basking sharks, *Cetorhinus maximus* (Gunnerus 1765) (Went and Ó Súilleabháin 1967; McNally 1976). Between 1908 and 1922, two Norwegian-owned whaling stations were established in Co. Mayo and during this period at least 894 whales were killed within a 95-100 km radius of the stations. Most of these were fin whales but also blue whale *Balaenoptera musculus* (Linnaeus 1758), sei whale *Balaenoptea borealis* (Lesson 1828), and sperm whale *Physeter macrocephalus* (Linnaeus 1758), were also frequently caught. Few humpback whales *Megaptera novaeangliae* (Borowski 1781) and northern right whales *Eubalaena glacialis* (Müller 1776) were captured as these species were already thought to be scarce in Irish waters due to earlier overexploitation (Evans 1992). Northern bottlenose whales *Hyperoodon ampullatus* (Forster 1770), were hunted in Irish waters up until 1969 (Evans 1991) and minke whales *Balaenoptera acutorostrata* (Lacépède 1758) until 1976 (Fairley 1981).

During the 1960s and 1970s, the growth of sea-watching from headlands to record seabird passage resulted in a new interest in cetaceans since they started to be recorded incidentally. Locations such as Cape Clear Bird Observatory reported cetacean sightings on a regular basis and these data were collated by the UK Cetacean Group, which formed in 1973 (Evans 1976; 1980). Similarly, offshore surveys directed at seabirds also documented cetacean sightings. Such surveys include those off the coasts of Counties Cork and Kerry in August 1968 (Newell *et al*. 1969), when large numbers of common dolphins *Delphinus delphis* (Linnaeus 1758) offshore and harbour porpoises near-shore were seen, as well as other species such as bottlenose dolphin, Risso's dolphin *Grampus* *griseus* (Cuvier 1812), fin whale and minke whale. In 1973, the UK Mammal Society's Cetacean Group (later to become the Sea Watch Foundation) established a cetacean sighting scheme that included Irish waters in its remit (Evans 1976; 1980). Evans (1980) reviewed 1,570 sighting records of 20,994 individuals collected between 1958 and 1978 from British and Irish waters and showed the highest overall concentrations in Ireland off the south west coast. A total of 18 cetacean species were reported from Irish waters. Land-based watches, especially in west Cork revealed not only regular summer concentrations of harbour porpoise, with locations such as Roaringwater Bay being particularly important, but also a wide variety of other species – fin whale, minke whale, humpback whale, northern bottlenose whale, killer whale *Orcinus orca* (Linnaeus 1758) Risso's dolphin, common dolphin, bottlenose dolphin, white-beaked dolphin *Lagenorhynchus albirostris* (Gray 1846) and Atlantic white-sided dolphin *Lagenorhynchus acutus* (Gray 1828) (Berrow 1993; Berrow *et al.* 2002a). Elsewhere, fin whales have been reported regularly from the coasts of south Cork and Waterford; bottlenose dolphins in Bantry Bay, the Shannon Estuary, Galway and Ballinakill Bays; common dolphins and pilot whales west of the Kerry coast, and killer whales off the coasts of west Kerry, Galway, Mayo and Donegal (Pollock *et al.* 1997: Berrow *et al.* 2002a).

METHODS USED TO SURVEY CETACEANS IN IRISH WATERS

Visual surveying

A number of different methods are used to gather cetacean sightings visually (Evans and Hammond 2004). *Casual or incidental sightings* are observations made while an individual's attention is not directed solely at watching for cetaceans. In contrast, *targeted observations* include watches where effort is recorded, these may be carried out from vantage points on land or survey platforms at sea or in the air. During targeted surveys the amount of effort is quantified and relative abundance estimates can be generated. *Targeted surveys* using platforms of opportunity e.g. ferries or survey vessels conducting other marine research, involve dedicated cetacean observers but the track of the vessel is not influenced by the observer or presence of animals. Therefore they are not considered to be dedicated surveys even though observations are targeted. *Dedicated surveys* can be conducted from vessels and aircraft, and they allow for the application of a pre-designed sampling regime in which case they are referred to as line transects. Line-transect sampling can be used to obtain absolute abundance estimates, with DISTANCE methodology commonly employed. During vessel based surveys, single or double observation platforms may be used to help provide an estimate of the proportion of animals missed along the track. Other techniques such as capture-recapture using photo-identification can also be carried out for particular species that bear individually unique identifiable marks (e.g. bottlenose dolphin), enabling the generation of population size estimates, which if repeated over time can provide a measurement of population change.

Since 1991, Ireland has established a systematic national stranding and sighting scheme, coordinated by the Irish Whale and Dolphin Group (IWDG). Recording cetacean abundance and distribution is recognised in Ireland as an Environmental Impact Indicator by Boelens *et al*. (2004). To gain maximum benefit, monitoring programmes should consist of frequent small-scale surveys over a long period of time. Strandings contribute towards the generation of a species list in Irish waters, while they also provide a rough measure of status and seasonal variation in abundance (Evans and Hammond 2004).

Incidental and targeted observations

Reviews of sightings data up to 1985 (Evans *et al.* 1986) and 1991 (Evans 1988; 1992) showed Irish waters to be important for harbour porpoise, common, bottlenose, white-sided, white-beaked and Risso's dolphins and minke, fin, sperm, Cuvier's beaked *Ziphius cavirostris* (Cuvier 1923), killer and long-finned pilot whales. By the time of their latest review (Evans *et al*. 2003) more than 50,000 sightings records and 50,000 hours of survey effort had been collected in British and Irish waters.

In 1991, the Irish Whale and Dolphin Group (IWDG) established a new sighting scheme, which included the collection of casual and effort related sightings data from a diverse range of contributors including, members of the public and the research community (Berrow 1993, Berrow *et al*. 2002a). Berrow *et al.* (2002a) compiled a similar list of species to that described above by reviewing 2,851 sighting records collected between 1991 and 2001 by the IWDG. During 996 hours of land-based effort watches, the highest sighting rates (0.5-1.0 per hour) were reported for harbour porpoise off Co. Dublin, bottlenose dolphin in the Shannon Estuary and common dolphins and minke whale off Co. Clare, although coverage remained patchy. Berrow *et al*. (2005a) reviewed 3,689 cetacean sightings and 903 quantified effort watches collected between 2003 and 2005. Sighting rates per hour were presented for 11 sites at which there were more than 30 watches carried out. The highest sighting rates per hour were recorded from Galley Head, Co. Cork, followed by Slea Head, Co. Kerry, and Black Head, Co. Clare.

The first systematic sighting survey for cetaceans in Irish waters occurred between July and October 1980, when the inshore waters from Co. Cork westwards and northwards to Co. Mayo were surveyed in a series of transects that extended across the edge of the continental shelf into deeper waters west of the shelf break (Evans 1981). The most frequently observed species were harbour porpoise (particularly along the south Cork coast), and common dolphin (particularly over the Labadie and Hurd Banks, off the south and west Cork coasts and along the shelf break). Other species recorded included bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin, small numbers of minke whale and offshore, long-finned pilot whale *Globicephala melas* (Triall 1809). During this survey, methodologies for surveying seabirds at sea were developed and tested, and then incorporated into the UK Nature Conservancy Council's Seabirds At Sea surveys (later to become the Joint Nature Conservation Committee, JNCC). However, no measures of relative or absolute abundance of cetaceans were derived from this first survey.

Leopold *et al*. (1992) carried out five line-transects from Galway to Cork in 1989 on a platform of opportunity using single platform methodology. Although the survey was not a dedicated cetacean survey the authors derived an abundance estimate of 19,120 (CV=0.34) harbour porpoise, equating to an overall density of 0.77±0.26 harbour porpoises per km^2.

Subsequently, as part of surveys conducted by the Joint Nature Conservation Committee (JNCC) Seabirds at Sea Team (SAST), cetaceans were recorded on platforms of opportunity in the seas around Ireland between 1994 and 1997 (Pollock *et al*. 1997; O'Cadhla *et al*. 2004). An analysis of SAST cetacean data by Northridge *et al.* (1995) identified possible concentrations of harbour porpoise in the southern Irish Sea and off the coasts of Kerry and west Cork. A total of 9,106 individual cetaceans of 13 species were recorded during 37,563 km of survey effort in all Irish waters between 1980 and 1997 by Pollock *et al*. (1997). Common dolphin and harbour porpoise were the most abundant species and minke whale was the most frequently recorded baleen whale. However, 25% of survey effort was during July and August and effort was predominantly coastal. These surveys were continued from 1999 with an increased emphasis on the offshore waters of Ireland's Atlantic Margin (O'Cadhla *et al*. 2001; 2004). During 442 survey days at sea, most of which were between April and September, a total of 772 sightings consisting of 20 species were positively identified by Ó Cadhla *et al*. (2004). Rarely observed species identified included right whale (1 individual) and blue whale (1 individual), Cuvier's beaked whale (1 individual), Sowerby's *Mesoplodon bidens* (Sowerby 1804) (1 individual) and True's beaked whale *Mesoplodon mirus* (True 1913), (5 individuals) and false killer whale *Pseudorca crassidens* (Owen 1846) (43 individuals). Areas of importance such as the continental shelf and slope, and Rockall Trough, which may represent critical habitats, were identified on the basis of species richness and relative abundance. These data sets contributed to the production of an atlas of Cetacean Distribution in Northwest European Waters (Reid *et al.* 2003).

In July and August 1995, line transect surveys to systematically sample the entire Irish Sea, were conducted by Sea Watch Foundation as part of an Earthwatch project (Evans and Boran 1995). A total of 3,167 km were surveyed, resulting in 132 encounters (727 individuals) among seven species. Ninety-four encounters were of harbour porpoise (155 individuals), 19 were of bottlenose dolphin (95 individuals), 10 of common dolphin (465 individuals), six of minke whale (eight individuals), one of two Risso's dolphins, and one each of a single white-beaked dolphin and a humpback whale. In August 1997 and May 1998, further line transect surveys were undertaken by Sea Watch Foundation staff and Earthkind volunteers aboard R.V. *Ocean Defender*, in the Celtic Deep between SE Ireland and West Wales (Rosen *et al*. 2000). Most commonly recorded species were common dolphin and harbour porpoise, although other species observed included bottlenose dolphin, killer whale, Cuvier's beaked whale, minke whale and fin whale.

In 2001, as part of the newly formed Atlantic Research Coalition (ARC), IWDG observers carried out six monthly surveys across the Irish Sea between July and December under the sponsorship of P&O ferries. Results showed important seasonal populations of common dolphins and harbour porpoise in the Celtic Sea, Western approaches of the English Channel, and Irish Sea (Brereton *et al.* 2001).

Wall *et al*. (2006) presented data for the distribution and relative abundance of cetaceans off the west coast of Ireland using platforms of opportunity during 2004. They recorded highest species diversity and relative abundance on the Rockall Bank with Atlantic white-sided dolphin the most abundant species. Further south, the common dolphin was the most commonly sighted of all cetacean species recorded on the Irish continental shelf, whereas relative abundance off the north coast was very low.

Dedicated surveys and abundance estimates

The following is a summary of the dedicated surveys carried out to date in Irish waters that have been used to generate estimates of absolute abundance. Cetaceans in Irish waters are likely to be part of a wider North Atlantic population but little information is available on genetic discreteness or stocks. Only abundance estimates from discrete areas are available (see Table 1 for summary).

Hammond *et al.* (2002) generated an abundance estimate of 36,280 with a coefficient of variation (CV) of 0.57 for harbour porpoises in the Celtic Sea as part of an international SCANS project (Small Cetacean Abundance in the North Sea) conducted in July 1994. The coefficient of variation provides a measure of variation of the mean. A low CV indicates a more accurate estimate. An abundance estimate of 1,195 minke whales (CV=0.49), and 833 *Lagenorhynchus* species (Atlantic white-sided dolphins and white-beaked dolphins) (CV=1.02) were recorded during 2,974 km of survey effort during SCANS I (Hammond *et al.* 2002). Rather surprisingly, harbour porpoise density (0.18 animals per km^2) in the Celtic Sea was amongst the lowest recorded in the Europe-wide survey, and only one-quarter of the highest reported density (0.78), recorded in the North Sea.

As part of the Petroleum Infrastructure Programme (PIP) the inshore and offshore waters off western Ireland were surveyed in 2000 (SIAR survey in Ó Cadhla *et al*. 2004). In July and August, during 2,356 km of survey effort using the double platform technique, 126 cetacean encounters were recorded with eight baleen whale and seven toothed whale species identified off the western seaboard from Kerry to Mayo (Ó Cadhla *et al.* 2004). The abundance of Atlantic white-sided dolphins was estimated at 5,490 (CV=0.43) and common dolphins at 4,496 (CV=0.39), with recorded densities of 0.046 and 0.039 per km^2 respectively.

Between June and November 2004-2006, line-transect surveys were conducted by Sea Watch Foundation over the Celtic Deep between SE Ireland and West Wales, in order to generate absolute abundance estimates for common dolphin (Evans *et al*. 2007). From a total of 2,900 km of line transect effort, 222 encounters of common dolphins were made, generating abundance estimates of 1,186 (CV=0.41) in 2004, 1,644 (CV=0.27) in 2005, and 2,166 (CV=0.17) in 2006. These estimates have not been corrected for responsive movement, which tends to increase values three or four fold (Evans *et al*. 2007).

A second international dedicated survey, SCANS II was carried out in July 2005, to generate new estimates of cetacean abundance of a much wider area of the European Atlantic continental shelf and the Irish Sea (SCANS-II 2008). Seven ships and three aircraft were used for the survey and double platform line transect surveys were undertaken by all ships. Shipboard surveys were carried out along the continental shelf and in the Celtic Sea. Aerial surveys were also conducted off coastal Ireland and in the

Irish Sea. Together, these were also used to calculate abundance estimates for harbour porpoise, white-beaked, bottlenose and common dolphins and minke whale. Harbour porpoise abundances were generated for three areas; Celtic Sea (80,613, CV=0.50), Irish Sea (15,230, CV=0.35) and Atlantic coastal Ireland (10,716, CV=0.37). Harbour porpoise density had doubled between SCANS I and SCANS II representing an increase of 11% per annum between 1994 and 2005. White-beaked dolphin abundance was estimated at 75 individuals (CV=0.80) in the Irish Sea, while bottlenose dolphin abundance estimates were made for the Irish Sea (235, CV=0.75), Coastal Ireland (313, CV=0.81), and Celtic Sea (5,370, CV=0.49). Common dolphin abundance estimates were made for the Irish Sea (366, CV=0.73), Atlantic coastal Ireland (15,327, CV=0.78), and Celtic Sea (11,141, CV=0.61), while minke whale abundance estimates were 1,073 (Celtic Sea, CV=0.89), 2,222 (Atlantic coastal Ireland, CV=0.84) and 1,719 (Celtic Sea, CV=0.43) (Table 1).

To date, three abundance estimates have been derived for a resident group of bottlenose dolphin in the Shannon Estuary on the west coast of Ireland using small scale dedicated transects and Capture-Recapture methodology. Population sizes of 113±16 bottlenose dolphins in 1997 (Ingram 2000), 121±14 (CV=0.12, 95%CI=103-163) in 2003 (Ingram and Rogan 2003) and 140 ±12 (CV=0.08, 95% CI 125-174) in 2006 (Englund *et al.* 2007). From the number of estimates carried out since 1997, there is an indication that the population of bottlenose dolphins in the estuary is increasing.

Ship and Aerial surveys

There are many potential platforms of opportunity from which to carry out cetacean surveys. Ferry companies crossing the Irish and Celtic Seas have provided space for researchers for many years, resulting in a better understanding of the distribution of cetaceans along these routes (Brereton *et al*. 2001). The two state research vessels R.V. *Celtic Explorer* and R.V. *Celtic Voyager* have also been used extensively in recent years for cetacean research (Wall *et al.* 2006). The Irish Navy has provided excellent platforms combining visual and acoustic cetacean techniques and also seabird surveys (Pollock *et al*. 1997; Rogan *et al*. 2003a; Aguilar de Soto *et al*. 2004; Ó Cadhla *et al*. 2004). Aerial surveys for cetaceans have been more limited. Berrow *et al*. (2003) used a twin-engine flying at an average height of 500m, and a velocity of between 100-120 mph to locate large baleen whales along the south coast. They found aerial surveying to be a successful method for locating cetaceans, recording large unidentified whale species, minke whale, harbour porpoise and common dolphin.

A small aircraft with experienced international observers was used to survey the Irish Sea and coastal Ireland for small cetaceans during SCANS II (SCANS-II 2008). Occasionally, cetacean sightings have been reported to the IWDG from aircraft, especially from the Maritime squadron. Aerial surveys may provide a fast, effective way of utilising often rare weather windows, especially on the west coast of Ireland when favourable sea conditions may be limited especially during winter months, although there is little experience and expertise in Ireland for aerial surveys of this nature.

Many more potential platforms have yet to be used including the Irish Observer Scheme on foreign research vessels working within Irish waters. To utilise these opportunities a group of trained surveyors is required, collecting data in a standardised format and inputting into a central database. Whale-watching vessels are also very useful platforms and these have been used in the Shannon Estuary (Berrow and Holmes 1999) and off west Cork (Whooley *et al.* 2005).

Strandings

Since 1991, the IWDG has co-coordinated an All-Ireland stranding scheme, which has improved geographical coverage and ensured that the collection of strandings data were carried out in a uniform way (Berrow *et al*. 2005a; 2005b). There has been a marked increase in the number of reported strandings since the 1970s (Figure 1). This is likely to be due to increased recording effort (Berrow and Rogan 1997). An increase in the number of reported live strandings has also occurred. Options for the handling and care of live stranded cetaceans in Ireland are limited since rehabilitation facilities are not available. Consequently, animals are either re-floated, euthanased or left to die. In recent years, dolphins not suitable for re-floating have occasionally been euthanased (e.g. Glanville *et al.* 2003; Whooley and Steele 2006).

A number of published studies have used strandings data from Ireland for analysis and review purposes (Evans 1980; Evans and Scanlan 1989; Berrow *et al*. 1993; Macleod 2000; Goold *et al*. 2002; Murphy *et al*. 2005a; 2006). It is noteworthy that the number and rate of sperm whale strandings has increased since the 1960s (Berrow *et al*. 1993). Goold *et al*. (2002) attribute these results to a combination of increased recording effort and increased mortality due to anthropogenic factors rather than population increase or changes in distribution. However, Evans (1997) considered that the reporting of stranded sperm whales was likely to have remained high given their large size, and showed from both strandings and sightings data that a greater number of groups of adolescent males were being reported in recent years, suggesting their increased and prolonged presence at high latitudes.

MacLeod *et al*. (2004) used records of stranded beaked whales to explore geographical and temporal variation in occurrence of different species around the UK and Ireland. This study highlighted significant seasonal variation in strandings of northern bottlenose whales with most stranding in late summer and autumn. There were significantly more Cuvier's beaked whale strandings than expected in January and February, June and July, prompting the authors to suggest that temporal segregation occurred between these two beaked whale species to reduce potential competition for prey. In contrast to the records for sperm whales, Murphy (2004) analysed common dolphin stranding records between 1901 and 2003 and showed a decline in the number of strandings between the 1930s and the 1970s. The author suggested that this decline may have been caused by a shift in the species' distribution northwards in search of other feeding grounds, possibly as a result of changing oceanographic conditions related to the North Atlantic Oscillation. This has been mirrored by range shifts observed elsewhere in the UK (Evans *et al*. 2003). Berrow and Rogan (1997) reported a significantly greater proportion of male Atlantic white-sided dolphins compared with females stranded on the Irish coast, suggesting that single sex schools, similar to those reported from the north-west Atlantic may occur in Irish waters.

Although there are difficulties in interpreting strandings data to assess population status and trends, these data can be used to identify unusual stranding events (Berrow and Rogan 1997) and to provide samples for post mortem-analysis. Post-mortem examination of stranded and by-caught animals can provide excellent opportunities to explore life history parameters such as diet and reproduction and to provide samples for studies such as genetics and to assess contaminant loads. Some of these topics can only be investigated through the provision of these biological samples. Between 100 and 150 stranded animals are reported every year (Figure 2), many of which would be suitable for post mortem examination. However, it is important to have clear aims and objectives if this technique is to be cost effective. A Marine Mammal Stranding scheme is recognised as a cost effective Environmental Impact Indictor in Ireland, and the only way of assessing the health of marine mammal populations (Boelens *et al*. 2004).

Acoustic surveys

Acoustic techniques have advantages over visual methods as data can be collected throughout the day and night and are much less susceptible to increasing sea states. However, it is dependent on cetaceans being vocally active. Although acoustic methods were used on the 1980 survey along the Atlantic seaboard of Ireland (Evans 1981), the first dedicated acoustic survey for cetaceans in Irish waters was carried out in 1993 by Gordon et al. (1999). A towed stereo hydrophone array was deployed during 20 days at sea, concentrating along the edge of the continental shelf off Co. Mayo. Cetacean vocalisations were recorded in 29% of samples, with dolphin whistles recorded in 16% and pilot whale whistles in 14% of samples. The spatial distribution of acoustic detections frequently matched visual sightings. Large baleen whales could not be detected however, as the hydrophone array used was not sufficiently sensitive to detect their very low frequency vocalisations. However, remote acoustic monitoring of large baleen whales using bottom-mounted hydrophones located in twelve large overlapping areas in the deep Atlantic north and west of Britain and Ireland, regularly detected blue, fin and humpback whales (Clark and Charif 1998; Charif et al. 2001). Moreover, the authors found from acoustic detections that all whale species displayed distinct seasonal patterns. Fin whale vocal activity declined steadily from February to minimal levels in May through July, and then increased again during August and September, remaining steady through to March. Blue whale detections increased gradually from mid July through September, peaking in October to December, and were detected at higher rates in western parts of the study area. Humpback whales were the least frequently detected species overall, occurring mainly between November and March. Singing humpbacks exhibited a south-westerly movement between October and March but with no corresponding trend between April and September. These results suggest that the offshore waters west of Ireland may represent a migration corridor for humpbacks (Charif *et al*. 2001).

Aguilar de Soto *et al*. (2004) reported on cetacean acoustic detections obtained over a total survey track length of 14,479 km along Ireland's Atlantic margin. In 2000 and 2001, a total of 671 acoustic encounters were identified with at least seven odontocete species recorded, including long-finned pilot whale (124 detections), sperm whale (110) and Cuvier's beaked whale (2), and bottlenose, common, striped and Atlantic white-sided dolphins (435). Acoustic detections from waters >1500m depth indicated a higher number of cetaceans than expected and suggested that the Rockall Trough is a potentially important habitat for deep-diving species such as sperm whales.

Acoustic equipment, in the form of T-PODs have also been used in surveys of Irish coastal waters during environmental impact assessments and other ecological studies (Ingram *et al*. 2004, Philpott *et al.* 2006). These devices consist of a fully automated passive acoustic monitoring system that detects porpoises and dolphins by recognising their echolocation click trains. O'Cadhla *et al*. (2003) used T-PODs to investigate habitat use by small cetaceans in the proposed area for deployment of a marine pipeline in Broadhaven Bay, Co. Mayo. Most detections of harbour porpoise occurred during the night. The authors concluded that the use of passive acoustics greatly enhanced visual information on distribution and habitat use of cetaceans in the area. Ingram *et al.* (2003) used T-POD data during a study conducted on the movement patterns and habitat use of bottlenose dolphins and harbour porpoises in Connemara, Co. Galway. T-PODs were also used to assess the effectiveness of acoustic deterrents on bottlenose dolphins in the Shannon Estuary. Leeney *et al*. (2006) used two pinger types: a continuously sounding pinger (CP) and a responsive pinger (RP), which emitted an acoustic alarm when activated by an echolocation click train received from >15m. They found that T-POD detection rates were significantly greater when moored with inactive CPs than for active ones, while detection rates were similar for active and inactive RPs. A second study by Rogan and Philpott (2006) also found a much lower echolocation encounter rate during active pinger trials compared to inactive control trials.

Berrow *et al.* (2006a) used a static underwater hydrophone in the Shannon Estuary to record bottlenose dolphin vocalisations. Results showed that a range of whistle types were produced by bottlenose dolphins and these could be classified into five categories using spectrographs on Adobe Audition software. The authors found that whistle type A, described as a rise, was the most frequently recorded whistle during foraging, while whistle type E, described as a fall was most common during travelling. Preliminary data recorded during this study suggest certain whistle types are associated with certain behaviour types. Hickey *et al.* (2009) compared 1,182 whistle types between the Shannon Estuary and Cardigan Bay in Wales, and found that of the 32 distinct whistle types observed, eight were unique to the Shannon and one to Cardigan Bay, while 21 were common to both sites. He suggested that the differences observed in whistle characteristics between the two populations could be representative of behavioural, environmental or morphological differences between regionally distinct areas or dialect.

Ansmann *et al*. (2007) analysed 1,835 short beaked common dolphin whistles, recorded in the Celtic Sea, and found that these whistles covered a frequency span from

3.56kHz to 23.51kHz, with most whistles occurring between 9 and 15kHz. They found that all of the whistle parameters measured showed statistically significant differences between different encounters, but whether this reflected population differences or contextual ones could not be determined.

OTHER SURVEY TECHNIQUES

Photo-identification

Photo-identification of dolphins and whales is a technique that is increasingly being used to study Irish cetaceans. Photo-identification was originally used in Ireland to determine the movements and site fidelity of bottlenose dolphins in the Shannon Estuary (Berrow *et al*. 1996; Ingram 2000) but has recently been used on bottlenose dolphins at other sites along the south and west coasts including Cork Harbour, Connemara and North Mayo (Ingram *et al*. 2001; 2003; O'Cadhla *et al.* 2003; O'Brien *et al*. 2006). Photo-identification has also been used to derive abundance estimates of bottlenose dolphins in the Shannon Estuary using mark-recapture analysis (Ingram 2000; Ingram and Rogan 2003). This technique has also been used successfully to investigate the inter- and intra-annual movements of fin and humpback whales along the south and west coast of Ireland (Whooley *et al*. 2005). For certain species, this technique is an extremely powerful tool and with the development of digital cameras, it is accessible to both researchers and the general public. Photo-identification may also be applied to other species (e.g. common and Risso's dolphins) to explore their movements, home range and longevity, although there can be limitations when only a small proportion of the population are well marked (Evans and Hammond 2004).

Remote sensing and data loggers

Techniques widely used for studying cetaceans elsewhere but not yet used in Ireland include remote sensing and data loggers such as satellite telemetry and time-depth-recorders. Satellite tagging has now been used successfully in Ireland for tracking the movements of harbour seals (Cronin *et al.* 2008) and leatherback turtles (Doyle *et al.* 2008) and could be used for tracking cetaceans providing welfare and ethical issues are considered.

Biopsies

Tissue samples for chemical analyses can be obtained using biopsy darts. A standard crossbow is used to fire a sampling tip into an animal, with the tips of each sampling dart equipped with three internal barbs. These hold the tissue sample after contact is made with the animal. A high-density foam collar ensures the darts bounce back off the animal's body after it has been struck and float at the surface, therefore making recovery possible after impact with the animal. In Ireland, the use of biopsies has been limited to a study of persistent pollutants in bottlenose dolphins (Berrow *et al*. 2002c) and population structure (Ingram, pers. comm.) of bottlenose dolphins in the Shannon Estuary, and stock identity of humpback whales in Irish waters (Berrow *et al*. 2003).

BIOLOGY AND ECOLOGY OF CETACEANS IN IRISH WATERS

Habitat usage

Of the 24 cetacean species recorded in Irish waters, one species is known only from strandings (Gervais beaked whale *Mesoplodon europaeus* (Gervais 1855), two species are known only from sightings (beluga *Delphinapterus leucas* (Pallas 1776) and northern right whale), while 21 species have been recorded both stranded and sighted (Berrow 2001). This high number (around a quarter of the world's total number of species) reflects the diversity of habitats from the relatively shallow (<200m) continental shelf to the deep water (>2000m) to the west including the shelf edge which itself comprises an important habitat for some species (Atlantic white-sided dolphin and long-finned pilot whale) (Wall *et al*. 2006). Both arctic (beluga) and sub-tropical species (false killer whale *Pseudorca crassidens* (Owen 1846), pygmy sperm whale (*Kogia breviceps* (Gray 1864), and striped dolphin *Stenella coeruleoalba* Meyen 1833) occur close to the limit of their known range. Offshore banks (Rockall and Hatton Banks) provide additional important habitats (Cronin and Mackey 2002; Wall *et al*. 2006). The diversity of beaked whales (Ziphiidae) reported highlights the range of deep-water canyons and troughs that occur west of Ireland. It has also been suggested that the western seaboard of Ireland is an important migratory corridor for large baleen whales including blue, fin and humpback whales (Clark and Charif 1998; Charif *et al*. 2001).

Information on habitat use by cetaceans in Ireland is poor. Sighting surveys, which have mapped distribution and relative abundance, have identified some potentially important offshore habitats (Evans 1981; Ó Cadhla *et al*. 2004; Wall *et al*. 2006). In coastal waters, the Shannon Estuary has been identified as the most important habitat for cetaceans due to its resident population of bottlenose dolphins (Berrow *et al.* 1996; Ingram 2000), whilst the coastal waters of County Cork, including areas like Roaringwater Bay, have been identified as important for a range of species, particularly the harbour porpoise (Evans 1980; 1992; Evans and Wang 2002; Evans *et al.* 2003). Studies on their use of the Shannon Estuary show that bottlenose dolphins regularly occur in two core areas with the greatest slope and depth, demonstrating the influence of environmental heterogeneity on habitat use by this species. Minimum convex polygons of known ranges for individual dolphins showed that a degree of habitat partitioning occurred in the inner estuary (Ingram 2000; Ingram and Rogan 2002a; 2002b). The identification of critical areas within a population's habitat is a priority in planning any conservation management strategy for marine mammals (Ingram 2000). The high site fidelity and inter-annual occurrence of fin and humpback whales inshore along the south coast from County Wexford to County Cork (e.g. Berrow *et al*. 2003; Whooley *et al.* 2005) suggest important habitats occur for these two species in these areas.

Habitat requirements of most cetacean species are not fully understood, but some important areas have been identified. The Shannon Estuary is home to the only known resident group of bottlenose dolphins in Ireland (Berrow *et al*. 1996) and was nominated as a candidate Special Area of Conservation (cSAC) under the EU Habitats Directive in 1999. Harbour porpoises and bottlenose dolphins are listed under Annex II of the Habitats Directive and therefore the NPWS are obliged to designate SACs for both species, but due to lack of information on critical habitats, this process is constrained. Two sites have also been designated for harbour porpoises (Roaringwater Bay, Co Cork and the Blasket Islands, Co Kerry), as these also represent important habitats for this species.

Diet

Published information on the diet of cetaceans in Irish waters is limited to a total of eight papers, while the remainder of the literature on diet consists of theses and anecdotes from notes on strandings. Below is a brief species by species description of the information (see Table 2 for summary).

<u>Harbour porpoise</u>

Rogan and Berrow (1996) found food remains in 19 stranded and by-caught harbour porpoises, noting that gadoids and clupeids comprised 95% of prey items recovered from their stomachs. The most frequent prey items were *Trisopterus* spp. (42%), whiting, *Merlangius merlangus* (42%) and poor cod, *T. minutu* (21%). Of the Clupeidae, most were herring, *Clupea harengus* (16%) and sprat, *Sprattus sprattus* (5%). The diet of harbour porpoise in Irish waters is typical of this species in the Northeast Atlantic (Evans 1994; Hassani *et al*. 1997; Santos and Pierce 2003).

<u>Common dolphin</u>

As part of a study of Dutch mid-water trawl fisheries, Couperus (1995) analysed the stomach contents of seven by-caught common dolphins and found mackerel, *Scomber scombrus*, horse-mackerel, *Trachurus trachurus*, hake, *Merluccius merluccius* and pearlsides, *Maurolicus muelleri*, a deep-water species. Berrow and Rogan (1995) found that gadoids (38%), clupeids (7%) and cephalopods (5%) were the main prey items recovered from 16 stranded and 10 by-caught common dolphins, with *Trisopterus* spp., herring, sprat and whiting again the most prevalent fish species present. Of the cephalopod prey, common dolphins fed primarily on *Gonatus*, *Histioteuthis* spp. *Toderopsis*, *Loligo forbesi* and the common octopus, *Eledone cirrhosa*. A thesis by Brophy (2003) analysed the stomach contents of 57 common dolphins incidentally captured in the Irish tuna driftnet fishery. Fish (94.6% of prey items) were the most important group followed by cephalopods (5.4%) and crustaceans (0.1%). Myctophids (*Diaphus* sp. 1, *Myctophum punctatum* and *Notoscopelus kroeyerii)* dominated the fish component accounting for 90.2% of items. Brophy (2003) suggested that common dolphins occurring off the southwest coast feed nocturnally on fish associating with the deep scattering layer. The diet of common dolphins in Irish waters is typical of this species in the Northeast Atlantic (Evans 1994; Hassani *et al*. 1997).

<u>Atlantic white-sided dolphin</u>

In the study by Couperus (1995), dietary analysis was also carried out on 46 by-caught white-sided dolphins. Mackerel accounted for 88% of fresh prey items but silvery pout, *Trisopterus luscus* (62%), myctophids (19%) and pearlsides (7%) were among the prey identified by otoliths. Gadoids (86%) were the most frequent prey item recovered from four white-sided dolphins stranded on the west coast (Berrow and Rogan 1995). Mackerel have also been found to be important prey of Atlantic white-sided dolphins in other studies (Berrow and Stark 1990; Berrow and Rogan 1995). Greeson (1968) suggested that five white-sided dolphins that live-stranded in Ventry harbour, Co. Kerry were following shoals of herring abundant in the area at the time.

Bottlenose dolphin

Couperus (1995) also carried out dietary analysis on two by-caught bottlenose dolphins. Species identified included greater argentine, *Argentina silus*, horse-mackerel, hake, mackerel, poor cod and silvery pout. Nash (1974) described an adult female bottlenose dolphin with a fully grown greater-spotted dogfish, *Scyliorhinus stellaris* wedged head first in its oesophagus, which he suggested caused its death after it attempted to swallow it. O'Brien and Berrow (2006) recovered otoliths from the stomach of a live-stranded bottlenose dolphin which had also ingested a large quantity of seaweed. Otoliths could only be identified as either pollock, whiting or saithe due to their degenerative state. Bottlenose dolphins have been observed chasing and catching salmon, *Salmo salar*, garfish, *Belone belone* and eels, *Anguilla anguilla* in the Shannon Estuary (Ingram 2000), while salmon and mackerel were also observed prey in studies in the northwest, Co. Mayo (O'Cadhla *et al.* 2003).

Striped dolphin

The only information available on the diet of striped dolphins is from 14 stranded and 31 by-caught animals. Of the 14 stranded animals examined, 9 had food remains with fish and cephalopods recorded in 50% of the stomachs. Of the 31 by-caught animals examined, two of the stomachs were empty, while 29 animals had food remains present. Cephalopods were found in 74% of stomachs, crustaceans in 29%, and tunicates in one (Rogan *et al*. 1999). Fish, including whiting, sprat, *Trisopoterus* spp. and *Gobidae* sp. were also recorded. Cephalopods included *Illex* sp. and *Gonatus* sp. Crustaceans including *Pasiphaea multidentata*, were found in 29% of the stomachs of by-caught animals. Berrow and Rogan (1995) described the diet from seven stranded specimens and found that 80% of the diet were gadoids, with clupeids (13%) and cephalopods (*Illex fubei*, *Gonatus* sp. and *Histioteuthis* sp.) comprising the rest. The diet of striped dolphin was found to be typical of Japanese waters (Miyazaki *et al*. 1973) and the Mediterranean Sea (Würtz and Marrale 1993). These studies suggest that striped dolphins in Irish waters, as elsewhere, are opportunistic feeders exploiting a wide variety of prey types.

Killer whale

Killer whales in Irish waters are thought to feed mainly on fish, including salmon and mullet, *Chelon labrosus* (Wilson and Pitcher 1979; Ryan and Wilson 2003). McHugh *et al.* (2007) found salmon fish bones in the stomach of a killer whale stranded at Roche's Point, Co Cork.

Pygmy sperm whale

Notes on the diet of pygmy sperm whales stranded in Ireland suggest they were feeding on both squid and fish (Mackey *et al*. 2001).

Sperm whale

As part of a study carried out on the stomach contents of sperm whales stranded in the north-east Atlantic, Santos *et al*. (2002) performed post-mortem examinations on a sperm whale stranded at Tory Island, Co Donegal. Food remains in the stomach consisted of cephalopod beaks, with *Haliphron atlanticus* being the most important prey species in the stomach of this animal. Santos *et al*. (2006) later described the diet of a sperm whale calf that live stranded at Quilty, Co Clare, and showed that although the whale had not weaned, more than 85% of the estimated weight of prey items comprised cephalopod species in the family *Histioteuthidae* which were also numerically the most important. Cephalopod species found in the stomach included *Mastigoteuthis scmidti*, *Taonius pavo, Galiteuthis armata*, *Teuthowenia megalops*, *Histioteuthis bonnellii* and *Haliphron atlanticus*.

Reproduction

The most comprehensive study of reproduction in an Irish cetacean species was carried out on the common dolphin by Murphy (2004). The study described its reproductive biology based on samples from stranded and by-caught individuals. Reproductive seasonality was found to occur, with mating and calving taking place between May and September. The author described a range of reproductive parameters including annual pregnancy rate, calving interval, lactation, resting and gestation periods for female dolphins and age at sexual maturity for male dolphins. She suggested that moderate sexual dimorphism and large testes suggested sperm competition and a promiscuous mating system. Murphy *et al*. (2005a) present data from male common dolphins stranded along the French and Irish coasts and from by-catch samples obtained through Irish and French observer programs. They categorized individuals into different reproductive stages by using characteristics of their gonadal morphology. They found that sexually mature individuals were 195-223 cm in length and 8-28 years of age, whilst the average age of sexual maturity was 11.86 years. Rogan *et al*. (2003b) examined the reproductive status of striped dolphins stranded or by-caught in Irish waters. Apparent lack of sexual dimorphism and relatively small testes size suggested that striped dolphins may have a promiscuous mating strategy. Finally, the reproductive status of 19 Atlantic white-sided dolphins live-stranded in Co. Mayo showed that both pregnant and lactating females and immature and sexually mature males occurred in the group (Rogan *et al*. 1997).

Evidence of parturition in Irish waters has been reported for a number of species. Neonate harbour porpoise, Atlantic white-sided dolphin, Risso's dolphin and pilot whale have been reported stranded on the Irish coast (Berrow and Rogan 1997). Five species, harbour porpoise (Berrow 1991) long-finned pilot whale (Greeson 1966), Risso's dolphin (Bruton and Rogan 1997), white-beaked dolphin (Bruton and Berrow 1994), and pygmy sperm whale (Murphy and Rogan 2002) have been reported with foetuses at advanced stages of development. Sexually mature male Atlantic white-sided dolphins (Bruton 1985) and female Cuvier's beaked whale (Cotton and Murphy 2004) have also been reported. Gassner and Rogan (1997) reported a twin pregnancy in a Risso's dolphin stranded in Co. Donegal. Berrow and O'Brien (2005a) described a live stranded sperm whale calf. However, this species is not thought to breed in Irish waters. A list of studies carried out on the reproduction of cetaceans in Irish waters is shown in Table 2.

Genetics

There have been a number of recent studies in Ireland using genetics to explore stock identity and social structure. A sample of 120 harbour porpoises from the Celtic/Irish Sea was used to investigate population structure around the UK and adjacent waters (Walton 1997). The author showed there was significant difference between animals from the northern North Sea and the Celtic/Irish Sea, but these differences were predominantly due to variation among females. Duke (2003) analysed a small number (n=47) of harbour porpoise samples from Ireland. She suggested that porpoises from the Celtic Sea and the North Atlantic Ocean were more similar to each other than either was to Irish Sea animals. The proposed population structure is one of an Ireland/western British Isles sub-population separated from the North Sea population (IWC 1996; Andersen 2003). Mirimin *et al.* (2005) examined the genetic relationships within a group of Atlantic white-sided dolphins live-stranded in Co. Mayo. He showed that genetic relatedness was observed between at least some adults and each calf could be unambiguously assigned to a single mother within the group. No sampled male could be identified as a putative father, and this study raised interesting questions about social structure and mating strategies in the species.

Genetics have also been used for species identification. Two strandings of beaked whales in Co Clare were identified as Cuvier's beaked whale from an international mtDNA reference database (Berrow *et al*. 2002b). Genetics was also used to determine the gender of bottlenose dolphins biopsied for a study of persistent pollutants in the Shannon Estuary (Berrow *et al*. 2002c). An interesting genetic anomaly was reported by Quigley and Flannery (2002), who described a leucoptic harbour porpoise caught in fishing nets off Co. Kerry.

Health/Pathology

Although a large number of post-mortem examinations on stranded and by-caught cetaceans have been carried out, no conclusive results are available. Reviews of harbour porpoise and striped dolphins carried out by Rogan and Berrow (1996), Rogan *et al.* (1999) report on the life history parameters of both species in Irish waters, but no conclusive causes of death were reported for either species. One post mortem examination carried out by Power and Murphy (2002) on a killer whale revealed its cause of death to be *Staphylococcus aureus* septicemia.

Berrow and O'Brien (2005b) describe vertebral column malformities observed in bottlenose dolphins off Counties Clare and Galway. Although probably not uncommon, malformities such as those described here have not been reported before in Ireland. They are most likely to be inherited congenital malformities. For such conditions genetic studies may be revealing, although samples from dolphins with scoliosis will be difficult to obtain.

Parasites

Parasites of cetaceans are predominantly internal due to the difficulties of external attachment and these have been shown to be important in influencing the longevity and health of many species. The harbour porpoise is considered to be one of the most heavily parasitised of all marine mammals. Rogan and Berrow (1996) recorded the nematode *Anisakis* in the cardiac stomach of 46% of harbour porpoises examined. Some of these animals had parasitic associated ulcerations in the mucosa of the stomach. Four species of nematode (*Pseudalis inflexus, Torynurus convolutes, Halocercus taurrica* and *H. invaginata*) were recorded from the lungs of 98% of the animals examined and *Stenurus* *minor* was found in the cranial sinuses in 65% of animals. Finally, parasitic cysts (probably *Phyllobothrium* sp.) were recorded in the blubber of one porpoise. *Anisakis simplex* is the most widespread and abundant stomach nematode in small cetaceans and was found in 68% of common dolphins (Nadarajah *et al.* 1996). Lungworm infection by pseudaliid nematodes (mainly *Skrjabinalius juevarai*) was recorded in 46% of striped dolphins (n=24) and 43% of common dolphins (n=75) (Rogan *et al.* 1998). Up to 18,686 individuals of *Stenurus globicephallae* were removed from 95% of the cranial sinuses of Atlantic white-sided dolphins mass stranded in Co Mayo (Keane *et al.* 1996). Generally, a high incidence of parasitism was reported in this mass stranding with 55% of females containing *Crassicauda* sp. in their mammary glands and *Pholeter gastrophilus* occurring in 28% of individuals. *Phyllobothrium delphini* was also recorded in the blubber. However, these parasites were not thought to have contributed to this mass stranding (Rogan *et al.* 1997). A tetraphyllidean cestode, *Monorygma* sp. has also been recorded in small cetaceans from Irish coastal waters (Gassner and Rogan 1997). External parasites, although uncommon, have been recorded on one dolphin and on three whale species. Six whale lice, *Isocyamus delphini* were observed on a common dolphin stranded in Dungarvan Bay, Co. Waterford (Smiddy 1986a), a male whale louse, *Neocyamus physeteris,* on a sperm whale calf (Berrow and O'Brien 2005a) and a species of *Pennella* was recorded protruding from the abdomen of a northern bottlenose whale stranded in Ring, Co. Cork (Smiddy 1986b). In addition barnacles, *Coronula reginae,* were found attached to a stranded humpback whale in Tralong Bay, Co. Cork (Smiddy and Berrow 1992) and Inverin, Co. Galway (Berrow *et al.* 2006b). A list of studies that included data on parasites is shown in Table 2.

Behaviour

Information on the movement of cetaceans around the Irish coast is very limited. Ingram *et al*. (2001) recorded bottlenose dolphins from the Shannon Estuary in Tralee Bay, Co. Kerry but did not find any dolphins from the estuary at three other sites along the west coast (Connemara, Co. Galway, Broadhaven Bay, Co. Mayo, and McSwyne's Bay, Co. Donegal) despite identifying 80 individual dolphins from six schools. This low encounter rate of dolphins from the Shannon Estuary suggested that the population size of bottlenose dolphins in Irish coastal waters must be large or that the movement of dolphins from the estuary is local (Ingram *et al.* 2001). Whooley *et al*. (2005) showed that fin and humpback whales off the south and west coasts of Ireland demonstrated high site fidelity and inter-annual consistency. Of 12 identifiable fin whales, two have been re-sighted over a 2-year period and of six individually recognisable humpback whales, four have been re-sighted, three over a four-year period and one every year for four consecutive years.

Evidence of a violent interaction between a common dolphin and bottlenose dolphins was suggested on examination of a dead common dolphin stranded on the Mullet Peninsula, Co. Mayo (Murphy *et al*. 2005b). Extensive rake marks thought to be from bottlenose dolphins were recorded on the common dolphin's carcass. This was the first record of such an interaction in Irish waters. Ryan and Wilson (2003) describe the movements and behaviour of a pod of killer whales, which stayed in Cork Harbour for a six-week period. During this time, over 75 hours were spent observing the whales, which consisted of an adult male, an immature male, and an adult female.

THREATS: ACTUAL AND PERCEIVED

Since little is known about the status of and threats to cetaceans in Irish waters, it is assumed that potential threats are similar to those identified for cetaceans elsewhere in Europe. These include pollution, fisheries interactions, habitat degradation and disturbance (Table 3).

Threats to Welfare

Over the years, some important cetacean welfare issues have been addressed in Ireland. Guidelines for the rehabilitation of live stranded cetaceans have been produced by the IWDG (Anon 1995b) and a network of personnel and equipment was set up around the coast to implement these guidelines. There has been an increase in reports of wild, sociable dolphins (e.g. Mannion 1993) and people wanting to swim with them. Although this is generally discouraged, many people insist on swimming with the animals, which increases the risk to both the dolphin and people. There are no guidelines in Ireland to minimise the impact of this interaction.

Fisheries Interactions

Cetaceans may interact with fisheries both operationally and biologically or both. The incidental capture of cetaceans has now been quantified in some gill-net and trawl fisheries in Ireland and by-catch records have been reviewed by Berrow and Rogan (1998). Tregenza *et al*. (1997) estimated that 2,200 harbour porpoises and 230 common dolphins were killed annually by bottom set gillnets in the Celtic Sea in 1993/94. This accounted for 6.2% of the estimated number of harbour porpoise in that region and there was serious concern about the ability of the population to sustain this level of mortality. No cetacean by-catch was reported in the Celtic Sea herring fishery (Berrow *et al*. 1998b) but five species (Atlantic white-sided (78%), long-finned pilot whale (12%), common dolphin (7%), white-beaked (1.5%) and bottlenose dolphins (1.5%)) were caught by Dutch mid-water trawlers off the south-west coast of Ireland (Couperus, 1995). In addition, Berrow and Rogan (1998) reported a further two species (striped dolphin and minke whale) incidentally caught in Irish waters.

Although the Irish albacore tuna fishery is largely conducted outside of territorial waters, especially in the earlier part of the season, an estimated 500 cetaceans, mainly common and striped dolphins but also bottlenose, Risso's and Atlantic white-sided dolphin, pilot, minke and sperm whales, were caught in 1996 (Rogan and Mackey 1999). A study by Rogan and Mackey (2007) reported on the megafauna caught in driftnets for albacore tuna in the NE Atlantic in 1996 and 1998. Clearly, incidental capture in fishing nets is one of the most immediate threats to cetaceans in Irish waters. However, not all fisheries experience cetacean by-catch but fisheries need to be monitored to determine which have the greatest impact and what mitigation measures can be developed.

Acoustic deterrents have been developed by Bord Iascaigh Mhara (BIM) in order to mitigate against dolphin by-catch in pelagic trawls (Anon 2004). Recent field trials suggest that they can alter the behaviour of bottlenose dolphins (Leeney *et al*. 2006). Trials on common dolphins, the main species caught in pelagic trawl fisheries, were conducted by Berrow *et al*. (2006c). They deployed both responsive and continuous pingers during trials. Results suggest that there was little change in dolphin behaviour after deployment of pingers when compared with their behaviour prior to deployment. They concluded that neither the continuous pinger nor the responsive pingers used elicited any evasive behaviour by common dolphins; these results were in contrast to similar trials carried out on bottlenose dolphins (Leeney *et al*. 2006).

Pollution

There have been several studies of persistent pollutants in marine mammals in Ireland (Nixon 1991; Berrow *et al*. 1998a; McKenzie *et al*. 1998; Smyth *et al*. 2000; Jepson *et al.* 2005; Zegers *et al*. 2005; Pierce *et al.* 2007; McHugh *et al.* 2007). These studies suggest that radio-nuclide levels are low in harbour porpoises in the Irish Sea (Berrow *et al.* 1998a), whilst levels of organochlorine pesticide contamination are among the lowest recorded in the north-east Atlantic (McKenzie *et al*. 1998, Smyth *et al*. 2000). However all animals analysed have some level of organochlorine contamination. Contaminant levels in by-caught harbour porpoise and common dolphins were similar to those reported from Scotland but levels were lower than those from Scandinavia (Smyth *et al*. 2000). Concentrations of PCBs in bottlenose dolphins in the Shannon Estuary, although 3-4 times higher than harbour porpoises in Ireland, were not thought to pose a risk to their health (Berrow *et al*. 1998a). McKenzie *et al*. (1998) suggested organochlorine contamination was ubiquitous in Atlantic white-sided dolphins from Irish and Scottish waters, which demonstrated the difficulties when interpreting results of pollution studies.

Jepson *et al.* (2005) investigated the possible relationship between PCB exposure and infectious disease mortality in harbour porpoises, during which three Irish samples were used. The authors summed the blubber concentrations of 25 chlorobiphenyl congeners (25CB) in healthy porpoises that died from acute physical trauma and compared this with animals that died of infectious disease. Results showed that the infectious disease group had significantly greater 25CB values than the physical trauma group, and this association occurred independently of age, sex, nutritional status, season, region and year found. Zegers *et al.* (2005) examined the levels of hexabromocyclododecane (HBCD) in harbour porpoises and common dolphins from western European seas and included Irish samples in their analysis. The authors found that the highest total HBCD levels were measured in harbour porpoises stranded in Irish and Scottish coasts of the Irish Sea, while median levels calculated from the south coast of Ireland were higher than those calculated for the Netherlands, Belgium, France, east coast of Scotland and Galicia. Similar results were found for common dolphins, as median levels off the west coast of Ireland were also higher than those off the French coast of the English Channel, and Galicia. Caurant *et al*. (2006) conducted a wide-ranging study to analyse lead contamination of small cetaceans in European waters by using stable isotopes to identify the sources of lead exposure. Samples of bones and teeth of Irish harbour porpoise, common dolphin and striped dolphin were used in this study. Results showed that from a toxicological point of view, the lead concentrations found in small cetaceans from European waters were probably not a matter of concern. They concluded that age was the most important factor influencing the total lead concentrations in hard tissues of small cetaceans in European waters, but neither species nor geographical area were discriminated by the concentration levels of this metal.

Pierce *et al*. (2007) analysed the bioaccumulation of persistent organic pollutants in female common dolphins and harbour porpoises from western European seas. Results showed that HBCD levels were highest in samples from Ireland and Scotland. Persistent organic pollutants (POP) were compared between harbour porpoises and common dolphins from Ireland, and the authors found that the average PCB and HBCD concentrations in harbour porpoises were higher than those in common dolphins. They also found that harbour porpoises that had died from disease or parasitic infection had higher concentrations of POPs than animals dying from other causes, while the POP profiles in the blubber of common dolphins were found to be related to individual feeding history, while those in porpoises were more strongly related to body condition. McHugh *et al*. (2007) examined the bioaccumulation and enantiomeric profiling of organochlorine pesticides and persistent organic pollutants in killer whales from British and Irish waters. They found nitrogen isotopic ratios ranged between 14.5-17.3‰, in the individuals sampled, suggesting that different trophic status levels may exist in the killer whales sampled.

Disturbance

Ireland has huge potential for whale-watching, which is considered as still under-developed, despite a major increase in the last 30 years (Hoyt 2000). In 1998, whale-watching was estimated to be worth €1,480,000 in direct revenues and €7,973,000 in indirect revenues to the Irish economy (Hoyt 2000). Dolphin-watching has expanded rapidly in the Shannon Estuary (Berrow and Holmes 1999) and two commercial dedicated whale-watching operators are now established off the coast of Co. Cork, but a large number of marine wildlife tour operators offer whale and dolphin watching from counties Dublin to Donegal. There is potential for disturbance caused by whale-watching, although operators in the Shannon Estuary adhere to a code of conduct and monitoring programme (Berrow and Holmes 1999). A recent Marine Notice (15 of 2005) issued by the Maritime Safety Directorate provides enforceable guidelines for recreational and commercial vessels on the correct operational procedures around cetaceans in Irish coastal waters.

During 1997 and 1998, nearly 47,000km of seismic surveys were carried out off the west coast of Ireland in search of oil and gas deposits, and has been conducted extensively in the seas around Northern Europe (Evans and Nice 1996). Seismic surveys utilise airgun arrays to produce sounds to map the seabed, with broadband source levels of 248-255 dB re 1 μPa-m, zero to peak, with most energy emitted at 10-12Hz, but some pulses contain some energy up to 500-1000Hz (Richardson *et al.* 1995). The impact of this operation on cetaceans is still unclear but a number of studies have shown that baleen whales (which are likely to be most sensitive to sounds at these low frequencies may react by moving away from seismic sources (Richardson *et al*. 1995), and even smaller odontocetes like the common dolphin have been shown to react to seismic activity at least 8km from the vessel (Goold 1999). The lower the frequency emitted, the greater the area from the source that will be affected. NPWS have recently published mitigation measures for the protection of marine mammals during acoustic seafloor surveys in Irish waters (NPWS 2007). Under this code of practice, Marine Mammal Observers (MMO's) are required to be present on board the survey vessel to conduct observations 30 minutes before the onset of operation in waters of 200m or less, and 60 minutes in waters greater than 200m. A soft start is recommended after the area has been confirmed clear of cetaceans, while exclusion zones of 1km should be in operation. These are similar to the guidelines established in the UK by the Joint Nature Conservation Committee.

In recent years, another sound source has been identified as having a detrimental effect upon some cetacean species. This is the use of mid-frequency active sonar (between 2-10 kHz frequency range), as deployed in military anti-submarine exercises. There is now strong evidence that this has caused in some way mass strandings of cetaceans, particularly members of the beaked whale family Ziphiidae (Evans and Miller 2004; Cox *et al*. 2006). West of Ireland, off the edge of the continental shelf, there are a number of deep water canyons (e.g. Whitard Canyon) that represent potentially important habitats for beaked whales like the Sowerby's beaked whale and True's beaked whale (Reid *et al*. 2003; O'Cadhla *et al*. 2004).

Climate change

Since the 1980's, there has been a general warming trend of 0.3° to 0.7°C per decade in Irish waters and this is predicted to continue (Dunne *et al.* 2008). Climate change is an issue of serious concern to cetacean species worldwide. Some of the potential indirect effects of climate change include, changes in prey availability affecting distribution, abundance and migration patterns, community structure, susceptibility to disease and contaminants, which will eventually impact on the reproductive success and survival of marine mammals, and hence will impact upon populations (Learmonth *et al.* 2006).

FUTURE CETACEAN RESEARCH IN IRELAND: RECOMMENDATIONS

For most areas and seasons, the distribution and abundance of cetaceans is still being mapped and little consideration has been given to monitoring trends. Future research should seek to identify favourable habitats and examine the seasonal distribution and abundance of animals encountered in such areas. However, differences in species' distribution and relative abundance across relatively short geographical distances may be great with implications for conservation management. The repetition of dedicated surveys seasonally would lead to a better understanding of the geographical and spatial distribution and provide a baseline for future management. Under the United Nations Convention on The Law of the Sea (UNCLOS), the Marine Institute has the authority to place Irish observers on foreign research vessels operating within the Irish EEZ. Such observers have official designation under UNCLOS and act as the representative of the State. Reports submitted to the Marine Institute under the Irish Observer Scheme were examined for the years 2004 and 2005. However, there were no cetacean records included in any of these reports. Foreign research vessels working in Irish waters should be required to record and submit cetacean sightings as part of their cruise reports. Biological and oceanographical parameters such as prey availability and primary productivity, sea temperature and salinity and ocean processes such as currents and up-wellings should also be used to explore what drives cetacean distribution and abundance. The use of passive acoustic monitoring exploiting existing structures such as offshore wave or navigation buoys should be considered. Passive acoustic monitoring could be incorporated into the suite of data acquisition objectives of the R.V. *Celtic Explorer* through the use of a fixed, hull-mounted hydrophone. The IWDG, under an initiative called ISCOPE, aims to promote better awareness and knowledge of cetaceans in Irish waters by encouraging public participation in cetacean recording. A national sighting and stranding scheme can provide a means of assessing unusual events, population increases or decreases, or changes in species distribution, and should therefore be promoted into the future.

Harbour porpoises and bottlenose dolphins are listed under Annex II of the EU Habitats Directive and therefore the NPWS are obliged to designate SACs for both species, but due to lack of information on critical habitats, this process is constrained. Currently, only one cSAC exists for bottlenose dolphins, while two cSACs exist for harbour porpoises and all of these cSACs are located in the southwest of the country. Harbour porpoises frequent all Irish coastal waters and the absence of an SAC off the south, east and northwest coasts means that not all the representative habitat in Ireland for these species is protected. Future research should attempt to identify sites for designation. NPWS are also required to develop monitoring programmes to assess the conservation status of not only harbour porpoise and bottlenose dolphin, but all other cetacean species (as listed on Annex

IV). Monitoring of the Shannon Estuary cSAC for bottlenose dolphins has involved deriving abundance estimates using photo-ID and examining for trends. Boelens et al. (2004) state that the recording of cetacean abundance and distribution in Ireland is recognised as an Environmental Impact Indicator and to gain maximum benefit, monitoring programmes should consist of frequent small-scale surveys over a long period of time. Harbour porpoise monitoring at present relies on visual survey techniques, but acoustic methods have also been explored (Leeney 2005; Berrow *et al.* 2008). It is likely that acoustic techniques will need to be used for monitoring small cetaceans, especially harbour porpoises, as visual techniques are constrained by poor weather. However, the relationship between acoustic detections and animal abundance needs to be explored further if this method is to be used to monitor population trends.

Since 1999, the IWDG have been reporting increasing numbers of large baleen whales, i.e. fin and humpback whales occurring off the south and west coast of Ireland (Berrow et al. 2002), while Whooley *et al.* (2005) showed that these whales demonstrate high site fidelity and inter-annual consistency. They have also shown that there is a strong seasonal component to the inshore distribution of these large baleen whales with sightings occurring from May to February and peaking in November-December. However, due to an absence of sightings from our headlands from mid-February to late May their whereabouts during this time is unknown. The use of satellite telemetry to track these animals could provide information on where these animals go during this period. Future research could use satellite telemetry to fill in key information gaps.

The fishing industry may have broad ecological impacts on cetacean populations. Incidental capture in fishing nets is one of the most immediate threats to cetaceans in Irish waters. However, not all fisheries experience cetacean by-catch but fisheries need to be monitored to determine which have the greatest impact and what mitigation measures can be developed. It is evident that a by-catch assessment of cetaceans in Irish waters needs to be updated as no published material is available since a review was carried out by Berrow and Rogan (1998). It is essential that future research attempts to quantify by-catch rates around the Irish coast by establishing a systematic approach to recording by-catch. A programme of post mortem examinations of stranded cetaceans could also determine the proportion of strandings attributed to by-catch including species, gender, length and report on seasonal and geographical differences. Interactive pingers have been trialled on bottlenose and common dolphins but a successful deterrent signal has not yet been established. Future research should focus on finding a successful signal for these devices, by perhaps exploring alarm calls that these animals themselves make in the wild. Alternative fishing methods should also be trialled such as “fish potting” since such techniques are more environmentally friendly.

Cetaceans and fishermen are also in potential competition for resources. There is relatively little published material available on the diet of cetaceans in Irish waters. There is some information on the diet of harbour porpoise and some dolphin species. Very little has been published on diet of bottlenose dolphins, even though Ireland has a resident group of bottlenose dolphins in the Shannon Estuary. A better understanding of their diet will facilitate the conservation of their prey.

In order to monitor the health status of cetaceans in Irish waters, data need to be systematically collected on pollutant levels in order to detect any changes in contaminant levels. Future research should also target the reproductive biology of cetaceans in Irish waters, as this area has received little attention, with studies only having been carried out on common and striped dolphins.

An overall increase in ambient levels of sound has occurred in the world’s oceans due to man’s activities from increased shipping, offshore oil and gas exploration, military activities, and offshore wind-farm construction. This increase could have an adverse effect on cetaceans. These effects include temporary and permanent hearing loss; displacement and disruption of normal daily activities such as feeding, resting, nursing and communication; tissue damage, haemorrhaging and even death. Full compliance with new NPWS mitigation measures for acoustic surveys should be monitored and acoustic assessments of other activities such as pile-driving, blasting and aggregate extraction should be carried out. Future research should focus on how effective mitigation measures are, while focused sound attenuation studies associated with the various industrial activities carried out around our coast would help in mitigation against their effects.

Other events such as changes in sea surface temperature and salinity and rise in sea level could have important effects on cetacean populations globally. Since the 1980’s, sea surface temperatures in NW Europe have risen at a rate of approximately 1℃ per decade, and are predicted to continue to increase. Learmonth *et al.* (2006) discuss the indirect effects of such events on the marine mammal populations which include changes in prey availability impacting on prey distribution, abundance and migration patterns, community structure, susceptibility to disease and contaminants, while a cetacean’s ability to adapt to the above changes is largely unknown. Climate change is an issue of serious concern since a number of species likely to be affected are already listed as endangered or vulnerable according to their Red List category (IUCN 2008; Simmonds and Isaac 2007). Of the 24 cetacean species found in Irish waters, five are listed as endangered or vulnerable under the IUCN Red List update (IUCN 2008). Species included on this list are fin whale, blue whale, sei whale, sperm whale and the north Atlantic right whale. Few studies have been carried out on the effects of climate change on cetaceans, which potentially could have profound effects on species distribution at an international scale. More refined studies on the effects are required to examine the consequences of such events on the migration patterns of large whales as well as a shift in the distribution of prey species.

This review has highlighted the rapid increase in awareness and knowledge of cetaceans in Irish waters over the last two decades. With national and international conservation obligations increasing, it is imperative that future research addresses a number of the information gaps highlighted in this review and seeks to collaborate with cetacean projects throughout Europe to ensure all cetacean species attain favourable conservation status.

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APPENDIX 1.

Table 1. Cetacean density and absolute abundance estimates generated during dedicated surveys in Irish waters.

Species	**Geographic area**	Year	**Density (animals km^{-2})**	**CV**	**Abundance**	**Source**
Harbour porpoise	Inshore west coast	1989	0.77	0.49	19,210	Leopold *et al*. (1992)
	Celtic Sea	1994	0.18	0.57	36,280	Hammond *et al*. (2002)
	Celtic Sea	2005	0.41	0.50	80,613	SCANS-II (2008)
	Irish Sea	2005	0.34	0.35	15,230	SCANS-II (2008)
	Coastal Ireland	2005	0.28	0.37	10,716	SCANS-II (2008)
	Offshore shelf edge[1]	2005	0.07	1.24	10,002	SCANS-II (2008)
Lagenorhynchus sp.	Celtic Sea	1994	0.004	1.02	88	Hammond *et al*. (2002)
White-beaked dolphin	Irish Sea	2005	0.002	0.80	75	SCANS-II (2008)
	Coastal Ireland	2005	0.007	0.85	267	SCANS-II (2008)
	Offshore shelf edge[1]	2005	0.014	0.60	2,030	SCANS-II (2008)
White-sided dolphin	Western seaboard	2000	0.046	0.43	5,490	O'Cadhla *et al*. (2004)
Bottlenose dolphin	Irish Sea	2005	0.005	0.75	235	SCANS-II (2008)
	Coastal Ireland	2005	0.008	0.81	313	SCANS-II (2008)
	Celtic Sea	2005	2.72	0.49	5,370	SCANS-II (2008)
	Offshore shelf edge[1]	2005	0.75	0.68	1,128	SCANS-II (2008)
	Shannon Estuary [2]	1997	-	0.14	113 ±16	Ingram (2000)
	Shannon Estuary [2]	2003	-	0.12	121 ± 14	Ingram and Rogan (2003)
	Shannon Estuary [2]	2007	-	0.08	140±12	Englund *et al*. (2007)
Common dolphin	Western seaboard	2000	0.039	0.39	4,496	O'Cadhla *et al*. (2004)
	Irish Sea	2005	0.008	0.73	366	SCANS-II (2008)
	Celtic Deep	2004	0.38	0.41	1,186	Evans *et al*. (2007)
	Celtic Deep	2005	0.52	0.27	1,644	Evans *et al*. (2007)
	Celtic Deep	2006	0.69	0.17	2,166	Evans *et al*. (2007)
	Coastal Ireland	2005	0.40	0.78	15,327	SCANS-II (2008)
	Celtic Sea	2005	0.056	0.61	11,141	SCANS-II (2008)
	Offshore shelf edge[1]	2005	0.10	0.81	1,454	SCANS-II (2008)
Minke whale	Celtic Sea	1994	0.006	0.49	1,195	Hammond *et al*. (2002)
	Celtic Sea	2005	0.009	0.43	1,719	SCANS-II (2008)
	Irish Sea	2005	0.024	0.89	1,073	SCANS-II (2008)
	Coastal Ireland	2005	0.058	0.84	2,222	SCANS-II (2008)
	Offshore shelf edge[1]	2005	0.012	0.46	1,856	SCANS-II (2008)

[1] Includes area west of Scotland, [2] Derived from mark-recapture techniques

Table 2. Published material available on the diet, reproduction and parasite burden of cetaceans in Irish waters.

Species	Diet	Reproduction	Parasites
Harbour porpoise	Berrow and Rogan (1995) Rogan and Berrow (1996)	Berrow (1991) Rogan and Berrow (1996) Berrow and Rogan (1997)	Rogan and Berrow (1996)
Common dolphin	Berrow and Rogan (1995) Couperus (1995) Brophy (2003)	Murphy (2004) Murphy *et al*. (2005)	Nadarajah *et al.* (1996) Rogan *et al.* (1998) Smiddy (1986a)
Bottlenose dolphin	Nash (1974) Couperus (1995) Ingram (2000) O'Brien and Berrow (2006)	Berrow *et al*. (1996) Ingram (2000)	
Striped dolphin	Berrow and Rogan (1995) Rogan *et al*. (1999)	Rogan *et al*. (2003a) Rogan *et al*. (1999)	Rogan *et al*. (1998) Rogan *et al*. (1999
Risso's dolphin		Berrow and Rogan (1997) Bruton and Rogan (1997) Gassner and Rogan (1997)	
White-sided dolphin	Gressen (1965) Berrow and Stark (1990) Berrow and Rogan (1995) Couperus (1995) Leopold and Couperus (1995)	Bruton (1985) Berrow and Rogan (1997) Rogan *et al*. (1997)	Rogan *et al*. (1997) Keane *et al*. (1996)
White-beaked dolphin		Bruton and Berrow (1994)	
Killer whale	Wilson and Pitcher (1979) Ryan and Wilson (2003)		
Long-finned pilot whale		Greeson (1966) Bruton and Rogan (1997)	
Sperm whale	Santos *et al*., (2003) Santos *et al*., (2006)	Berrow and O'Brien (2005)	Berrow and O'Brien (2005)
Pygmy sperm whale	Mackay *et al*., (2001) Berrow and O'Connell (2005)	Murphy *et al*. (2002)	
Cuvier's beaked whale		Cotton and Murphy (2004)	
Humpback whale			Smiddy and Berrow (1992) Berrow *et al*. (2006)
Northern bottlenose whale			Smiddy (1986b)

Table 3. Species checklist and the status and potential threats to cetaceans in Irish waters (updated from Berrow, 2001), using NPWS (2008).

Species	Conservation Status	Threats	References
Harbour porpoise*	Good	By, Po, Ha, So	Tregenza *et al.* (1997a), Berrow *et al.* (1998a), Smyth *et al.* (2000), Evans *et al.* (2003)
White-beaked dolphin	Unknown	By	Couperus (1995), Evans *et al*. (2003)
White-sided dolphin	Good	By, Po	Couperus (1995), McKenzie *et al.* (1998)
Common dolphin	Good	By,So?	Couperus (1995), Berrow and Rogan (1998), Rogan and Mackay (1999), Goold (1999), Evans *et al.* (2003; 2006)
Bottlenose dolphin*	Good	By, Po, So?	Couperus (1995), Berrow and Holmes (1999), Berrow *et al*. (2002), Evans *et al.* (2003)
Striped dolphin	Unknown	By	Berrow and Rogan (1997), Berrow and Rogan (1998), Rogan and Mackay (1999), Evans *et al.* (2003)
Killer whale	Unknown	?	Evans (1988), Evans *et al.* (2003)
Risso's dolphin	Unknown	By	Rogan and Mackay (1999), Evans *et al.* (2003)
Pilot whale	Unknown	By, Ss	Couperus (1995), Evans (2003), Evans *et al.* (2003)
Northern bottlenose whale	Unknown	?	Evans (1991), Evans *et al.* (2003)
Cuvier's beaked whale	Unknown	So	Berrow and Rogan (1997), Evans *et al.* (2003), Evans and Miller (2004), Cox *et al.* (2006)
Sowerby's beaked whale	Unknown	So	Berrow and Rogan (1997), Evans *et al.* 2003, Evans and Miller (2004), Cox *et al.* (2006)
Gervais beaked whale	Unknown	So	Berrow and Rogan (1997), Evans *et al.* (2003), Evans and Miller (2004), Cox *et al.* (2006)
True's beaked whale	Unknown	So	Berrow and Rogan (1997), Evans *et al*. (2003), Evans and Miller 2004, Cox *et al.* (2006)
Pygmy sperm whale	Unknown	?	Berrow and Rogan (1997), Evans *et al.* (2003)
Sperm whale	Unknown	By, Ss	Berrow *et al.* (1993), Rogan & Mackay (1999), Evans (2003), Evans *et al.* (2003)
Humpback whale	Unknown	By	Evans (1991), Evans (1998), Evans *et al.* (2003)
Blue whale	Unknown	So	Evans (1991), Evans (1998), Evans *et al.* (2003)
Fin whale	Good	So, Ss	Evans (1991), Evans (1998; 2003), Evans *et al.* (2003)
Sei whale	Unknown	So	Evans (1998), Evans *et al.* (2003)
Minke whale	Good	By, So	Berrow and Rogan (1998), Rogan and Mackay (1999), Evans (1998), Evans *et al.* (2003)
Northern right whale	Unknown	?	O'Cadhla *et al.* (2004)
False killer whale	Unknown	?	O'Cadhla *et al.* (2004)
Beluga	Unknown	?	Carmody (1988), O'Riordan (1972)

*** Species on Annex II of the Habitats Directive**
By = Bycatch, Po = Pollution, Ha = Habitat degradation, So = Sound disturbance, Ss = ship strikes
Status categories: Very common, common, fairly common, uncommon, rare, very rare, vagrant.

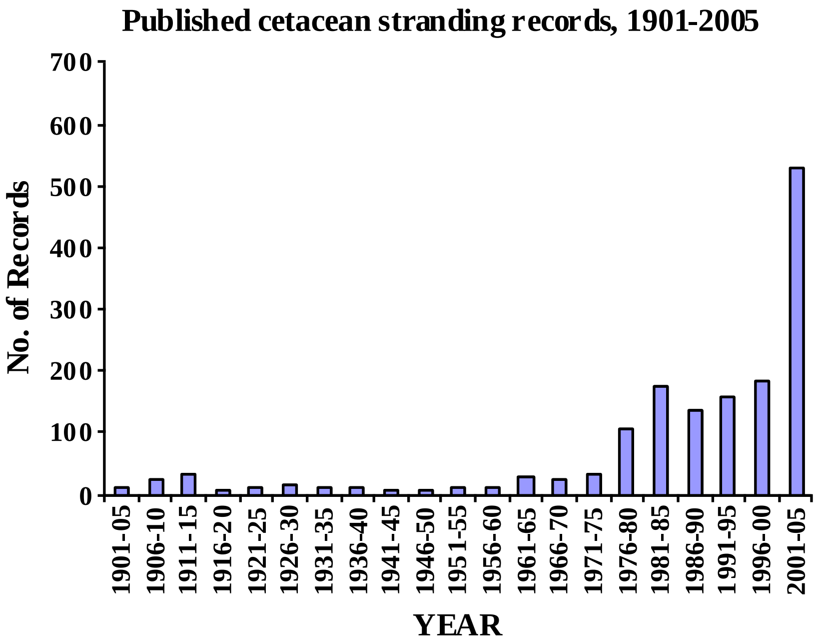

Figure 1. Number of published cetacean stranding records from 1901 to 2005 (Source: Berrow *et al.* 2005a).

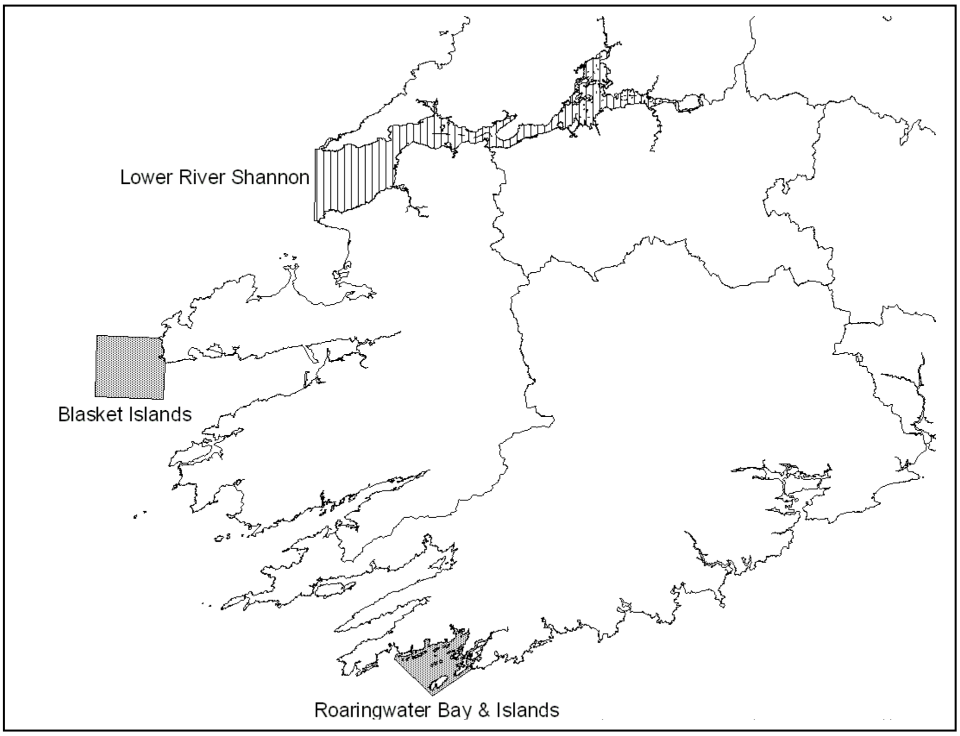

Figure 2. Cetacean cSACs, Lower River Shannon (Bottlenose dolphin), Blasket Islands (Harbour porpoise), Roaringwater Bay and Islands (Harbour porpoise).

CHAPTER 2

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN GALWAY BAY: AN EVALUATION OF MONITORING TECHNIQUES AND ASSESSMENT OF SITE SUITABILITY FOR FUTURE SAC DESIGNATION

ABSTRACT

The overall aim of this study was to examine the suitability of Galway Bay for designation as a Special Area of Conservation (SAC). The distribution and abundance of small cetaceans, particularly bottlenose dolphin and harbour porpoise (species which merit SAC designation), were assessed through both acoustic and visual surveying, and in the process allowing for an appraisal and comparison of these alternative techniques of monitoring. Static Acoustic Monitoring (SAM) using T-PODs was carried out from a site east of Spiddal for 333 days and from a second site at Gleninagh for 108 days, between May 2006 and September 2007. Land and vessel-based visual monitoring was carried out between March 2005 and March 2007. Land-based quantified effort watches were carried out from a number of headlands around the bay, while vessel-based surveying took place on board dedicated survey vessels and on platforms of opportunity (POPs). A total of nine cetacean species were recorded in the bay during the study through a combination of these visual methods, supplemented by casual sightings and strandings. More cetaceans were recorded in outer Galway Bay than inner Galway Bay. Results from all methods used showed that harbour porpoise was the most frequently recorded species, while bottlenose dolphin was rarely recorded. Relative abundance of harbour porpoise in the bay from land-based surveys was greatest from Black Head ($2.12hr^{-1}$), while a relative abundance estimate km^{-1} generated from dedicated transects ($0.17km^{-1}$) was larger than that generated from POP surveys ($0.02km^{-1}$). No relationship was found between the presence or absence of harbour porpoises from land-based sites over the various stages of the tidal cycle (Black Head ($P=0.4$), Fanore ($P=0.995$) and Spiddal ($P=0.617$)), nor was there any relationship found between tidal phase and behaviour ($P=0.54$). Statistical analysis across methods showed there to be no significant effect of seasonality on the abundance of harbour porpoise in the bay. Relative abundance estimates generated from land-based data were compared with data collected from a further five sites around the country (Castle Point, Slea Head, Galley Head, Ram Head, Ramore Head). Results showed Black Head to have the greatest relative abundance. Two of the sites used in the comparison (Castle Point and Slea Head) are located within already designated SACs, and therefore the evidence would support the designation of Galway Bay as an SAC for harbour porpoise.

INTRODUCTION

All species of cetaceans present in European waters are protected under Annex IV of the EU Habitats Directive. Harbour porpoises and bottlenose dolphins, which are recognised as species of European Community interest are also listed under Annex II of this Directive, and therefore require the designation of Special Areas of Conservation (SAC's). The EU Habitats Directive states that a site, which "*corresponds to the ecological requirements of the species*", may be designated as an SAC. The Directive also states, relating to the selection of sites eligible for identification of community importance, "*for aquatic species which range over wide areas, such sites shall be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction*". The management of Ireland's nature conservation under National, European and International law is the responsibility of the National Parks and Wildlife Service (NPWS) of the Department of the Environment Heritage and Local Government, and therefore NPWS are responsible for the designation of SACs (Buckley, 2004). To date, the Blasket Islands (Co. Kerry) and Roaringwater Bay (Co. Cork) are the only sites designated as SACs in Irish coastal waters for harbour porpoise, while the Shannon Estuary is the only designated SAC for bottlenose dolphins. The data presented in this chapter were analysed in order to assess the suitability of Galway Bay for designation as an SAC for harbour porpoises and bottlenose dolphins.

Cetaceans in Galway Bay; an overview

Historical reviews of sightings, strandings and captures of cetaceans in Ireland were published by Scharff (1900), Moffat (1938), O'Riordan (1972) and Berrow and Rogan (1997) among others (Table 1), which include a number of references to cetaceans in Galway Bay. O'Riordan (1972) reported two bottlenose dolphin records from Galway Bay described as "captured". One incident of "capture" is recorded from Ballynahown in 1918, while a second was recorded at Rinville point in 1962. However, it is unsure whether these animals were accidentally or intentionally captured. The only contemporary data on the distribution and abundance of cetaceans in Galway Bay is from sightings data collected as part of the Irish Whale and Dolphin Group (IWDG) sighting scheme, in operation since 1991. No dedicated vessel-based surveying had been carried out Galway Bay since the 1980 (Evans 1981). Previous dedicated land-based watches were confined to the southern shore at Fanore, and a lesser number from Black Head. Of the 24 cetacean species recorded in Irish waters, 16 species have been recorded in Galway Bay. Of these, seven species have been recorded both stranded and visually observed, two species have only been recorded observed, while nine species are known only to occur through strandings (Table 1). There are limitations associated with strandings data, as it may be that the animals washed up originated outside of the study area, and therefore provide false data on the presence of certain species occurring within an area.

Berrow *et al.* (2002) analysed 2,200 sighting records from the Irish Whale and Dolphin Group (IWDG). They found that 13.2% of all records were from Co. Galway, with harbour porpoises being the most frequently reported species, and Galway producing the third most sightings of the species in the country. Most records were reported between June and August, with few sightings in the winter and spring. Berrow *et al.* (2002) also showed that bottlenose dolphins were the third most frequently sighted species in the country, with concentrations of sightings occurring within Galway Bay. Furthermore, they showed that bottlenose dolphin sightings increased rapidly from April to June, suggesting an inshore movement, which peaked in August.

Table 1. Cetacean species recorded either visually or through the recording of strandings in Galway Bay.

Species	Visually recorded	Reference	Stranded	Reference
Bottlenose dolphin	*	Cooke (1990)	*	Moffat (1938)
Harbour porpoise	*	www.iwdg.ie	*	O'Riordan (1976)
Common dolphin	*	www.iwdg.ie	*	O'Riordan (1972)
Killer whale	*	McGrath (1983)		
Minke whale	*	www.iwdg.ie	*	Fairley (1998)
Pilot whale	*	www.iwdg.ie	*	Fairley (1979)
Risso's dolphin	*	www.iwdg.ie	*	D'arcy Thompson (1900)
Sperm whale	*	www.iwdg.ie	*	Cabot (1967)
False killer whale	*	O'Cadhla *et al.* (2004)		
Atlantic white-sided dolphin			*	Fairley and Dawson (1981)
Cuvier's beaked whale			*	Andersen (1904)
Fin whale			*	Harmer (1914-27)
Humpback whale			*	Berrow *et al.* (2006)
Northern bottlenose whale			*	Fraser (1934)
Pygmy sperm whale			*	Fairley and Mooney (1985)
Sowerbys beaked whale			*	Harmer (1914-27)
Striped dolphin			*	Fairley and MacLoughlin (1990)
True's beaked whale			*	Harmer (1914-27)

STUDY AREA

Galway Bay

Galway Bay is situated on the west coast of Ireland bounded by the northern and southern shores of counties Clare and Galway between the lines of longitude of 8º55'W and 9º50'W and latitude of 53º00'N and 53º15'N (De Bhaldraithe 1977) (Figure 1). It is one of the largest bays on the west coast of Ireland, and is about 50km long and from 10 to 30km in breadth. A chain of three islands, the Aran Islands, stretches across the mouth of the bay forming a partial boundary between the bay and the Atlantic Ocean. Water exchange between the bay and the Atlantic Ocean is between four sounds, the North and South Sounds, Gregory and Foul Sounds. The meridian of 9º16'W between Black Head and Spiddal conveniently divides Galway Bay into the inner and outer bays (Lei 1995). Depths range between 8-20m in the inner bay and 20-60m in the outer bay (Nolan 1997; Lei 1995). Tidal range during springs is 4.5m and 1.9m during neaps. The main freshwater influence in the bay comes from the River Corrib, while the Clarinbridge and Kilcolgan rivers also have a marginal contribution. However, this freshwater influence is restricted mainly to the north shore (Fernandes 1988). The bay is mostly low-lying with occasional elevated areas.

The Galway Bay Complex SAC (000266) comprises a diverse range of marine, coastal and terrestrial habitats and includes some of the best examples of shallow bays, reefs, lagoons and salt marshes in the country (Galway Bay Complex, Site Synopsis, www.npws.ie). The site supports an important common seal colony and a breeding otter population, both of which are listed under Annex II of the EU Habitats Directive. Although bottlenose dolphins and harbour porpoises are also listed under Annex II, they are not included in the site synopsis of the bay as qualifying interests. During the present study, most of the survey effort was focused in the area defined as the outer bay.

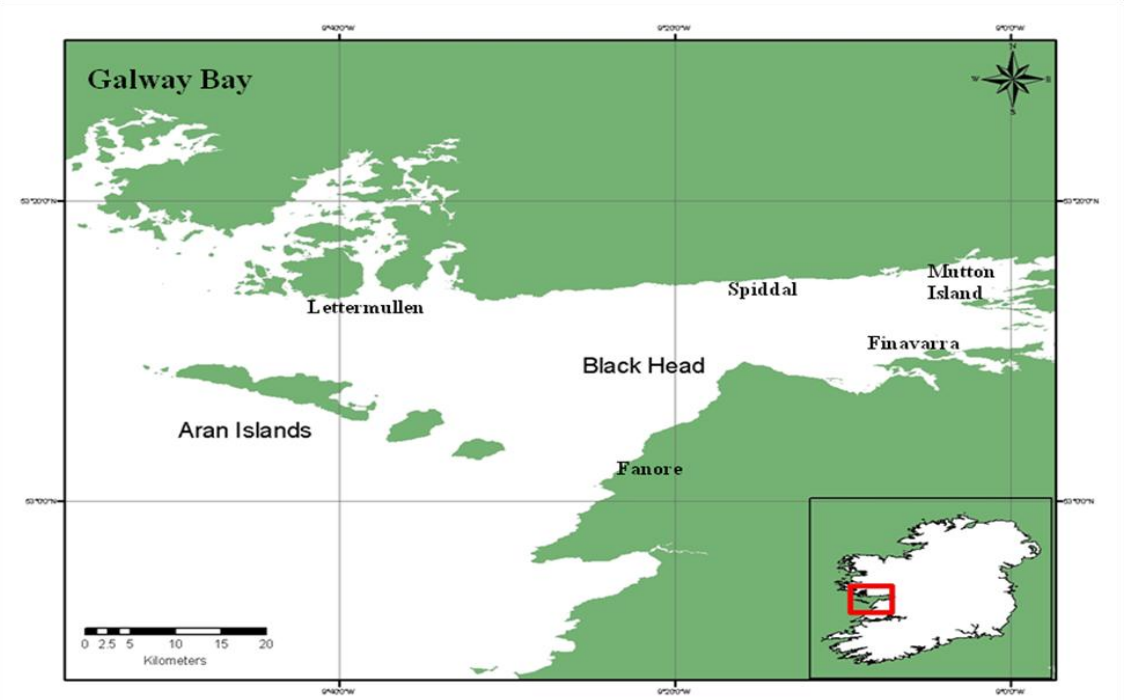

Figure 1. Map of Galway Bay study area, including site locations for land-based observations.

MATERIALS AND METHODS: VISUAL SURVEYING TECHNIQUES

Land and vessel-based surveying techniques were used to monitor the seasonal occurrence, distribution and abundance of cetacean species in Galway Bay, between March 2005 and May 2007. The same single observer was used during all observations to reduce the influence of inter-observer variability. The same optical equipment was used throughout land-based quantified effort watches (Opticron 7x50 binoculars and Kowa TGW2 with 20X wide eyepiece), POP surveys (Opticron 7x50 binoculars), and dedicated transects (Opticron 7x50 binoculars), therefore standardising the collection of data and making observations comparable. There are many limitations associated with visual monitoring techniques, mainly as they are influenced by variables such as sea state (Clarke 1982; Evans and Chappell 1994; Palka 1996; Teilmann 2003; Evans and Hammond 2004), observer variation (Young and Peace 1999; O'Brien *et al*. 2006), optics and height above sea level. Evans and Hammond (2004) state that visual surveys should not be carried out in sea states above Beaufort scale 2, as the probability of detecting animals is greatly reduced above this. Palka (1996) found that the sighting rate of harbour porpoises in Beaufort sea state 1 was 80% of that in sea state 0, and that sighting rates in sea state 2 and 3 were approximately 25% of that in Beaufort 0. Further investigation by Teilmann (2003) found that sea state had a significant effect on estimated sighting rate, effective search width, density and abundance within a sea state three. Clarke (1982) also reports a decrease in the probability of detecting animals with increasing sea state. Based upon results and recommendations from these previous studies, all visual observations both land and vessel-based, were where possible, only carried out in sea state two or less.

LAND-BASED WATCHES

Land-based observations were carried out between March 2005 and February 2007 when weather and sea state permitted. Land-based sites were not randomly chosen, but were selected following a number of criteria such as: 1) sites offering an elevated vantage point, 2) views of the surrounding area offered by the site, 3) ease of accessibility to the site, and 4) personal security of the observer (watch site not too remote). Initially, watches were carried out on a bi-monthly basis from a total of six sites around the bay. A review of results from land-based watching after 12 months, lead to the reduction in the number of sites to three (Spiddal, Black Head and Fanore), and to reduce the watch frequency to one per month from each site. Watch sites were located on the north and south shores of

Galway Bay (Figure 1). All watches were 100 minutes in duration, enabling the amount of effort to be quantified, and therefore allowing the generation of relative abundance estimates (animals sighted per hour). Environmental conditions (sea state, wind speed and direction, cloud cover and visibility) were recorded for the duration of all surveys. When a sighting was made, the species observed was identified, as well as the numbers of groups and individuals present. A group was defined after Shane (1990) and Smolker *et al.* (1993), as a solitary animal or aggregation of animals, observed in apparent association, moving in the same direction, and exhibiting similar behaviour where a member was within 10m of any other member in the first 10 minutes that the animals were observed. The presence and numbers of juveniles or calves were also noted. A calf was defined as no more than two-thirds the length of an adult (Shane 1990). The distance of the observed animals from land was estimated and the behaviour type recorded. Further details noted included direction of travel and surfacing mode.

To facilitate statistical analyses land-based data from both years were pooled, and classified according to season (spring summer, autumn and winter), and location (Black Head, Spiddal and Fanore). The assumption of equal variances was confirmed using Bartlett's test. A two way ANOVA was used to test the null hypothesis that there was no difference in the number of harbour porpoises recorded per month between seasons. The factors season and region were orthogonal facilitating the examination of interactions. A second analysis was conducted to test for differences between years. The data were pooled across locations but separated according to year (2005, 2006) and season. A two way orthogonal ANOVA was used to test for significant differences in the number of harbour porpoises recorded per hour between seasons and years.

For the purposes of analysing data in relation to tidal cycle, the twelve hour tidal cycle was divided into three categories, 1) slack, 2) ebb and 3) flood tide. The time of sightings recorded from each location were then classified according to each of the three tidal categories. It must be noted that all watches were carried out randomly for each location, while the date of each watch was randomised by weather conditions. The state of tide was unknown to the observer during each watch. Contingency tables were constructed before statistically testing the influence of tidal cycle on harbour porpoise sightings. Watches were categorised according to tidal category and the presence or absence of porpoises. A Chi-squared test was used to test for an association between the presence of harbour porpoises and tidal cycle. All Chi-squared analyses were conducted using web-based interactive software (Preacher, 2001).

The data were also analysed in respect of sea state. Only data where watches were carried out in a sea state 2 or less were used. Pivot tables were constructed in order to organise the data, and this enabled the presence or absence of harbour porpoises to be assigned to the various sea states in preparation for statistical analysis. Chi-squared tests were used to test for differences in the presence or absence of porpoise sightings between sea states. At least 20% of the expected frequencies were less than 5, therefore Yates correction P-value was used, reducing the significance value to P=0.03.

Finally the last test carried out on the porpoise data from Galway Bay was to determine the most frequently recorded behavioural type as documented from each site over the three tidal phases. The behavioural categories were as follows: 1) fast travel, 2) slow normal surfacing (slow travel), 3) foraging and 4) milling/resting. Contingency tables were constructed to facilitate the categorisation of behavioural data according to the three tidal phases, and chi-squared tests were carried out.

IWDG DATA ANALYSIS EFFORT WATCHES FROM DEREEN, FANORE, CO. CLARE

The IWDG sightings and strandings scheme was established in 1991. As part of this scheme, a large number of land-based effort watches were carried out from Dereen, Fanore, Co Clare (53°05N 9°20W) by a single observer, Liam McNamara. This area is situated on the southern, outer shore of Galway Bay, overlooking the Aran Islands to the west, and is very close to the site at Fanore, used for land-based observations during the present study. These data were used to further explore the seasonal occurrence and abundance of cetaceans at this site. A Kruskal Wallis test was used to statistically test for significant difference in the number of hours watched between years. Equal variances were confirmed using a Levene's test, and a two-way ANOVA was used to test for significant difference between the factors years and season, and furthermore to test for an interaction between the two factors. Two years which had adequate data (1994 and 1995) were then selected in order to compare with the Fanore data collected as part of the present study. A two-way ANOVA was used to test for significant difference in the number of bottlenose dolphin sightings recorded between years and season from Fanore, while the influence of an interaction was also tested.

ANALYSIS OF LAND-BASED EFFORT WATCHES FROM FIVE SITES AROUND IRELAND

A total of five sites were selected from around the entire Irish coast, where monthly dedicated quantified effort watches are carried out as part of the IWDG sighting scheme (ISCOPE). The sites selected were; 1) Castle Point, Roaringwater Bay, Co. Cork, 2) Galley Head, Co. Cork, 3) Slea Head, Co. Kerry, 4) Ram Head, Co. Waterford and 5) Ramore Head, Co. Antrim. Data from these sites were available for the same period as the Galway Bay study (1 March 2005 to 28 February, 2007). This allowed for critical analyses of Galway Bay data in view of future SAC designation, as it allowed comparison with other areas around the coast, including areas already designated as harbour porpoise SACs, The Blasket Islands (Slea Head) and Roaringwater Bay (Castle Point). As the number of watches carried out per month varied between locations, a single watch for each month was used for analyses. This was randomly chosen for each location where multiple watches existed for that month, and, where possible, watch data were extracted for a single observer. Data from the two years were then pooled as previously done for the Galway Bay data. In order to carry out statistical tests, the number of individuals recorded per month from each of the locations was categorised into the four seasons. The location of sites was further divided into regions, where Black Head, Spiddal and Slea Head were included in the region west. Ramore Head and Ram Head were classed as eastern, while Galley Head and Castle Point were classed as southern. Equal variances were confirmed using a Levene's test, and a three way ANOVA was used to investigate if the differences in harbour porpoise numbers recorded per hour between sites, seasons and regions, and additionally to determine if any interaction term was significant. Season and region were fixed, while site was random. The factors season and region are orthogonal as each region was surveyed in all four seasons, while site was nested within region. Site is also orthogonal to season as each site was surveyed in each of the four seasons.

DEDICATED TRANSECTS

Dedicated cetacean surveys can cover a large area, and provide a means of systematically sampling either by sea or by air. They are however relatively expensive due to the cost of ship or air time when compared to land-based surveys and surveys carried out on POPs. Dedicated boat transects are essential for the systematic coverage of an area which cannot be achieved using POPs. They also provide an opportunity for the application of other methods such as photo-identification (Würsig and Würsig 1977), mark re-capture analysis (Wilson *et al.* 1999), and line transect sampling (Hammond *et al.* 1995).

An angling vessel, the M.V. *Maiden Mara* (Aquastar 43, 13m half decker) operating out of Spiddal, Co. Galway, was the platform used for dedicated transects. The survey route was pre-determined and the same route was followed on each survey. Transects were scheduled to take place once per month when weather and sea state permitted. The route followed a line from Spiddal across the bay towards Black Head lighthouse and down along the coast towards Doolin, Co. Clare. From there, the route was directed across to the Aran Islands and north towards to the north shore before running east and returning to Spiddal pier (Figure 2).

The survey track was recorded using a handheld Garmin GPS, while environmental conditions similar to those listed under land-based observations were recorded every 30 minutes. The observer was positioned on the bow of the vessel and scanned an area dead ahead and 60˚ to either side. Scans were conducted using binoculars and the naked eye. When a sighting was made during these transects, the track-line was broken. This was done for a number of reasons; 1) to get closer to the animals to enable more accurate species identification, 2) to enable more accurate estimation of the number of individuals present, 3) to accurately record the presence of calves or juveniles, and 4) to obtain photographic images of animals, especially in the event of bottlenose dolphin encounters for photo-identification. A Canon 20D digital camera equipped with 300mm auto-focus lens was used for this purpose. When all animals were photographed, or a behavioural change such as tail slapping or boat avoidance was evident, the boat left the vicinity of the animals. At no point did an encounter exceed 30 minutes, a time restriction enforced by Maritime Safety Directive through a Marine Notice (number 15), issued in 2005 to minimise impacts on the animal's behaviour. The track line was resumed from the position it was broken after a sighting was recorded. Data collected during dedicated transects enabled the generation of abundance estimates for the area. Photo-identification of bottlenose dolphins enabled the identification of individual animals by taking photographic images of their dorsal fins. Some individuals have unique notches along the trailing edge of their dorsal fins or scratches, tooth rakes, pale patches or scars along their bodies. The use of these natural markings allows for the identification of individuals. This is an invaluable technique as it can be used as a means to track animals, thereby providing information on their movements, site fidelity (Kerr *et al.* 2005), associations (Wells *et al.* 1987), and population dynamics (Wells and Scott 1990).

Statistical analyses were carried out on the harbour porpoise data collected during dedicated transects, as bottlenose dolphin sightings were rarely recorded. Sightings data were pooled both years, and classified into two halves, i.e. data collected during the winter and spring (November-April) were combined, while summer (May, June, July) and autumn (August, September, October) constituted the other half. Using a Levene's test, the data were found to have unequal variances and therefore a non-parametric Kruskal-Wallis test was used for analysis.

HARBOUR PORPOISE ABUNDANCE AND DENSITY ESTIMATE IN OUTER GALWAY BAY, USING DISTANCE

Line-transect sampling can be used for objects which are sparsely distributed, that occur in well defined, low or medium cluster density. It involves an observer travelling along a line and recording any detected objects (Buckland *et al.* 2001). Instead of counting all objects within a strip of known width, an observer may instead record the angular position and distance from the track-line to the detected object. The software programme DISTANCE assumes that all objects on the track-line at zero distance are detected, i.e. g(0)=1 (Thomas *et al.* 2006). Harbour porpoise sightings recorded during dedicated transects were analysed using DISTANCE software version (5.0) in order to generate a density estimate km^{-2} for the area defined as outer Galway Bay (approximately $350km^2$). During the present study, the dedicated transect route was not initially designed to conform to line transect sampling protocol. Therefore, the angular position of the observed animals to the track line was not recorded, but the radial distance was always noted. In order to apply the data to the DISTANCE software a number of assumptions were made. Observers carrying out visual observations during line transects, generally survey one side of the survey line from 45-60° to 5-10° on the opposite side of the line to port or starboard depending on which side of the vessel they are positioned (Buckland *et al.* 2001). In order to fit the requirements of the DISTANCE software, the angular position was assumed and entered as the midpoint angles of 60° either side of dead ahead (30° and 330°). A number of models can be fitted to the data collected and the model with the lowest AIC (Akaike's Information Criterion) was selected (Buckland *et al.* 2001). AIC treats the model selection within an optimization rather than a hypothesis testing framework and attempts to identify a model that fits the data well but does not have too many parameters (Buckland *et al.* 2001).

PLATFORMS OF OPPORTUNITY (POPS)

POP surveys provide a very cost effective means of surveying an area over extended periods as the high cost of hiring vessels is not incurred. However, there are limitations associated with this method, such as lack of control over the route undertaken and speed of the vessel (Evans and Hammond 2004). A number of vessels were used as POPs over the duration of the present study, including a cargo vessel, angling vessel, passenger ferry and the national research vessels, the R.V. *Celtic Voyager* and R.V. *Celtic Explorer*. During each survey, an arc dead ahead of the vessel and 60° to either side was constantly scanned for the presence of cetaceans, with approximately 60% of scans done using binoculars and the remainder by eye. Environmental conditions similar to those described under land-based watches were recorded at 30 minute intervals for the duration of each survey. When a sighting was made, a note of the start and end time was taken, along with the ship's position using a Garmin handheld GPS. Sightings details as described above under land-based watches were also recorded. POP surveys were carried out in Galway Bay between March 2005 and May 2007, and 80% surveys were carried out from the cargo vessel, M.V *Mamaiya*. A typical route surveyed from this vessel is shown in Figure 3.

Sightings data collected on POP surveys were pooled for both years, and were classified into two halves, i.e. data collected during the winter and spring were combined, while summer and autumn constituted the other half, as previously done for dedicated transect data. The data were then statistically analysed to determine if significant differences existed in the sightings distribution of harbour porpoises between the two halves of the year. Equal variances were demonstrated using a Levene's test and a one-way ANOVA was used to test for significant difference.

CASUAL SIGHTINGS

The collection of casual sightings provide a useful means of gathering auxiliary data from areas which are not the focus of continuous research as they can provide information on numbers as well as atypical species within an area. Sightings packs, containing recording forms, species identification keys and general information on the project were distributed to individuals around the study site who would be on or near the water on a regular basis. Casual sightings were reported directly via sighting forms that had been circulated to ferry operators, angling vessels, fishermen and the general public. Additional casual sightings reported within the bay were also sourced from the IWDG.

STRANDINGS

Any stranded animals encountered in Galway Bay were also recorded to further expand our knowledge of cetaceans in the bay. Strandings can be used to provide a rough measure of status and seasonal variation in abundance (Evans and Hammond 2004), but data must be treated with caution as the animal may have originated outside the area of interest. Post-mortem analysis was carried out where possible, to examine the stomach contents and therefore obtain data on the dietary preferences of these animals.

EFFECT OF DEPTH ON SIGHTING'S DISTRIBUTION IN GALWAY BAY AS DETERMINED FROM VESSEL BASED OBSERVATIONS

In order to examine the relationship between the distribution of harbour porpoise sightings and water depth in Galway Bay, all sightings recorded on dedicated transects and POP surveys were plotted using GIS. These sightings data were overlain on depth data for Galway Bay, collected as part of INFOMAR, a partnership between the GSI and the Marine Institute. This was mainly done for descriptive purposes, as no statistical analysis could be carried out as not enough sighting replicates were available for each depth category.

STATIC ACOUSTIC MONITORING (SAM)

SAM was carried out in Galway Bay through the use of acoustic devices called T-PODs. T-PODs are manufactured by Chelonia LTD in the UK. These units consist of a self contained hydrophone that logs the times and duration of echolocation clicks produced by dolphin species and harbour porpoises. These units are powered by 12 lithium D-celled batteries and have 128 megabytes of memory. Version 4 and 5 T-PODs were used for the duration of this study. T-PODs were first deployed in Galway Bay on the 12 May, 2006, and were subsequently deployed for various periods thereafter, when weather permitted retrieval and re-deployments (Table 1). Deployments totalled 333 days at Spiddal and 108 days at Gleninagh on the southern shore. Deployments on the southern shore were over a shorter duration than at Spiddal due to the limited availability of acoustic devices. All T-PODs were set to detect both harbour porpoise and dolphin species using the generic setting used by the manufacturers Chelonia (www.chelonia.co.uk). All click trains logged in the 130 kHz porpoise channels were assumed to be of porpoise origin as the a click bandwidth of 4 was used during all deployments. This reduction in bandwidth was used to reduce the number of porpoise false positive detections coming from high frequency dolphin trains. Furthermore, in support of this assumption, harbour porpoises were the most frequently recorded species during visual surveys in the area, with dolphins only rarely recorded. Data were extracted from all files as detection positive minutes per day (*dpm).* In order to test for any seasonal variation in the harbour porpoise data collected from Spiddal, 10 random days for each of the four seasons (spring, summer, autumn and winter) over the two years were chosen using random number tables. Equal variances were tested using a Levene's test and non parametric Kruskal-Wallis tests were carried out. *Post hoc* Mann-Whitney U-tests, using the Bonferroni correction, were carried out to determine where significant difference existed between seasons.

T-POD deployments and moorings

T-PODs were deployed at two locations in Galway Bay (Figure 4). The first site was located 3km east of Spiddal pier within the Marine Institute's wave energy test site. This site was chosen as it provided a secure area, with no fishing activity taking place in the vicinity, while the area was out of the main shipping route. The second site was located on the southern shore, east of Black Head. This site offered a location where the mooring was out of the way of the shipping channel, and was not exposed to strong tidal currents where the risk of losing gear was high, especially since this part of the bay is exposed to prevailing winds. The second site was only used for a short duration (May to August, 2007). The mooring systems used consisted of a surface marker running to a 40kg weight, with a line of approximately 60m running across the bottom to another weight of 20kg. From this, a line ran to the surface and was marked by a smaller marker. As the T-POD is positively buoyant, it was freely suspended from mid way along the bottom line which ran between the two weights. The T-POD was attached to 15m of rope and was therefore suspended in the middle of the water column, since both porpoises and dolphins were the target species. A number of salmon floats were attached on the T-POD line to ensure it is kept vertical in the water column (Figure 5).

RESULTS

LAND-BASED OBSERVATIONS

A total of 138 land-based quantified effort watches were carried out in Galway Bay equating to 230 hours of visual observations from the various headlands. Cetaceans were recorded on 45 occasions (33%), comprising 110 schools, of four species, and a total of

250 individuals (Table 2). Harbour porpoises were the most frequently observed species (92% of all sightings), followed by bottlenose dolphins (3%), common dolphins (3%) and minke whale (2%) (Figure 6). Relative abundance estimates of cetaceans per hour of effort (cet hr^{-1}) for Galway Bay are also shown in Table 2. These results were generated using a combination of all cetacean species recorded during land-based observations. Animals were sighted on 61% of watches from Black Head, making it the most successful site for observing cetaceans. This was followed by Fanore (41%) and Spiddal (39%). Black Head had the highest relative abundance of cetaceans recorded per hour in comparison with any other site in the bay (2.36 cet hr^{-1}), followed by Fanore (1.44 cet hr^{-1}) and Spiddal (0.97 cet hr^{-1}). More detailed analyses were only carried out on sightings of harbour porpoises from three sites (Black Head, Fanore and Spiddal), as the number of sightings recorded for other species and the remaining locations were too low (Figure 6). Black Head had the highest relative abundance estimate of harbour porpoise per hour (2.12 hr^{-1}), followed by Fanore (0.79 hr^{-1}), and Spiddal (0.69 hr^{-1}) (Table 3).

Analysis of the effect of location and seasonality on harbour porpoise abundance

The assumption of equal variances was confirmed using Bartlett's test (P=0.23). No significant difference was found in the number of harbour porpoise sightings between seasons (P=0.23), while a significant difference was found between locations (P=0.01). The interaction term was not significant (P=0.48), showing that the difference between locations was consistent across all four seasons (Table 4). Tukey's pair-wise comparisons showed that the number of porpoises recorded at Black Head were significantly higher compared to numbers recorded at Fanore (P=0.02) and Spiddal (P=0.01). No significant difference in numbers was found between Fanore and Spiddal (P=0.89).

No significant differences were found in the pooled data between seasons (P=0.52) or years (P=0.43) and furthermore the interaction term between season and year was not significant (P=0.24).

Effect of tidal cycle on the sighting probability of harbour porpoises

Results showed that sightings were recorded from all locations during all tidal states. From Black Head, most sightings were recorded during a flood tide (39%), while from Fanore and Spiddal, 45% and 60% of sightings were recorded during slack periods of the tidal cycle (Figure 7). However, there was no association between the presence of harbour porpoises and tidal cycle at any location (Black Head; P=0.40, Fanore; P=0.99 and Spiddal; P=0.62 (Table 5)).

Effect of sea state on sighting probability

The percentages of sightings recorded within a sea state 0-1 from all three locations were between 78-80%, while sighting rates in a sea state 2 were between 14 and 22% (Figure 8). The percentage of effort carried out sea states 0-3 from three locations are shown in Table 6. Chi-squared results showed an association between the presence of harbour porpoises and sea state at Black Head (P=0.00) (Table 7). Additional two-way chi-squared tests were carried out to confirm this. There was no association between the presence of harbour porpoises and sea state at Fanore (P=0.29), or Spiddal (P=0.19) (Table 7).

Most frequently recorded behaviour

The behavioural type "fast travel" was the most frequently recorded behaviour exhibited by harbour porpoises from all three sites (Figure 9). Contingency tables were constructed to facilitate the categorisation of behavioural data according to the three tidal phases classified. Results from chi-squared tests showed no association between tidal phase and behaviour (P=0.54) (Table 8).

RESULTS: IWDG DATA ANALYSIS ON LAND-BASED EFFORT WATCHES FROM DEREEN, FANORE, CO. CLARE

Between 1994 and 1999, 213 quantified effort watches were carried out from Fanore equating to 307.08 hours of watch effort (Figure 10) and 32 cetacean sightings (Figure 11). Bottlenose dolphins were recorded on 25 occasions (78% of watches), while harbour porpoises were only recorded twice (6% of watches). Five sightings were not positively identified, but only recorded as dolphin species due to uncertainty by the observer.

A Kruskal-Wallis test showed there to be no significant difference in the number of hours watched between years (P=0.416). A Levene's test on the dolphin numerical data confirmed equal variances (P=0.236). A two-way ANOVA showed there to be no significant difference between years (P=0.31), however there was a significant difference between seasons (P=0.02), with more sightings occurring in the summer and autumn. An interaction term between years and season was also tested for but this was not significant (P=0.49), showing that the difference between seasons was consistent across years. Further analysis using just two years of data from Fanore, show bottlenose dolphins to be recorded on 16 occasions during 1994-95, comprising 78 individuals, while only a single sighting of 19 individuals was recorded during the present study. A two-way ANOVA, found a significant difference in the number of bottlenose dolphin sightings recorded between years from Fanore (P=0.04), and also between seasons (P=0.04), with more sightings recorded during the summer and autumn. The interaction term was found not to be significant (P=0.60). Analysis of the inter- year data showed more sightings from 1994 and 1995, while only a single sighting was recorded from Fanore between March 2005 and 2007.

RESULTS: ANALYSIS OF LAND-BASED EFFORT WATCHES FROM FIVE SITES AROUND IRELAND

The relative abundance estimate of harbour porpoises for each of the five sites outside of Galway Bay are shown in Table 9. Results showed Black Head to have a higher relative abundance (2.11 hr^{-1}) when compared with any of the other sites. This was followed by Slea Head (1.68 hr^{-1}), Castle Point (1.14 hr^{-1}) and Spiddal (1.01 hr^{-1}).

The assumption of equal variances was confirmed using a Levene's test (P=0.366). Results showed there to be no variation between sites within each region (P=0.392), and this was consistent across seasons (season*site interaction insignificant, P=0.875). A significant difference was found to exist between regions (P=0.01), but not between seasons (P=0.05), while the between region difference is consistent across seasons (region*season interaction not significant, P=0.08) (Table 10). *Post hoc* tests were carried out to examine differences between regions. Results from the Tukey's Simultaneous Tests showed that the numbers of harbour porpoises sighted in the east and west were higher than numbers sighted in the south (P<0.001), although there was no significant difference in numbers sighted between the east and south (P=0.99).

RESULTS: DEDICATED TRANSECTS

Between May 2005 and April 2007, a total of 14 dedicated surveys were carried out in favourable sea conditions (Beaufort sea state two or less) (Table 11). The total length of track-lines surveyed within outer Galway Bay was 1,239km. Cetaceans were sighted on all but two surveys (86% sighting success rate). The track-lines surveyed averaged 88.5km, with each survey lasting between six and seven hours depending on the number of encounters. Four cetacean species were recorded during dedicated transects, with harbour porpoises the most frequently sighted species (70%), followed by bottlenose dolphins (18%), common dolphins (5%) and minke whale (5%). On one occasion, an unidentified dolphin species was observed off Fanore. A relative abundance of 0.17 cetaceans km^{-1} for outer Galway Bay was generated from this method.

Effect of Seasonality

Results from a Levene's test showed the data had unequal variances (P=0.04), and therefore non-parametric Kruskal-Wallis test was used. Results showed no significant difference in the number of harbour porpoises sightings between the two halves of the year (P=0.13).

Estimation of harbour porpoise abundance in Galway Bay using DISTANCE

Fourteen dedicated transects were carried out in Galway Bay, and each individual transect was treated as a single sample or track line when applied to DISTANCE software. A number of different models were applied to the data, and the Half Normal Cosine model was selected to calculate the abundance estimate as this model provided the lowest Akaike's Information Criterion (AIC). Results from DISTANCE analysis gave rise to a density estimate of 0.29 harbour porpoises km^{-2}, with an average cluster size of 1.68 (Table 12, Figure 12). An abundance of 102 (95% CI 49-212) harbour porpoises was estimated to be within the area defined as the outer bay.

RESULTS: PLATFORMS OF OPPORTUNITY

Nineteen surveys were carried out on POP during the present study (Table 13). A total of 1,608km were surveyed and a total of 21 sightings were recorded, comprising four cetacean species and 45 individuals equating to a relative abundance of 0.02 animals km^{-1}. However, the POP surveys also covered the inner bay. Again, harbour porpoises were found to be the most frequently sighted species from this method of surveying (85% of sightings), with a total of four sightings out of the 21 recorded occurring within the region defined as the inner bay.

Effect of seasonality on the sighting probability of harbour porpoises

The data were confirmed to have equal variances using a Levene's test (P=0.21). A one-way ANOVA showed no significant difference in the number of porpoises recorded between the two halves of the year (P=0.24).

DISTANCE analysis from POPs

Data gathered during POP surveys were also used for DISTANCE analysis. Only sightings and lines surveyed in outer Galway Bay were used. The total length of track lines surveyed equated to 926km. A density estimate of 0.44 harbour porpoises km^{-2} was calculated, with an average cluster size of 1.38, while an abundance estimate using POP data led to 154 (95% CI 81-294) harbour porpoises in the outer bay (Table 14, Figure 13).

RESULTS: BOTTLENOSE DOLPHIN SIGHTINGS RECORDED DURING DEDICATED TRANSECTS AND POP SURVEYS

Bottlenose dolphins were recorded infrequently during the present study (Table 11). They were recorded once during POP surveys, and on five occasions during dedicated transects over the two year study period. Bottlenose dolphins were never recorded from land at Black Head, and were only recorded on a single occasion from Fanore, while they were recorded on two occasions from Spiddal. This equates to just 9 sightings of bottlenose dolphins across all methods used. Group size ranged from between 1 to 12 individuals. However, in March 2007, a very large aggregation of bottlenose dolphins was observed during a dedicated transect on the south shore off Fanore, Co. Clare. Three groups in close association were observed, and it was estimated that between 70 and 100 dolphins were present. Relative abundance estimates of the number of bottlenose dolphins per hour were calculated from land-based data (0.2/hr^{-1}), dedicated transects (0.08/km), and from POPs (0.002/km) (Table 15).

Photo-identification

Thirty four individual bottlenose dolphins were photographed and catalogued in Galway Bay over the study duration and none of these identified individuals were re-sighted within the bay. All images of dolphins identified were compared with archived photo-identification catalogues from Cardigan Bay (SEA WATCH Foundation, n=279), the Shannon Estuary (Shannon Dolphin and Wildlife Foundation, n=204) and Clew Bay (GMIT, n=11), Cork Harbour (Conor Ryan, n=17), and Youghal (Simon Ingram n=3). No matches were found between Galway Bay and Cardigan Bay, or with the Shannon Estuary catalogue, even though the mouth of the Shannon is only approximately 80km south of Galway Bay. However, one individual was matched when the Galway Bay catalogue was compared with that of Clew Bay. A deformed individual sighted in Galway Bay in June

2005 with a condition described as scoliosis (Berrow and O'Brien 2006), was re-sighted and identified in Clew Bay in June 2007 (O'Brien *et al.* 2008). Two individuals recorded in Galway Bay in March 2007, were re-sighted in Cork Harbour in May 2008. These individuals were recorded in the same group when sighted in Galway Bay, and were again recorded together when sighted in Cork Harbour (Conor Ryan, pers. comm.) A fourth individual recorded from Galway Bay in March 2007, was found to be a positive match with an individual recorded off Youghal in August 2005 (Dr. Simon Ingram pers. comm.).

RESULTS: CASUAL SIGHTINGS

Casual sightings resulted in an increase in the species list for Galway Bay when compared with sightings recorded from dedicated vessel and land-based surveys over the study period. A total of 125 casual sightings were recorded, comprising six positively identified species. Bottlenose dolphins were the most frequently reported species (40% of sightings), followed by common dolphins (34%), while harbour porpoises only constituted 11% of the casual sightings reported. Other species recorded included minke whale (4%), killer whale (2%) and Risso's dolphins (1%). Eight percent of the total casual sightings reported could not be positively identified, but only as whale species (2%), or dolphin species (6%) due to the uncertainty of the observer.

RESULTS: STRANDINGS

During the study period, a total of seven species were recorded stranded in Galway Bay (Table 16). Post mortem analyses were carried out on two bottlenose dolphins, a single harbour porpoise and a humpback whale calf, in order to gather information on their dietary preferences. The Inis Mór bottlenose dolphin stranded in April 2005 had a number of fish otoliths (n=36) in the stomach and intestines. Species identification was done using Härkönen (1986), and due to the corroded state of the otoliths, they could only be determined as being from one of three fish species; Pollock *Pollachius pollachius,* Whiting *Merlanguis merlangus* or Saithe *Pollachius virens* (O'Brien and Berrow 2006).

On 21 July 2006 a small baleen whale was found washed up at Baile na hAbhainn, near Inverin, Co Galway. It was identified as a male humpback whale calf measuring 6.0m. Post-mortem examination found no food remains in the stomach but around 1.5 litres of fluid and a piece of clear plastic measuring 300 x 150mm in size (Berrow *et al.* 2006).

A number of otoliths (n=6) were recovered from the stomach of a female bottlenose dolphin stranded at Maree, Oranmore on September 8, 2006, which could only be identified as probable haddock *Melanogrammus agelfinusdue* due to the level of corrosion. An image of the dolphin's dorsal fin stranded at Maree was captured in order to check for matches with the Shannon dolphin catalogue and any other animals photographed on the west coast; no match was found. Post mortem examination was also carried out on a male harbour porpoise calf measuring 1.02m which was found stranded in Oranmore on 5 September, 2007. Post mortem analysis found no food remains in this animal's stomach or intestines.

RESULTS: EFFECT OF DEPTH ON SIGHTING'S DISTRIBUTION IN GALWAY BAY AS DETERMINED FROM VESSEL BASED OBSERVATIONS

It was evident from both the dedicated and POP survey maps combined that harbour porpoise sighting distribution was mainly restricted to the shallow coastal regions, with few sightings recorded in deeper waters (Figure 14). The distribution of sightings reflects the tracks undertaken on surveys, but it is evident that little or no sightings were recorded in the deeper regions in the middle of the bay, even though these regions were surveyed mainly during POP surveys.

RESULTS: STATIC ACOUSTIC MONITORING

Static acoustic monitoring data were collected during 333 days of monitoring from the site east of Spiddal, while 108 days were monitored at Gleninagh. Results showed that harbour porpoises were detected on average during 88% of days monitored at Spiddal, while dolphin detections were only recorded 3% of the time (Table 17). Harbour porpoises were acoustically detected on 40% of the days monitored at Gleninagh, while dolphins were only detected on 5%. The highest number of harbour porpoise detection positive minutes (1,001*dpm*) was recorded from Spiddal in October, 2006 (Table 17). Results from non parametric Kruskal-Wallis tests (Levene's test P=0.00) showed that there was a significant difference in the number of porpoise detections between seasons (P=0.00). Using the Bonferroni correction, the significance level of *post hoc* Mann-Whitney U-tests were reduced from 0.05 to 0.01 as three pair-wise comparisons were carried out. Results confirmed that spring was significantly different from autumn (P=0.00), with most detections logged during the autumn and winter months (Figure 15). Autumn had the highest mean detection rate (24.4 ppm), followed by winter (20.4 ppm), summer (11.4 ppm) and spring (1.6 ppm), (Figure 16).

DISCUSSION

A total of 16 cetacean species have been recorded in Galway Bay since the late 1800's, while a single species was added to this list from a stranding record over the duration of the present study. This record was of a humpback whale calf recorded at Baile na hAbhann, Inverin, Co Galway in 2006 (Berrow *et al.* 2006), taking the total to 17. The harbour porpoise was the most frequently recorded species during the present study and this was consistent across results from all techniques used (land-based watching, dedicated transects, POP surveys and static acoustic monitoring). Other species recorded included bottlenose dolphin, common dolphin and minke whale, but these sightings were rare by comparison with harbour porpoise records. This result is in stark contrast with the land-based data provided by the IWDG from Fanore between the years 1994-99, which showed the bottlenose dolphin to be most commonly observed species. There are two possible reasons for this. Firstly, bottlenose dolphins may have been the most abundant species in the area at that time. There is some support for this theory, as when statistical analysis was carried out on the Fanore data 1994-95, bottlenose dolphin sightings were eight times more abundant than during the present study. Increased numbers of bottlenose dolphins may have led to a reduction in harbour porpoises as these two species tend to avoid each other. Ross and Wilson (1996) showed that the majority of harbour porpoises stranded around the Moray Firth, Scotland died from fatal injuries inflicted by bottlenose dolphins. Thompson *et al.* (2004) found that the probability of sighting bottlenose dolphins and harbour porpoises were not independent, and suggested a number of reasons for the fine scale segregation of the species such as avoidance behaviour exhibited by the porpoises, or alternatively mutual avoidance by both species, in order to minimize competition for food. Secondly, this difference may be due to observer error. Casual sightings gathered from Galway Bay over the duration of the present project are in conflict with the results obtained from dedicated visual observations, as they show bottlenose dolphins to be the most frequently sighted species. This is probably due to naive observers' inability to spot the elusive harbour porpoise, and therefore leading to an under-reporting of the abundance of this species.

The outer region of Galway Bay was found to be more successful for locating and recording cetaceans than the inner section of the bay. Cetaceans were recorded on 61% of watches from Black Head, 41% from Fanore, and 39% from Spiddal located in the outer bay, in contrast to 13% from Mutton Island and 6% from Finavarra, both located in the inner bay. As the harbour porpoise was the only species recorded regularly during all visual surveying techniques used, statistical analysis was concentrated on this species. Harbour porpoises were recorded singly, in pairs and in small groups during land-based watches, also described by Berrow *et al*. (2009). When the porpoise data from the three former sites were statistically analysed, Black Head was significantly different from the other two (Fanore and Spiddal). Harbour porpoises were sighted on 58% of visits at Black Head in contrast to 36% and 29% at Fanore and Spiddal respectively. The largest relative abundance of harbour porpoises was also found at Black Head (2.12 hr^{-1}) by comparison with Spiddal (0.69 hr^{-1}) and Fanore (0.79 hr^{-1}). These relative abundance estimates are very similar to those generated by Weir *et al.* (2007) off Aberdeenshire waters in the UK. They report on harbour porpoise relative abundance estimates determined from two sites, as ranging from 0.20 to 1.84 hr^{-1} from a total of 228 hours of effort, while in Galway Bay relative abundance estimates ranged from 0.69 to 2.12 hr^{-1}. Black Head also showed high rates of porpoise sightings when compared to five other sites around the Irish coast. Two of the sites used in this comparison, Slea Head and Castle Point, are located within already designated SACs. This indicates the importance of the habitat offered by Galway Bay for the Irish harbour porpoise population. Statistical analysis of the data from all methods of visual surveying showed there was no seasonal variation in the density of porpoises in the bay. This result conflicts with those from two previous Irish studies. Although not statistically analysed, Berrow *et al.* (2002) showed harbour porpoise to be most frequently recorded during the months June to August, with few sightings in the winter and spring. Published reviews of incidental sightings from Cape Clear, show porpoises to be recorded in all months, but there was an increase in the number of sightings in the autumn (August to October) (Preston 1975). As previously pointed out by Northridge *et al.* (1995), the seasonal movement of harbour porpoises has been the topic of much speculation. Suggestions include inshore–offshore movements, as well as east-west and north-south migrations. Harbour porpoise calves were only recorded in Galway Bay on two occasions and therefore there is no strong evidence to suggest that Galway Bay is a calving ground. However it must be noted that the timing of these sightings does coincide with the calving period of this species in the North Sea (Lockyer 1995).

It must also be noted that in Galway Bay, as with previous studies (Clarke 1982; Evans and Chappell 1994, Palka 1996; and Teilmann 2003), sea state had a profound effect on the recording of harbour porpoise. Porpoises were most frequently recorded at a sea state between 0 and 1 (79-83%), while the number of sightings recorded at a sea state 2 were between 17 and 21%. It is recommended that surveys for harbour porpoise are not carried out in a sea state greater than one. If surveys are carried out during a sea state 2 or greater, then the data should be treated with caution and adjusted to compensate for a decrease in the probability of sighting.

There was no evidence to suggest that phases of the tidal cycle influenced the occurrence of harbour porpoises or their behaviour, and therefore no inference can be made that porpoises use certain sites in Galway Bay at a certain state of tide for specific activities such as foraging, as highlighted from previous studies in other locations (e.g. Pierpoint *et al.* 1994). The latter authors describe the behaviour of harbour porpoises in tidal races, and how these animals always orientate themselves by facing into the tidal stream, and went on to describe a behaviour which the authors interpret as foraging. Silva *et al.* (1999) presented results from land-based observations, and found the number of harbour porpoise sightings were low at 09.00h and continued to decrease throughout the day. The authors also showed the number of sightings to be at a minimum at the high and low water stage of the tidal cycle, while most sightings were recorded at the stage of the tidal cycle when the level was 1m below the height of high water.

Results from static acoustic monitoring gave similar results to those generated from visual sightings in the bay. This method also showed harbour porpoise to be the most frequently detected species (88% of days monitored), while dolphins were rarely recorded (5% of days monitored). The sighting success rate of harbour porpoise from visual surveys was much less than the detection success rate from acoustic monitoring. SAM provides data, 24 hours a day, 7 days a week, therefore out-competing visual surveys, since data can be collected outside of daylight hours and in all weather conditions. As previously pointed out, sea state has a severe impact on an observer's ability to visually record harbour porpoise. This is not a limiting factor for SAM, which also eliminates inter-observer variation. The results from SAM in Galway Bay emphasise the importance of such techniques for surveying and monitoring harbour porpoises. The results showed that harbour porpoises were present at the site off Spiddal almost daily. A clear seasonal pattern was found with a maximum occurring in autumn and winter, and a minimum number of detections occurring in spring and summer. SAM provided data that can detect trends (such as seasonal) over a shorter time period than visual observations, and thus the importance of this method is crucial for long-term monitoring programmes, especially in SACs. However, SAM does have limitations, in that it does not provide data on densities and some researchers have reported on inter-unit variation (Dähne *et al.* 2006; Kyhn *et al.* 2008). It is suggested that this problem will be addressed with future generations of the T-POD.

Harbour porpoises are thought to be the most abundant species in Irish waters, and a number of abundance estimates have been carried out to date. Berrow *et al*. (2008; 2009) carried out abundance estimates for harbour porpoises in the Blasket Islands SAC, North County Dublin, Dublin Bay, Cork Coast, Roaringwater Bay SAC and Galway Bay (Table 17). Density estimates generated for Galway Bay were lower than all the others except the Cork coast. However, the overall abundance estimate was over two times greater than those at all other sites. Furthermore, Berrow *et al.* (2008) recorded the highest number of individuals in Galway Bay, while the proportion of adults to calves was 7%. Abundance estimates were also generated as part of the present study even though flaws existed in the sampling design. As the angular position of each sighting was not recorded, this value was entered as the midpoint angles of 60° either side of dead ahead (30° and 330°), in order to conform with the requirements of DISTANCE. The abundance estimates provide a measure of the numbers of porpoises likely to be present in the bay and can therefore be compared with density estimates recently generated for the area. A density estimate of 0.29 harbour porpoises km^{-2} in Galway Bay was generated from dedicated transects and 0.44km^{-2} from POP surveys and are similar to most previous density estimates carried out in Irish waters. Hammond *et al.* (2002) generated a density estimate of 0.18 harbour porpoises km^{-2} in the Celtic Sea, while in 2006, Hammond and MacLeod (2006) generated a density estimate 0.41 km^{-2} for the Celtic Sea, and 0.37km^{-2} for coastal Ireland (Table 17). The density estimate from Galway Bay is considerably lower than that generated for the area by Berrow *et al.* (2009). The latter authors estimated there to be 402 (±84.1), with a density estimate of 0.73 porpoises km^{-2}. IWDG (2007) estimated there to be somewhere in the region of 100,000 harbour porpoises in Irish waters, therefore Galway Bay alone could hold between 0.4% within 547 km^2 as determined by Berrow *et al.* (2009).

When line transect sampling is used during density and abundance estimates, it is assumed that g(0)=1. However, as harbour porpoises are elusive, not easily spotted, exhibit a responsive movement to vessels and spend only a short time at the surface it is likely that g(0) is actually less than 1. In this case it could be argued that the density estimate should be adjusted. Read and Westgate (1995) estimated that harbour porpoises spend approximately 5% of their time with dorsal fins showing above the surface of the water. These animals are therefore undetectable visually 95% of the time, and the latter authors suggest the adjustment of data to correct for submerged animals whilst performing line-transects when estimating porpoise abundance. It is also likely that this harbour porpoises abundance and density estimate for Galway Bay is underestimated as only single platform surveying took place, with a single observer on board during the present study, while Berrow *et al.* (2009) also used single platform, but used two primary observers.

In Galway Bay, harbour porpoises appear to have a preference for shallower coastal waters. Barlow (1988) found the abundance of harbour porpoises along the California, Oregon, and Washington coasts to be roughly constant from shore to 55m, then declining linearly with depth, and he found that no harbour porpoises were detected in waters deeper than 110m.

The lack of bottlenose dolphin sightings recorded over the duration of the study in Galway Bay is apparent, even though Galway Bay is located approximately 80km north of the Shannon Estuary where Ireland's only resident group of bottlenose dolphins are found. Photo-identification found no matches between the Shannon Estuary, or Cardigan Bay in Wales. However, the four bottlenose dolphin matches obtained between Galway Bay, Clew Bay, Youghal and Cork Harbour, highlights the large-scale movements of these non-resident dolphins, as Galway Bay is approximately 400km north of Cork Harbour. These large scale movements highlight a difficulty in demarcating single contiguous protection areas for this species. The re-sighting of the deformed individual between Galway Bay and Clew Bay, shows that although this animal exhibits a very pronounced spinal deformity, it can function efficiently i.e. swimming and feeding.

101 harbour porpoise sightings were recorded from land-based observations, by comparison with three sightings of bottlenose dolphins. 31 sightings of harbour porpoise were recorded during dedicated transects, while only five sightings were recorded of bottlenose dolphins, and a similar trend was observed during POP surveys. The number of bottlenose dolphins recorded during the present study may be atypical given the higher numbers recorded at Fanore in the past (IWDG data). While the data did not support robust statistical analysis, observations from Fanore in other years, 1994-1999 suggest that dolphins were more common than during the present study. Caution must be expressed in using the present study for the assessment of the bottlenose dolphins in Galway Bay.

Nonetheless, the data from the two years does support designation of Galway Bay as an SAC for the harbour porpoise.

CONCLUSIONS

The primary aim of the present study was to evaluate the site usage of harbour porpoises and bottlenose dolphins within Galway Bay, and the suitability of this site for designation as an SAC. Parts of Galway Bay are currently designated as marine cSACs, including inner Galway and Ballyvaughan Bays, Inis Mór and Kilkieran Bay, but the Annex II cetacean species, harbour porpoise and bottlenose dolphin, are not included in their remits. It is clear that harbour porpoises are widespread and regularly recorded in all seasons. The abundance estimates generated for Galway Bay are not as high as in the Blasket Islands cSAC, but they are of similar order to density estimates from other locations (Table 18). The habitat is ecologically significant since animals are present throughout the year. As Galway Bay is already designated as an SAC, the inclusion of harbour porpoises on its remit is warranted. The research carried out in Galway Bay between 2005 and 2007 does not support the area being designated for bottlenose dolphins. They were rarely recorded, usually observed in small numbers and there was no evidence of a resident population. These bottlenose dolphin results from the present study should be treated with some caution, however, given the significantly high numbers recorded in the past from Fanore.

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APPENDIX 2: LIST OF TABLES

Table 2. Number of watches carried out in Galway Bay; including number of sightings and relative abundance using all species from each site (watch duration n=100 minutes).

Site	No.of watches	No. of watches when HP recorded	%	Total no. of HP	Relative abundance (harbour porpoises hour^{-1})
Black Head	31	18	58	110	2.12 hr^{-1}
Spiddal	28	8	29	32.5	0.69 hr^{-1}
Fanore	29	10	36	38.5	0.79 hr^{-1}

Table 3. Calculations of harbour porpoise relative abundance from Black Head, Spiddal and Fanore, 2005-2007.

Site	No. of watches	Latitude	Longitude	No. of watches when sightings recorded	%	Relative abundance (animals sighted per hour of watch effort)
Lettermullen	**17**	53 13.820	09 44.959	0	0	0
Spiddal	**28**	54 14.450	09 18.335	11	39	0.97 hr^{-1}
Mutton Is.	**15**	53 15.439	09 05.487	2	13	0.12 hr^{-1}
Finavarra	**18**	53 09.812	09 04.348	1	6	0.10 hr^{-1}
Black Head	**31**	53 09.229	09 15.816	19	61	2.36 hr^{-1}
Fanore	**29**	53 06.670	09 17.462	12	41	1.44 hr^{-1}

Table 4. Results from ANOVA carried out on land-based data from Black Head, Spiddal and Fanore.

Source of variation	df	SS	MS	F	P
Location	2	321.72	160.86	1.68	0.19
Season	3	120.08	40.3	6.76	0.01
Season*Location	6	201.17	33.53	1.41	0.25

Table 5. Contingency table showing the number of harbour porpoises at various times of the tidal cycle, and chi-square results.

		Tidal cycle			Chi-square results		
Location		**Slack**	**Flood**	**Ebb**	**Chi^2**	**df**	**P**
Black Head	Total +	8	5	10	1.832	2	0.40
	Total -	2	2	8			
Fanore	Total +	11	7	12	0.01	2	0.99
	Total -	6	4	7			
Spiddal	Total +	2	2	4	0.963	2	0.62
	Total -	8	4	6			

Table 6. Percentage of watches carried out in sea state 0-1 from Spiddal, Black Head and Fanore.

Location	**% of watches carried out over the various sea states**			
	0	1	2	4
Spiddal	12	28	56	4
Black Head	13	42	42	3
Fanore	10	38	31	21

Table 7. Contingency table showing the number of harbour porpoises at various sea states at Black Head, Fanore and Spiddal.

Location		**Sea state**			**Chi-square results**		
		0	**1**	**2**	**Chi²**	**df**	**P**
Black Head	**Total +**	6	10	3	9.761	2	0.01
	Total -	0	4	8			
Fanore	**Total +**	3	11	13	2.493	2	0.29
	Total -	0	6	11			
Spiddal	**Total +**	3	4	2	3.3	2	0.19
	Total -	2	6	10			

Table 8. Contingency table showing the behaviour types exhibited by harbour porpoises at various states of tide at Black Head, Fanore, and Spiddal. Chi-square=5.013, *df*=6, P=0.54.

Behaviour	**Tidal cycle**		
	S	**F**	**E**
Fast travel	17	15	11
Slow normal surfacing	11	14	9
Foraging	5	3	0
Milling	2	2	3

Table 9. Relative abundance estimates of harbour porpoises from around Ireland (IWDG data), including data from Galway Bay.

Location	**County**	**No. of watches**	**Total time (minutes)**	**Total Individuals**	**Relative abundance (HP hr^{-1})**
Slea Head*	Kerry	35	4565	128	1.68
Castle Point*	Cork	16	1315	25	1.14
Galley Head	Cork	19	1300	13	0.59
Ram Head	Waterford	24	2690	12	0.27
Ramore Head	Antrim	18	2035	17	0.5
Black Head	Clare	31	3100	110	2.11
Fanore	Clare	24	2400	38.5	0.96
Spiddal	Galway	19	1900	32.5	1.01

Table 10. Results from ANOVA carried out on land-based data from Black Head, Spiddal and Fanore.

Source of variation	df	SS	MS	F	P
Region	2	711.19	355.60	29.5	0.0
Season	3	124.67	41.56	3.86	0.05
Season*Region	6	178.92	29.82	2.77	0.08
Location(Region)	3	36.08	12.03	1.12	0.39
Season*Location(Region)	9	96.92	10.77	0.49	0.87

Table 11. Number of dedicated transects carried out in Galway Bay including species, number of sightings and individuals recorded. Species key; HP-Harbour porpoise, BND-Bottlenose dolphin, MW-Minke whale, CD-Common dolphin, Dol. Sp.-Dolphin species.

Date	Vessel	No. of sightings.	Species	Numbers
31.05.2005	Maiden Mara	3	HP	6
29.06.2005	Maiden Mara	6	HP+BND	9+12
09.08.2005	Maiden Mara	2	HP	9
05.09.2005	Maiden Mara	4	HP+BND	7+3
12.12.2005	Maiden Mara	1	HP	1
09.02.2006	Maiden Mara	0	0	0
14.03.2006	Maiden Mara	1	BND	1
27.04.2006	Maiden Mara	0	0	0
11.05.2006	Maiden Mara	16	HP+MW	18+2
04.07.2006	Maiden Mara	4	HP+CD	8+14
03.10.2006	Maiden Mara	1	CD	30
09.11.2006	Maiden Mara	1	Dol. sp	1
26.03.2007	Maiden Mara	1	BND	85
12.04.2007	Maiden Mara	2	BND+HP	2+2
Relative abundance of HP/hr			0.71 HP/hr	

Table 12. Results from DISTANCE analysis performed on dedicated transects, using the half-normal cosine model (estimate of animals in specified area, approximately 547km^2 , (D=density, ESW=effective search width)

Total lines surveyed (km)	N +/- (95% CI)	CV	D	A/v cluster size	ESW
1239	102 (49-212)	0.36	0.29	1.68	97

Table 13. Surveys carried out on POPs in Galway Bay, including number of sightings, species and relative abundance estimates. Species key as in Table 8.

Date	Vessel	No.of Sightings	Species	Numbers	Effort	Rel. abundance Animals/km
14.02.2005	Celtic Voyager	0	0	0	53 km	0
22.03.2005	Stenland	0	0	0	103 km	0
31.03.2005	Stenland	0	0	0	103 km	0
19.04.2005	Stenland	1	BND	4	103 km	0.03
12.05.2005	Stenland	1	HP	1	103 km	0.009
09.06.2005	Stenland	1	HP	2	103 km	0.019
24.06.2005	Stenland	1	HP	2	103 km	0.019
07.08.2005	Island Ferries	3	HP	6	93 km	0.06
18.08.2005	IslandFerries	1	HP	2	93 km	0.02
18.03.2006	Celtic Explorer	0	0	0	130 km	0
19.03.2006	Celtic Explorer	0	0	0	55.5 km	0
05.06.2006	Maiden Mara	5	HP/MW	11+1	43 km	0.27
06.06.2006	Mamaia	2	HP	4	103 km	0.038
21.07.2006	Mamaia	1	HP	1	103 km	0.009
25.07.2006	Mamaia	0	0	0	103 km	0
21.10.2006	Mamaia	0	0	0	103 km	0
02.02.2007	Celtic Voyager	3	HP	7	30 km	0.23
03.05.2007	Island Ferries	1	CD	2	40 km	0.05
29.05.2007	Island Ferries	1	HP	2	40 km	0.05
Total Relative Abundance				**45**	1607.5	**0.02/km**

Table 14. Results from DISTANCE analysis as generated from POPs.

Total lines surveyed (km)	N (95% CI)	CV	D	A/v cluster size	ESW
926	154 (81-294)	0.32	0.44	1.38	107

Table 15. Summary of bottlenose dolphin relative abundance in Galway Bay, generated from land-based and vessel based observations.

Survey Method	Location	No.of sightings	Total no. of Individuals	% of sightings	Total effort (km/hr^{-1})	Relative abundance Per (km/hr^{-1})
Land-based	Black Head	0	0	0	52 hr	0 hr^{-1}
	Spiddal	2	11	10	47 hr	0.23 hr^{-1}
	Fanore	1	19	4	48.5 hr	0.39 hr^{-1}
	Total Relative Abundance from land based observations					**0.2 BND/hr^{-1}**
Dedicated	Galway Bay	5	103	11	1239 km	0.08km^{-1}/1.33hr^{-1}
POPS	Galway Bay	1	4	4	1607.5km	0.002km^{-1}/0.03hr^{--1}

Table 16. Number of strandings recorded in Galway Bay from February 2005 to 2007.

Date	Species	Sex	Length (m)	Location
23.04.2005	Bottlenose dolphin	Male	2.95	Inis Mór, Aran Islands
17.03.2006	Pilot whale	-	6.8	Renvyle Point,
08.07.2006	Common dolphin	Male	2.0	Traught, Kinvarra
21.07.2006	Humpback whale	Male	6.0	Inverin
09.08.2006	Striped dolphin	Male	-	White Strand, Galway
08.09.2006	Bottlenose dolphin	Female	-	Maree, Oranmore
13.12.2006	Common dolphin	-	1.92	Barna
16.12.2006	Cuvier's beaked whale	-	6.7	Inisheer
30.12.2006	Common dolphin	-	1.5	Inis Mór
02.01.2007	Bottlenose dolphin	-	3.35	Inishmaan
07.01.2007	Common dolphin	Male	2.0	Salthill, Galway
05.09.2007	Harbour porpoise (calf)	Male	1.02	Oranmore

Table 18. Harbour porpoise abundance estimates previously carried out in Irish waters.

Survey area	Density (animals km-^{2})	CV	Abundance	Source
Inshore west coast	0.77	0.49	19,210	Leopold *et al*. (1992)
Celtic Sea	0.18	0.57	36,280	Hammond *et al*. (2002)
Celtic Sea	0.41	0.50	80,613	Hammond and MacLeod (2006)
Irish Sea	0.34	0.35	15,230	Hammond and MacLeod (2006)
Coastal Ireland	0.28	0.37	10,716	Hammond and MacLeod (2006)
Offshoreshelf edge[1]	0.07	1.24	10,002	Hammond and MacLeod (2006)
Blasket Islands	1.33	0.25	303	Berrow *et al.* (2007)
Galway Bay	0.73	0.21	402	Berrow *et al.* (2008)
Cork coast	0.53	0.33	138	Berrow *et al.* (2008)
Roaringwater Bay	1.24	0.21	159	Berrow *et al.* (2008)
Dublin Bay	1.19	0.24	138	Berrow *et al.* (2008)
North County Dublin	2.03	0.22	211	Berrow *et al.* (2008)

Table 17. Summary table of static acoustic data recorded in Galway Bay (%PPH=percentage porpoise positive hours, PPM/hr=porpoise positive minutes per hour, %DPH=percentage dolphin positive hours, DPM/hr=percentage dolphin positive minutes per hour.

Details				Porpoise detections				Dolphin detections			
Year	Location	Month	No. days deployed	% of days with porpoise detections	%PPH	Total PPM	PPM/hour	% of days with dolphin detections	%DPH	Total DPM	DPM/hour
2006	Spiddal	May	20	100	22	241	0.5	5	0.2	1	0.002
	Spiddal	June	17	94	18	165	0.4	0	0	0	0
	Spiddal	July	28	100	21	271	0.4	4	0.1	1	0.001
	Spiddal	August	17	94	17	129	0.3	6	0.2	1	0.002
	Spiddal	October	29	97	40	1001	1.4	0	0	0	0
	Spiddal	November	31	100	24	637	0.85	5	0.1	1	0.001
	Spiddal	December	23	100	21	265	0.48	0	0	0	0
2007	Spiddal	February	28	43	2	22	0.03	0	0	0	0
	Spiddal	March	26	58	4	50	0.08	4	0.1	1	0.001
	Spiddal	April	19	100	14	179	0.39	0	0	0	0
	Spiddal	May	31	97	19	373	0.5	0	0	0	0
	Spiddal	June	19	100	12	136	0.29	0	0	0	0
	Spiddal	July	10	100	6	102	0.42	0	10	23	0.09
	Spiddal	September	30	73	9	104	0.1	7	0.2	2	0.002
	Spiddal	October	5	80	8	16	0.13	0	0	0	0
2007	Gleninagh	May	16	38	4	32	0.08	13	0.5	2	0.005
	Gleninagh	June	30	40	4	60	0.08	0	0	0	0
	Gleninagh	July	31	48	3	64	0.08	3	0.1	1	0.001
	Gleninagh	August	31	35	2	39	0.05	6	0.4	3	0.004

APPENDIX 3: LIST OF FIGURES

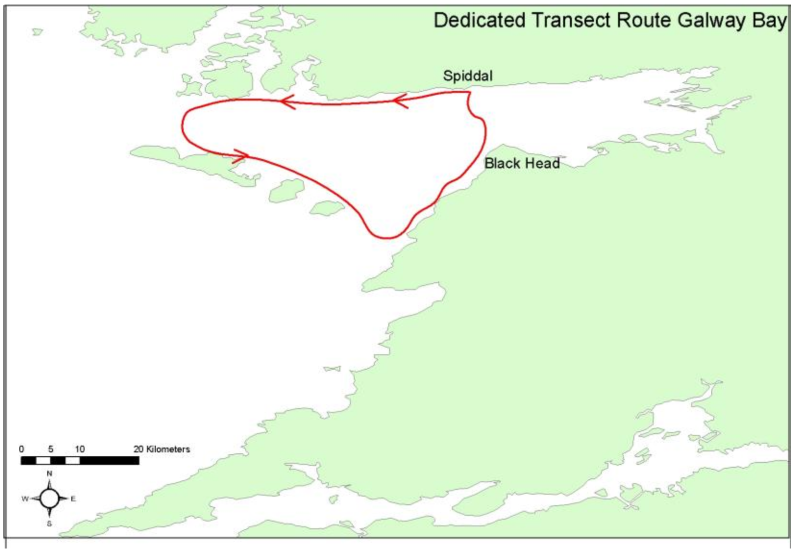


Figure 2. Dedicated transect route followed during each transect in Galway Bay.

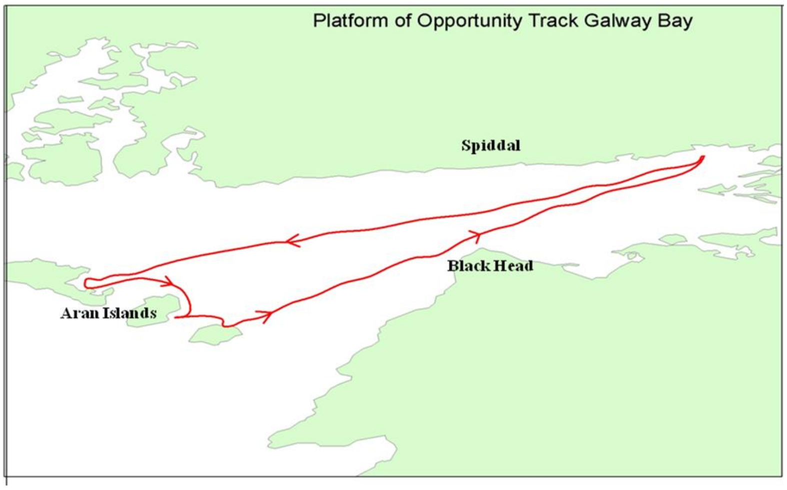


Figure 3. POP route in Galway Bay on board the M.V. Mamaiya.

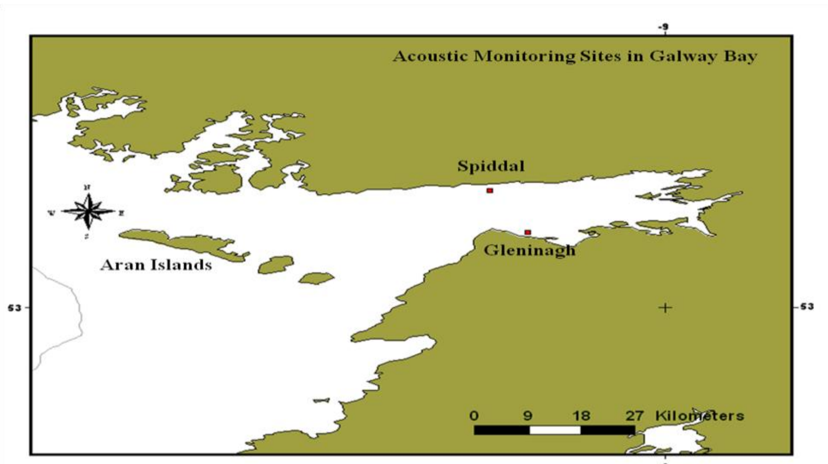


Figure 4. Acoustic monitoring sites in Galway Bay where T-PODs were deployed.

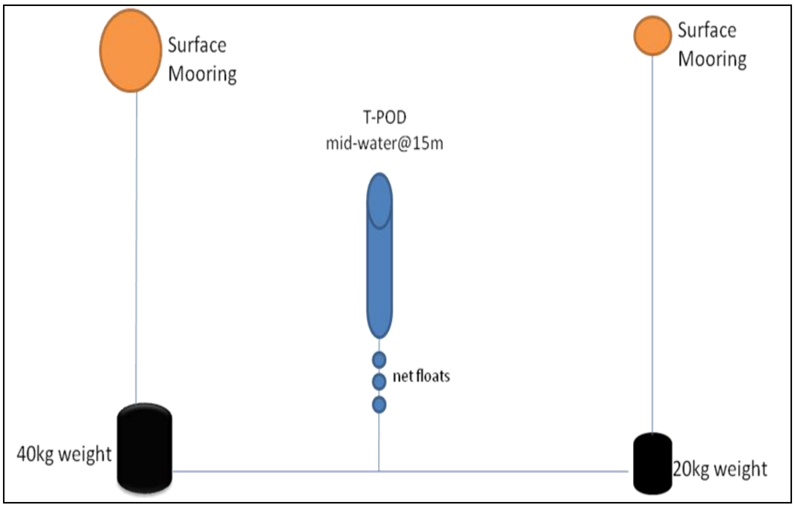


Figure 5. Mooring system used to deploy T-PODs in Galway Bay.

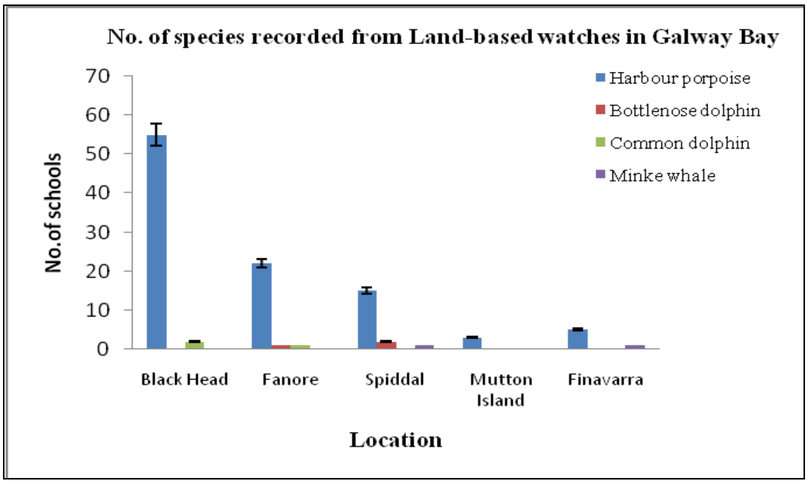


Figure 6. Breakdown of species sightings as recorded between locations.

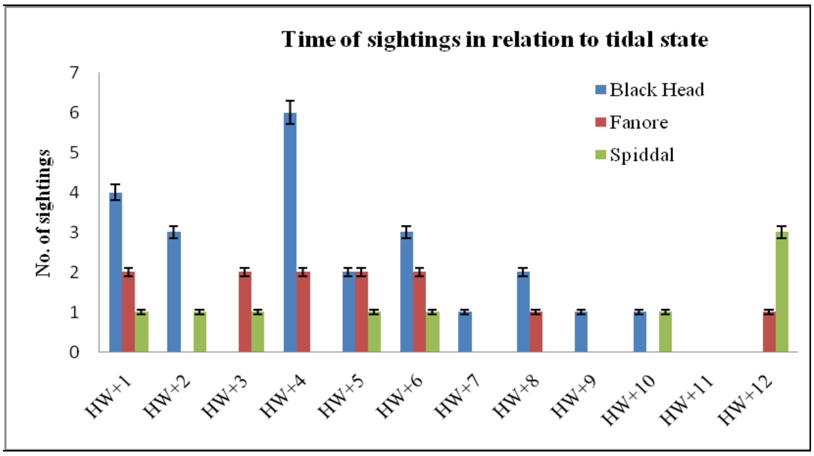


Figure 7. Number of sightings recorded at various hours of the tidal cycle in Galway Bay.

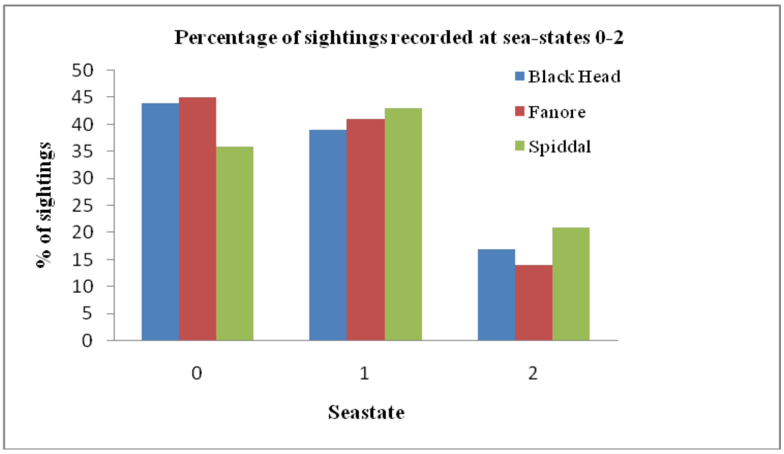


Figure 8. Number of sightings recorded from sites in Galway Bay, at various sea states.

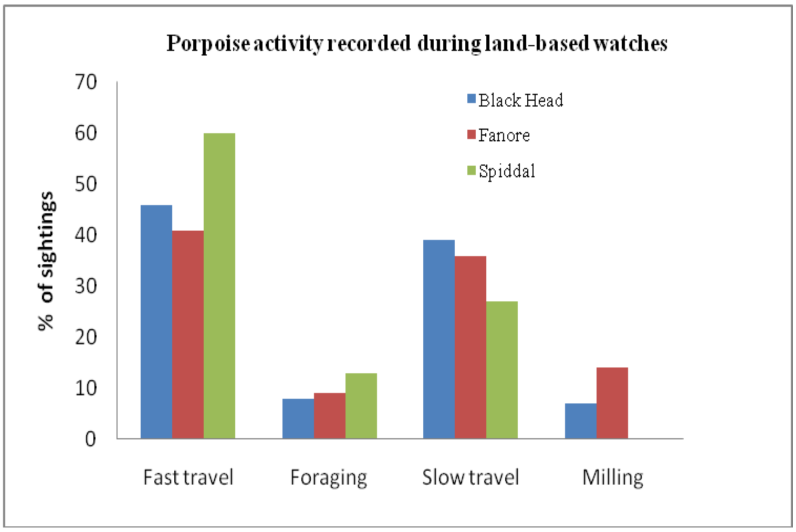


Figure 9. Harbour porpoise behavioural categories recorded during land-based watches from Black Head, Fanore and Spiddal.

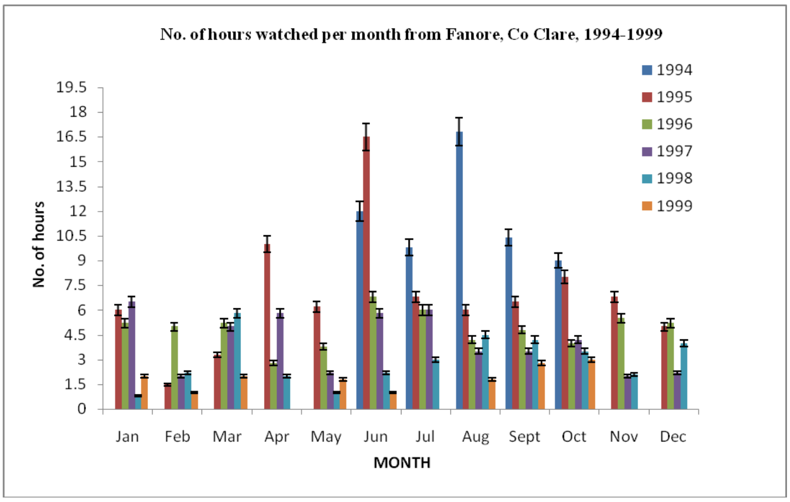


Figure 10. Number of hours watched per month from Fanore, (source www.iwdg.ie).

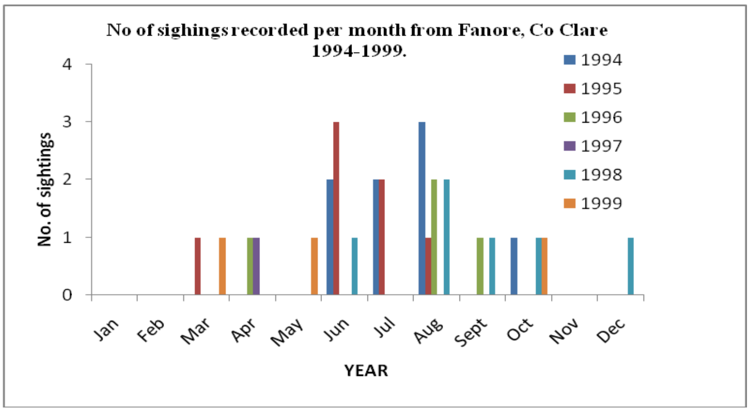


Figure 11. Number sightings recorded per month from Fanore, Co. Clare, (source www.iwdg.ie).

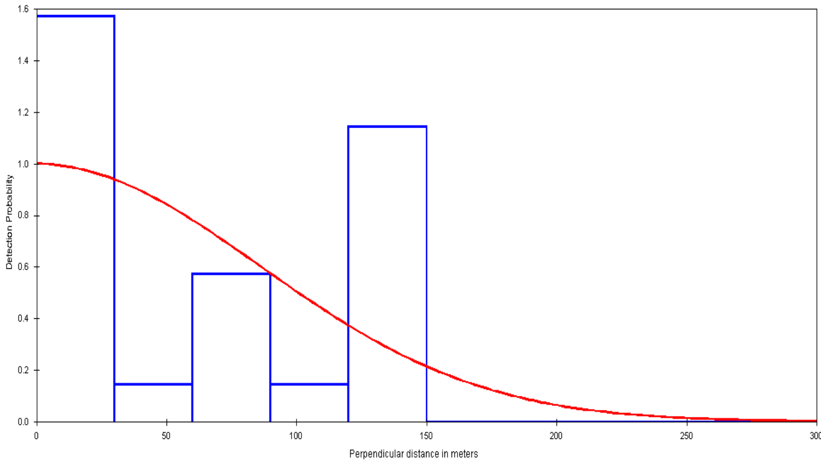


Figure 13. Distance Analysis: Detection probability plot from POP data in Galway Bay, ($\chi^2$12.4, df=3, P=0.006).

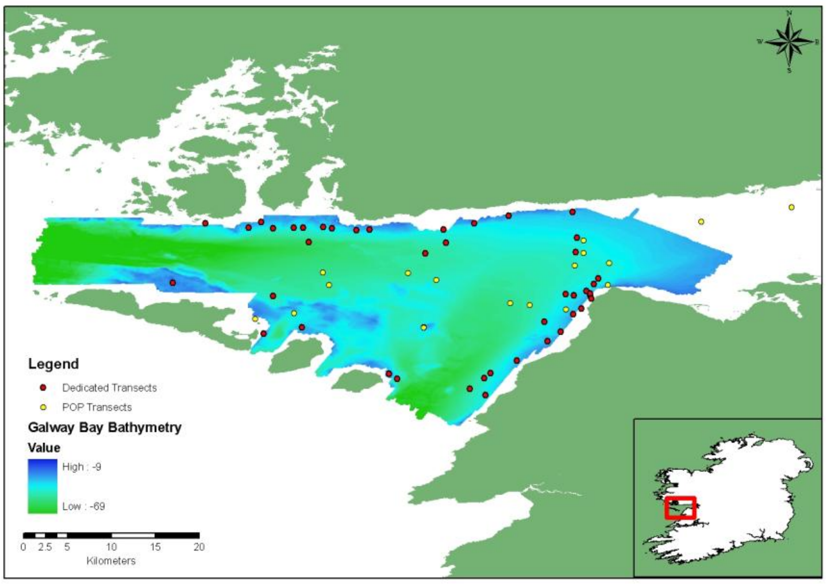
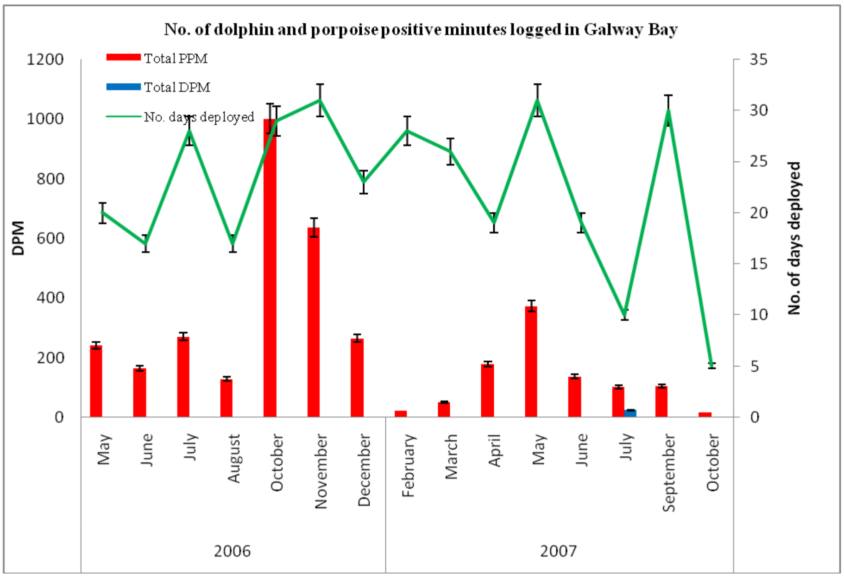


Figure 14. Galway Bay bathymetry, overlain by harbour porpoise sightings recorded from all vessel-based methods.



2006 **2007**

Figure 15. Graph of *porpoise positive minutes* and *dolphin positive minutes* as detected in Galway Bay.

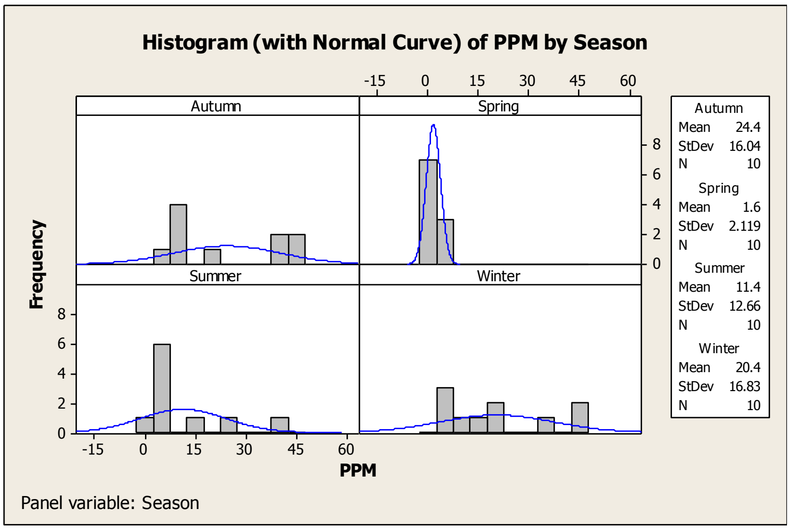


Figure 16. Descriptive statistics of harbour porpoise *dpm* as detected over seasons

CHAPTER 3

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN CLEW BAY: AN EVALUATION OF MONITORING TECHNIQUES AND ASSESSMENT OF SITE SUITABILITY FOR FUTURE SAC DESIGNATION

ABSTRACT

Land and vessel-based visual surveying for small cetaceans, in particular bottlenose dolphins and harbour porpoise was conducted in Clew Bay between May and September, 2005 and 2007. Simultaneous static acoustic monitoring (SAM) was also carried out using T-PODs from a site east of Clare Island for 234 days. A total of two cetacean species were recorded in the bay over the study duration from dedicated land and vessel-based surveying. Vessel-based surveying took place on board dedicated survey vessels, while land-based quantified effort watches were carried out from 5 headlands around the bay. The bottlenose dolphin was the most frequently recorded cetacean from visual observations, while harbour porpoise was the most frequently detected species during acoustic monitoring. A total of 11 individual bottlenose dolphins were identified through photo-identification, and four individuals were re-sighted on a second occasion within the bay. One individual with a condition described as scoliosis identified in Galway Bay in 2005 was re-sighted in Clew Bay in July and August 2007. The overall aim of the present study was to explore the distribution and abundance of small cetaceans within the bay in order to assess the suitability of this site for future SAC designation.

INTRODUCTION

All species of cetaceans present in European waters are protected under Annex IV of the EU Habitats Directive (92/43/EEC) and Amendment (378/2005). Harbour porpoises and bottlenose dolphins, which are recognised as species of European Community interest are listed under Annex II of this Directive, and therefore require the designation of Special Areas of Conservation (SAC's). The EU Habitats Directive states that a site, which "*corresponds to the ecological requirements of the species*", may be designated as an SAC. The Directive also states that relating to the selection of sites eligible for identification of community importance "*for aquatic species which range over wide areas, such sites shall be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction*". The management of Ireland's nature conservation under National, European and International law is the responsibility of the National Parks and Wildlife Service (NPWS) of the Department of the Environment Heritage and Local Government, and therefore NPWS are responsible for the designation of SACs (Buckley 2004). To date, the Blasket Islands (Co Kerry) and Roaringwater Bay (Co Cork) are the only sites designated as SAC's in Irish coastal waters for harbour porpoise, while the Shannon Estuary is the only designated SAC for bottlenose dolphins. The aim of the present study was to assess the suitability of Clew Bay for designation as SAC for harbour porpoises and bottlenose dolphins.

Cetaceans in Clew Bay; An overview

Of the 24 cetacean species recorded in Irish waters, 16 have been recorded in the Clew Bay region from historical to present times. Five species are known from both strandings and sightings, four species are known only from visual sightings, while seven species are known only from strandings (Table 1). One species, the beluga whale, was recorded in Clew Bay on two consecutive days in 1948, a species previously unrecorded in Irish waters (O'Riordan 1972).

Table 1. Cetacean species observed visually or recorded stranded in Clew Bay.

Species	Visually recorded	Reference	Stranded	Reference
Bottlenose dolphin	*	www.iwdg.ie	*	www.iwdg.ie
Harbour porpoise	*	www.iwdg.ie	*	Anon (1996)
Common dolphin	*	www.iwdg.ie	*	Harmer and Fraser (1914-1974)
Killer whale	*	www.iwdg.ie	*	O'Riordan (1972)
Minke whale	*	www.iwdg.ie		
Pilot whale			*	Fairley and Wilkins (1980)
Risso's dolphin	*	www.iwdg.ie		
Sperm whale			*	Fairley (1979)
False killer whale			*	O'Riordan (1982)
Atlantic white-sided dolphin	*	www.iwdg.ie	*	Moffat (1938)
Cuvier's beaked whale			*	Harmer and Fraser (1914-1974)
Fin whale	*	www.iwdg.ie		
Striped dolphin			*	Fairley and Doherty (1987)
True's beaked whale			*	Viney and Fairley (1983)
White-beaked dolphin			*	www.iwdg.ie
Beluga	*	O'Riordan (1972)		

Study area

Clew Bay is located on the west coast of Ireland, 90km north of Galway Bay. The inner bay consists of a complex series of interlocking channels with 365 small islands. It is shallow with an average depth of 10m increasing seawards to an average depth of 20m and has a maximum tidal range of 5m. The bay is open to westerly swells and winds from the Atlantic with Clare Island approximately 5km from the mainland providing a small amount of protection (Figure 1). Clew Bay supports a wide variety of diverse habitats from seashore to dunes, coastal grasslands as well as salt marsh, bog and fen, all of which are listed under Annex I of the EU Habitats Directive (Clew Bay Complex, Site Synopsis, www.npws.ie). The bay also supports important populations of otter and common seals, both of which species are listed under Annex II of the same directive. At present, no cetacean species are included on the remit of the site's synopsis.

For the purposes of the present study, land-based quantified effort watches and dedicated vessel-based surveys were used to generate measures of relative abundance within the bay, aimed at assessing its potential for designation as an SAC for harbour porpoise, bottlenose dolphin or both. It was envisaged that capture-recapture techniques would be used to generate an abundance estimate of bottlenose dolphins in the area, but due to the low re-capture rate, this was not feasible. Passive acoustic monitoring was also carried out in the bay, in order to obtain information on cetaceans using the area outside of the visual survey period May to September (2005-07), and additionally during night-time hours and adverse weather conditions.

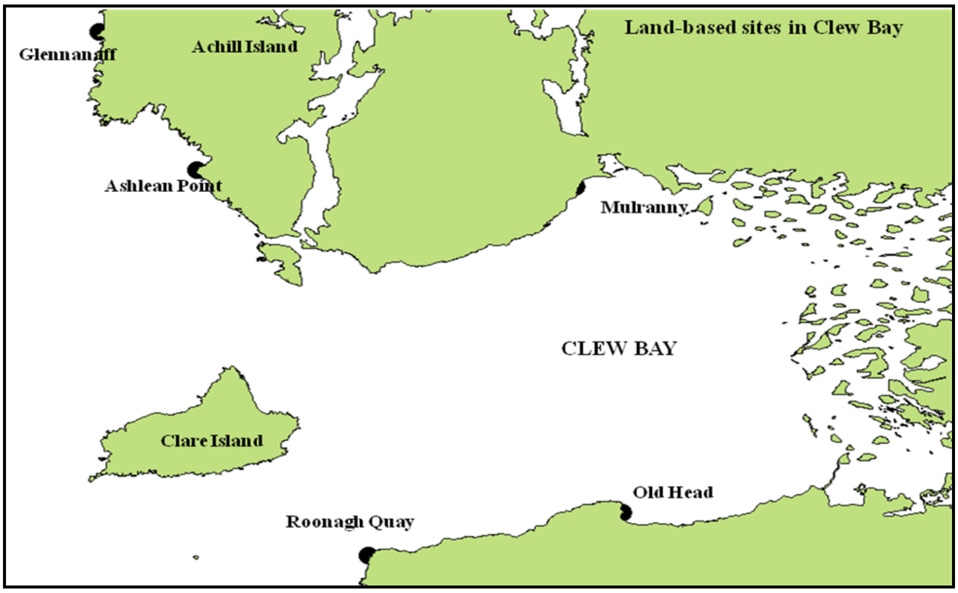


Figure 1. Map of Clew Bay study area, including locations where land-based observations were carried out.

MATERIALS AND METHODS: VISUAL SURVEYING TECHNIQUES

Data collection

Land- and vessel-based surveying was used to monitor the distribution and abundance of cetacean species in Clew Bay. A single observer was used during all observations to eliminate inter-observer variability encountered when multiple observers are used (Young and Peace 1999; O'Brien *et al*. 2006). The same optical equipment was used during land-based quantified effort watches and dedicated transects, thereby standardising the collection of data and making observations comparable. Evans and Hammond (2004) suggest that visual surveys should generally not be carried out in sea states above Beaufort scale 2, as the probability of detecting animals is markedly reduced above this. Furthermore, Palka (1996) found that the sighting rate of harbour porpoises in Beaufort sea state 1 was 80% of that in sea state 0 and that sighting rates in sea state 2 and 3 were approximately 25% of that in Beaufort 0. Clarke (1982) also reported a decrease in the probability of detecting animals with increasing sea state. Based upon the results and recommendations from the studies described above, all visual observations were, where possible, only carried out in sea state two or less. Optical instruments used during visual observations included binoculars (Opticron, 7X50) and a spotting scope (Kowa 20X).

Binoculars alone were used during boat-based observations. Environmental conditions were recorded at regular intervals for the duration of all surveys. Details recorded included sea state, wind speed and direction, cloud cover and visibility. When a sighting was made the observed species was identified, as well as the numbers of groups and the number of individuals present. A group was defined as a solitary animal or aggregation of animals, observed in apparent association, moving in the same direction, and exhibiting similar behaviour where a member was within 10m of any other member in the first 10 minutes that the animals were observed (Shane 1990; Smolker *et al.* 1993). The presence of juveniles or calves was also noted. A calf was defined as an individual no more than two-thirds the length of an adult (Shane 1990). An estimated distance of the observed animals from the vantage point or vessel was recorded, direction of travel, surfacing mode as well as the behaviour exhibited by the animals.

Land-based watches

Land-based quantified effort watches were carried out in Clew Bay during two years, 2005 and 2006. A total of three months were sampled in the first year- June, August and November, while June and July were sampled during 2006 (Table 2). The duration of each watch was 100 minutes, enabling the amount of effort to be quantified, and therefore allowing the generation of relative abundance estimates (animals sighted per hour). Land-based sites were not randomly chosen, but were selected upon a number of criteria such as 1) ease of accessibility to the site, 2) view of the surrounding area offered by the site, 3) sites offering an elevated vantage point and 4) personal security of the observer (watch site not too remote). When a sighting was made, information such as that listed above was recorded.

Dedicated transects

Dedicated cetacean ship-based surveys can cover a large area, and provide a means of systematically sampling an area, but they can be expensive due to the cost of ship time. They also provide an opportunity for the application of other methods such as photo-identification (Würsig and Würsig 1977), capture re-capture analysis (Wilson *et al.* 1999), and line transect sampling (Hammond *et al.* 1995). Under the present study, the first dedicated transects were carried out in Clew Bay in June and July, 2006, while a further four surveys were carried out in 2007 (June, July, August and September). A 6.5m rigid inflatable (RIB) was used during dedicated transects in the bay. Although not ideal due to its low observation deck, a rib was used in order to make use of weather windows, as larger angling vessels were not flexible due to requiring up to a week's notice prior to a survey. The survey followed a route from Newport, west out to Roonagh Quay, towards Clare Island, and east towards Achillbeg. From there, the route was directed west along the coast of Achill Island, and out towards the Bills rocks, and from there back to Clare Island and into Newport along the northern shore of Clew Bay (Figure 3). Surveys typically lasted for six to eight hours, depending on the number of sightings encountered. All surveys were carried out in a Beaufort sea-state of two or less, in order to minimise the number of missed sightings due to the effect of increasing sea state (Evans and Hammond 2004). The survey track averaged 110km and conducted at a speed of 15km hr^{-1} to 20km/hr^{-1}. During each survey, the observer was positioned on the bow of the vessel and an arc dead ahead and 60° to either side was constantly scanned for the presence of cetaceans. Roughly 60% of scans were done using binoculars and the remainder by eye. When a sighting was made, a note of the start and end time of that sighting was recorded, along with the ships position using a Garmin handheld GPS. Information on the observed species recorded included distance from the track-line of the vessel, confidence in species identification (definite, probable, possible) the number of animals observed and behaviour. Environmental conditions (sea state, swell height, wind speed and direction) were recorded every half hour. When a sighting was made during dedicated transects, the track-line was abandoned. This was done for a number of reasons including: 1) getting closer to the animals to enable more accurate species identification, 2) to enable more accurate estimation of the number of individuals present, 3) to record the presence of calves or juveniles, and 4) to attain photographic images of bottlenose dolphins for photo-identification purposes.

Equipment

A Canon 20D digital camera with an auto focus 300mm lens was used for the purpose of capturing images of the observed dolphins. If dolphins were located during a transect, the track line was abandoned and the boat approached the animals slowly in order to minimise interference. During an encounter, attempts were made to photograph all individuals present. On some occasions, groups were quickly lost or some animals avoided the boat. When all animals were photographed or a behavioural change such as tail slapping or boat avoidance was evident, then the boat left the vicinity of the animals. The track line was then resumed and visual observations recommenced.

Analysis of Bottlenose dolphin images for photo-identification

All images were downloaded from the Canon 20D camera onto a laptop computer and stored in a folder labelled as location, trip number and date. Images were then sorted in accordance with their quality and any unusable ones were deleted. In order to start identifying individual animals, single images were selected and identifiable qualities unique to single animals, such as nicks, marks, scratches or identifiable skin pigmentations were determined. Fin tracings were done of dorsal fins with nicks evident, while any scratches or marks were drawn onto fin tracings, as this aided the identification and recognition process. Images were identified by eye, using Adobe Photoshop elements 2.0 and those images suitable for identification were then printed, enabling the construction of a photo-identification catalogue. This consisted of an A4 folder with a page detailing information for each dolphin identified. Details included identifiable marks, date first seen, location and associations if any with other animals. The catalogue was divided into a number of sections according to identifiable traits. These sections included: 1) one nick, 2) two nicks, 3) three nicks, 4) four or more nicks 5) scratches or pale marks, and 6) deformities. This provided a means to search for animals according to their identifiable traits, while was also consistent with the SDWF (Shannon Dolphin and Wildlife Foundation) Shannon dolphin photo-identification catalogue.

Static Acoustic Monitoring

SAM was carried out in Clew Bay through the use of acoustic devices called T-PODs (Timed Porpoise Detectors). T-PODs are manufactured by Chelonia LTD in the UK. These units consist of a self contained hydrophone that logs the times and the duration of echolocation clicks produced by dolphin species and harbour porpoises. These units are powered by 12 lithium D-celled batteries and have 128 megabytes of memory. Version 4 and 5 T-PODs were used for the duration of this study. A single T-POD was deployed off a salmon cage belonging to Clare Island Sea Farm, at their Portlee site, on the eastern side of Clare Island (Figure 1), between April 2006 and September 2007 for various periods of time (Table 5). T-PODs were put into net bags, and a rope ran from the top end of the bag to the surface where it was tied off the side of the salmon cage. A second rope was attached to the bottom end of the bag, and a free floating weight was suspended from the end. This was to ensure the T-POD remained in a vertical position, and to prevent it from floating to the surface as the units are positively buoyant. The T-POD was positioned at mid-water, 15m, as both dolphins and harbour porpoise were the targeted species.

All T-PODs were set to detect both harbour porpoise and dolphin species using the generic setting specified by the manufacturers Chelonia (www.chelonia.co.uk) (Table 4). Operational settings using a click bandwidth of 5 was used for all three dolphin channels, while a click bandwidth of 4 was used for all three 130kHz porpoise channels. Based on previous work carried out in the Shannon Estuary where Philpott *et al.* (2007) found that on a rare occasion (2.6% of total click train detected) bottlenose dolphin click trains were logged in porpoise channels. This reduction in bandwidth should reduce the incidence of high frequency dolphin clicks being classified in porpoise channels. Therefore, all click trains logged in the 130kHz channels were assumed to be of porpoise origin.

To facilitate statistical analysis, acoustic data were extracted from all files as detection positive minutes per day (*dpm)*, detection positive minutes per hour (*dph),* and number of encounters per day. The data collected during 2006 and 2007 were combined and classified according to season (spring, summer, autumn and winter) in order to explore the effect of temporal distribution. A total of nine random days were chosen (using random number tables) from each season. Statistical analysis was carried out using Minitab 15. Unequal variances were confirmed using a Levene's test, and non parametric Kruskal-Wallis was the chosen test statistic. *Post hoc* Mann-Whitney U-tests using the Bonferroni correction were used to determine where these differences existed. The significance level of *post* hoc tests was reduced from 0.05 to 0.01, as four pair-wise comparisons were carried out.

RESULTS

Results: Land-Based Observations

Thirty quantified effort land-based watches have been carried out in the region, spread across five sites, between 2005 and 2006, equating to 50 hours of quantified effort watching. Of the 30 watches carried out, cetaceans were only recorded on two occasions, both in July 2006 (Table 2). The first cetacean sighting of a single harbour porpoise was recorded from Old Head on the south shore of the bay, while the second sighting recorded was of a group of 12 bottlenose dolphins, including one calf from the vantage point at Mulranny. A relative abundance of 0.26 cetaceans/hr^{-1} was generated for the Clew Bay region, or broken down to species level this equates to 0.02 harbour porpoise/hr, and 0.24 bottlenose dolphins hr^{-1}. Due to the low sighting rate, statistical analysis was not feasible.

Results: Dedicated transects

Two dedicated transects were carried out in Clew Bay during summer 2006, while a further four transects were carried out during summer 2007 (Table 3). Only a single cetacean sighting was recorded in 2006, and this was of three individuals, which could only be identified as whale species due to the briefness of the encounter. In June 2007 a group of bottlenose dolphins were located in close proximity to salmon cages operated by Clare Island Seafarm, at their Portlee site. Four individuals were present and images were obtained of all dolphins for photo-identification purposes. One individual present had a mild spinal deformity. Immediately behind the dorsal fin, a curve on the spine was evident and in this region a lot of tooth rake marks were present. This individual did not seem to have any trouble swimming or keeping up with the rest of the group, neither was this individual any smaller than other members of the group. During a dedicated transect in July 2007, six bottlenose dolphins were located off Achillbeg. These animals were very active, and ignored the presence of the boat. They exhibited a lot of aerial jumping and the group comprised male and female dolphins, as the sexes of some individuals could be determined due to aerial activity. A deformed individual was also present in this group, but this was a different animal to that identified on the survey the previous month. In fact, no individuals identified on the previous survey were re-sighted on this transect. However, upon analysis of images captured with those previously captured in Galway Bay, it was found that one of the deformed individuals observed in Clew Bay (no. 1), was the same individual recorded in Galway Bay in June, 2005 (Berrow and O'Brien 2005). During the August survey of the same year, bottlenose dolphins were again located around the salmon farm at the Portlee site off Clare Island. On this occasion, six individuals were present including the dolphin with the spinal deformity observed the previous month and in Galway Bay two years previously. Four of the other individuals present had been photographed the previous month. Photographic images were obtained of the sixth member of the group and this animal had not previously been recorded. No sightings were recorded during the September survey. A relative abundance of 0.02 bottlenose dolphins km^{-1} was generated from the sightings recorded during dedicated transects. In summary, a total of 11 individual bottlenose dolphins were identified in Clew Bay from transects carried out in 2007. Of these individuals identified, four were re-sighted on a second occasion within the bay, and one individual with a condition described as scoliosis identified in Galway Bay in 2005 (Berrow and O'Brien 2005), was re-sighted in Clew Bay in July and August 2007.

Results: Static Acoustic Monitoring

Acoustic monitoring was carried out in Clew Bay for 234. Harbour porpoises were detected on average 89% of days monitored, while dolphin detections were recorded on average 37% of the time. Although the harbour porpoise was almost detected on a daily basis, the presence of these animals within the vicinity of the T-POD was very short, with a range of 0.07 minutes to 4.47 minutes per hour of deployment (see PPM/hour, Table 5). On average, porpoise detections were logged during 23% of the total hours monitored, while dolphins were logged during 5% of total hours. The highest number of porpoise positive minutes (1,352 PPM), was recorded in October 2006. The highest number of dolphin positive minutes (118 DPM*)* was recorded in August 2007.

Effect of Seasonality

Non parametric Kruskal-Wallis tests showed that there was a significant difference in the number of porpoise detections between the seasons (P=0.004). However, no significant effect was found between seasons for the dolphin data (P=0.85). *Post hoc* Mann-Whitney U-tests were performed on the porpoise data to what seasons were significantly different to each other. A Bonferroni correction reduced the significance of *post hoc* tests from 0.05 to 0.01, as a total of 4 pair-wise comparisons were carried out. Results confirmed that winter was significantly different from spring (P=0.006), summer (P=0.002), and autumn (P=0.008), with more porpoise detections logged over the winter months (Figure 6).

DISCUSSION

Of the 24 cetacean species recorded in Irish waters, 67% have been either visually recorded or recorded stranded in Clew Bay. Clew Bay has been the focus of little previous dedicated cetacean surveys. In fact, data only exist from casual sightings and incidental strandings reported to the Irish Whale and Dolphin Group as part of its sighting and stranding scheme, in operation since 1991. Prior to this scheme, some records of sightings and strandings in the area were reported in a number of reviews (Harmer and Fraser 1914-1974, Moffat 1938, O'Riordan 1972, Evans 1981) and through the Irish Naturalists' Journal.

Results from land-based watching carried out in Clew Bay as part of the present study yielded a surprisingly low number of sightings, especially since observations were carried out from sites which offered excellent elevated views of the bay. Results from the two survey techniques used in this area, show that one species the bottlenose dolphin was more frequently encountered than any other. In fact, harbour porpoises were only recorded on a single occasion during a land-based watch from Old Head, in 2006, and were never recorded during the six dedicated transects carried out in the bay.

Photo-identification is a technique commonly used to study the movements and behaviour of whales and dolphins worldwide, and was first applied to bottlenose dolphins by Würsig and Würsig (1977). Photo-identification works on the principle of photographing individual animals and picking out natural markings unique to individuals (Würsig and Würsig 1977; Wilson *et al.* 1999; Rogan *et al.* 2000; Ingram and Rogan 2003; Englund *et al.* 2007). For many dolphin and whale species, these marks are present on their dorsal fins, while others possess unique marks on their bodies e.g. the under surface of the tail fluke. The trailing edge of a bottlenose dolphin's dorsal fin is very thin and is readily tattered during the animal's life (Würsig and Würsig 1977). Other teeth marks and pigment bites are also found on the dolphin's fin and other body parts but usually only last from 6 months to a year (Würsig and Würsig 1977). In Ireland, photo-identification was originally used to determine the movements and site fidelity of bottlenose dolphins in the Shannon Estuary (Berrow *et al*. 1996; Ingram 2000), and other sites along the south and west coasts including Cork Harbour, Connemara and North Mayo (Ingram *et al*. 2001; 2003; O'Cadhla *et al.* 2003; O'Brien *et al*. 2006). It has also been used successfully to investigate inter- and intra- annual movements of fin and humpback whales along the south and west coast of Ireland (Whooley *et al*. 2005). Photo-identification can also be used in conjunction with capture-recapture methods in order to generate absolute abundance estimates of a population. In Ireland, three abundance estimates have been made for a resident group of bottlenose dolphin in the Shannon Estuary on the west coast of Ireland using small scale dedicated transects and Capture-Recapture methodology. Population sizes of 113±16 bottlenose dolphins in 1997 (Ingram, 2000), 121±14 (CV=0.12, 95%CI=103-163) in 2003 (Ingram and Rogan 2003) and 140 ±12 (CV=0.08, 95% CI 125-174) in 2006 (Englund *et al.* 2007). This technique is extremely powerful and, with the development of digital cameras, is accessible to both researchers and the general public. Photo-identification may also be applied to other species (e.g. common and Risso's dolphins) to explore their movements, home range and longevity, although there can be limitations when only a small proportion of the population is well marked (Evans and Hammond 2004). The deformed individual recorded in Galway Bay in June 2006 was a definite match for the deformed dolphin recorded in Clew Bay in July and August 2007.

On both occasions that this individual was observed in Clew Bay, it was involved in behaviour associated with mating, due to the amount of surface rolling, splashing and aerial behaviour. None of the group members that this animal was in association with in Galway Bay were present in Clew Bay. Due to the low level of individuals identified in this region, combined with few re-sightings, the data were not robust enough to apply the capture-recapture technique to estimate absolute abundance.

It is apparent from static acoustic monitoring results in Clew Bay that harbour porpoises are frequently detected within the bay. Harbour porpoises were found to be detected on 89% of days monitored in the area. This result is in stark contrast with results from land and vessel-based visual surveys carried out within the region, where harbour porpoises were only sighted on a single occasion during a land-based effort watch and never during boat-based surveys. The absence of porpoises during dedicated transects of the bay is most likely attributed to the observer platform, as a rib is not a suitable platform from which to carry out observations for these small inconspicuous animals. Dawson *et al.* (2008), suggest that increased height allows observers to see animals further away and lessens the incidence of a responsive movement. Dolphin detections were recorded in lesser numbers (on 37% of days) than porpoise detections, and this contrasts with vessel-based surveys where bottlenose dolphins were most frequently recorded. Acoustic data can provide more robust datasets than visual observations, as they can acquire data 24 hours a day, and even in adverse weather conditions. Although porpoises were recorded frequently, these encounters were short. This could be due to the range of the T-POD, as these devices were found to be most sensitive at 50 to 100m, with few detection recorded beyond 250m (Tougaard *et al.* 2006). In summary, the acoustic data from Clew Bay gives a whole new dimension to the knowledge of cetaceans in the bay. Results from land-based watches provide no data on the frequency of porpoises in the bay; in fact it would be concluded that they are rarely present in the bay if only visual data were relied upon. However, these acoustic data must be treated with caution as no information is available on the abundance of porpoises in the bay, and these detections may be attributed to a few individuals.

CONCLUSIONS

The present study serves as a brief overview of cetacean occurrence in Clew Bay, especially during the months May through to September from visual observations, but year-round from acoustic data. The most obvious factor is the absence of harbour porpoise sightings during visual surveys, with only one sighting of a single individual recorded. This may be attributed to animals been more active at night and therefore not in the area during the day. Their absence during dedicated transects may be attributed to the poor elevation offered by the observation platform. Therefore, it is recommended that future observations be carried out from an elevated platform to allow observers to see further away from the survey vessel. Bottlenose dolphins were frequently recorded and therefore it is also likely that their presence in this area could lead to elimination of the harbour porpoise. This is the opposite situation to Galway Bay, where O'Brien *et al.* (2008) found harbour porpoise to be the most frequently recorded species in an area where bottlenose dolphin encounters were rare. It is recommended that future work in this region focus on bottlenose dolphin populations and to include areas close-by such as the Killary Harbour, where this species has been regularly recorded over the years. This would enable the survey route to cover an area with a higher probability of encounter and would therefore make provisions for the feasibility of the capture-recapture technique to be carried out in the future. The present study highlights Clew Bay as a region where no quantified effort watches are regularly carried out and therefore an area which requires future focus. This study also highlights how important the use of static acoustic monitoring is for inconspicuous species like the harbour porpoise. Had it not been for acoustic data, their presence in the bay would not have gone undetected. However, as no information on harbour porpoise abundance could be generated as part of the present study, future research should be aimed at determining the size of the population in the area, as acoustic detections could be attributed to a few animals.

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APPENDIX 4: LIST OF TABLES

Table 2. Land-based quantified effort watches carried out in Clew Bay.

Location	Total no. of watches	No. of watches when sightings recorded	Species	No's	Relative abundance (cetaceans/hr)
Roonagh Quay	6	0	0	0	0
Old Head	6	1	Harbour porpoise	1	0.1
Mulranny	6	1	Bottlenose dolphin	12	1.2
Ashlean Point	6	0	0	0	0
Glennanaff	6	0	0	0	0
Total relative abundance					**0.26 cetaceans /hr**

Table 3. Number of dedicated transects carried out in Clew Bay including species, numbers recorded and effort.

Transect no.	Date	No. of sightings	Species	Numbers	Effort
1	15.06.2006	1	Unidentified whale sp	3	110km
2	19.07.2007	0	-	0	110km
3	11.06.2007	1	BND	1+4	110km
4	30.07.2007	1	BND	6	110km
5	28.08.2007	1	BND	6	110km
6	27.09.2007	0	-	0	110km

Table 4. Settings used during all T-POD deployments

Scan	1	2	3	4	5	6
Target A Filter reference kHz	50	130	50	130	50	130
Reference B Filter reference kHz	70	92	70	92	70	92
Click Bandwidth	5	4	5	4	5	4
Noise Adaptation (normal operational setting)	++	++	++	++	++	++
Sensitivity	6	6	6	6	6	6
Scan limit on N of clicks logged	240	240	240	240	240	240

Table 5. Summary of information gathered from Acoustic data over the deployment periods in Clew Bay (%PPH=the percentage of hour with porpoise detections, PPM/h=average number of minutes porpoises were detected for within each minute of that month), (%DPH=the percentage of dolphin positive days, DPM/h= average number of minutes dolphins were detected for within each hour of that month).

Details				Porpoise detections				Dolphin detections			
Year	Month	No. days deployed	Encounters/month	% of days with porpoise detections	%PPH	Total PPM	PPM/hour	% of days with dolphin detections	%DPH	Total DPM	DPM/hour
2006	April	10	36	80	11	49	0.2	20	2	10	0.04
	May	15	28	67	5	26	0.07	27	2	9	0.025
	June	17	84	100	15	132	0.3	18	1	9	0.02
	July	7	68	100	24	70	0.4	57	3	20	0.11
	Sept	10	74	50	19	229	0.9	30	5	14	0.05
	October	31	549	94	34	1352	1.81	45	5	60	0.08
	November	9	374	100	57	967	4.47	67	6	27	0.12
2007	February	20	212	90	23	474	0.98	75	13	116	0.24
	March	21	235	95	24	519	1.02	8	11	94	0.18
	June	20	122	100	16	144	0.3	45	5	72	0.15
	July	31	378	100	33	625	0.84	26	2	32	0.04
	August	31	351	100	28	487	0.65	23	3	118	0.15
	September	12	64	75	11	78	0.27	50	4	46	0.15

APPENDIX 5: LIST OF FIGURES

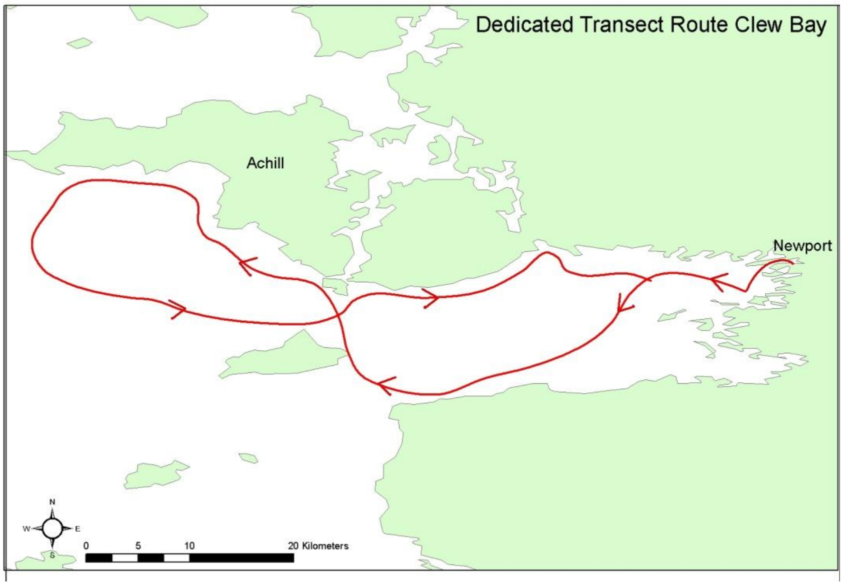


Figure 2. Dedicated transect route carried out in Clew Bay.

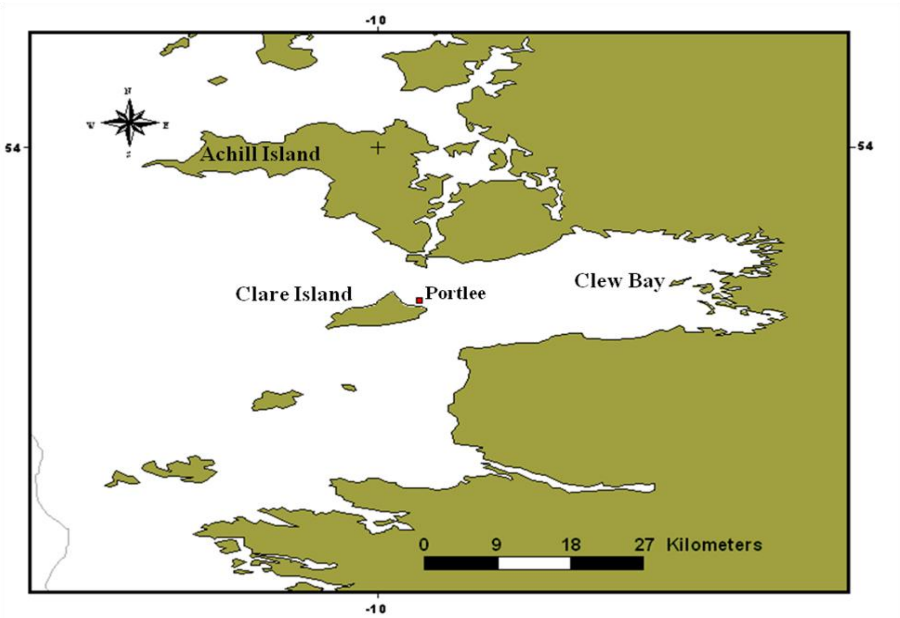


Figure 3. T-POD deployment location at Porlee, Clew Bay.

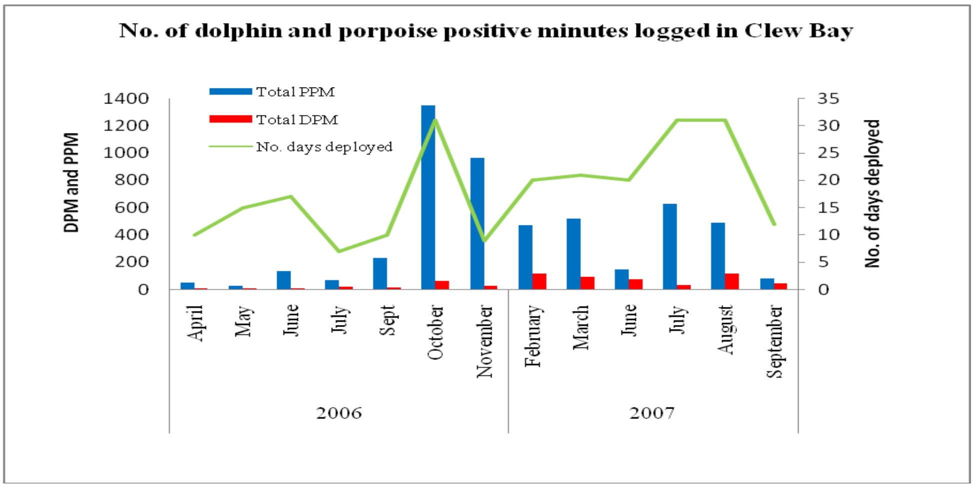


Figure 4. Distribution of DPM and PPM during all deployments in Clew Bay (N=234 days).

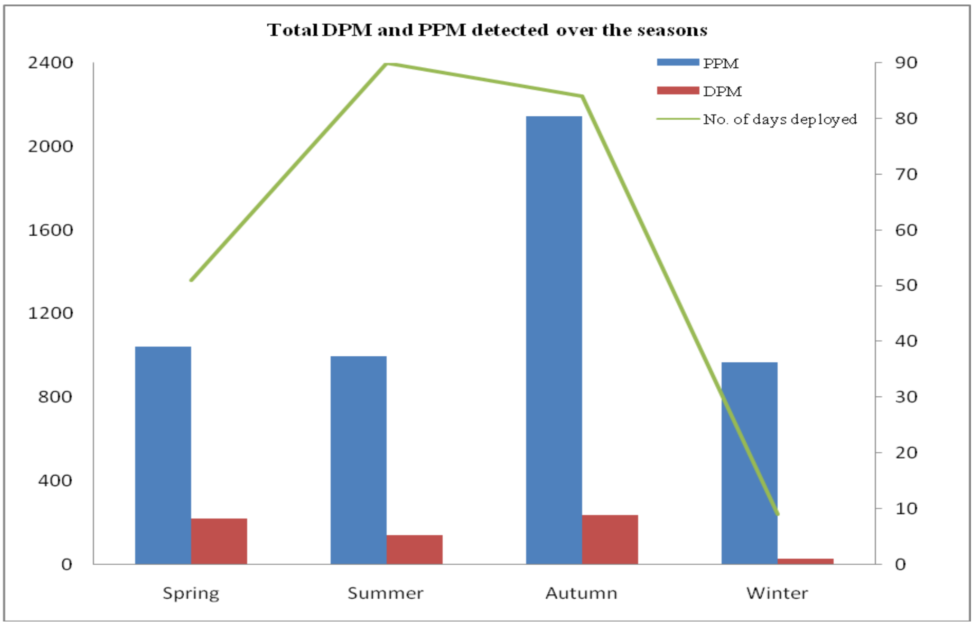


Figure 5. Number of dolphin and porpoise positive minutes recorded per season, in comparison with no. of days deployed.

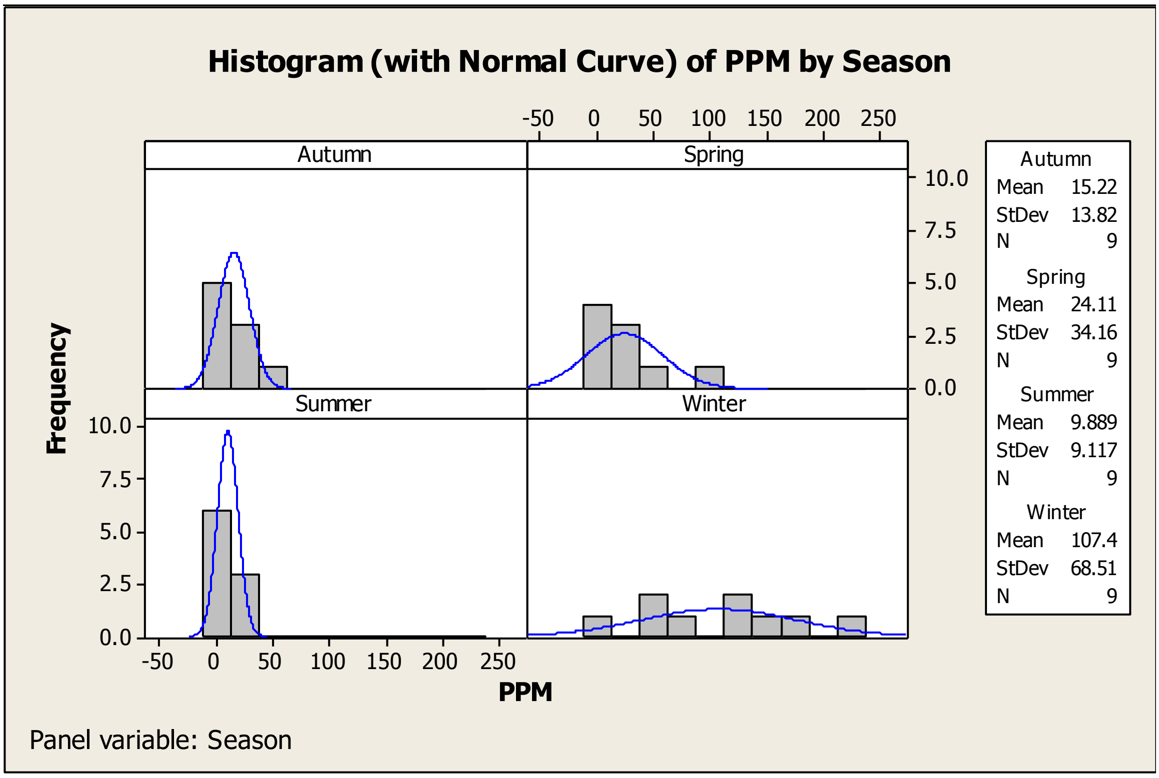


Figure 6. Porpoise positive minutes detected in Clew Bay throughout the seasons.

CHAPTER 4

STATIC ACOUSTIC MONITORING OF HARBOUR PORPOISES *(PHOCOENA PHOCOENA)* AND BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS)* ON THE WEST COAST OF IRELAND USING T-PODS

ABSTRACT

The present study was aimed at assessing the potential designation of Galway and Clew Bay as *Special Areas of Conservation* (SACs) and furthermore to investigate the efficacy of acoustics as a monitoring technique to meet statutory obligations, under the EU Habitats Directive. A static passive acoustic monitoring device called a T-POD was used to record the occurrence of small cetaceans at three locations on the west coast of Ireland (Galway Bay, Clew Bay and the Blasket Islands) over varying deployment durations. Long-term static acoustic monitoring (SAM) was carried out in Galway Bay and Clew Bay, while a 28 day deployment at two locations in the Blasket Islands took place. The short-term deployments in the Blaskets allowed for a comparison of harbour porpoise acoustic detection rates between areas of known importance for the species and potential SACs. Spatial and temporal variation of both harbour porpoise and dolphin data were explored using the parameters, season (spring, summer, autumn and winter), diel (day, night), tidal state (slack high, slack low, ebb and flood) and tidal phase (spring, neap). A significant seasonal component was identified in the long-term harbour porpoise dataset (Galway Bay and Clew Bay), with peak activity occurring during the winter months. A significant diel variation showed porpoises to be more active during the night time hours. No significant trends occurred across tidal state, but significantly more detections were logged during the tidal phase classed as spring. Localised fine scale spatial variation was found to exist in the porpoise data from Galway Bay, where significantly greater activity was recorded on the northern shore at Spiddal when compared with Gleninagh, some 10km apart. Further localised fine scale variation existed temporally in the Blasket Islands, where significantly more detections were logged during the day at Wild Bank when compared with Inishtooskert (P=0.00), while more detections were logged at Inishtooskert during the night when compared with Wild Bank (P=0.00). These two sites, Inishtooskert and Wild Bank are 10km apart. Dolphin detections from Clare Island were analysed separately, as detections from Spiddal were very rare. The T-POD cannot differentiate between dolphin species, therefore all dolphin detections from Clew Bay were assumed to be bottlenose dolphins as this was the most frequently sighted species during visual surveys in the area. No seasonal component was found to exist in the dolphin dataset (P=0.24), but significant temporal variation in the diel cycle (P=0.02) was shown with significantly more detections logged during the night-time period (P=0.01). No significant variation was found in detections between tidal state (P=0.40), or tidal phase (P=0.66). Although SAM using T-PODs cannot provide information on absolute abundance, it does provide information on occurrence outside of daylight hours and independent of weather

conditions and furthermore on localised fine scale temporal trends. The combination of visual and acoustic monitoring highlights Galway Bay as an important area for the harbour porpoise, warranting SAC designation. Clew Bay needs more targeted surveying over the seasons to generate abundance estimates.

INTRODUCTION

Under the EU Habitats Directive (1992), Ireland is obliged to designate Special Areas of Conservation (SAC) for the harbour porpoise *Phocoena phocoena* Linnaeus 1758 and bottlenose dolphin *Tursiops truncatus* Montagu 1821 and to provide strict protection to all cetacean species (listed under Annex IV) within the entire Irish Exclusive Economic Zone (EEZ). Currently two candidate SACs have been designated for the harbour porpoise (Blasket Islands and Roaringwater Bay and Islands) and one for bottlenose dolphins (Lower River Shannon), which are all located in the south west of the country. In order to identify sites that may qualify as an SAC, data are required on species distribution and abundance. Several areas have been the target of seasonal acoustic monitoring on the west, south and east coasts of Ireland (O'Cadhla *et al.* 2003; Ingram *et al.* 2004; Englund *et al*. 2006; Berrow *et al.* 2008; Berrow *et al.* 2009a), but none of these surveys focused on an area for more than six consecutive months. In order to evaluate the importance of an area, it is fundamental that the presence of small cetaceans at a site is fully understood and this requires monitoring over time scales of at least years. This must be underpinned through scientific research, from dedicated survey effort, both visual and acoustic. The combination of visual and acoustic techniques can prove very powerful, as one complements the other.

The various species of odontocetes that echolocate have different characteristics associated with their click production such as click duration, inter-click interval, frequency, source level, and range. The use of biosonar by porpoises and dolphins has been extensively studied (Au, 1993), and has shown that porpoise and dolphin sonar characteristics differ greatly from each other, therefore making it possible to differentiate between these species. Harbour porpoises use echolocation signals for foraging and orientation (Verfuß *et al.* 2005) and these signals are characterised as being narrow-band, high frequency between 110 and 150kHz, with a detection range (for a single fish of ingestible size) of up to 30m, while an average click has a duration of 2µs with a mean source level of 150dB re 1µPa @ 1m (Møhl and Andersen 1973; Goodson and Sturtivant 1996; Au *et al.* 1999; Carlström, 2005; Villadsgaard *et al.* 2007; Verfuß *et al.* 2007). Variations in inter-click intervals (ICIs) can be used to identify different acoustic behaviours such as feeding, approach behaviour and communication (Koschinski *et al*. 2008). Harbour porpoises also have a low frequency component to their click (2kHz), which Møhl and Andersen (1973) suggest may have communication value. Boat sonar and echo-sounders are the only sounds in the sea which are similar to harbour porpoise sonar, as other sounds are more broadband, have longer durations and occur at lower frequencies (Kyhn *et al.* 2008). The characteristics of the harbour porpoise echolocation sonar makes them ideal candidates for Static Acoustic Monitoring (SAM), especially since they seem to constantly echolocate (Akamatsu *et al.* 2007). Bottlenose dolphins also have a highly developed sonar system for discriminating, recognising and classifying objects (Azzaili *et al*. 1999; Pack *et al.* 2002; Branstetter *et al.* 2003 and DeLong *et al.* 2006). Evans (1973) reported that bottlenose dolphin echolocation clicks are broadband, of between 200Hz and 150kHz, with a peak energy at 30-60kHz with a source level of 40-80dB *re* 1 µbar @ 1m. In contrast, Au (2000) described bottlenose dolphin's echolocation clicks as having peak frequencies of 120 and 130kHz, with a source level of 220dB re 1µPa @ 1m, and duration of 40 to 60µs. More recently, Dos Santos and Almada (2004) described bottlenose dolphin clicks as having peak frequencies at 70kHz, close to the optimum hearing frequency of best hearing for bottlenose dolphins. Unlike harbour porpoises, bottlenose dolphins do not constantly echolocate. Studies in Sarasota Bay found that bottlenose dolphins can often swim for 10 minutes without echolocating and that their use of echolocation varied depending on water clarity (Au 2000). Studies showed that when dolphins were feeding in clear water, they rarely echolocate, but when they were feeding over grass flats, echolocation was used more often.

SAM involves the recording or detection of cetacean vocalisations or echolocation clicks and is a very valuable tool for the exploration of fine scale habitat use by the various odontocete species. SAM can be carried out with a number of devices including, static hydrophones (Berrow *et al.* 2006), T-PODs (Carlström 2005, Verfuß *et al.* 2007, Berrow *et al.* 2008, Berrow *et al.* 2009a), A-Tags (Akamatsu *et al.* 2008), porpoise click loggers (PCLs/Aquaclick), (Roos, 2007), Ecological Acoustic Recorders (EARs), (Lammers *et al*, 2008), Pop-Ups (http://www.birds.cornell.edu/brp/hardware/pop-ups) and sonobuoys (Moore *et al.* 1989). By comparison with SAM, visual observations carry with it many constraints and are influenced by variables such as sea state (Evans and Hammond, 2004; Teilmann, 2003; Palka, 1996; Clarke, 1982), observer variability (Young and Peace, 1999; O'Brien *et al*., 2006), optics and height above sea level. Evans and Hammond (2004) state that visual surveys should generally not be carried out in sea states above Beaufort scale 2, as the probability of detecting animals is strikingly reduced above this. SAM is especially useful for monitoring small vocal cetaceans since it can be carried out without the interference of the variables mentioned above, and most importantly does not negatively impact upon the animals. A SAM device called a Timed Porpoise Detector (T-POD) has been used during a number of studies for various purposes including environmental impact assessments (EIAs)

(Carstensen *et al.* 2006), interactions between cetaceans and fisheries (Cox *et al.* 2001; Leeney *et al.* 2007; Berrow *et al.* 2009b), monitoring population trends (Verfuß *et al.* 2007; Berrow *et al.* 2009a), and behaviour including diel and tidal trends in vocal activity (Carlström 2005). Initially, the POD or porpoise detector, designed and manufactured by Chelonia LTD (www.chelonia.co.uk) in the UK, was intended specifically to detect harbour porpoises, while more recent versions (T-PODs) were designed to detect both harbour porpoises and dolphins. The echolocation characteristics of porpoises and dolphins differ, but an overlap in frequencies can make the discrimination between species difficult. When using T-PODs where porpoises and dolphins co-exist, using filter settings of 50kHz with a reference of 70 or 90kHz will eliminate detections of porpoises in those channels. However due to a dolphins ability to echolocate across a wide range of frequencies (200Hz to 150kHz, Evans 1973) applying settings with a lower click bandwidth (e.g. 4) will reduce the number of dolphin clicks in the porpoise categories (Tregenza pers. comm.). The use of such settings makes the automated detection and discrimination between porpoise and dolphin species by the T-POD achievable. However, it is not possible to discriminate between dolphin species using POD data. As a monitoring tool, the T-POD essentially provides information on the presence of animals and gives a measure of vocalisation activity and behaviour. However, these data are non-quantitative in relation to showing how the number of clicks detected by a unit relates to the number of animals present (Ingram *et al.* 2004). A study by Tougaard *et al.* (2006) generated a measure of absolute density by assuming that sampling an area *n* times through SAM is equivalent to sampling *n* sub-areas e.g. during an aerial survey, and found that the estimate they generated from acoustic data was similar to that determined as part of an international SCANS project (Small Cetacean Abundance in the North Sea) survey conducted in July 1994. However this method of analysis is novel and has not been widely adapted.

The T-POD is equipped with a hydrophone element which is connected to two band pass filters, a comparator/detector circuit and a microprocessor which has memory capability to store information logged from the target species (Kyhn, 2006). All electronics are contained within a waterproof PVC housing. These devices are fully automated, and can detect harbour porpoises, dolphins and other toothed whales by recognising and logging details of echolocation click trains (www.chelonia.co.uk). The dedicated software T-POD.exe is used to download the data from the logger, which identifies and classifies click trains of cetacean origin. A T-POD runs six successive scans each of 9.3 seconds duration, and selects only tonal clicks and logs the time and duration of each click. However, sensitivities between units differ and therefore tank calibration tests are recommended prior to their deployment. These tests should determine the detection threshold of each unit as this is directly related to detection range (Kyhn *et al.* 2008). In addition, field calibrations are also recommended prior to employment of the devices in monitoring programmes in order to facilitate comparisons between datasets collected in different areas using multiple loggers (Dähne *et al.* 2006). A detection distance of over 1000m for T-PODs and bottlenose dolphins was generated in the Shannon Estuary by Philpott *et al.* (2007) using version three T-PODs, but it is likely that this may differ with more recent versions. Detection distances for the harbour porpoise and T-PODs were generated by Tougaard *et al.* 2006 (200m) and Villadsgaard *et al.* 2007 (300m to 500m).

The objective of the present study was to acoustically explore the occurrence of small cetaceans on the west coast of Ireland and to assess the suitability of two sites for SAC designation (Galway Bay and Clew Bay). Short term deployments in the Blasket Islands were used as comparisons with an already designated SAC as well as assessing the efficacy of SAM as a monitoring tool. Temporal trends such as seasonal variation, diel variation (day-night), influence of tidal state (ebb, flood, slack high, slack low) and tidal phase (spring, neap tides) were also explored and compared with results from visual observations carried out within the same areas (see O'Brien *et al.* 2008a; O'Brien *et al*. 2008b). No previous acoustic monitoring had been carried out in Galway Bay or Clew Bay. The spatial and temporal variation in the acoustic activity of small cetaceans on the west coast of Ireland was explored through testing the following hypotheses:

1. There is no temporal variation in the number of harbour porpoise detections between years (2006, 2007) or between the seasons, spring (February, March, April), summer (May, June, July), autumn (August, September, October) and winter (November, December, January).
2. There is no significant temporal variation in the number of harbour porpoise acoustic detections between the factors, diel cycle (day, night), tidal state (eb, flood, slack) and tidal phase (spring, neap).
3. There is no fine-scale variation in the number of porpoise positive days in Galway Bay (Spiddal and Gleninagh).
4. There is no fine scale variation between locations in the Blasket Islands across the temporal factors, diel and tidal states (Wildbank and Inishtooskert).

5. There is no significant temporal or spatial variation in harbour porpoise detections between the Blasket Islands (Inishtooskert and Wild Bank) and Clew Bay (Clare Island) over a 28 day sampling period.
6. Dolphin detections in Clew Bay do not vary over the factors, season, diel or tidal cycle.

MATERIALS AND METHODS

Study areas

Galway Bay is located between the lines of longitude of 8º55'W and 9º50'W and latitude of 53º00'N and 53º15'N (De Bhaldraithe 1977) and is bounded by the northern and southern shores of Counties Clare and Galway. It is one of the largest bays on the west coast of Ireland, and is about 50km long and from 10 to 30km wide. A chain of three islands, the Aran Islands, stretches across the mouth of the bay. These form a partial boundary between the bay and the Atlantic Ocean. Water exchange between the bay and the Atlantic is between four sounds, the North and South Sounds, Gregory and Foul Sounds. The meridian of 9º 16'W between Black Head and Spiddal conveniently divides Galway Bay into the inner and outer bays (Lei 1995). Depths range between 8-20m in the inner bay and 20-60m in the outer bay (Lei 1995; Nolan, 1997). Tidal range during springs is 4.5m and during neaps is 1.9m. T-PODs were deployed at two locations in Galway Bay (Figure 1). The first site was located 2km east of Spiddal pier within the Marine Institute's wave energy test site (N53º14' W9º14'), (333 days). This site was chosen as it provided a secure area, with no fishing activity taking place in the vicinity and furthermore the area was outside the main shipping route. The second site was located on the southern shore of the bay off Gleninagh (N53º08' W9º13') (108 days). Once again, the mooring was outside the main shipping channel and was not exposed to strong tidal currents this part of the bay is exposed to prevailing winds.

Clew Bay is 90km north of Galway Bay. The inner bay consists of a complex series of interlocking channels with 365 small islands. The inner bay is shallow with an average depth of 10m increasing seawards to an average depth of 20m, and has a maximum tidal range of 5m. The bay is open to westerly swells and winds from the Atlantic with Clare Island approximately 5km from the mainland providing a small amount of protection. T-PODs were deployed from salmon cages off the eastern site of Clare Island off Portlee (N53º49' W9º57', Figure 1), between April 2005, and September 2007 (234 days).

The Blasket Islands are a cluster of six main islands located off the Dingle Peninsula Co. Kerry. This area is open to Atlantic gales and westerly swells, and is one of two candidate SACs for harbour porpoise in Ireland. T-PODs were deployed in 2 locations for a 28 day period between July and August, 2007: Inishtooskert (N52º07 W10º34') and Wild Bank (N52º 03 W10º28') (Figure 1).

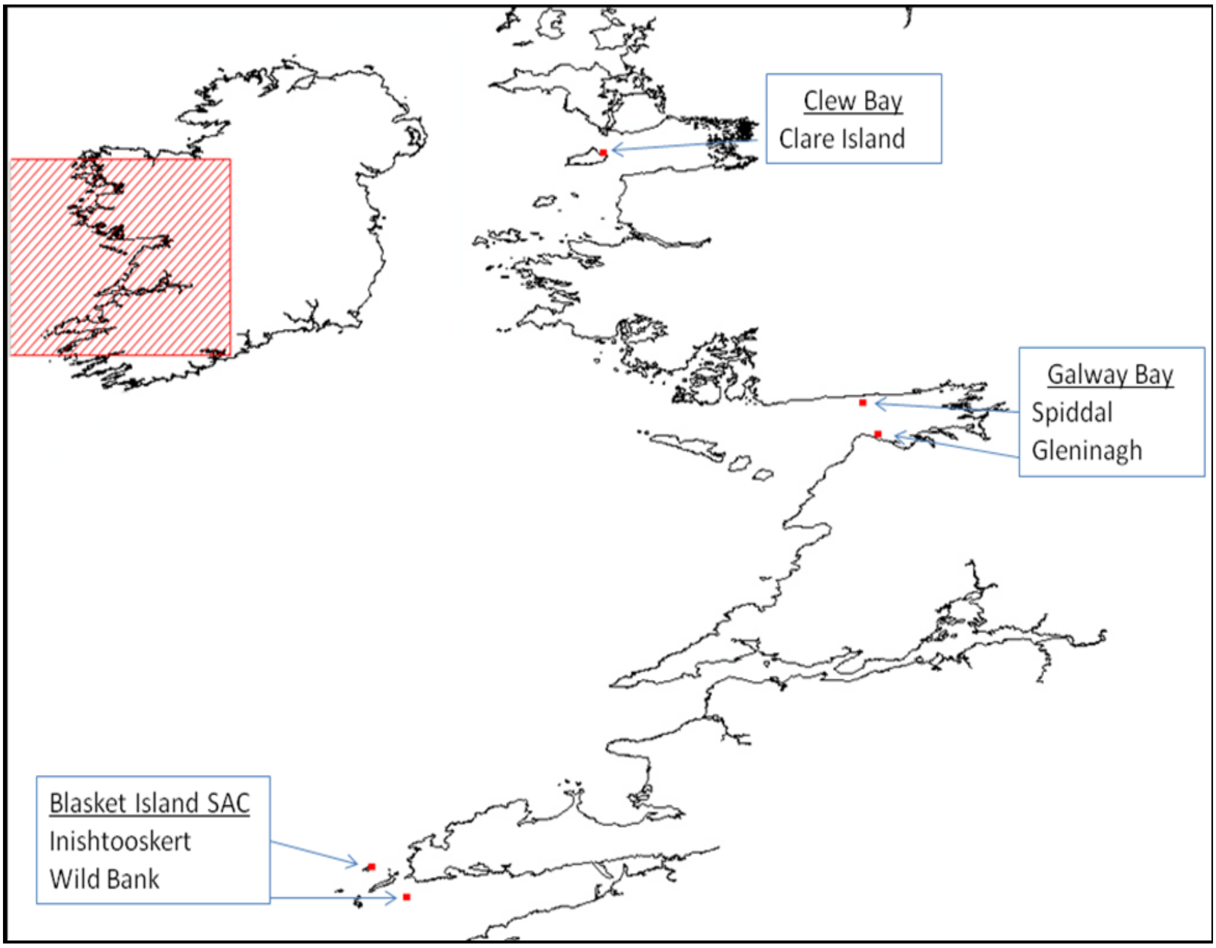
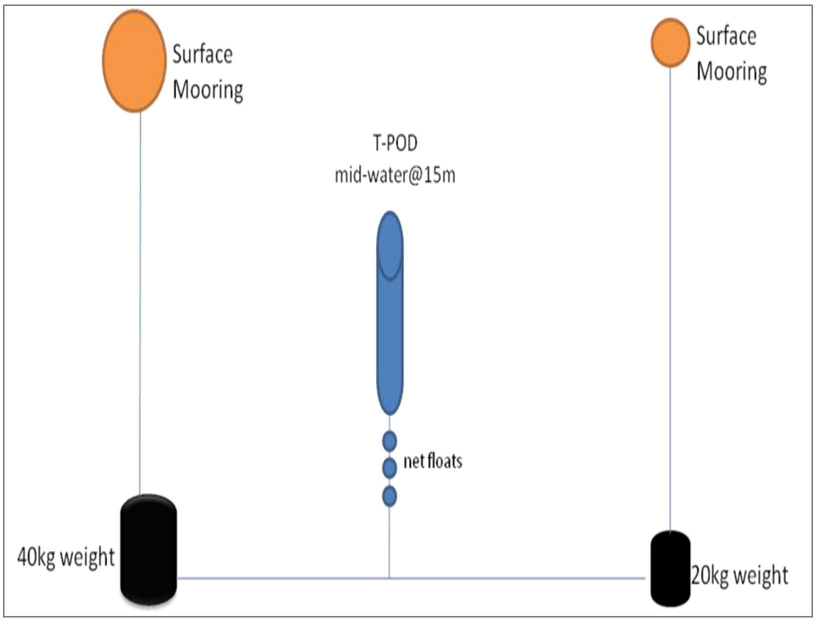
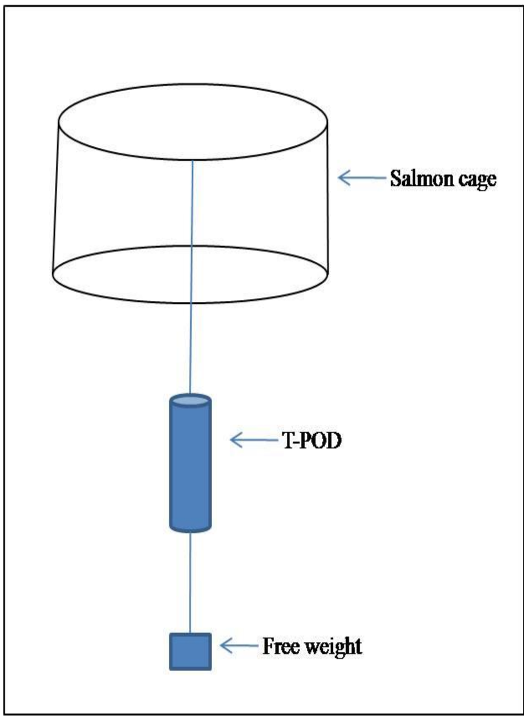


Figure 1. Map of deployment locations at Clew Bay, Galway Bay and Blasket Islands.

Mooring systems

The type of mooring systems used during the present study varied across locations. In Galway Bay and the Blasket Islands, systems consisted of a line running between a surface marker to a 40kg weight, with a line of approximately 60m running across the bottom to another weight of 20kg. From this second weight a line ran to the surface and was marked by a smaller buoy. As the T-POD is positively buoyant, it was freely suspended from mid-way along the bottom line which ran between the two weights. Depending on water depth, the T-POD was suspended from the bottom with enough rope to position it in the middle of the water column, since both harbour porpoises and dolphins were the target species. A number of small salmon floats were attached on the T-POD line to ensure it was kept vertical in the water column (Figure 2). In Clew Bay, T-PODs were deployed off salmon cages for the duration of this study. T-PODs were put into net bags, and a rope from the top end of the bag went to the surface where it was tied off the side of the salmon cage. A second rope was attached to the bottom end of the bag, and a weight (20kg) was hung from the end to prevent the T-POD from floating to the surface (Figure 3). Water depth was 20m, and the T-POD was hung from the cage so that it could be suspended at mid water (c10m).





Figures 2 and 3. Mooring systems used to deploy T-PODs in Galway Bay, Blasket Islands and Clare Island Sea farm.

Data collection

The T-POD consists of a self contained hydrophone that logs the times and duration of echolocation clicks produced by dolphin species and harbour porpoises. These units are powered by 12 lithium D-celled batteries and contain 128 megabytes of memory. Five versions of T-POD have been produced, with version 5 being the latest and final version. A new digital version of the T-POD, called the C-POD now exists. Version 4 and 5 units were used for the duration of this study. Ten different units were deployed between all sites and locations (Table 1).

Table 1. Details of deployment locations and T-POD numbers randomly assigned to the three sites over the duration of the study.

Location	Site	Deployment date	Recovery date	T-POD No.	Deployment duration
Galway Bay	Spiddal	12.05.2006	17.06.2006	404	36d 8h 0m
Galway Bay	Spiddal	04.07.2006	23.12.2006	505	43d 21h 58m
Galway Bay	Spiddal	03.10.2006	09.11.2006	451	37d 4h 37m
Galway Bay	Spiddal	09.11.2006	23.12.2006	324	43d 23h 41m
Galway Bay	Spiddal	01.02.2007	26.03.2007	505	52d 23h 18m
Galway Bay	Spiddal	26.03.2007	12.04.2007	506	0d 0h 19m
Galway Bay	Spiddal	12.04.2007	12.06.2007	652	61d 9h 38m
Galway Bay	Spiddal	12.06.2007	10.07.2007	568	28d 0h 03m
Galway Bay	Spiddal	10.07.2007	01.08.2007	506	21d 18h 41m
Galway Bay	Gleninagh	15.05.2007	12.06.2007	505	28d 3h 27m
Galway Bay	Gleninagh	12.06.2007	31.08.2007	505	79d 16h 55m
Clew Bay	Clare Island	21.04.2006	15.06.2006	506	23d 23h 32m
Clew Bay	Clare Island	15.05.2006	14.06.2006	405	0d 0h 0m
Clew Bay	Clare Island	14.06.2006	07.07.2006	506	23d 4h 2m
Clew Bay	Clare Island	26.09.2006	09.11.2006	506	49d 0h 34m
Clew Bay	Clare Island	09.02.2007	21.03.2007	451	40d 3h 29m
Clew Bay	Clare Island	05.04.2007	01.05.2007	506	0d 0h 0m
Clew Bay	Clare Island	11.06.2007	12.09.2007	324	93d 2h 38m

The calibration of equipment prior to the commencement of the study was not feasible as some units were only acquired after the study had begun. Units were randomly assigned to sites by re-placing PODs with a different unit when they were retrieved. This mixing of units across locations was to ensure that the possible confounding factor of variation in sensitivity between units was excluded from the experiment. All units used during monitoring in Galway and Clew Bay were set to detect both harbour porpoise and dolphin species, using the generic settings as set out by the manufacturer (Table 2). These settings consist of 2 filters, a target (A filter) and a reference (B filter), where each filter blocks all frequencies except those around its centre frequency, and this is set depending on the target species. For example dolphin channels are set with a target filter set to 50kHz, and a reference filter of

70kHz. This results in a peak sensitivity at 50kHz, with no detections being logged on these channel beyond 60kHz. For porpoises, a target filter of 130kHz and reference of 92kHz ensures that only clicks with a frequency of 110kHz or greater are logged. In order to reduce or eliminate the number of false positive porpoise detections coming from dolphins echolocating at high frequencies, the click bandwidth is reduced. During the present study, a click bandwidth of 5 was used for dolphin channels as this enables the detection of more dolphin clicks which would be lost if a smaller bandwidth was used. The use of a smaller bandwidth on porpoise channels eliminates the vast majority of false positive porpoise detections. A noise adaptation of ++ was selected for all deployments as this is the normal operational setting. A sensitivity value of 6 was used during all deployments as well as a scan limit of 240. T-POD deployments varied over the study duration. Boat availability and weather conditions impacted on the servicing of devices during the winter months, and therefore gaps exist in the dataset. On a number of occasions, T-PODs malfunctioned during deployments and no data were logged. This was most likely due to interference or rough weather conditions leading to the T-POD becoming positioned upside down in an off position.

Table 2. T-POD generic settings used during long-term deployments in Clew Bay and Galway Bay.

SCAN	1	2	3	4	5	6
A filter (kHz)	50	130	50	130	50	130
B filter (kHz)	70	92	70	92	70	92
Click bandwidth	5	4	5	4	5	4
Noise adaptation	++	++	++	++	++	++
Sensitivity	6	6	6	6	6	6
Scan limit	240	240	240	240	240	240

Data analysis

The dedicated software programme T-POD.exe (version 8.23) was used to filter and extract all data files. Only clicks in the category of cetacean all (*cet all*) were used during analyses, which is a combination of clicks classed as being of high probability cetacean clicks (*cet hi*) and clicks classed as being of low probability cetacean origin (*cet lo*). Both dolphin and porpoise detections were extracted as detection positive minutes per hour and these hourly extractions were classified according to the factors, season (spring, summer, autumn and winter), diel cycle (day and night-time), tidal state (ebb, flood, slack high, slack low) and tidal phase (spring, neap). Although some dolphin clicks could have being detected in the porpoise channels, the setting of the click bandwidth used should have greatly reduced this incidence. Therefore it was assumed that all detections in 130kHz channels were of harbour porpoise, while those in the 50 to 70kHz channels were of dolphins. The term *PPM* represents the number of minutes in a day or an hour that harbour porpoises were acoustically detected, while *DPM* represent the number of minutes dolphins were detected. The term encounter refers to the detection of a series of clicks/click trains followed by a period of quietness at least 10 minutes in duration. Seasonal categorisations were assigned according to the seasons spring (February, March, April), summer (May, June, July), autumn (August, September, October) and winter (November, December, January). Data files in the format *PPM/h* and *DPM/h* were divided into day and night-time categories using local times of sunrise and sunset times, obtained from the U.S. Naval Observatory (www.aa.usno.navy.mil/data/docs/RS). Hourly data segments were further categorised into each of the four tidal states, where three hours was assigned to each state (one hour either side of the hour). Files were further split to correspond with tidal phase (spring and neap cycles) using admiralty data (WXTide 32) where two days either side of the highest tidal height was deemed spring, and two days either side of the lowest tidal height was deemed neap. This classification followed that of Leeney (2005).

Hypotheses tested

A significance level of $P<0.05$ was used in all statistical tests. Pivot tables were used to summarise the data and to determine how many replicates were needed in order to create a balanced design. Testing for homogeneity of variances and normality were carried out using Levene's statistic and the Andersen Darling Test to comply with the assumptions of ANOVA. ANOVA assumes that the values in each cell of the design are normally distributed and that variances in each of the cells are not different from each other. Where these assumptions were violated, transformations were used to normalise the data and to homogenise the variances by using the log, square root and inverse functions. Factorial ANOVAs were the chosen test statistics in all cases. General Linear Models (GLM) consisting of ANOVA and linear regressions (Dytham 1999) were also used as they allow for the investigation of more than one treatment to be examined simultaneously (Underwood 1997).

1. The long-term datasets from Clare Island and Spiddal were used as replicates for the bay habitats on the west coast of Ireland. Data were collected during 2006 and 2007. Random samples from each of the years were extracted to create a balanced design (n=380 days). The response variable used was porpoise positive minutes

per day (*PPM/d*) and significant difference between the years and locations and an interaction between location and years were tested.

2. The same long-term dataset was analysed in order to test for temporal variation in the number of harbour porpoise detections between seasons. The seasons, spring (February, March, April), summer (May, June, July), autumn (August, September, October) and winter (November, December, January) were categorised. Random samples from each of the seasons were extracted (n=500 hourly segments per season) from the dataset in the format *PPM/h* to create a balanced design. The data were transformed to fulfil the assumptions of ANOVA using the log function. A one-way ANOVA was used to test for significant differences in acoustic activity between seasons, while *Post hoc* pair-wise comparisons were used to determine between what seasons differences existed.
3. The long-term datasets from Clare Island and Spiddal were further interrogated to determine if a significant variation existed in acoustic activity between the temporal factors, diel cycle (n=1,920 day-time samples and 1,920 night-time samples), tidal state (n=960 ebb samples, 960 flood samples, 960 slack high samples, 960 slack low samples) and tidal phase (n=1,920 spring samples, 1,920 neap samples). The data from both years were combined and therefore year was not used as a factor in the analyses. The data were transformed using the inverse functions to conform with homogeneity of variances and normality. Factorial ANOVA through the use of a General Linear Model (GLM) was used. Since the factors diel, tidal state and tidal phase are orthogonal, this allowed for the testing of interactions. *Post hoc* pair-wise comparisons were also carried out to determine where differences existed.
4. Localised fine scale temporal variation was explored between Spiddal and Gleninagh (approx 10km apart). A sample of 70 days from the months May to August 2007, were extracted as *PPM/day*. The data were tested for equal variances and normality using a Levene's test and the data were transformed using the log function. A one-way ANOVA was used to test for significant variation between months.
5. Further localised fine scale temporal variation was explored using data from the Blasket Islands from two sites, Inishtooskert and Wild Bank (10km apart) for a 28 day deployment period. Data were extracted as *PPM/h* and were tested for equal variances and normality using a Levene's test. A random sample of 760 hours

from both locations was used for the analyses. The data were transformed using the log functions in order to conform with homogeneity of variances and normality. Factorial ANOVA using GLM was again used to test the three factors location, diel and tidal state and also the possibility of significant interaction between the factors, followed by *post hoc* pair-wise comparisons.

6. Inishtooskert, Wild Bank (Blasket Islands) and Clare Island were sampled simultaneously over a 28 day deployment and this dataset statistically analysed to determine if there was significant temporal variation in harbour porpoise detections between the sites. This was an interesting experiment as it facilitated the comparison of results from an already designated SAC with a potential one. As before, a random sample of data (n=760 hours) were tested for equal variances and the data were transformed using the log functions in order to conform with homogeneity of variances and normality. Factorial ANOVA GLM were used to test for interactions, followed by *post hoc* pair-wise comparisons.
7. The final analyses focused on dolphin detections from Clare Island. A balanced design using random samples of the dataset (n=4000 hours) were tested for temporal variations in detections similar to the porpoise data, including season, diel and tidal state. As before, the data were tested for equal variances using Levene's statistic and Andersen Darling Test, while factorial ANOVA GLM was the chosen test statistic.

RESULTS

In Galway Bay, a single T-POD was deployed off Spiddal for a total of 333 days (between May 2006 and October 2007). The second site at Gleninagh was used for a shorter duration of 108 days (between May and August, 2007), (Tables 2&3). In Clew Bay, deployment durations totalled 234 days (between April 2006 and September 2007) (Tables 2 and 3). Harbour porpoises were detected on average 89% of days monitored for both of the long-term sites at Spiddal and Clare Island, and on 40% of days at Gleninagh. Their presence within the vicinity of the T-POD was very brief, ranging from 0.03 to 4.47 minutes per hour of deployment (see *PPM/hour*, Table 3). A mean encounter rate of harbour porpoises over the duration of deployments amounted to 7.8 encounters per day, peaking in October (Table 3). Over the simultaneous 28-day deployment at the Blasket Islands (Wild Bank and

Inishtooskert) and Clare Island, harbour porpoises were detected at all 3 sites on 100% of days monitored.

Dolphins were detected on 3% of days monitored at Spiddal, 5% of days at Gleninagh but on 37% of days monitored at Clare Island (Table 3). T-PODs set in the Blaskets were not set to detect dolphin species.

Table 3. Details of deployments over the duration of the study, including the % of days with porpoise detections (*%PPD*), % of hours with porpoise detections (*%PPH*), the total porpoise positive hours recorded during that month (*Total PPM*), and number of porpoise positive minutes per hour (*PPM/h*).

Details				Porpoise detections				
Year	**Location**	**Month**	**No. days deployed**	**Enc/day**	**% of PPD**	**%PPH**	**Total PPM**	**PPM/h**
2006	Spiddal	May	20	141	100	22	241	0.5
	Spiddal	June	17	103	94	18	165	0.4
	Spiddal	July	28	176	100	21	271	0.4
	Spiddal	August	17	69	94	17	129	0.3
	Spiddal	October	29	421	97	40	1001	1.4
	Spiddal	November	31	260	100	24	637	0.85
	Spiddal	December	23	141	100	21	265	0.48
2007	Spiddal	February	28	20	43	2	22	0.03
	Spiddal	March	26	33	58	4	50	0.08
	Spiddal	April	19	83	100	14	179	0.39
	Spiddal	May	31	184	97	19	373	0.5
	Spiddal	June	19	80	100	12	136	0.29
	Spiddal	July	10	31	100	6	102	0.42
	Spiddal	September	30	75	73	9	104	0.1
	Spiddal	October	5	16	80	8	16	0.13
2007	Gleninagh	May	16	21	38	4	32	0.08
	Gleninagh	June	30	39	40	4	60	0.08
	Gleninagh	July	31	44	48	3	64	0.08
	Gleninagh	August	31	31	35	2	39	0.05
2006	Clew Bay	April	10	36	80	11	49	0.2
	Clew Bay	May	15	28	67	5	26	0.07
	Clew Bay	June	17	84	100	15	132	0.3
	Clew Bay	July	7	68	100	24	70	0.4
	Clew Bay	Sept	10	74	50	19	229	0.9
	Clew Bay	October	31	549	94	34	1352	1.81
	Clew Bay	November	9	374	100	57	967	4.47
2007	Clew Bay	February	20	212	90	23	474	0.98
	Clew Bay	March	21	235	95	24	519	1.02
	Clew Bay	June	20	122	100	16	144	0.3
	Clew Bay	July	31	378	100	33	625	0.84
	Clew Bay	August	31	351	100	28	487	0.65
	Clew Bay	September	12	64	75	11	78	0.27

Results from hypotheses testing

Results from the long-term dataset at Spiddal and Clare Island showed that there was a significant difference in the number of porpoise detections between locations (P=0.00) and between years (P=0.01), while an interaction term was also found to be significant (P=0.01).

Significantly more *PPM/d* were detected during 2006 (P=0.01, Table 4), while significantly more detections were logged at Clare Island when compared with Spiddal (P=0.00).

The long-term Spiddal and Clare Island datasets were further analysed to determine if a significant seasonal effect was present in the acoustic detection rate of the harbour porpoise. Descriptive statistics showed that winter had the highest mean *PPM/h* (1.2 *PPM*), while summer had the lowest *PPM/h* (0.4 *PPM*, Figure 4). Analyses using ANOVA showed that there was a significant seasonal component in the dataset (P=0.02, Table 4), while *post hoc* pair-wise comparisons confirmed that this difference existed between the seasons winter and summer, with winter detections significantly greater (P=0.02).

Table 4. One way ANOVA results, *PPM/d* at Clare Island and Spiddal, factors year, location and seasonally (4 factors, spring, summer, autumn and winter, equal variances, Inverse of *PPM/h* (P=0.06)).

Source of variance	DF	MS	F	P
1.Year	1	1.64	14.75	0.00
2.Location	1	22.14	112.5	0.00
3.Year*Location	1	1.96	9.97	0.01
4.Season	3	0.4120	3.40	0.02

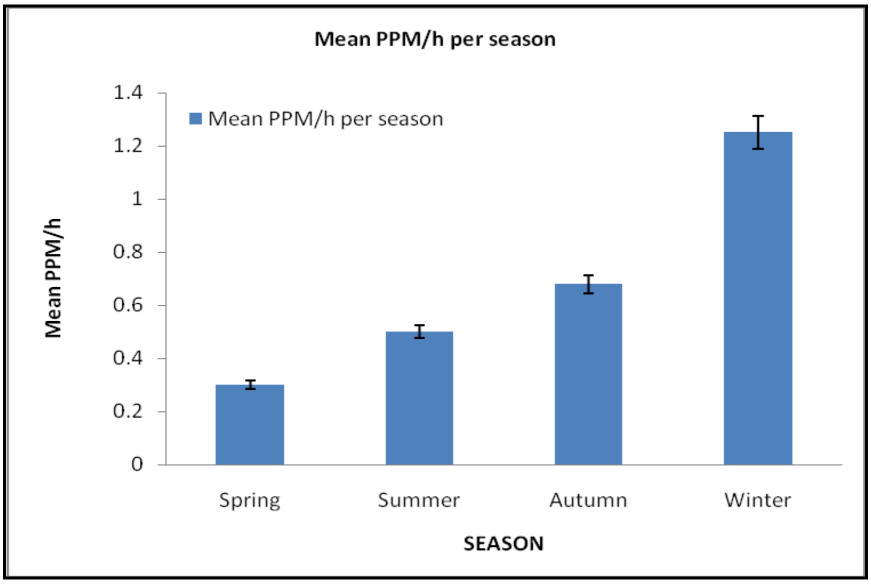


Figure 4. Mean number of *PPM/h* as detected per season at Clare Island and Spiddal (winter having the highest mean number of detections, and spring having the lowest).

The long-term dataset from Spiddal and Clare Island was further explored using *PPM/h* for each day under the temporal factors, diel, tidal state and tidal phase. A significant difference was found to exist between day and night-time detections (P=0.01, Table 5), with pair-wise comparisons confirming that harbour porpoises were more acoustically active at night (P=0.01, Table 8). Significant variation was also found in the number of *PPM/h* according to tidal phase, with *post hoc* pair-wise comparisons showing that detections during spring tidal phase were significantly greater (P=0.03, Tables 5 and 6). There was no significant variation in detections according to tidal state. No significant interactions were found to be present in any of the three analyses (Table 5). Possible differences between sites were not tested as there was no replication for the factors Galway and Clew Bays.

Table 5. ANOVA results (general linear model), where porpoise positive minutes per hour (*PPM/h*) were examined under each of the following categories; 1) Diel (time of day or night) (DL), 3) Tidal cycle (slack high, slack low, flood and ebb) (TC), and Tidal phase (spring, neap) (TP).

Source of variance	DF	MS	F	P
DL	1	374.28	6.49	0.01
TC	3	59.75	1.04	0.38
TP	1	257.49	4.46	0.04
DL*TC	3	11.14	0.19	0.90
DL*TP	1	160.48	2.78	0.86
TC*TP	3	43.40	0.75	0.52
DL*TC*TP	3	56.51	0.98	0.40

Table 6. Results from *Post hoc* pair-wise comparisons.

Results from pair-wise comparisons					
Cycle	Comparisons	Diff of X	SE	T-value	Adj. P-value
1.Diel	D - N	1.4	0.56	2.55	0.01
2.Tidal cycle	E - F	1.4	0.79	-1.73	0.30
	E - SH	0.8	0.82	-0.99	0.75
	E - SL	0.6	0.82	-0.74	0.88
3.Tidal phase	S - N	1.18	0.56	2.11	0.03

Fine-scale temporal and spatial variation was found in the Blasket Islands data over the 28 day deployment period. Results showed a significant difference existed between locations, Wild Bank and Inishtooskert (P=0.03) and diel cycle (P=0.02). The interaction between location and diel cycle was also found to be significant (P=0.00), (Table 7). *Post hoc* pair-wise comparisons showed significantly more porpoise detections logged during the day at Wild Bank when compared with Inishtooskert (P=0.00), but more detections logged at Inishtooskert during the night when compared with Wild Bank (0.00), (Table 8).

Table 7. ANOVA results (GLM), where porpoise positive minutes per hour (PPM/h) were examined under each of the following categories in the Blasket Islands; 1) Location (Inishtooskert and Wild Bank (LOC)), 2) Diel (time of day or night (DL)), 3) Tidal cycle (slack high, slack low, flood and ebb) (TC).

Source of variance	DF	MS	F	P
LOC	1	0.75	8.67	0.03
DL	1	0.82	9.42	0.02
TC	3	0.06	0.75	0.90
LOC*D	1	1.08	12.47	0.00

Table 8. Results from pair-wise comparisons carried out as above on the Blasket Islands data.

Results from pair-wise comparisons					
Cycle	Comparisons	Diff of X	SE	T-value	Adj. P-value
1.Location	I - W	0.10	0.03	2.94	0.03
2.Diel	D – N	0.11	0.04	3.07	0.00
3.Diel*location	ID – IN	0.23	0.06	3.81	0.00
	ID-WD	0.23	0.05	4.27	0.00
	ID-WN	0.21	0.05	3.91	0.00

Data collected simultaneously at three sites, Clare Island, Inishtooskert and Wild Bank were used to further explore temporal and spatial variation in harbour porpoise acoustic activity. Porpoises were detected on 100% of days at the three sites over the duration. A significant variation was found to exist spatially between locations (P=0.01), but no temporal variation was evident across diel cycle (P=0.80) or tidal state (P=0.17, Table 9).

Table 9. ANOVA results (GLM), where porpoise positive minutes per hour (*PPM/h*) from Blasket Island and Clare Island were examined under each of the following categories, 1) Location; Inishtooskert and Wild Bank and Clare Island (LOC), 2) Diel (time of day or night (DL)), 3) Tidal cycle (slack high, slack low, flood and ebb) (TC). Pairwise comparisons showed Clare Island to be significantly different from Wild Bank (0.01), but not from Inishtooskert (0.98).

Source of variance	DF	MS	F	P
LOC	2	0.61	5.83	0.00
DL	1	0.12	1.21	0.27
TC	3	0.02	0.21	0.89

Localised fine-scale temporal variation was explored between sampling points in Galway Bay between the months June to August, 2007. Results showed greater number of acoustic detections by porpoises at Spiddal by comparison with Gleninagh, (P=0.01), with detections recorded from Spiddal on average 7% of hours monitored, but only on 3.7% of hours at Gleninagh. The number of porpoise positive days per month (*PPD/m*) from Spiddal was also significantly higher by comparison with Gleninagh (P=0.00, Table 10).

Table 10. ANOVA results (One way ANOVA), where porpoise positive days per month (*PPD/m*) were examined for significant difference between locations (P=0.00).

Source of variance	DF	MS	F	P
Location	1	7.9	51.9	0.00

In summary, the long-term dataset showed that harbour porpoises were detected in all months in both Galway Bay and Clew Bay with a significant peak in detections occurring during the winter months. Significant temporal variation in the long-term dataset showed more harbour porpoises detections were logged during night-time hours and during the spring tidal phase. Fine-scale temporal variation was evident in the data from the Blasket Islands, where significantly more detections were logged during the day at Wild Bank when compared with Inishtooskert, and significantly more detections were logged at Inishtooskert during the night when compared with Wild Bank. Localised spatial variation was found in the Galway Bay data between Spiddal and Gleninagh, where a significantly greater number of porpoise detections were logged at Spiddal. No significant effect of tidal state was found during any of the analyses carried out on the harbour porpoise data.

Although the T-PODs were set to detect dolphins during all long-term deployments, only data from Clare Island were analysed as the number of dolphin detections logged at Spiddal was extremely low. No seasonal component was found in the long-term dolphin dataset from the single site at Clare Island, even though they were detected in all seasons (P=0.24, Table 11 and 12, Figure 5). Significant temporal variation in the form of diel cycle (0.02) was shown, with significantly more detections logged during the night-time period (P=0.01, Table 12, Figure 9). No significant variation was found in detections between tidal states (P=0.40) or tidal phase (P=0.66), and no significant interactions were found to be present during any of the three analyses (Table 12, Figure 6).

Table 11. Details of deployments over the duration of the study in Clew Bay, including the % of days with dolphin detections (*%DPD*), % of hours with dolphin detections (*%DPH*), the total dolphin positive hours recorded during that month (*Total DPM*), and the number of dolphin positive minutes per hour (*DPM/h*).

Details			Dolphin detections			
Month	**No. days deployed**	**Encounters /month**	**% of days with dolphin detections**	**%DPH**	**Total DPM**	**DPM/hour**
April	10	36	20	2	10	0.04
May	15	28	27	2	9	0.025
June	17	84	18	1	9	0.02
July	7	68	57	3	20	0.11
Sept	10	74	30	5	14	0.05
October	31	549	45	5	60	0.08
November	9	374	67	6	27	0.12
February	20	212	75	13	116	0.24
March	21	235	8	11	94	0.18
June	20	122	45	5	72	0.15
July	31	378	26	2	32	0.04
August	31	351	23	3	118	0.15
September	12	64	50	4	46	0.15

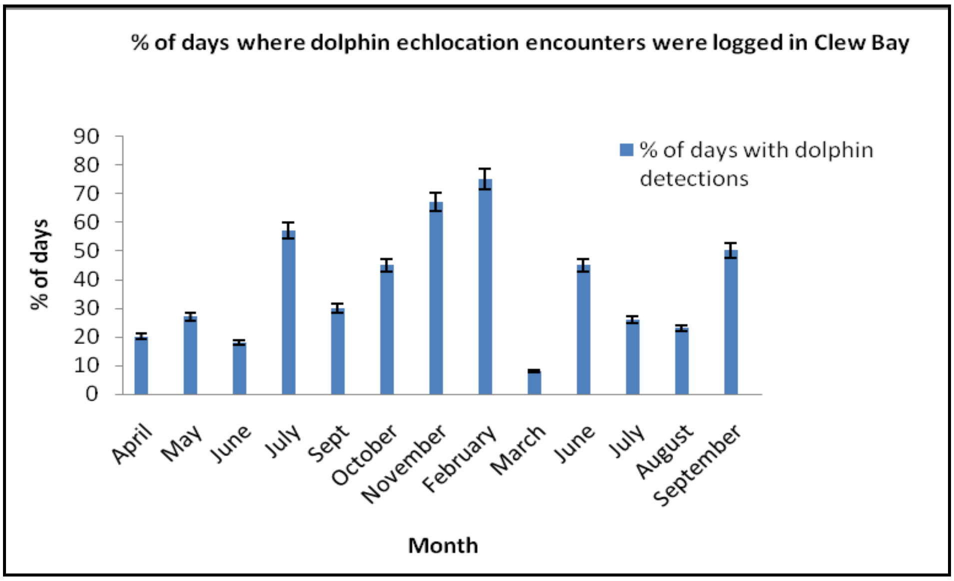
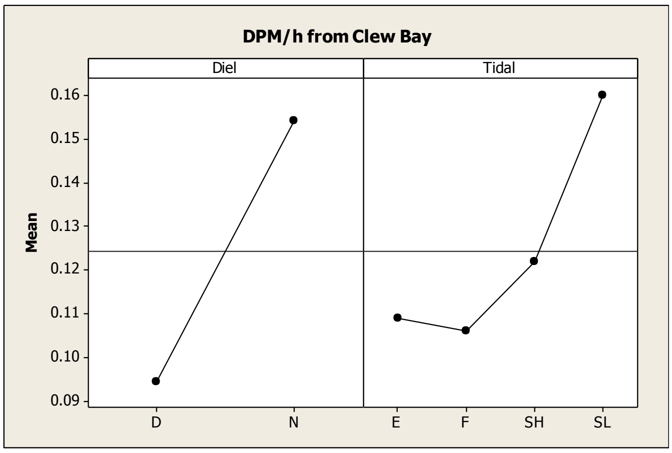


Figure 5. Percentage of days dolphins were detected in Clew Bay over the deployment duration.

Table 12. ANOVA results (One way and general linear model), where dolphin positive minutes per hour (*DPM/h*) were examined under each of the following categories; 1) Season , Diel; Time of day or night (DL), 2) Tidal cycle (slack high, slack low, flood and ebb) (TC), 3) Tidal phase (Spring, neap, TP). Pair-wise comparison Day-Night, night significantly greater (P=0.01).

Source of variance	DF	MS	F	P
Season	3	0.315	5.66	0.24
DL	1	3.54	5.66	0.02
TC	3	0.61	0.98	0.40
DL*TC	3	0.05	0.09	0.97
TP	1	0.07	0.19	0.66



The performance of moorings used during the present study proved very successful. On a single occasion gear went missing in Galway Bay. This was due to surface markers becoming loose in rough weather conditions, so commercial divers were used to locate and retrieve the gear. The mooring system at Clare Island was also lost on one occasion due to ropes being undone during maintenance of the pens, but yet again this gear was retrieved by divers. In the Blasket Islands, the gear stayed in place for the first 28 days and after that it was re-deployed but went missing and was never relocated.

DISCUSSION

The aim of the present study was to acoustically explore the occurrence of small cetaceans at various sites on the west coast of Ireland through SAM and to evaluate the potential of these sites for future SAC designation. The efficacy of SAM as a monitoring technique used as part of statutory obligation was also assessed. The potential designation of an area needs to be underpinned with precise scientific knowledge of small cetacean activity occurring within the area. Data from the Blasket Islands facilitated a comparison with an already designated SAC. Under the EU Habitats Directive (92/43/EC), Ireland is required to maintain the total national population of Annex II species (harbour porpoise and bottlenose dolphin) at "*favourable conservation status*" through ensuring that there is a sufficiently large habitat of suitable quality available to support the long term survival of these species. Mandatory criteria necessary to warrant and support an area as suitable for SAC designation includes the continuous or regular presence of the species, a high density estimate for the area by comparison with adjacent areas, and a good adult to calf ratio. If an area can be shown to support the above criteria and can be highlighted as an area essential to the life and reproduction of the species, then it should be considered for SAC designation (Johnston *et al.* 2002).

Passive acoustics monitoring has been used for decades, and in recent years has become increasingly widespread for cetacean observations (Moore *et al.* 2006). The first dedicated acoustic survey for cetaceans in Irish waters was carried out in 1993 by Gordon *et al.* (1999), where a towed stereo hydrophone array was deployed during 20 days at sea, concentrating along the edge of the continental shelf off Co. Mayo. Remote acoustic monitoring of large baleen whales using bottom-mounted hydrophones located in twelve large overlapping areas in the deep Atlantic north and west of Britain and Ireland, regularly detected blue, fin and humpback whales (Clark and Charif 1998; Charif *et al.* 2001). SAM is now being used as part of statutory obligations for monitoring the presence of small cetaceans in inshore waters. As a monitoring tool, the T-POD essentially provides information on presence or absence, by giving a measure of the level of vocalisation activity across hours, days, months etc. The main limitation with these data is that it is difficult to show how the number of clicks detected by a unit is directly related to abundance/density. The generation of a density estimate from acoustic data has been attempted by Tougaard *et al.* (2006), although this method is not widely adapted and needs to be refined before it can be used proficiently. As the T-POD will only provide information on echolocating animals, silent or non echolocating individuals will remain undetected by the T-POD. This should be less likely for the harbour porpoise as a study by Akamatsu *et al.* (2007) found that the harbour porpoise produces a sonar click train every 12.3 seconds, while 90% of the periods with no echolocation lasted 20 seconds or less. Hence the authors concluded that harbour porpoises seem to continuously echolocate. In the event of constant echolocation this should reduce the number of false negatives associated with acoustic monitoring of the species, as they should not go undetected for longer than 20s if in range of the device. The T-POD is limited by detection range which is directly related to detection threshold. However, if the detection threshold is increased, the detection range also increases this reduces the sensitivity of the T-POD, and the incidence of false negatives increases. Previous studies elsewhere focusing on the detection range of T-PODs found that for harbour porpoises, T-PODs were most sensitive between 50-100m, with very few detections beyond 250m (Tougaard *et al.* 2006). The latter authors also found that if harbour porpoises were moving directionally that they were only recorded on their approach to the T-POD but once they had passed it, no further clicks were detected. Furthermore, the authors speculated that the number of detections at increasing distance (50-100m) initially rises as a larger sea area is encompassed in successive bans of equal width. Although T-PODs are recognised as a valuable monitoring tool, some researchers have expressed concern as regards differing sensitivities between units and therefore the comparability of data between T-POD versions, sensitivities and region (Dähne *et al*. 2006). A study by Kyhn *et al*. (2008) found that the more sensitive a T-POD was in the laboratory, the more clicks it recorded in the field. The authors tested the performance of 10 individual units and found differences between them all. Hence, the authors conclude that calibrations are necessary in order to gather comparable results from differing units and across locations. Dähne *et al*. (2006) examined the variation between two version 4 T-PODs and found a 7% variation between the units, which they conclude as a good performance by comparison with the amount of variation associated with visual monitoring. Berrow *et al.* (2009a) carried out field calibrations using 9 T-PODs (versions 4 and 5) and found a 6% variation between the most and least sensitive units. No calibrations were carried out as part of the present study as not all units were available at the beginning, as some units were only being purchased over the duration of the study when funds became available. Before units are dispatched from the manufacturer (Chelonia), they are calibrated to a standard and therefore should not exhibit a high degree of variability. All units used over the duration of the present study were deployed randomly across locations. This random deployment should distribute the variability if it exists between units across sites and therefore reduce its impact upon the results.

Long-term SAM carried out during the present study in Galway Bay and Clew Bay showed that the harbour porpoise was the most frequently detected species. Results from visual monitoring in Galway Bay found similar results, from both land and vessel-based methods (O'Brien *et al.* 2008a). Harbour porpoises were only detected visually on 33% of land-based watches carried out in Galway but were acoustically detected on 88% of days monitored. Visual results from Clew Bay were in stark contrast with SAM results for the region, where only a single harbour porpoise was recorded visually (O'Brien *et al.* 2008b) but the species was acoustically detected on 89% of days monitored at Clare Island. The area of outer Galway Bay alone is 547km^2, while Clew Bay is 262km^2. When the detection range of a single unit is applied to the area of these locations, then a single porpoise in Galway Bay within 547,000,000m^2 must pass within 100m of the device at a single location in order for its presence to be logged. The high incidence of porpoise positive days at both locations could be suggestive of a large population within the bays where animals move about randomly and are detected acoustically as they do so, or if the population is small then they could be selective to certain areas of the bays and therefore increasing the probability of detection. Although porpoises were detected at Spiddal and Clare Island on the majority of days monitored, their presence within the range of the POD was short ranging from 0.03 to 4.47 minutes, which could be indicative that they don't spend much time within an area, but are constantly on the move.

Although porpoises were detected in all seasons a significant seasonal component was evident from Spiddal and Clare Island with more detections recorded during the winter months. Again, by contrast to the acoustic data, no significant seasonal effect was found within the visual data on the presence of porpoises in Galway Bay (O'Brien *et al.* 2008a). Acoustic results from the present study suggest that temporal trends can be detected quicker through acoustic monitoring data. Within an Irish context, published reviews of incidental sightings from Cape Clear show porpoises to be recorded in all months, but there was an increase in the number of sightings in the autumn (August to October) (Preston, 1975). Although not analysed statistically, these visual results are similar to the present study where autumn ranked as the season with the second highest mean *PPM/h*, behind winter with summer been the least significant season. Northridge *et al.* (1995) discussed how the seasonal movement of harbour porpoises has been the topic of much conjecture, with suggestions including, inshore–offshore movements, as well as east-west and north-south migrations. Further research into the effect of seasonality on porpoise detections using T-PODs was carried out in the German Baltic by Verfuß *et al.* (2007) who found that more detections were recorded in the spring to autumn when compared with winter. They suggested that the German Baltic is an important breeding and mating area for the harbour porpoise. Further studies on the seasonal presence of harbour porpoises were carried out by Diederichs *et al.* (2008), who, similar to Verfuß *et al.* (2007), found that maximum detections were recorded in summer with a minimum in autumn and winter. These results are in contrast with those from the present study. However, results from studies carried out in Cardigan Bay (Pesante *et al.* 2008) are very similar to those from the present study, with autumn and winter peaks. It is not clear as to why peaks have been detected in Irish waters during the autumn and winter months, but autumn peaks do coincide with the predicted mating and breeding times of the species in the North Sea (Sonntag *et al*. 1999), or they may be due to the abundance of preference prey.

Further temporal trends were also found to be evident in the long-term harbour porpoise acoustic dataset from Clare Island and Spiddal. These data were analysed to determine if diel cycle had a significant effect on the presence of the harbour porpoise. Results showed harbour porpoises were more active nocturnally, as night-time detections were significantly greater than day-time. Further localised temporal variation was found in the Blasket Islands where over the diel cycle porpoises were found to be more acoustically active at night at Inishtooskert, but were more active during daylight hours at the Wild Bank. The distance between these two sampling points was only approximately 10km. Cox *et al.* (2001) had similar results to the present study where they found that the harbour porpoise echolocation detection rate was higher at night than during the day in the Bay of Fundy, while in Newport Bay on the south-west coast of Wales, Pierpoint *et al.* (1999) found that the levels of harbour porpoise activity were consistently higher at night. In Kamon Strait, Japan, Akamatsu *et al.* (2008) using static stereo even recorders (A-tags, detection distance of 126m), found finless porpoises were detected only during the night, which was opposite to shipping traffic, which occurred during the daytime. However, Teilmann *et al.* (2007), using satellite linked dive recorders found that harbour porpoises dive continuously both day and night but with peak activity during daylight hours. Since harbour porpoise diel trends on the west coast of Ireland have been found to differ geographically, this emphasises the fact that the reliance upon visual monitoring alone is a poor measure of their occurrence in an area, especially if they are more active at night. The reasons for increased nocturnal activity are uncertain but could be linked to an increase in prey abundance or activity in the absence of light, as suggested by Todd *et al.* (2009). This hypothesis was not explored as part of the present study, since detected sonar was not analysed and classified according to behaviour. Further analyses of the acoustic dataset from Clare Island and Spiddal explored the incidence of significant temporal trends such as the effect of tidal state and tidal phase on the detection of the harbour porpoise. Results showed no significant variation in harbour porpoise detections in response to tidal state. However, a significant effect of tidal phase was established, with significantly more detections logged over the spring tidal phase when compared with neap. In contrast to the present study, Pierpoint *et al*. (1999) found that greater harbour porpoise activity was found during an ebbing tide.

The inability of the T-POD to differentiate between dolphin species is another limitation. An assumption was made whereby all dolphin detections logged at Clare Island were bottlenose dolphins, when in fact they could have been common dolphins which are also known to occur in the area, although sightings are infrequent (Berrow *et al.* 2002). Therefore, the probability that the dolphin detections were of bottlenose is high as they were the most frequently recorded species during visual observations in Clew Bay (O'Brien *et al*. 2008b). The low number of dolphin detections logged at Spiddal meant the data were only used for descriptive purposes, and would not support a case for designating the bay as an important area for bottlenose dolphins. This is also suggested from the visual data (O'Brien *et al.* 2008a). The dolphin acoustic data from Clare Island were analysed for temporal trends in the same way as that for porpoises. Results showed no significant seasonal component within the dataset. Dolphins may use the area year round even during critical times such as calving or while on nursery grounds. It may also be attributed to the same group of dolphins using the area and hence no difference in echolocation encounters between seasons. Diel variation was found to be significant, whereby dolphins were found to be more acoustically active at night. Again, this highlights the difference in the use of visual data alone in the examination of dolphin attendance at a site. Researchers in the Shannon Estuary have expressed concern when using the T-PODs to monitor bottlenose dolphins (Hansen *et al*. 2009, J.O'Brien pers. obs). Here researchers failed to acoustically detect bottlenose dolphins using the T-POD even when the animals were approaching the units from 1000m, travelling in their direction and passing them by within a few metres, as determined from simultaneous visual recording using a theodolite. Even changes to the generic settings failed to register detections on the T-PODs. The animals were echolocating at the time as proven through simultaneous hydrophone recordings. Previous work in the Shannon Estuary carried out by Philpott *et al.* (2007) successfully generated detection distances for T-PODs in the region, using version 3 T-PODs. The reason for these false negatives are yet to be resolved, while the new digital version of PODs called the C-POD has proven to successfully detect bottlenose dolphins regularly at the same site, but has yet to be ground truthed with visual observations (J.O'Brien, pers. obs).

In summary, SAM using T-PODs can provide high resolution data in time but has limited spatial coverage (Koschinshi *et al.* 2003). This can be overcome with the deployment of many units within an area to achieve a more even spatial coverage. If multiple units can be used in a programme, the strategic placing of moorings would enable the tracking of movements within an area. Results from the present study highlight how seasonal as well as temporal trends such as diel and tidal influences can be detected through SAM. In fact, the results suggest that seasonal trends can be detected much more readily through SAM than through visual methods (O'Brien *et al.* 2008a). Localised temporal trends were detected acoustically in the Blasket Islands, where harbour porpoises showed fine-scale diel variation between two location 10km apart. A fine scale difference such as this could not be achieved through visual surveying, as porpoises were found to use Inishtooskert more during the night than Wildbank. Although SAM can provide data on temporal and spatial trends, unless information on the densities of animals using an area is known, then an effective management plan cannot be devised. It is fundamental that both visual and acoustic monitoring be carried out within an area over a substantial period targeting all seasons, to accurately assess species presence and numbers and to gain an understanding of the driving forces influencing their occurrence. If an area is deemed important enough to be granted SAC status then such background information will prove vital in designing an effective management plan.

If an area is to be designated an SAC, then it is imperative for the effective management of a site that the seasonal and temporal trends in distribution and abundance are clearly understood. If certain activities such as dredging, pile driving for wind turbine construction, or underwater blasting were to take place in these areas, then it is imperative to know at what time of the year these animals are less likely to be affected or whether such activities should be allowed to take place at all in an area. Temporal variations such as season, diel and tidal phase were found to influence both harbour porpoise and dolphin presence on the west coast of Ireland, and this highlights the need for SAM, as results from visual data alone does not truly represent the habitat usage by these populations. If human activities that would have an impact on harbour porpoises or dolphins, especially bottlenose dolphins, were to go ahead in Clew Bay/Galway Bay, then visual monitoring would not be appropriate to mitigate against disturbance as the animals would be more susceptible to disturbance at night when visual observations could not take place. The difference in site usage illustrates the importance of establishing a comprehensive understanding of how animals use a habitat. Again, such knowledge underpins the effective management of any SAC and the conservation of Annex II cetacean species.

Acoustic monitoring alone is presently not advanced enough to establish local area use as a basis for prioritising SACs (Skov and Thomsen, 2008). Therefore it is recommended that a combination of visual and acoustic monitoring techniques is employed to fully appreciate cetacean activity in a given area, and therefore contribute to the effective conservation of the species.

CONCLUSIONS

Combining results from the present study with those from visual surveys (O'Brien *et al.* 2008a), Galway Bay is clearly a very important area for the harbour porpoise. Furthermore, Berrow *et al.* (2008) generated a density estimate of 0.73 porpoises km^{-2} in Galway Bay, with an abundance estimate of 402±84, compared to the Blasket Islands SAC where Berrow *et al.* (2009) generated density estimates ranging between 0.71 to 3.39 porpoises km^{-2}, with an overall abundance of 303±76. Galway Bay is a much bigger site by comparison with the Blasket Islands, but it does support a population of similar numbers to an already designated SAC, which highlights the importance of the area. The present study highlights its importance as a year-round site with a significant seasonal component. These results meet those criteria as listed earlier for identifying an important area warranting designation. Therefore it is recommended that this site should be designated an SAC in order to fully comply with the Habitats Directive. The area appears not to be important for bottlenose dolphins as they were rarely recorded visually or acoustically.

Clew Bay is an important area for both harbour porpoise and bottlenose dolphin, as both were detected in all seasons. Harbour porpoises were acoustically detected 89% of days monitored but were rarely sighted visually, so a relative abundance of animals in the bay could not be generated. In order to determine the number of porpoises using Clew Bay, a series of dedicated line transect surveys should be carried out. Bottlenose dolphins were regularly recorded visually in the bay, and photo-identification surveys carried out resulted in the re-sighting of the same individuals (O'Brien *et al.* 2008b). However, these surveys were only carried out from May to September and sample size and re-capture rate were too low to estimate abundance using capture re-capture methodology. Therefore more surveys should be carried out in Clew Bay for bottlenose dolphins and through photo-identification, to explore the possibility of a resident or semi-resident population using the area.

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CHAPTER 5

FIRST EVIDENCE FOR LONG-DISTANCE MOVEMENTS OF BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) AROUND THE IRISH COAST USING PHOTO-IDENTIFICATION

(O'Brien, J.M., Berrow, S.D., Ryan, C., McGrath, D., O'Connor, I., Pesante, G., Burrows, G., Massett, N., Klötzer, V. and Whooley, P. (IN PRESS) A note on long distance matches of bottlenose dolphins (*Tursiops truncatus*) around the Irish coast using photo-identification. Journal of Cetacean Research and Management.

ABSTRACT

Images of bottlenose dolphins from around the Irish coast were obtained from a number of sources. A total of three catalogues were combined and examined for photographic matches, including Galway, Clew and Donegal Bays and a collection of images submitted to the Irish Whale and Dolphin Group (IWDG) from all coasts. This combination of catalogues is referred to as the Irish Coastal Dolphin Catalogue (ICDC), comprising 120 individually recognisable dolphins, of which 23 individuals were subsequently re-sighted (19% re-sighting rate). The distance between re-sightings ranged from 130 and 650km and the duration varied from 26-760 days. The largest distance between a single re-sighting was c 650km (between Dublin Bay and Galway Bay) and the longest duration was of an individual with scoliosis recorded in Galway Bay in June 2005 and subsequently re-sighted in Clew Bay in July 2007, 760 days later. In order to further track the movements of these individuals, comparisons were made with additional catalogues. One catalogue was that of 180 resident bottlenose dolphins from the Shannon Estuary SAC on the west of Ireland and a second catalogue of 331 bottlenose dolphins from West and North Wales was also used. No matches were found. This short study provides evidence that bottlenose dolphins in Irish waters are undertaking long distance movements around the Irish coast, for which there are little previous data. These results have broad implications for the conservation and management of this species.

INTRODUCTION

Common bottlenose dolphins (*Tursiops truncatus*) are found throughout temperate and tropical waters of the world between 60 degrees north and 50 degrees south of the equator and in the Mediterranean Sea (Reynolds *et al.* 2000). Two forms of bottlenose dolphins are known to exist in the US and South Africa, each with different genetic profiles, parasite loads, stomach contents and morphology; one group is referred to as “coastal” and the other referred to as “offshore” (Mead and Potter 1990; 1995; Wells *et al.* 1999). Coastal dolphins are found in habitats with shallow waters such as bays, lagoons and at the mouths of estuaries (Leatherwood and Reeves, 1990), while offshore dolphins, as the term suggests, are found beyond continental shelves (Connor *et al.* 2000). However, at present, there is no evidence to suggest that these two ecotypes exist in the eastern North Atlantic. Bottlenose dolphins are widespread and abundant in Irish waters (Ingram *et al.* 2001), which contain some of the highest concentrations of this species in Europe (Evans 1992).

Photo-identification (Photo-ID) is a technique commonly used to study the movements and behaviour of whales and dolphins worldwide and was first applied to bottlenose dolphins by Würsig and Würsig (1977). This technique works on the principle of photographing individual animals and identifying natural markings unique to that individual (Würsig and Würsig 1977; Thompson and Hammond 1992; Wilson 1995; Wilson *et al*. 1999). For many dolphin and whale species these features are present on their dorsal fins. The trailing edge of a bottlenose dolphin dorsal fin is very thin and is readily tattered during the animal’s life (Würsig and Würsig 1977), and these marks are reliable over time. Other teeth marks and pigmentation patches are also found on the dolphin’s fin and other body parts but usually only last from six months to a year (Würsig and Würsig 1977). Previous studies using photo-identification have shown that 70-80% of individual bottlenose dolphins are thought to be identifiable through natural markings (Bearzi *et al.* 1997; Karczmarski and Cockcroft 1998).

Photo-identification provides a means to gather information on movement patterns, site fidelity (Kerr *et al.* 2005), associations (Wells *et al.* 1987) and population dynamics (Wells and Scott 1990; Whitehead *et al.* 2000). Movement patterns are sometimes unpredictable, ranging from year-round residency in a defined area to seasonal or continual migrations (Shane *et al.* 1986), and the use of natural markings as a means of tracking animals can prove extremely effective. There have been several previous attempts to use photo-identification catalogues to record long-distance movements undertaken by bottlenose dolphins. In 1998, a joint catalogue called TURSIOPS was setup to co-ordinate information on the status, movements and ecology of coastal populations of bottlenose dolphins from Cornwall to the Bay of Biscay (Liret *et al.* 1998). A larger scale initiative called EUROPHLUKES was set up in 2002 and was funded by the European Commission. This latter project aimed to collate images from more than 90 catalogues of various cetacean species held throughout Europe.

In Ireland, all cetaceans are protected by a range of national legislation including the Wildlife Act (39/1976) and Amendment (38/2000), which prohibits the hunting, injury or wilful interference of individuals and destruction of their breeding places. The protection of cetaceans is further extended through the EU Species and Habitats Directive (43/1992) which was transposed into Irish law with the European Communities (Natural Habitats) Regulations (S.I. 94/1997) and Amendment (S.I. 378/2005). These legislative instruments oblige Ireland to designate Special Areas of Conservation (SAC) for the bottlenose dolphin within the entire Exclusive Economic Zone. Currently only one candidate SAC for bottlenose dolphins has been designated (Lower River Shannon), as it is the only known site in Ireland with resident dolphins. A number of studies using photo-identification have been carried out in the Shannon Estuary (Berrow *et al.* 1996; Ingram 2000; Ingram and Rogan 2002; Englund *et al.* 2007). Further unpublished studies from Ireland by a number of authors have found some degree of site fidelity at a number of other locations including Donegal Bay, Broadhaven and Clew Bays, Co. Mayo, Connemara, Co Galway, Brandon Bay and Kenmare River, Co Kerry, and Cork Harbour (Wilson and Smiddy 1988; Ingram *et al.* 2001; Ingram *et al.* 2003; O'Cadhla *et al.* 2003; Englund *et al.* 2007; and O'Brien *et al.* 2008). A large scale survey of bottlenose dolphins in Irish waters was carried out as part of SCANS II, which was a pan-European project aimed to generate absolute estimates for small cetaceans in the European Atlantic Continental Shelf area, including the Irish Sea (SCANS-II 2008). Using the estimates generated for four areas; western Scotland and Irish outer shelf (1,128, CV=0.87), Irish Sea (235, CV= 0.75), Coastal Ireland (313, CV=0.81), and the Celtic Sea (5,370, CV=0.49), an abundance estimate amounts to 6,482 bottlenose dolphins for all Irish waters. The figure from western Scotland and Irish outer shelf was halved as about 50% of this area was surveyed. From these figures, although arbitrary and taken from abundance estimates with high confidence intervals, it is apparent that Irish waters could hold 51% of the total European population of bottlenose dolphins.

In this chapter, matches of individually recognisable bottlenose dolphins from around the Irish coast are presented, and the implications for management, including the designation of SACs are discussed.

MATERIALS AND METHODS

Images of bottlenose dolphins from around the Irish coast were obtained from a number of sources (Table 1). The Galway-Mayo Institute of Technology (GMIT) holds a photo-identification catalogue which comprises 48 identifiable individuals from Galway and Clew Bay (Catalogue 1). Between July and September 2008, systematic surveys were carried out in Donegal Bay by the Irish Whale and Dolphin Group (IWDG), some of which were funded by the National Parks and Wildlife Service (NPWS). A total of eight surveys were carried out and 45 individual dolphins were identified (Catalogue 2). The IWDG have recently established an on-line photo-identification catalogue for a range of cetacean species recorded in Irish waters. Included in this catalogue are 27 individual bottlenose dolphins with recognisable markings, collected from around the Irish coast, accessible online at www.iwdg.ie/photo-id (Catalogue 3). Images from the three available catalogues were combined and referred to as the Irish Coastal Dolphin Catalogue (ICDC). Markings used to identify individuals during the present study included nicks or notches on the trailing edge of the dorsal fin (ranging from one to several), while some dolphins had unique scratches as well as a condition described as scoliosis, an abnormal curvature of the spine. Images from these three catalogues totalling 120 individuals were compared to determine whether any matches could be found between them. All images from Donegal Bay, Galway Bay and Clew Bay were taken using high resolution digital cameras, with minimum file sizes of 1.5 megabytes for each image. Some of the images submitted by the public were of lesser resolution but were of usable quality. All images were viewed using Photoshop imaging software, in order to identify unique markings. Images were graded using a Q-scale (0-3), where grade three images were of good quality and were mostly used to initially identify an individual while also to confirm matches. Images of grade two were of lesser quality but were sometimes sufficient to verify a match, while grade zero to one, were determined poor quality and were therefore unusable. The images presented throughout this document are compressed and therefore do not represent their true quality when viewed in their original format. Distances between re-sightings were calculated using Mapsource software as the latitude and longitude were known for all sightings.

In order to further explore the movements undertaken by the individuals identified under the ICDC, comparisons were made with two further catalogues, one from Ireland and one from the UK. The Shannon Dolphin and Wildlife Foundation (SDWF) manage a catalogue of 180 individually recognisable bottlenose dolphins from the Shannon Estuary obtained between May 1993 and October 2008. Sea Watch Foundation (SWF) manage a catalogue of bottlenose dolphins from West and North Wales since the 1990s comprising 219 marked individuals (recognizable from both sides through nicks, big scars or pigmentations), plus 112 individuals identifiable only from one side (with no nicks or big scars/pigmentations) (Pesante and Evans 2008).

RESULTS

The ICDC catalogue comprises 120 individually recognisable dolphins and of these 23 were subsequently re-sighted elsewhere (Table 1), equating to a 19% re-sighting rate (Table 2). Re-sighting rates of dolphins in each sub-catalogue were consistent and high, with 31-36% of dolphins re-sighted at other locations (Table 2). Most (14 individuals) were from the Galway Bay (GB) catalogue, thirteen from Donegal Bay (DB) and ten from the IWDG catalogue. The latter included dolphins from Counties Antrim, Cork, Dublin, Kerry, Galway and Mayo (Table 1, Figure 1). The 23 individual matches are shown below with key identifications used for each match including distance and time between each re-sighting.

1. BNDIRL1: This individual was first recorded in Cork Harbour in May 2007 and was later re-sighted in Bantry Bay in June 2007. Re-sighting interval: 26 days. Distance between sightings: 175km. At a minimum, this dolphin travelled 6.7km per day between the two locations (Table 2). Key identification features: 2 nicks towards the bottom of the dorsal fin, pale leading edge at top of fin and white horizontal mark around two-thirds down right-hand side of the dorsal fin.

BNDIRL1 Cork Harbour; 15.05.2007
Photo credit: Conor Ryan

BNDIRL1 Bantry Bay; 10.06.2007
Photo credit: Maurice Fitzgerald

2. GB20: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay. It was re-sighted on 10 May 2007 in Cork Harbour. Re-sighting interval: 45 days. Distance between sightings: 380km. Key identification features: 5 nicks along the trailing edge, largest two present towards the bottom of the fin.

GB20 Galway Bay; 26.03.2007
Photo credit: Joanne O'Brien

BNDIRL7 Cork Harbour; 10.05.2007
Photo credit: Conor Ryan

3. GB19: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and re-sighted in Cork Harbour in the same group as GB20 on 10 May 2007. Re-sighting interval: 45 days. Distance between sightings: 380km. Key identification features: four large nicks from the middle to the bottom of the fin.

GB19 Galway Bay; 26.03.2007
Photo credit: Joanne O'Brien

BNDIRL8 Cork Harbour; 10.05.2007
Photo credit: Conor Ryan

4. BNDIRL24: This dolphin was first recorded off the Antrim coast on 17 June, 2007 and was later recorded in Donegal Bay in August, 2008. Re-sighting interval: 423 days. Distance between sightings: 280km. There was a second re-sighting of this animal in Ventry Harbour on 30 April, 2009. Re-sighting interval: 258 days. Distance between re-sightings 390km. Key identification features: 3 nicks, the largest present at the base of the fin and tooth rakes on leading edge.

BNDIRL24 Antrim; 17.06.2007
Photo credit: Pauline Majury

DB36 Donegal Bay; 15.08.2008
Photo credit: Simon Berrow

Ventry Harbour; 30.04.2009
Photo credit: Nick Massett

5. GB01: This individual had a spinal deformity called scoliosis (Berrow and O'Brien, 2005) and was first photographed on the north-shore of Galway Bay on 29 June 2005. It was re-sighted in Clew Bay, on 30 July 2007. Re-sighting interval: 760 days. Distance between re-sighting: 130km. Key identification features: the spine,

immediately behind the dorsal fin has a pronounced hump and lesions anterior to the dorsal fin.

GB01Galway Bay: 29.06.2005CB01
Photo credit: Joanne O'Brien

Clew Bay: 30.07.2007
Photo credit: Joanne O'Brien

6. GB27: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and was re-sighted in Donegal Bay on 15 August 2008. Re-sighting interval: 506 days. Distance between re-sighting: 300km. Key identification features: 2 nicks, one mid and one base of the trailing edge and white leading edge.

GB27 Galway Bay: 26.03.2007DB39
Photo credit: Joanne O'Brien

Donegal Bay: 15.08.2008
Photo credit: Simon Berrow

7. GB16: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and re-sighted on 8 August 2008. Re-sighting interval: 499 days. Distance between re-sightings: 300km. Key identification features: 7 nicks along the trailing edge, largest nick preset at the base of the fin and extensive scarring on leading edge.

GB16 Galway Bay: 26.03.2007
Photo credit: Joanne O'Brien

DB02 Donegal Bay: 08.08.2008
Photo credit: Simon Berrow

8. GB18: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and re-sighted in Donegal

Bay on 23 July 2008. Re-sighting interval: 483 days. Distance between re-sightings: 300km. Key identification features: 2 nicks, one near the top of the dorsal fin, and the second near the base.

GB18 Galway Bay: 23.03.2007
Photo credit: Joanne O'Brien

DB04 Donegal Bay: 23.07.2008
Photo credit: Simon Berrow

9. GB22: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and re-sighted off Valentia, Co. Kerry on 2 July 2008. Re-sighting interval: 462 days. Distance between re-sightings: 200km. Further sightings of this individual were recorded in Donegal Bay on 23 July and 15 August, 2008. Key identification features: triangular shaped dorsal fin, with 6 nicks along the trailing edge and pale tip with tooth rakes and scars.

GB22 Galway Bay: 26.03.2007
Photo credit: Joanne O'Brien

BNDIRL21 Portmagee: 02.07.2008
Photo credit: Phyllis Olsen

10. GB23: This individual was first recorded on 26 March, 2007 in a large group of between 70-100 dolphins on the south shore of Galway Bay and re-sighted in Donegal Bay on 23 July and 15 August 2008. Re-sighting interval: 460 days. Distance between re-sightings: 300km. Key identification features: four nicks from the middle of the fin to the base and extensive scarring.

GB23 Galway Bay: 23.03.2007
Photo credit: Joanne O'Brien

DB07 Donegal Bay: 15.08.2008
Photo credit: Simon Berrow

11. GB07: Another dolphin from the group recorded in Galway Bay on 26 March 2007 and re-sighted in Donegal Bay on 8 August 2008. Re-sighting interval: 499 days. Distance between re-sightings: 300km. There was a second re-sighting of this animal on the North Antrim coast on 19 May 2009. Re-sighting interval: 284 days. Distance between re-sighting 240km. Key identification features: 2 nicks, one at the top of the fin, and a second larger nick present at the base and white leading edge.

GB07 Galway Bay: 26.03.2007
Photo credit: Joanne O'Brien

DB14 Donegal Bay: 08.08.2008
Photo credit: Simon Berrow

GB07 North Antrim coast:19.05.2009
Photo credit: Gary Burrows

12. GB25: Another individual from the group recorded in Galway Bay on 26 March 2007 and re-sighted in Donegal Bay on 8 and 15 August 2008. Re-sighting interval: 499 days. Distance between re-sightings: 300km. Key identification features: 2 nicks at the base of the fin, a bump towards the upper end and white leading edge.

GB25 Galway Bay: 26.03.2007
Photo credit: Joanne O'Brien

DB27 Donegal Bay: 08.08.2008
Photo credit: Simon Berrow

13. GB08: This animal was first recorded in Galway Bay on 12 April 2007 and was re-sighted in Donegal Bay on 15 August 2008. Re-sighting interval: 490 days. Distance between re-sightings: 300km. Key identification features: three nicks, one present at the top, mid and base of the fin and white scarring near top of fin.

GB08 Galway Bay: 12.04.2007
Photo credit: Joanne O'Brien

DB32 Donegal Bay: 15.08.2008
Photo credit: Simon Berrow

14. CB40: This individual was first recorded in Clew Bay on 11 June 2007, and re-sighted off Valentia, Co. Kerry on 2 July 2008. Re-sighting interval: 385 days. Distance between re-sightings: 260km. Key identification features: scoliosis, two nicks at the base of the dorsal fin, and tooth rakes along the spine directly behind the dorsal fin.

CB40 Clew Bay: 11.06.2007
Photo credit: Joanne O'Brien

BNDIRL25 Portmagee: 02.07.2008
Photo credit: Phyllis Olsen

15. BNDIRL17: This animal was first photographed off Dublin Bay on 2 June, 2008 and was recorded in Galway Bay on 31 August 2008. Re-sighting interval: 90 days. Distance between re-sightings: 650km. Assuming a direct route was undertaken between Dublin and Galway, this animal would have travelled a minimum of 6.6km per day. A further re-sighting of this individual was recorded off the North Antrim coast on 19 May, 2009. Re-sighting interval: 261 days. Distance between re-sighting 460km. Key identification features: 2 broad nicks and a third small one near base of the fin. The large upper nick gives a downward-pointing spike.

BNDIRL17 Dublin Bay: 02.06.2008
Photo credit: Susan Early

GB46 Galway Bay: 31.08.2008
Photo credit: Joanne O'Brien

North Antrim coast: 19.05.2008
Photo credit: Gary Burrows

16. BNDIRL11: This dolphin was recorded in Cork Harbour on 10 May 2008 and re-sighted in Donegal Bay on 8 August 2008. Re-sighting interval: 89 days. Distance between re-sightings: 650km. This individual could have swam an average of 7.3km per day between the two areas. Key identification features: 5 small nicks, 1 large at the base of the fin and extensive scarring.

BNDIRL11 Cork Harbour: 10.05.2008
Photo credit: Conor Ryan

DB26 Donegal Bay: 08.08.2008
Photo credit: Simon Berrow

17. BNDIRL22: This dolphin was recorded in Red Bay, Antrim on 17 June, 2007 and re-sighted in Ventry Harbour on 30 April, 2009. Re-sighting interval: 683 days. Distance between re-sighting: 575km. Key identification features: More than 4 nicks, 2 on lower dorsal give "anvil"-like profile shape.

BNDIRL22 Antrim: 17.06.2007
Photo credit: Pauline Murray

BNDIRL22 Ventry Harbour: 30.04.09
Photo credit: Nick Massett

18. DB35: This dolphin was first recorded on 15 August, 2008 in Donegal Bay, and was re-sighted on 30 April, 2009 in Ventry Harbour, Co Kerry. Re-sighting interval: 258 days. Distance between re-sighting: 365km. Key identification features: 4 large nicks along dorsal fin, and several small nicks near top and base of fin.

DB35 Donegal Bay: 15.08.2008
Photo credit: Simon Berrow

Ventry Harbour: 30.04.2009
Photo credit: Nick Massett

19. DB09: This individual has been sighted twice before in Donegal Bay on 23 July and on 15 August, 2008. It was re-sighted on the North Antrim coast on 19 May, 2009. Re-sighting interval: 277 days. Distance between re-sighting: 365km. Key identification features: One elongated notch from top to mid-fin.

DB09 Donegal Bay: 15.08.2008
Photo credit: Simon Berrow

North Antrim coast: 19.05.2009
Photo credit: Gary Burrows

20. DB18: This dolphin was first sighted on 8 August 2008, and was re-sighted off the North Antrim coast on 19 May 2009. Re-sighting interval: 284 days. Distance between re-sighting: 260km. Key identification features: One nick on upper dorsal, and a broad fin profile.

DB18 Donegal Bay: 08.08.2008
Photo credit: Simon Berrow

North Antrim coast: 19.05.2009
Photo credit: Gary Burrows

21. BNDIRL10: First recorded in Cork Harbour on 10 May 2008 and re-sighted in Donegal Bay on 15 August 2008. Re-sighting interval: 97 days. Distance between re-sighting: 575km. A second re-sighting of this individual was recorded off the North Antrim coast on 19 May 2009. Re-sighting interval: 276 days. Distance between re-sighting: 365km Key identification features: One elongated nick and other clearly visible nicks: one close to top of dorsal fin, and several below the elongated nick, with the lowest notch located on the dorsal ridge, posterior to the dorsal fin.



BNDIRL10 Cork Harbour 10.05.2008
Photo credit: Conor Ryan

DB31 Donegal Bay: 15.08.2008
Photo credit: Conor Ryan

North Antrim coast: 19.05.2009
Photo credit: Gary Burrows

22. GB11: This dolphin was first sighted in Galway Bay on 26 March 2007 and was been re-sighted in Galway Bay on 31 August 2008. A second re-sighting was recorded on 19 May 2009 off the North Antrim coast. Re-sighting interval: 261 days. Distance between re-sighting: 460km. Key identification features: 2 elongated notches and several nicks of various sizes along the length of the dorsal, giving the fin edge a jagged look.


GB11 Galway Bay: 26.03.2007
Photo credit: Joanne O'Brien


North Antrim coast: 19.05.2009
Photo credit: Gary Burrows

23. GB47: This dolphin was first sighted in Galway Bay on 31 August 2008 and was re-sighted off the North Antrim coast on 19 May 2009. Re-sighting interval: 261 days. Distance between re-sighting: 460km. Key identification features: Two nicks, one smaller at the top of dorsal fin, one larger at the base.


GB47 Galway Bay 31.08.2008
Photo credit: Joanne O'Brien


North Antrim coast: 19.05.2009
Photo credit: Gary Burrows

Of the 23 dolphins re-sighted around the Irish coast, 13 animals (57%) were first identified in Galway Bay in March 2007. There is evidence of associations between individuals as two dolphins recorded together in Galway Bay on 26 March 2007 were also recorded together in Donegal Bay on 23 July, three dolphins recorded on 26 March 2007 were together in Donegal Bay on 8 August 2008, two dolphins in Galway Bay on 26 March 2007 were recorded together on 10 May 2008 in Cork harbour, and three dolphins recorded together in Galway Bay in March 2007 were recorded together off Antrim in May 2009. Only 25 individual dolphins were identified among 70-100 dolphins recorded in Galway Bay on 26 March 2007, with many not photographed. It is likely that if other individuals were photographed then additional matches would have been made as this group accounts for a high proportion of the long distance matches, e.g. Galway to Dublin (c650km), Antrim (460km), Cork Harbour (380km) and Donegal Bay (300km). This group would appear to be highly migratory and transient.

The time between re-sightings ranged from 26 to 760 days, while distances apart also ranged greatly from 130 to 650km (Table 1). For three individuals, the minimum mean distance travelled per day was recorded as 6.3km (BNDIRL1), 6.6km (BNDIRL17) and 7.3km (DB26).

No matches were found between the ICDC catalogue and the SDWF catalogue of the resident dolphins in the Shannon Estuary. No matches were found between the ICDC catalogue and the SWF catalogue from West and North Wales. Intensive photo-identification is being carried at out at both of these sites with high re-sighting rates of individuals. Therefore we might expect re-sightings if dolphins from the ICDC catalogue entered these areas.

DISCUSSION

Results from the present study provide some of the most comprehensive evidence of wide-scale, long-distance movements of bottlenose dolphins in European waters, and highlights the power of photo-identification for studying long-distance movements. Previous photo-identification studies carried out in Irish waters by Ingram and Rogan (2003), recorded re-sightings of 9 individuals, between two years on the south coast between Youghal Bay and Cork Harbour, and one individual first recorded off Connemara was re-sighted off the Cork coast. The only other comparable study carried out in European waters was by Wood (1998).

Using the same technique, Wood (1998) reported on the large-scale movement of Cornish dolphins over a 650km stretch of coastline between Cornwall and West Wales during a three year period and on one occasion recorded dolphin re-sightings 1,076km apart. The results presented in the latter paper provide evidence of movements of a similar scale to that seen around the Irish coast, with re-sightings ranging over distances of c130km and c650km. Given that the sample size of images used during the present study was small and that images were received from all coasts, the high re-sighting rate is remarkable. A relatively small population of dolphins around the Irish coast may be responsible for the high sighting rate. This speculation would be in agreement with the SCANS II data, as abundance estimates were reported as 313 individuals for coastal Ireland (CV=0.81). It is apparent however, that the re-sighted individuals archived in the ICDC are highly migratory and transient.

Results from satellite telemetry studies carried out internationally have found that bottlenose dolphins travel over large distances. Tanaka (1987), reported on bottlenose dolphin movements of 604km over an 18 day period, while similarly Wells and Scott (1990), reported movements of 670km. The largest movements reported in Britain were by Wood (1998), where dolphins were recorded in two different areas 1,076km apart, with sightings only 20 days apart. The shortest time between sightings during the present study was recorded between Portmagee, Co. Kerry and Donegal Bay (21 days, number 9) over a distance of 370km, while another individual (number 1) was recorded between Cork Harbour and Glengariff (26 days), over a distance of 175km. This means that at an absolute minimum, dolphin number 1 travelled 6.7km per day during the passage between the two areas, while number 9 travelled at an absolute minimum of 17.6km per day while on route to Donegal Bay.

Bottlenose dolphins are listed under Annex II of the EU Habitats Directive which requires that they be given strict protection in clearly identifiable areas (Special Areas of Conservation, SACs). Under this Directive, SACs will be proposed where there is "a clearly identifiable area representing the physical and biological factors essential to their life and reproduction", while further criteria is listed as the continuous or regular presence of the species, subjected to seasonal variation (EEC 1992). A total of 18 SACs have either been designated or proposed specifically for bottlenose dolphins in EU member states (Anon 2006). In Ireland, there is currently only one candidate SAC for bottlenose dolphins (Shannon Estuary) on the western seaboard of the country. It has been hypothesized that coastal stocks of bottlenose dolphins comprise residents, which are localised to certain areas, and transient animals, which migrate seasonally into and out of areas (Scott *et al.* 1988), and the data presented here supports this theory. Since no matches were found between ICDC and Ireland's only known resident group of bottlenose dolphins, we can speculate that the dolphins identified from around the Irish coast are transient and do not mix with the resident animals in the Shannon. Hence, it would be interesting to examine through future research whether they are genetically isolated from each other. The large-scale movement undertaken by these transient dolphins does pose concern for the conservation management of this species, especially since their migrations take them into both Irish and UK waters. Of the 23 re-sighted individuals, nine (39%) have been recorded off the Co. Antrim coast. Therefore the Irish government needs to adopt a collaborative conservation approach with the UK, to ensure successful conservation of the species.

In order to comply with the EU Habitats Directive, and to ensure the designation of SACs is effective, an understanding of the driving force behind these movements is required. We need to know the distribution and ranging patterns of these animals in order to identify where they spend the majority of their time. Identifying key areas where they are most vulnerable, such as calving and nursery grounds should be paramount. This information is vital before effective management through the use of protective areas can be instigated. Isolated SACs may not be effective for these far ranging animals and management may require a network of SACs with migrating corridors as a better approach. The results presented in this paper should help to inform management of the importance of photo-id for monitoring such mobile Annex II species, outside of the management plans devised for designated areas. We recommend that a National Bottlenose Dolphin Photo-identification catalogue is established where researchers and the public are encouraged to submit images obtained as part of both dedicated surveys and casual records. As a means to promote the usefulness of photo-identification, the ICDC will be available online from the IWDG website (www.iwdg.ie). It is recommended that photo-identification should be prioritised as a research tool for bottlenose dolphin conservation. As demonstrated here, significant findings can be derived from minimal effort and also through the use of opportunistic encounters and input from the public.

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APPENDIX 6

Table 1. Summary of individual bottlenose dolphin sightings and re-sightings

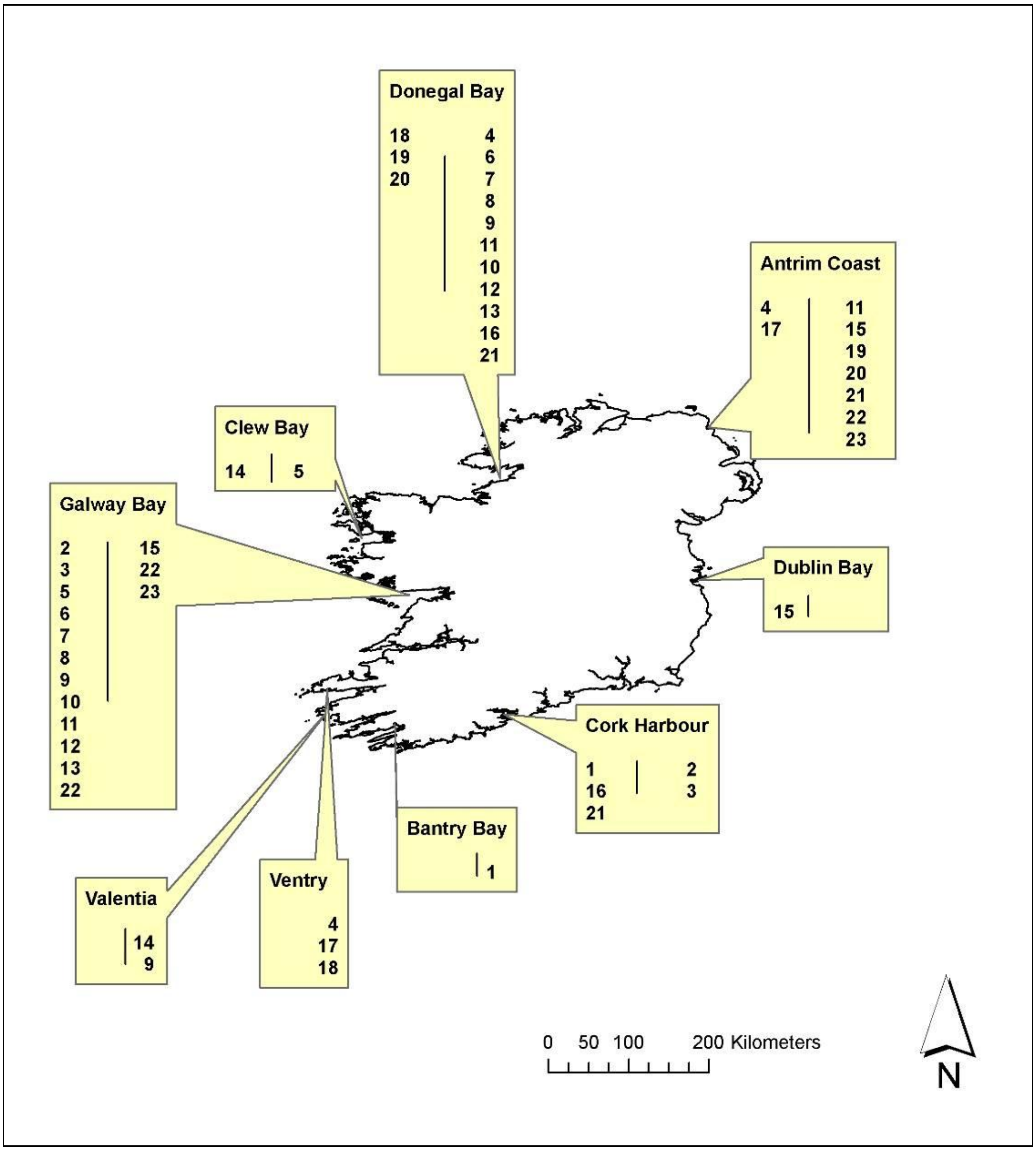
No. of animals identified	Details of 1st sighting				Details of 1st Re-sighting			Details of 2nd Re-sighting		
	Catalogue No.	Date 1st sighting	Lat	Long	Date	Lat	Long	Date	Lat	Long
1	BNDIRL1	15.05.2007	51.85	-8.32	10.06.2007	51.74	-9.53			
2	GB20	26.03.2007	53.14	-9.28	10.05.2008	51.84	-8.27			
3	GB19	26.03.2007	53.14	-9.28	10.05.2008	51.84	-8.27			
4	BNDIRL24	17.06.2007	55.07	-6.02	15.08.2008	54.49	-8.37	30.04.2009	52.1	-10.3
5	GB01	29.06.2005	53.21	-9.68	30.07.2007	53.86	-9.94			
6	GB27	26.03.2007	53.14	-9.28	15.08.2008	54.49	-8.37			
7	GB16	26.03.2007	53.14	-9.28	08.08.2008	54.56	-8.43			
8	GB18	26.03.2007	53.14	-9.28	23.07.2008	54.56	-8.43			
9	GB22	26.03.2007	53.14	-9.28	02.07.2008	51.93	-10.28	23.07.2008	54.56	-8.43
10	GB23	26.03.2007	53.14	-9.28	23.07.2008	54.56	-8.43			
11	GB07	26.03.2007	53.14	-9.28	08.08.2008	54.56	-8.43	19.05.2009	55.1	-6.12
12	GB25	26.03.2007	53.14	-9.28	08.08.2008	54.56	-8.43			
13	GB08	26.03.2007	53.14	-9.28	15.08.2008	54.49	-8.37			
14	CB40	11.06.2007	53.80	-9.90	02.07.2008	51.93	-10.28			
15	BNDIRL17	02.06.2008	53.35	-6.15	31.08.2008	53.23	-9.56	19.05.2009	55.1	-6.12
16	BNDIRL11	10.05.2008	51.84	-8.27	08.08.2008	54.56	-8.43			
17	BNDIRL22	17.06.2007	55.1	-6.02	30.04.2009	52.1	-10.3			
18	DB35	15.08.2008	54.5	-8.37	30.04.2009	52.1	-10.3			
19	DB09	23.07.2008	54.6	-8.43	19.05.2009	55.1	-6.12			
20	DB18	08.08.2008	54.6	-8.43	19.05.2009	55.1	-6.12			
21	BNDIRL10	10.05.2008	51.8	-8.27	15.08.2008	54.5	-8.37	19.05.2009	55.1	-6.12
22	GB11	26.03.2007	53.1	-9.28	31.08.2009	53.2	-9.57	19.05.2009	55.1	-6.12
23	GB47	31.08.2008	53.2	-9.57	19.05.2009	55.1	-6.12			

Table 2. Summary of sighting rates from four bottlenose dolphin ID catalogues

Catalogue	Total identified	Number re-sighted	Re-sighting rate	% of re-sightings
GMIT	48	15	0.3	31
IWDG	25	9	0.4	36
DB	42	14	0.3	33
Total	**114**	**24**	**0.2**	**21**
SDWF	209*	0	0	0
SWF	204*	0	0	0

* not identified as part of this study

Figure 1. Distribution map of bottlenose dolphin sightings (under each location column one represents where the animals was first sighted and column two represents where the animals were re-sighted). Numbers are according to Table 1, column "no. of animals identified"



CHAPTER 6

EXPLORING THE SOURCES OF VARIABILITY ASSOCIATED WITH VISUAL MONITORING OF SMALL CETACEANS

INTRODUCTION

The EU Habitats Directive (92/43/EEC) requires member states to monitor the distribution and abundance of all cetaceans listed under Annex IV of the Directive. Further emphasis is placed on cetaceans listed under Annex II (bottlenose dolphin and harbour porpoise), for which *Special Areas of Conservation* (SACs) must be implemented, protected and monitored. According to Dawson *et al.* (2008) information on the absolute abundance of a population is the most basic knowledge that can be acquired in conservation ecology. As the size and distribution of animal populations changes over time, conservation research deals with the reasons for such shifts (Evans and Hammond 2004). Trends in cetacean abundance can indicate the status of a population. For example, a sudden decrease may highlight the need for implementation of specific conservation measures, the success of which can be determined through subsequent monitoring. Information on the distribution and abundance of a population within a defined area may highlight an area as important, warranting designation as an SAC or *"Marine Protected Area"* (MPA). As defined by the *International Union for Conservation of Nature* (IUCN) an MPA is a "clearly defined geographical space, recognized, dedicated, and managed, through legal or effective means, to achieve the long-term conservation of nature with associated ecosystem service and cultural value".

Monitoring spatial and temporal trends in coastal cetacean abundance encompasses a wide range of survey techniques including land, air and boat-based observer methods, as well as the use of technology such as satellite telemetry and acoustics, both passive and active. Two projects currently underway in Irish waters under statutory obligation include ISCOPE and PReCAST. ISCOPE (Irish Scheme for Cetacean Observation and Public Education) is an Irish Whale and Dolphin Group (IWDG) initiative aiming to promote better awareness and knowledge of cetaceans in Irish waters, by encouraging public participation in cetacean recording. PReCAST (2008-2011) is a partnership between the Galway-Mayo Institute of Technology (GMIT) and the IWDG aimed at providing robust scientific data to support conservation policy and providing guidance to state agencies in implementing national and international obligations. At a time when new developments are increasing around our coasts e.g. wave and wind energy developments, it is essential to gain a solid understanding of the distribution and abundance of cetaceans, in order to mitigate against disturbance. To gain such an understanding, the efficacy and suitability of various survey techniques need to be appreciated. This chapter seeks to critically review all visual survey methods used in Ireland and to explore the potential sources of variability encountered when surveying inshore cetacean populations.

Casual Sightings

The simplest way to gather information on a population or area is the collection of casual sightings. These observations are made while an individual's attention is not solely directed at watching or recording cetaceans but where individuals e.g. anglers, beach walkers and people living near the coast opportunistically sight and record species. A stringent measure of quality control through a validation process has to be adhered to when using such casual observations in order to correct for misidentification. Casual observations do not provide the opportunity of estimating abundance and are often inherently biased, due to variability in observer effort.

Strandings

Another practised approach to recording cetaceans is the use of strandings data. These data may contribute towards the generation of a species list within an area, while they also provide a rough measure of status and seasonal variation in abundance (Evans and Hammond, 2004). These data can also serve to detect disease outbreak, fisheries interactions, or changes in cetacean distribution (Berrow and Rogan 1997). However, stranding records do not fully represent an area of interest as their providence is unknown and some corpses may remain undiscovered in remote areas.

Dedicated Surveys

Dedicated land-based cetacean monitoring can provide very useful information on the geographical and seasonal distribution of species, abundance, presence of young and habitat use, as well as acting as a means of recognising important habitats and locations needing more intensive conservation plans. However, as shown in chapter two of this thesis, many years of observations are required before data are robust enough to detect trends. A study by Taylor *et al.* (2007), suggests that current survey technology and design will not allow for the reliable detection of even marked decreases in cetacean populations. Land-based monitoring is quantitative and is achievable at a very low cost when compared to other methods, such as dedicated ship or aerial-based surveying (Young and Peace 1999). This technique can therefore be used as a monitoring tool and is accessible to a wide range of researchers, both experienced and inexperienced. Given such a broad range of competencies involved, inter-observer variability may render the reliability of this method questionable where data using different observers is compared. A significant problem may arise where location and observers are confounded. Young and Peace (1999) found that estimation of group size was the largest source of observer variability encountered during land-based surveys. Another form of bias, spatial auto-correlation may also be experienced during land-based watches, where the same animals may be counted as on preceding watches However, this bias should minimised or eliminated where watches are carried out monthly.

Monthly dedicated land-based effort watches are carried out by the IWDG to gather information at a number of sites around the coast of Ireland as part of an inshore monitoring programme. Basic training is provided by the IWDG through ISCOPE courses run nationally, but there is no standardised protocol regarding survey methodology, nor the intricacies involved therein. The variability amongst observers needs to be identified and quantified, with a view to mitigating any bias that may exist, in the interests of strengthening and assuring the quality of this important dataset.

Dedicated cetacean surveys can also be carried out visually from sea going vessels and aircraft. This method allows for a pre-designed sampling regime (line transects), from which a measure of absolute abundance can be generated. Line transect methodology requires the measurement of the perpendicular distance of each sighting from the track-line of the vessel, as well as the bearing of the sighting from the track. Vessel-based surveys can use double or single platform methodology, where single platform entails observers stationed on the main deck of the vessel, while double platform requires two observers positioned on a higher deck using binoculars to track ahead of the secondary observers at a lower level surveying by eye. This approach is used to reduce the occurrence of missed animals on the track-line. Depending on sea conditions, high quality line transect data can be collected from vessels as small as 6m, but vessels in the size range of 10-20m are probably ideal (Dawson *et al*. 2008). It is recommended that boat-based surveying be carried out at a speed of 2-3 times greater than the typical average speed of the survey species or a positive bias may result (Hiby 1982; Dawson *et al*. 2008). Travelling at these recommended speeds is not possible during aerial surveying, and therefore this method gives rise to false negatives as animals under water may be missed when passing over an area at such high speed. An important requirement for successful aerial surveying is the ability to see directly under the aircraft. Surveys need to be carried out at a low altitude (500ft/152m is typical) and at a relatively slow speed (100 knots/185km per hour) (Dawson *et al*. 2008). The likelihood of experiencing a responsive movement of animals from the survey platform is less likely from aerial surveying than boat-based surveys for species such as the harbour porpoise (Buckland *et al*. 2001; Slooten *et al.* 2004).

A software programme called DISTANCE developed by Buckland *et al.* (2001) was designed for analysing line transect data, and is used to generate absolute abundance with a measure of precision through confidence intervals. This software package allows users to select a number of models in order to identify the most appropriate for their data and sampling design, while it also allows for the truncation of outliers when estimating variance in group size and testing for evasive movement prior to detection (Buckland *et al*. 2001).

Photo-identification

Absolute abundance can also be generated using mark-recapture methodology from photo-identification data. Photo-identification (Photo-ID) is a technique commonly used to study the movements and behaviour of whales and dolphins worldwide and was first applied to bottlenose dolphins by Würsig and Würsig (1977). This technique works on the principle of photographing individual animals and identifying natural markings unique to that individual (Würsig and Würsig, 1977; Wilson 1995; Wilson *et al*. 1999). For many dolphin and whale species, these features are present on their dorsal fins, bodies and tails. The trailing edge of a bottlenose dolphin dorsal fin is very thin and is readily tattered during the animal's life (Würsig and Würsig 1977), and these marks are most reliable over time. Other teeth marks and pigmentation patches are also found on the dolphins fin and other parts of the body, but usually only last from six months to a year (Würsig and Würsig, 1977). Previous studies using photo-identification have shown that 70-80% of individual bottlenose dolphins are thought to be identifiable through natural markings (Bearzi *et al.* 1997; Karczmarski and Cockcroft 1998), although these numbers may vary geographically. However, Hammond (1986) suggests that the permanence of a marking for one individual may not be the same for all individuals within that population. Quality of photographs used for photo-identification is paramount. Traditionally, images for photo-identification studies were taken using SLR cameras equipped with slide film, while analysis took place using a lighted table and loupe from which to pick out identifiable qualities. Photographs would be graded and accurate tracings made of the trailing edge of the animal's dorsal fin. From these tracings a method called "fin ratio", which was first devised by Defran *et al.* (1990) is also incorporated. This method measures the distance between notches to the tip of a bottlenose dolphin's dorsal fin. This ratio method allows for an accurate measure of re-sightings and also allows for individuals who pick up new markings to be re-identified. Furthermore, the identification of other marks such as shape of fin, pigmentation patterns, wound marks and scars result in a matrix of features and this coupled with the calculation of fin ratios ensure correct re-identification of individuals (Karczmarski and Cockroft 1998).

With recent developments in digital technology, almost all images collected for photo-ID studies are taken using digital SLR cameras, with wide angle zoom lenses. The use of digital imaging minimises the amount of effort involved in grading and analysing photographs. Such improvements include the advancement from light benches to computer monitors and from the use of photographic loupes, slide projectors and paper tracings to executive tools such as Adobe Photoshop (Mazzoli *et. al.* 2004). Digital imaging also enables the use of software programmes such as FinScan, Finex, Phlex, and Phluke Phinder. FinScan was designed to assist in the photo-identification process electronically providing researchers with a smaller number of likely matches and therefore reducing the amount of time required to match individuals (Kreho *et al*. 1999). Europhlukes operated between 2001 and 2004 and aimed at producing a European cetacean photo-identification system and database. These software programmes work on a similar technique to the dorsal fin ratio as mentioned above.

As the technique of matching animals photographically can be carried out manually using different observers, a degree of subjectivity may exist between individuals. A study by Friday *et al.* (2000) found inconsistent levels of agreement between observers when identifying humpback whale flukes. Stevick *et al*. (2001) point out that the use of good quality images can lead to a reduction in this bias. The photographic recognition of dolphins can then be applied to mark-recapture software called CAPTURE, and absolute abundance estimates can be generated from this data. This software works on a number of assumptions such as the population being closed during the sampling period, animals do not lose their markings over the duration, and that all animals have an equal chance of being "captured" during each encounter. If an abundance survey is carried out over durations of months and years, then it is highly unlikely that these populations remain closed or that each animal has the same probability of encounter. Well marked animals can be identified more regularly than those which are lesser marked, whilst some individuals have no marks at all. The proportion of unmarked animals must be estimated in order to transform the data to account for these individuals within an estimate. Failure to do so, will lead to an under estimation of the population.

In Irish waters, bottlenose dolphins are thought to be the third most abundant species (Berrow *et al.* 2002). They have been recorded off all coasts and the Shannon Estuary is home to Ireland's only known resident group. Bottlenose dolphins are listed under Annex II of the EU Habitats Directive which stipulates that they be given strict protection in clearly identifiable areas or SACs. In Ireland, there is currently only one area protected as SAC for bottlenose dolphins (The Shannon Estuary as part of the Lower River Shannon SAC 002165). The Lower River Shannon SAC has been the focus of previous research where several abundance estimates have been derived for the resident group of bottlenose dolphins through the use of small scale dedicated transects and Capture-Recapture methodology. Population sizes of 113±16 bottlenose dolphins in 1997 (Ingram 2000), 121±14 (CV=0.12, 95%CI=103-163) in 2003 (Ingram and Rogan 2003) and 140 ±12 (CV=0.08, 95% CI 125-174) in 2006 (Englund *et al.* 2007; 2008). The Shannon Estuary was used during the present study as the probability of sighting animals is high, therefore providing the opportunity to treat the area as a laboratory from which to carry out a number of experiments.

This chapter aims to explore the effect of inter-observer variability using land and vessel-based techniques, and furthermore through the circulation of a questionnaire to the network of inshore-observers who carry out monthly dedicated quantified effort watches. A SWOT (strength, weakness, opportunities and threats) and cost analyses of visual techniques used were carried out, in order to facilitate further comparison between visual methods. With the evaluation and identification of potential variability between monitoring methods and observer techniques, it is envisaged that a protocol can be devised to reduce the level of variability during future training courses and surveys set out to measure abundance. Additionally, the efficacy of boat and aerial-based surveying was assessed for the generation of abundance estimates in the Shannon Estuary for bottlenose dolphins as well as assessing the difference that an elevated platform has on the detection of bottlenose dolphins. This chapter is set out in four parts, where parts 1 and 2 investigate the potential sources of variability that can lead to inconsistencies between observers and therefore introducing and expanding bias within a visual dataset. Part 3, assesses the efficacy of survey techniques for estimating abundance, and part 4 is a cost analyses of visual techniques used.

I. EXAMINATION OF INTER-OBSERVER VARIABILITY

MATERIALS AND METHODOLOGY

Trials to assess inter-observer variability were carried out in the Shannon Estuary on the west coast of Ireland, on the 22 and 24 July, 2005 and again between 6 and 8 June, 2008. A total of five locations around the estuary were selected where there was a high probability of sighting dolphins (Figure 1). These sites included Loop Head (52°32’N, 9°54’W), Kilcredaun Lighthouse (52°34’N, 9°42’W), Kilcredaun Point (52°35’N, 9°42’W), Aylevarroo (52°37’N, 9°28’W), and Money Point (52°36’N, 9°24’W).

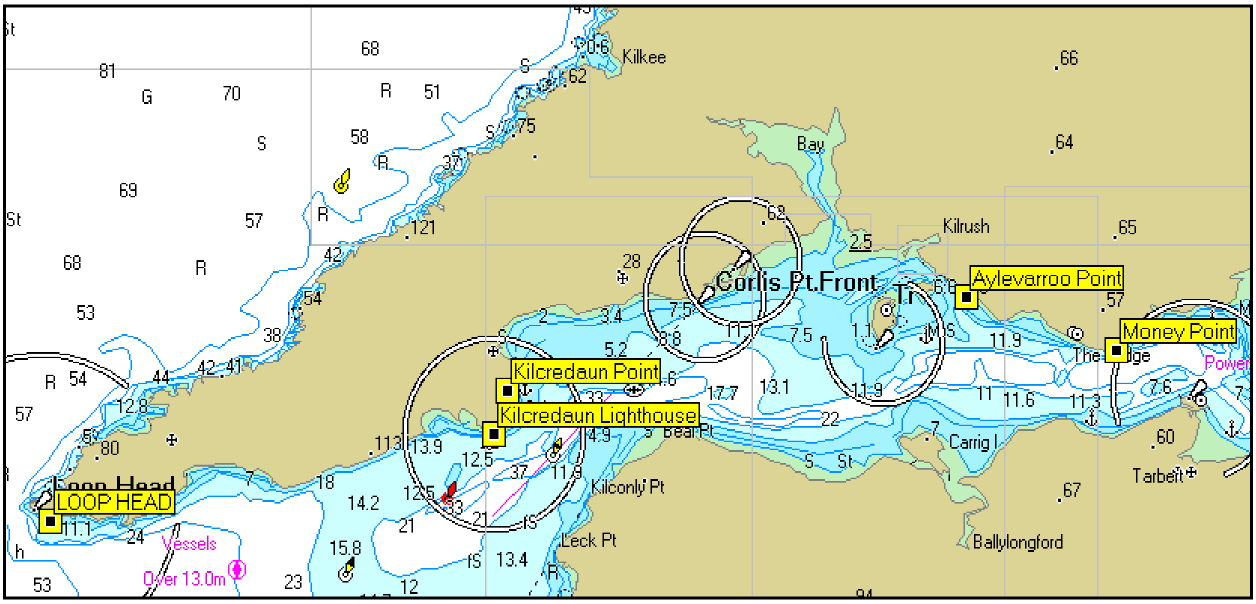


Figure 1. Map of land-based sites where observer trials were carried out

- In 2005, six observers were present during each trial. Three observers had little or no experience previously observing cetaceans, while the remaining three observers were classed as skilled observers, who had extensive experience in the field. In 2008, three teams of four were used to explore the degree of observer variability between individuals, and on this occasion all observers used had a good degree of experience observing cetaceans in the field.

- During trials, all observers were positioned together on a headland and each observer was instructed to scan the area constantly with the aid of binoculars during 15 minute sampling periods. Beach screens were used to ensure observers were visually excluded from one another, therefore watches were confidential to each observer (Figures 2 and 3).

- Binoculars of various specifications were randomly distributed between observers. Each observer was supplied with a folder containing recording sheets and a synchronised stopwatch.

- During 2005, a total of four 15-minute sampling periods were monitored for cetaceans and this was repeated at each of the four selected sites. While in 2008, twenty 15-

minute sampling periods were sampled across three locations (Money Point, Kilcredaun Lighthouse and Kilcredaun Point).

- Prior to commencement of each sampling period, environmental conditions (sea state, visibility, wind force and direction, and cloud cover) at the time was recorded at each site. All observations were carried out in a sea state two or less.

- Once a sighting was made by an individual observer, he/she filled out their recording form, making note of such information as the time the sighting was made, the number of groups observed, number of individuals observed, the distance of the observed animals, as well as behaviour. At the end of the sampling period each observer returned recording forms to a folder before discussing observations with other observers.

- Additionally in 2008, a number of trials were carried out to explore inter-observer variability when estimating distance from shore. For the purpose of these trials observers were lined up along a headland and asked to estimate the distance of a rigid hull inflatable boat (RIB) at varying distances from the shore. The distance of the RIB from shore was determined prior to each trial using a Leica Rangemaster 1200. This range finder was accurate to within ±2m over 800m or ±0.5% over 600m (Berrow *et al*. 2008). Observers were given no feedback on the first trial, while on the second before the estimation of each distance, observers were told the previous distance as determined using the range finder.


Figures 2 and 3. Positioning of observers along the headland and also the beach screen used to separate each observer.

RESULTS

Observer trials 2005

Three species of cetaceans were recorded during observations, harbour porpoise, bottlenose dolphin, and common dolphin. Common dolphins and harbour porpoises were recorded from Loop Head, while bottlenose dolphins were observed from the other three sites further east along the estuary. In order to establish which statistical tests were to be used, the data were tested for homogeneity of variances using a Levene's test and these were not significantly different (P=0.96). All statistical analyses were carried out using the software package SYSTAT 11. As all observers were looking at the same patch of water during trials, the data were treated as dependent variables. An analysis of variance (ANOVA), using a repeated measures test, was the chosen test statistic, allowing the same variable to be measured several times for each subject. Results showed that there was no significant difference between observers in the time taken to record the first sighting (P=0.76). However, a significant difference was found between observers when estimating the number of groups to be present (P=0.02), and furthermore when estimating the total number of individuals within a group (P=0.00) (Table 1). *Post hoc* paired comparison t-tests showed where these differences existed between observers and also allowed for the exploration of the hypothesis that there was no significant difference between experienced and naive observers.

Table 1. ANOVA Results for time taken to record first sighting, estimation of number of groups, and no. of individuals present (N=6 observers)

	Test parameter	*df*	*SS*	*MS*	*F*	*P*
2005 data	Time	5	644	129	1.2	0.36
	Groups	5	17.1	3.4	6.8	0.00
	Numbers	5	299	60	7.4	0.00

Table 2. Results from *Post hoc* pair-wise comparisons (Bonferroni correction factor)

Results from pair-wise comparisons					
Categories	Obs No.	Diff of X	df	T-value	Adj. P-value
4.No. of groups	1-3	0.8	15	2.8	0.01
	2-3	0.96	15	2.6	0.02
	2-4	0.73	15	2.7	0.01
5. No. of individuals	2-3	5.1	15	3.6	0.00
	3-4	0.7	15	2.7	0.01

Post hoc paired-comparisons showed that there was a significant difference between 3 of the 15 pairs of observers analysed (20%) when estimating the number of groups and 2 out of the 15 pairs (16%) when estimating the number of individuals to be present (Table 2). Of the five pairs showing significant differences when estimating the number of groups and individuals to be present, one observer was consistently present. Results from ANOVA repeated measures test found significant difference between naive and experienced observers when estimating number of groups (P=0.02) and individuals (P=0.01), with naive observers estimating significantly less groups and individuals to be present.

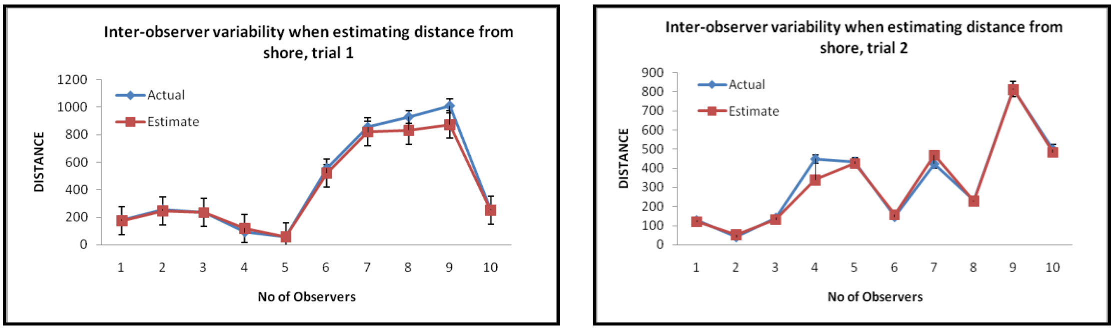
Observer trials 2008

Data from 2008 were examined similarly to the data from 2005. Each of the three groups who participated in the trial were analysed separately. Statistical analyses examined the variation in time taken to record first sighting, number of groups present, number of individuals within a group, distance of the observed dolphins from the shore and behaviour were addressed. Only bottlenose dolphins were recorded during trials in 2008 as only three sites were used during observations, Kilcredaun Lighthouse, Kilcredaun Point and Money Point which are all located within the estuary (Figure 1). The data were tested for equal variances (P=0.90), and ANOVA repeated measures test was again used due the variables being dependant. No significant difference was found between any of the groups or the parameters tested (Table 3).

Table 3. Results from Anova repeated measures test, 2008 data.

Group Number	Test parameter	*df*	*SS*	*MS*	*F*	*P*
Group 1	Time	3	16.3	5.46	0.41	0.75
	Groups	3	41.3	13.8	0.57	0.63
	Numbers	3	9.1	3.0	1.82	0.17
	Distance	3	45	151	1.3	0.29
	Behaviour	3	16.3	5.44	2.37	0.09
Group 2	Time	3	8.5	2.8	0.08	0.97
	Groups	3	2.5	0.85	0.37	0.78
	Numbers	3	12.5	4.17	0.09	0.96
	Distance	3	175	583	2.33	0.22
	Behaviour	3	0.37	0.13	0.06	0.98
Group 3	Time	3	32.5	10.83	0.76	0.54
	Groups	3	1.68	0.56	0.73	0.56
	Numbers	3	12.5	4.17	0..75	0.54
	Distance	3	191	688	1.10	0.39
	Behaviour	3	6.19	2.06	1.43	0.28

Inter-observer variability when estimating distance from shore was also tested. Results from these trials showed no significant variation in estimation across observers (Figures 4 and 5), (ANOVA repeated measures test, F=4.38, P=0.20). The distance estimates from the 10 observers were particularly accurate out to 200m, while observers tended to underestimate at greater distances (Figure 4). During the second trial observers were given feedback on the previous distance estimation and this was reflected in more accurate estimation by all observers (Figure 5).



Figures 4 and 5. Results from distance trials carried out from land

II. OBSERVER QUESTIONNAIRE

INTRODUCTION AND METHODS

Given the important variation found between some observers in field trials, the underlying reasons for this variation were investigated. Observer experience, dependent only on time spent in the field was deemed independent of standardisation or control, so investigations focused on the approach and methodology adopted by individual observers. A sample of 15 volunteer observers within the IWDG constant effort network were selected and interviewed regarding their field methodology and techniques. Observers were queried under four broad categories concerning 1) frequency and duration of watches, 2) recording of environmental conditions, 3) scanning technique and use of optics, and finally, 4) detailing of sightings.

RESULTS

1. Frequency and duration of watches

The frequency with which the 15 observers watched for cetaceans as part of the scheme varied from as seldom as less than once a month (occasional) to as often as three times a month or more (frequently). Table 4 outlines the frequency of effort amongst observer

Table 4. Frequency of watch effort by individual volunteers

Frequency of effort	Percentage of volunteers
Frequently (≥3 times/month)	7%
Weekly (4 times a month)	13%
Monthly (once a month)	60%
Bi-monthly (twice a month)	13%
Occasional (less than once a month)	7%

Sixty percent of observers adhered to a standard watch duration, with individuals using fixed times from anything between 10 minutes and 210 minutes (3.5 hours). The average watch duration was 117 minutes, as 40% of observers did not adhere to a standard duration of watching. The IWDG require observers to carry out watches for 100 minutes. The duration of a watch also varied depending on weather, presence or absence of cetaceans, time of day and family commitments.

2. Recording of environmental conditions

One hundred percent of observers recorded weather conditions as set out on the IWDG constant effort forms. Such details include sea state, wind force and direction, visibility and glare.

3. Scanning technique and use of optics

All observers carried out watches with the aid of optical equipment. Eighty percent of observers used both telescopes and binoculars, while 20% used binoculars alone. Of those who used binoculars and telescope in combination, 93% had no standard system of alternating between the two. While carrying out observations, 87% of those surveyed claimed to have a personally standardised scanning method. Such personally standardised methods were innately different between individuals, for example speed of scanning, distance scanned and commitment to optics varied widely. Sixty percent of observers had a personally defined watch area, to which they confined scanning efforts. The size of these areas differed between individual observers and sites. If cetaceans were encountered during a watch, a single observer admitted to following these animals until out of sight or to the end of the watch, but 93% of observers promptly returned to scanning to record new animals during the remainder of the watch. After initial identification had been ensured and behaviour noted, 67% of observers remained aware of previously encountered animals. This allowed detailing of how long such animals remained in the area under observation, as well as reducing the chances of double-counting.

4. Detailing of sightings.

When cetaceans were encountered, observers logged mandatory details such as species, numbers and behaviour. A further obligatory field on the IWDG recording sheet, distance from shore, was recorded by all but one observer. Sixty percent of observers recorded an additional detail of orientation of animals from the vantage point, which is not required by the IWDG recording sheet. Eighty seven percent of observers don't stop the clock while recording details of observed animals. If animals were observed at an early stage of a watch, 53% of observers did not continue to make additional notes on those animals. In order to avoid double counting, observers noted and used the following as guides: direction of travel, distance apart, time between sightings, behaviour previously noted, species, experience, distinguishing marks and presence of juveniles.

III. DERIVING AN ABSOLUTE ABUNDANCE ESTIMATE OF BOTTLENOSE DOLPHINS IN THE SHANNON ESTUARY

MATERIALS AND METHODOLOGY

Study area

Boat-based surveys were carried out between Foynes Island, Co. Limerick, west to the mouth of the estuary between Loop Head and Kerry Head, a distance of 60 km. For the purposes of the present study the estuary was divided into two parts and referred to as the inner and outer (Figure 6) (c.360km^2). The purpose of this division was to use two vessels for surveying and therefore achieve more coverage of track-lines within the area on a single day.

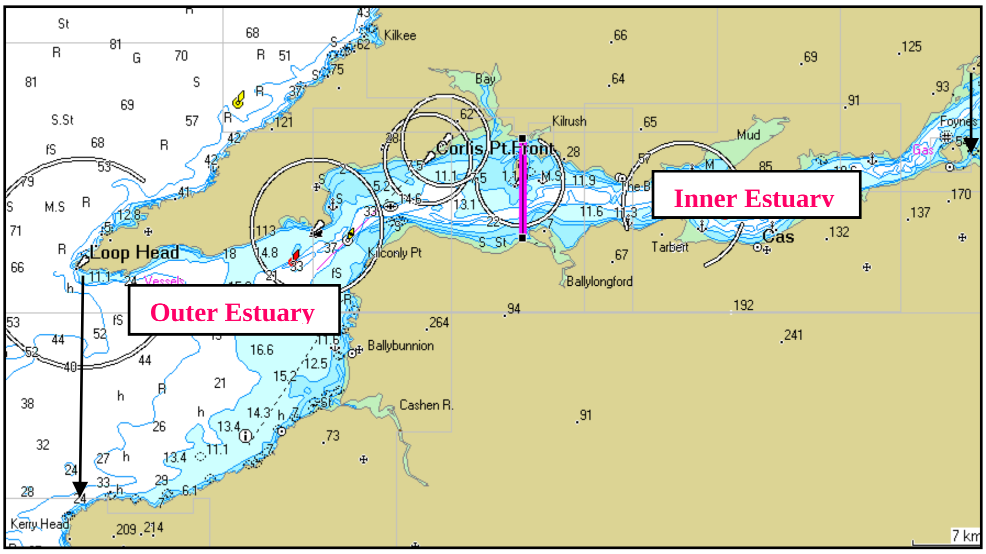


Figure 6. Map of the Shannon Estuary and division of the inner and outer estuary for the purposes of the present study

Survey Platforms

Three survey platforms were used during the present study. Two vessels were used during boat-based surveys (Figures 8 and 9). The M.V. Rinevella Bay, a 17.6m motor yacht with a flying bridge 3.0m above the water line, while the second vessel the M.V. Jennifer Ann is a 12m with a flying bridge 2.5m above the water line.

A small single passenger Cessna plane (Figure 7) was used for aerial surveying, and therefore only a single observer could carry out visual observations from the cockpit alongside the captain of the aircraft.

Figure 7, 8 and 9. Plane and boats used during surveys.

Ship-based methodology

Single platform line-transect surveys were carried out within the boundaries of the inner and outer estuary along the pre-determined track-lines (Figure 10). All track-lines undertaken were pre-determined as suggested by Dawson *et al.* (2008) who stipulated that systematic line spacing results in better precision than the generation of randomized tracks. During the survey, both vessels travelled at an average speed of $20km^{h-1}$ (12 knots).

For the duration of the survey , two primary observers were positioned on the flying bridge of each vessel , and were instructed to watch dead ahead and to 90° on the side of the vessel and out to a distance 300m within this survey arc. Observers were rotated every 30 minutes. All observations were carried out by eye, while all sightings were truncated at 300m to reduce the effect of size bias as distance increases variability and obscures the DISTANCE model in fitting with g(0). Two additional observers were positioned on the lower decks of each of the vessels. These observers surveyed by eye from 0 to 90° on the side of the vessel they were positioned. The aim of this latter exercise was to determine if height played a role in locating and recording bottlenose dolphins. A fifth person recorded survey effort. The survey effort of each of the vessels was tracked continuously through the use of an external GPS receiver, which was connected to a laptop computer which ran the LOGGER software (©IFAW). Environmental conditions were recorded every 15 minutes, and these included; sea state, wind strength and direction and glare. When a sighting was made, the position of the vessel was recorded immediately, quickly followed by the angle of the sighting from the track-line, as well as the distance of the sighting from the vessel. These data were communicated to the LOGGER station orally if the observer was positioned on the bridge deck or via VHF radio if the station was positioned in the wheel house.

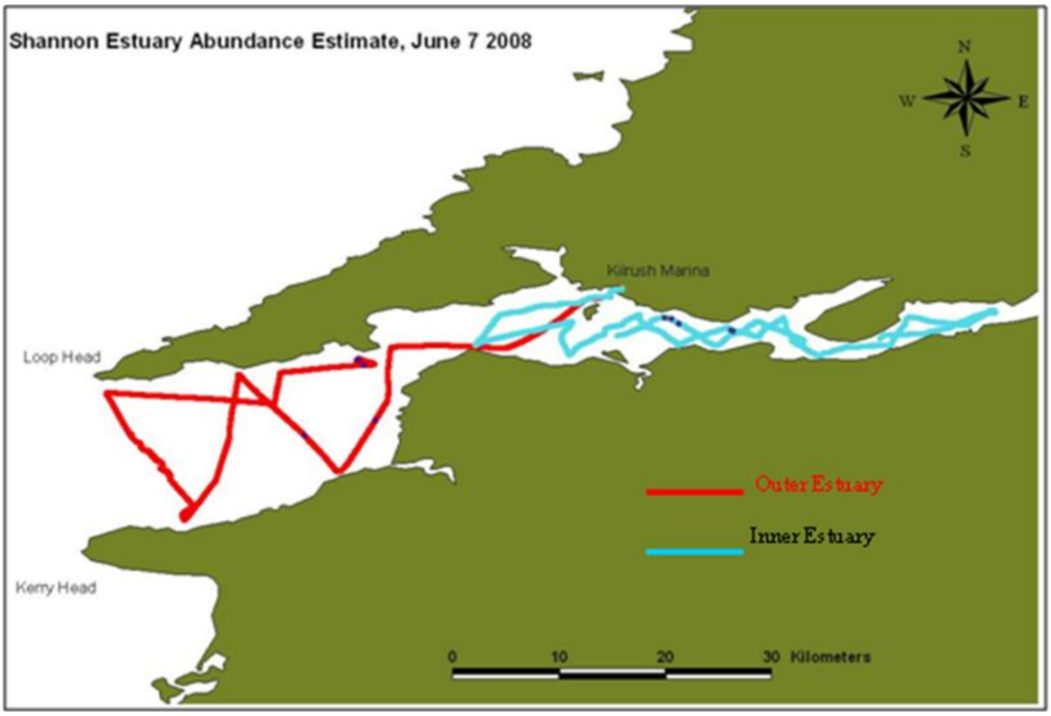


Figure 10. Boat-based tracks covered during surveying, (n=154 km).

Aerial-based methodology

During the aerial survey, a single observer was positioned onboard a small Cessna 152 aircraft. The survey was carried out at an altitude of 700ft/214m and at an average velocity of 160km/h^{-1}. The observer was positioned on the left hand side of the plane and transect lines ran up and down the estuary from Loop Head to Tarbert Island (Figure 11). The observer focused on a different track-line during the four legs which ran east to west up and down the estuary. The altitude of the plane was high, due to the positioning of high chimneys located at the power stations on either side of the estuary, Money Point (225m/715ft) and Tarbert (151m/497ft) and furthermore because the Shannon Estuary is within the approach air strip to Shannon airport. The track of the aircraft was recorded using a Garmin handheld GPS, and the track was later downloaded using the software Mapsource.exe. All sightings were logged manually on recording forms including details such as distance of the observed animals, number of groups and number of individuals.

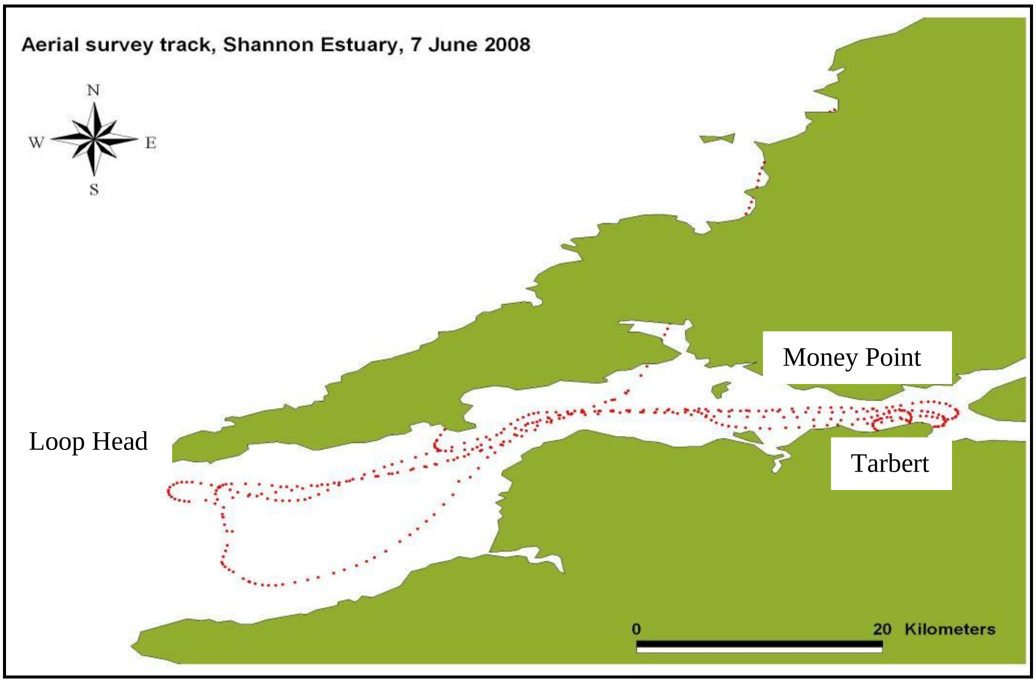


Figure 11. Aerial survey track, covering both the inner and outer estuary (n=175 km).

Inter-observer variability (boat-based)

Non-parametric Kruskal-Wallis tests were carried out on the data to test for significant difference between the heights from which the primary and secondary observers carried out visual observations.

Comparison between methods

A comparison between boat and aerial-based surveying was also carried out. A non-parametric Kruskal-Wallis test was carried out in order to test for significant difference between methods and to highlight which method was most successful.

RESULTS

Boat and aerial based surveying

Boat-based surveys covered the entire Lower River Shannon SAC (inner and outer) within a single day (7 June 2008), totalling 154km of survey effort. Simultaneous aerial surveying also took place between Loop Head (outer estuary) and Tarbert (inner estuary) totalling 175km of survey effort. The combination of methods totalled 329km of visual survey effort within an area of 360km^2. Sea conditions were very good over the duration of all surveying, with 90% of surveying carried out in a sea state 0-1, and 10% carried out in a sea state 2. Bottlenose dolphin sightings were recorded in both the inner and outer estuary during surveying. During boat-based surveying, clusters of sightings were recorded off Kilcredaun in the outer estuary and off Money Point in the inner estuary. A total of 10 sightings were recorded from boat-based surveying, while only a single sighting was recorded during the aerial survey (Table 5). All sightings from boat-based observations were input into the software programme DISTANCE 5.0 (Thomas *et al.* 2006) and absolute abundance was estimated. DISTANCE software requires a minimum number of sightings to run the analysis, so this assumption was violated as only 10 sightings were used. An abundance estimate from boat-based surveying equated to 270 (95% CI 182-401) with a goodness of fit of χ^2=46.2, 4*df*, P=0.00 (Table 5, Figure 12). As only a single sighting was recorded from aerial-based surveying, these data could not be used for generating an abundance estimate.

Table 5. Sightings recorded during surveys

Survey platform	**No. of sightings**	**No. of animals**
Aerial	1	5
Boat (inner)	5	13
Boat (outer)	5	11

Table 6. Absolute abundance generated from boat aerial and a combination of both techniques

Survey platform	Total distance surveyed (KM)	N +/- 95%CI	Confidence interval	Density	Av cluster size	Effective Search Width
Boat	154	270 (182-401)	0.2	0.75	0.66	102.77

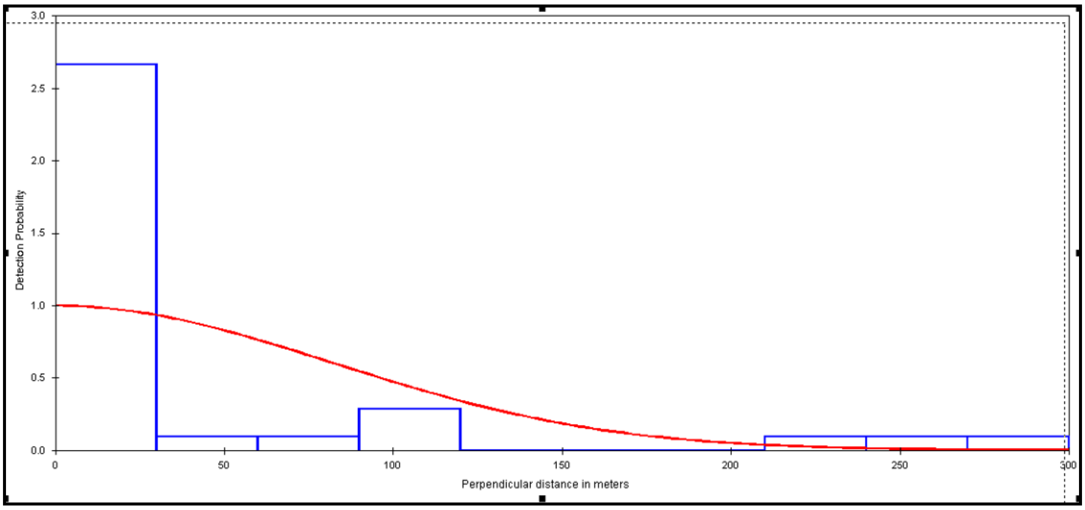


Figure 12. Detection function from boat-based surveys.

Inter-observer variability (ship-based)

During boat-based surveys, on no occasion did the observers on the lower platform see dolphins before observers on the primary platform (KW, H=19, *df*=1, P=0.00).

Comparison between methods

A comparison between methods showed that more coverage could be obtained quicker through aerial surveying when compared with boat-based. However, more sightings were recorded from boat-based surveys and only a single sighting was recorded during aerial observations. Statistical analysis showed that there was no significant difference between methods (KW, H =0.99, *df*=1, P=0.31), but this is most likely attributed to a low sample size.

IV. COST ANALYSES OF SURVEY TECHNIQUES USED AND THE ASSESSMENT OF THE EFFECTIVENESS OF 100 MINUTES WATCH DURATION AS REQUIRED BY IWDG

COST ANALYSES OF SURVEY TECHNIQUES

A cost analysis of survey techniques was undertaken in order to critically compare results and to derive approximate measures of costs incurred from the various survey techniques used. Land-based watches from Black Head and Spiddal in Galway Bay for the years 2005 to 2007 were used for the generation of land-based costs (Chapter 2) allowing a cost per unit sighting and per individual recorded to be derived. Costs were generated to account for observations where only mileage was incurred, but furthermore in the incidence where an observers' time was also covered, as in the case of some IWDG personnel who carry our monthly dedicated watches in SACs. The rate of mileage was calculated according to that set out by GMIT staff rates for a car with an engine size of 1,201cc to 1,500cc (0.4625c). The provision of observer rates was based on the IWDG's flat-rate of €250 per day which is paid to cover monthly watches only in SACs. The costs incurred from land and aerial-based surveying carried out in the Shannon Estuary in 2008 were used to generate a cost per unit sighting and per individual based on covering the cost of plane and boat hire. Furthermore, unit costs were also generated from these results, assuming three observers were paid a flat-rate of €300 per day during boat based surveys, and one observer was paid the same daily rate for aerial surveying.

RESULTS

Watches were carried out bi-monthly and monthly at Black Head and Spiddal between March 2005 and February 2007. Based on mileage alone, the cost per unit sighting ranged between €21.33 and €36.25, while the cost per individual sighted ranged between €7.79 and €13.00 (Table 7). However, with the coverage of an observer's time for a flat-rate of €250 per day, these costs increased significantly from €210.00 to €411.00 per sighting and between €63.80 and €152.20 per individual (Table 7). Costs would be even higher where an observer had a car with an engine size of 1,501 cc or greater.

Table 7. Cost analyses of land-based effort watches

DETAILS OF LAND-BASEDWATCHES					Expenses					
					Excl. obs rate (€250 pp)			Incl. obs rate (€250pp)		
Location	No. of watches	Distance (km)	No of sightings	No. of indiv.	Travel cost (0.4625 /km)	Cost per sight	Cost per indiv.	Obs rate	Cost per sighting	Cost per indiv.
Black Hd	37	66	44	145	30.5	25.60	7.79	250	210.0	63.8
Spiddal	28	18	17	46	12.95	21.33	7.88	250	411.8	152.2

A similar approach was taken for calculating the costs incurred during boat and aerial-based surveying of the Shannon Estuary in 2008. Firstly, the cost was generated using volunteers and therefore, only considering the cost of boat and plane hire. Secondly, costs were generated based on covering three observers at a flat-rate fee of €300 each per day for boat based surveys, and for two observers aerial surveying additional to the cost of boat and plane hire. Ideally, three observers are required to successfully perform boat-based line transect surveys, where two observers are required for primary platforms and one observer operates LOGGER to record survey effort and sightings. Aerial costs were generated for one observer on a Cessna plane at €300 per day. Using volunteers for aerial and vessel-based surveying, as during the present study, the cost per unit sighting ranged between €100 and €120 and between €20.00 and €54.55 per individual. When an observer's time was included in the cost, sightings cost between €300 and €400 each. Per individual animal sighted, costs ranges from €80 to €136.36.

Table 8. Cost analyses of boat-based line transect surveying

SURVEY DETAILS				Survey platforms (boats €600 each and plane €100)		Observer flat-rate (€300 per day 3 obs per vessel)	
Survey technique	Total distance	No. of sightings	No. of indiv.	Cost per sighting	Cost per indiv.	Cost per sighting	Cost per indiv.
Boat 1	80	5	13	100	46.15	300.00	115.38
Boat 2	74	5	11	120	54.55	300.00	136.36
Aerial	175	1	5	100	20	400	80.00

LAND-BASED QUANTIFIED EFFORT WATCHING

Land-based quantified effort watching was carried out in Galway Bay as part of the present study (Chapter 2), where each watch was carried out for a duration of 100 minutes. As determined through the observer questionnaire, observers commented that they often found 100 minutes lengthy when carrying out a watch. Based on these statements, it is possible that successfully locating and recording cetaceans is greatly reduced when observers are distracted or not fully concentrating on a watch. Therefore, the dataset from Galway Bay was explored to assess the distribution of sightings recorded across the 100 minute samples in order to determine if 100 minutes is entirely necessary.

RESULTS

A total of 45 watches were extracted from the Galway Bay dataset, where cetaceans were recorded. The number of minutes taken to record the first and last sightings were noted for all watches (Figure 13). It was found that the average number of minutes taken to record first sighting was 32 and where multiple sightings were recorded during a watch, on average the last sighting was recorded in the 55th minute. Therefore, the first half of the 100 minute duration was more productive than the latter half.

Figure 13. Average distribution of sightings recorded over time.

DISCUSSION

All visual techniques used to monitor cetaceans have various advantages and disadvantages associated with both data collection and analyses (Table 9). The present study explored the efficacy of vessel and aerial-based visual surveying as a means of estimating absolute abundance in a highly turbid environment, while also carrying out an evaluation of survey platforms. Track-lines covered during aerial-based surveying using a single observer amounted to 175km and were completed within 1 hour 15 minutes. On the other hand boat surveying used 10 observers on two boats, which took approximately 5 hours each (aggregate 10 hours). Therefore, 10 hours of boat surveying took just 1.25 hours in the air to cover the same approximate area. However, a total of 10 sightings were recorded during boat-based observations, while only a single sighting was recorded from aerial surveying. Statistical analysis showed no significant difference between methods, but this was most probably attributed to the low number of sighting recorded across both methods.

The cost of dedicated surveys is a universal limitation experienced by researchers the world over. Aerial surveying can be achieved at a lower cost per km surveyed when the total area covered and number of observers required is taken into consideration. However, it may not yield the same number of sightings that can be achieved from boat-based surveying. The main disadvantages of aerial surveying in the Shannon Estuary are that the number of false negatives is probably high due to the plane's elevation and the turbidity of the water, as well as the fact photo-identification cannot be achieved. Aerial surveying of the estuary would prove beneficial if incorporated with boat-based surveying over the long-term as it could be carried out at a low cost and would provide additional coverage within the area. This would be especially useful during winter months to optimise short spells of suitable weather conditions. As the number of observers used during boat-based surveying was greater than aerial, greater variability in the data would be expected. The use of one observer during aerial-based surveying was not ideal but it potentially reduced the incidence of bias. Surveys should be tailor-made to study requirements, but results from the present study show that aerial and boat-based line transects would be an efficient way of estimating abundance in the area if carried out systematically to ensure a large sample of sightings to conform with the requirements of the DISTANCE model. During boat-based surveys, the survey line can be broken and resumed once animals have been photographed. Absolute abundance was estimated from boat-based surveys only. This estimate (154, CV=0.2, 95% CI 182-401) generated during the present study is only marginally greater the most recent absolute abundance estimate as determined through mark-recapture between June and September 2008 (114, CV=0.15, 95% CI 85-152, Englund *et al.* 2008). The confidence interval from both studies overlaps, but the overall abundance estimate is higher from the present study and was most likely attributed to too few sightings used in the model.

As platforms differ between surveys and techniques, it was hypothesised that the height from which observers survey on boats would have no effect on the ability to detect bottlenose dolphins in the area. RIBs are the most common platform type used in the Shannon Estuary for monitoring the bottlenose dolphin population (Ingram 2000, Ingram and Rogan 2003; Englund *et al.* 2007; 2008). During boat-based trials, experiments were set up to test for differences in platform height. All primary observers positioned on the flying bridge recorded all sightings before secondary observers positioned on the lower deck. Through statistical analysis (KW P=0.00, *df*=1, H=19), it was found that observer height played a significant role on the successful location of bottlenose dolphins. This result could not be attributed to observer experience or inability, as all observers were randomly positioned at all locations over the survey duration. Once the primary observers recorded the sighting, the secondary observers never recorded any further details, therefore further analysis was not feasible. However, from these results, it is recommended that all surveys for small cetaceans aimed at estimating abundance and density be carried out from vessels with a platform of at least 2m or greater above water level. Although a RIB is useful to manoeuvre amongst animals once located, it does have an impact on finding and locating animals in the first instance and it may lead to an increased number of false negatives. In places where regular surveys are carried out, or where observers have a good knowledge of the distribution of cetaceans, this might not be as evident, but where surveys are targeting new areas, or where there is little known about the distribution and abundance, the incidence of missed animals from low platforms may be more prominent. Dawson *et al.* (2008), suggest that increased height allows observers to see animals further away and lessens the incidence of a responsive movement.

Cost analyses of the various visual monitoring techniques provided a comparison of costs incurred and an evaluation of value for money. Generally, land-based watching is considered a cheap way of gathering information on an area. However, when an observer is remunerated, this increases the cost considerably. The ISCOPE scheme, run by the IWDG incorporates the use of a network of volunteers and is therefore a cost effective means of gathering data. If expertise amongst the wide range of observers involved can be refined to a level of limited inter-observer bias, then the efficacy of this method will have a huge contribution to the knowledge and conservation of coastal cetaceans. One of the limitations associated with land-based watching is that an observer is not actively moving when searching for cetaceans and therefore the probability of encountering animals is lower. Boat-based and aerial-based surveying are expensive methods when the cost of observers and platform hire is taken into account. In the instance of paying observers, only experienced personnel are generally used and therefore the accuracy of these surveys is ensured. For the generation of accurate abundance estimates for a large area or for carrying out photo-identification studies, boat-based surveying is unrivalled.

Results from inter-observer trials give an important insight into the level and range of variation that exists between observers, which potentially affects all visual techniques employing multiple observers. Previous studies estimating inter-observer variability between paired counts of observers, found a 21% variation between observers surveying within the same viewing area for gray whales (Rugh *et al.* 1990), while Young and Peace (1999) suggest that the estimation of group size is the largest source of variation between observers surveying bottlenose dolphins. Undevitz *et al.* (2005) showed that inter-observer variability was more prominent when groups of over 10 hauled-out walruses were counted. As numbers increased so did inter-observer discrepancies. If the same observer is used across surveys then at least any bias is constant, but where the number of observers increases, the level of variability may also increase accordingly. Land-based trials testing for inter-observer variability in 2005, used both experienced and naive observers, while in 2008 only observers with many years experience in the field participated in the trials. Interestingly, significant variation between observers was only found in the 2005 data, where both experienced and naive observers took part. From the 2005 data, experience was found to play a role in the successful location of cetaceans, when estimating group numbers and size. No differences were found between observers in the 2008 data, showing that the use of experienced observers will eliminate significant bias in a dataset, leading to small confidence intervals and a higher precision.

Further sources of inter-observer variability were explored through the use of the observer questionnaire. Observer experience is dependent on the amount of time spent in the field and was deemed independent of standardisation or control, so investigations focused on the approach and methodology adopted by individual observers. Observers were queried under four broad categories concerning 1) frequency and duration of watches, 2) recording of environmental conditions, 3) scanning technique and use of optics, and finally, 4) detailing of sightings. It was clear that the frequency with which volunteers carried out watches varied widely, with certain observers carrying out relatively few watches, while others watched almost constantly. Under such circumstances, it could be expected that the field skills of those regularly carrying out watches would be improved compared to those carrying out watches irregularly. This may be an important source of variation in recording cetaceans around Ireland, in the same way that experience played a part during field trials. Further fallout from the variation in frequency with which individuals watch, is the amount of information built up for individual sites, as in the majority of cases, individual sites are covered by single individual observers. The IWDG request volunteers to cover their allocated site(s) at least once a month, and while 60% of volunteers surveyed met this requirement, it was not always realised. On the other hand, some sites are monitored well in excess of this frequency and the time scale required (100 minutes).

Overall, large-scale spatial coverage with the use of multiple observers will always experience bias and variability, which will confound a dataset. However, in identifying these variables, an opportunity is provided to mitigate their influence. In the long run, this will lead to a more robust dataset, which can be used with a high level of accuracy and credibility. A number of recommendations are made at the end of this discussion, aimed at targeting observer variability and reducing observer bias within datasets.

Table 9. SWOT "strengths weaknesses, opportunities and threats" of visual survey techniques

Type	Strengths/Opportunities	Weaknesses/Threats
Aerial	•Large coverage area in short timeframe •Useful to avail of short weather windows •Only require two observers •Fatigue less likely •Observer not open to the elements, important during cold conditions	•Turbid waters increase incidence of missing submerged animals •Fast speed may miss submerged animals •Hard to spot small species e.g. harbour porpoise
Ship-RIB	•Useful for manoeuvering amongst animals for photo-id •Less expensive than chartered vessels	•Height-harder to detect animals further away •Harder to estimate a responsive movement from the vessel
Ship-flying bridge	•Height, useful for locating animals further away •Availability of power for running computers •Stable platform	•Less manoeuvrable around animals for photo-id •Expensive method of surveying •Animals react to the vessel
Land-based effort watching	•Cheap method of surveying •Can be carried out without impacting on animals •Effort can be quantified	•Available to a wide range of observers, prone to inter-observer variability •Spatial auto-correlation

RECOMMENDATIONS

The following recommendations are made with a view to informing management on standardising visual data collection, which will contribute to a more successful means of conservation of small cetaceans around our coasts.

Vessel-based surveying

1. All boat-based surveys aimed at generating absolute abundance of small cetaceans should be carried out from a platform with a flying bridge of at least 2m above water level. The use of such a platform reduces false negatives by expanding an observers' available search width, making it easier to successfully sight and locate cetaceans.
2. If multiple observers are used, personnel should be kept constant, as this can lead to a reduction in the amount of inter-observer variability incurred.
3. All observers engaged in boat based surveying should have prior experience in the field, with at least 6 weeks ship time (NPWS MMO Requirements) spent surveying specifically for cetaceans. This is extremely important if the data collected are contributing towards abundance estimation or are collected as part of a monitoring scheme. Furthermore, all observers should be equipped with a distance stick (based on *Heinemann* (1981) equation). A distance measuring stick according to the *Heinemann equation* takes into account an observers' height above sea level, their

arm length and marks are made on the stick accordingly, unique to each individual observer. For this method to work the horizon must be in view. This will reduce the level of inaccuracy and inter-observer differences in recording distance, a critical requirement for the generation of abundance estimates from line transect surveying.

Aerial-based surveying

1. At least two observers should be used when carrying out aerial surveys, as surveying can be carried out from both sides of the aircraft.
2. Observers should be experienced in the field and have previously carried out 6 weeks of day surveying from the sea or air.
3. Ideally, observers should be able to see underneath the aircraft, therefore the need for a bubble window is mandatory. Slooten *et al.* (2004) reported that the estimated cost of fitting a bubble window to an aircraft was approximately $100, although this cost is estimated to be significantly greater in Europe. The price of converting a window especially if an aircraft is being used for surveying on a regular basis would be invaluable.
4. Aerial-based surveying is an effective means of surveying coastal bottlenose dolphins, and could be carried out at a cost much less than that of boat-based surveys. Many small flight clubs are positioned around the Irish coast where pilots are routinely flying to clock up air time as part of their licensing requirements. In the majority of cases such platforms can acquired for the cost of fuel expenses only. However, it is recommended that aerial surveys are carried out in conjunction with dedicated boat-based surveys when generating absolute abundance or density estimates, as the number of false negatives could be high, especially in turbid environments such as the Shannon Estuary.

Land-based watching

TRAINING

The IWDG operate one and two day training courses as part of their ISCOPE scheme but they are not designed specifically to train effort watchers. Therefore, it is recommended that rigorous training protocols are set up to instruct and calibrate observers to a certain degree before they start to form part of the inshore monitoring network or contribute to the IWDG constant effort scheme. This could be achieved through the following:

1. As part of the training process, observers should be taken into the field and asked to estimate distances of objects from a vantage point, similar to trials carried out as part of the present study. This will further instruct and help to calibrate naive observers in distance estimation.
2. During training courses, observers should be instructed on how to make their own distance stick based on the *Heinemann* (1981) equation to ensure the accurate recording of distances from shore. Observers should also have an angle board and compass in order to record the bearing of the observed animals from the observation point. Not only will this standardise the distance data collected during watches, but it will also expand the application of the data, enabling a measure of absolute abundance to be generated from sites or at least regions for single species.
3. A clear, concise methodology covering all aspects of a watch should be presented at each course in order to instruct observers on how to carry out a cetacean watch. This is very important for new observers beginning observations for the first time as it should not be left up to individuals to devise their own methodology.
4. A calibration test should be set up to evaluate an observer after training has been completed. This could be done simply by playing back footage of cetacean groups, and individuals asked to identify species, estimate number of groups, and individuals present.

Observers and observations

1. When recruiting new observers to cover sites, as part of the IWDG inshore monitoring scheme, observers should have a minimum number of hours or sightings logged in the field before their data start to be incorporated into the larger dataset. For example, if these observers were to start constant effort watches, then at least 10 hours should be spent observing in the field before their records contribute to the overall dataset. While they are gaining this experience, all sightings should be recorded during observations but they should only contribute towards the casual sightings database. This will reduce the amount of bias and in turn provide for a more robust dataset, making results easier to interpret.
2. It is recommended that an alteration be made to the IWDG constant effort forms to provide a column to record the angle of each sighting using a compass. Such information would facilitate identifying more accurately where a sighting was

positioned. But furthermore, it could lead to the generation of absolute abundance estimates through the use of spot counts using DISTANCE software, especially where watches are repeatedly carried out.

3. All observers should be instructed to record distance using distance measuring sticks based on the *Heinemann equation*, therefore standardising the collection of this data and enabling the collection of more accurate measurements. This is extremely important if data are used for spot count abundance estimates.

Questionnaire

1. A number of topics within the observer questionnaire were found to differ between observers and sites. These include the area an individual covered during a watch. Although this can be site specific, a recommendation needs to be made to instruct observers to watch out to a minimum or maximum distance, or an optimum ratio of elevation to distance.
2. More importantly, as highlighted through the questionnaire, observers carry out visual observations in a haphazard way, i.e. there is no universal configuration as to how individuals carry out their watches. Changing between optics is carried out randomly, some observers watch animals for the duration of the watch once they are located and some observers stop the clock when observing cetaceans. A universal approach to watch techniques and methodology needs to be adopted in order to reduce variability between sites, observers and optics. Such methodologies don't need to be complex, but a systematic approach to surveying would make data more robust and the comparability between locations less confounded. The following could be implemented:
   - Observers should always scan the area by eye once at least every five minutes to reduce eye strain, while also affording the opportunity to scan the entire search area at once. Alternating between optic tools should be systematic, e.g. 50% of watch carried out using binoculars, 30% using a telescope and 20% scanning by eye.
   - When animals are located, the clock should be stopped while details are being recorded, or while observers are only watching the observed group. The clock should immediately re-start once observers return to scanning.

- Observers should not watch a group of animals for longer than required and should never spend the remainder of a watch just observing these individuals.

3. Although recommendations are made by the IWDG to what optics best suit cetacean watching, it is at an observers own discretion as to what they use. Binoculars with a wide range of view should be used to scan for cetaceans, while a spotting scope to identify and count once located. Alternating between methods should be more systematic and therefore data collection would be more consistent.
4. Recording two additional parameters such as distance and bearing of the observed cetaceans to the observer will allow for greater application of the data, such as the generation of absolute abundance from spot counts for specific species. It is acknowledged that this is additional to what is already required of observers, but should not prove onerous, especially to experienced observers.
5. While environmental conditions were recorded by all volunteers as per the IWDG observer network, a further environmental factor, namely temperature, may also play a part in the ability of individuals to detect cetaceans. Colder conditions can lead to shivering and discomfort and may possibly lessen the efficacy of surveying, especially during lengthy watches. Featuring a scoring system on the recording sheet as a measure of viewing conditions would facilitate the IWDG to correlate sighting rates with observer comfort.

In summary, the use of a few experienced observers is much more beneficial than the use of a wide range of observers with varying degrees of ability. Greater spatial coverage may be achieved using greater numbers of observers. However, this may be at a cost, as the data can be confounded, mainly by naive observers' inexperience, and caution is advised when interpreting such results. It is recommended that the IWDG formalise a protocol for observers to adopt when carrying out land-based effort watches in order to standardise the structure of watch techniques and thereby reduce the level of variability that currently exists between observers across locations. Future training courses should be more regimental whereby observers are clear on the methodology and do not have to devise their own in the field. A measure of observer ability should also be determined at these courses, with a field test and a simulator using video footage used to gain a relative measure of observer ability. Results from these quick assessments should provide IWDG with a view as to how many watches an observer should carry out before their data are used as part of the inshore monitoring scheme. This would lead to a dataset less confounded by observer variability and methodology used, hence making the interpretation of results more clear.

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APPENDIX 7. ACKNOWLEDGEMENTS

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APPENDIX 8. Notes submitted to the Irish Naturalists' Journal based on results from the present study.

Note published in the Irish Naturalists' Journal

Berrow, S. D., O'Brien, J. (2006). "Scoliosis in bottlenose dolphins *Tursiops truncatus* (Montagu) in Ireland." *Irish Naturalists' Journal*, 28(5): 217-218.

Scoliosis in bottlenose dolphins *Tursiops truncatus* (Montagu) in Ireland and Britain

A world-wide review of vertebral column malformities in delphinids has recently been published (Berghan, J. and Visser, I.N. 2000 *Aquatic Mammals* **26**(10):17-25). Similar malformities have recently been observed in bottlenose dolphins *Tursiops truncatus* off the coasts of Cos Clare and Galway, which are now described, together with a review of other unpublished observations from Ireland and Britain.

A young bottlenose dolphin with a spinal abnormality was seen in the Shannon estuary in August 2001 (Geoff Magee, *pers. comm*.). On 4 August 2002, SB came across what may have been the same dolphin in the Shannon estuary off Kilstiffin Bank (52˚34'N, 9˚45'W). It was estimated to be less than 2.5m in length (from comparison with the 5.4m boat) and was pale in colour suggesting it was a juvenile (<2 years of age) and still dependant on its mother for nutrition (Thompson, P. and Wilson, B. 1996 *Bottlenose dolphins* Colin Baxter). It approached to within 1m of the boat providing excellent views and the opportunity to obtain video footage. It was obvious that it had a spinal deformity that affected its ability to swim and surface. The dolphin's spine was bent upwards and to the left, immediately posterior to its dorsal fin. A number of deep creases could be observed running from behind the dorsal fin down the dolphin's flank and onto its belly, demonstrating how deep was the malformity. This dolphin has not been reported since September 2002.

On 29 June 2005 a bottlenose dolphin with a spinal deformity was observed and photographed off English Rock, south of Garumna Island, on the north shore of Galway Bay (53˚13'N, 9˚39'W) by JO'B. This dolphin was approximately 3-3.5m in length and thought to be older than the one previously described, due to its uniform dark grey colour. It was observed in a group of between 10-12 adults and was only marginally smaller than the others present, thus it is likely to be an immature or small adult, and nutritionally independent. The dolphin swam within 5m of the boat and a clear view was obtained of the dolphin's malformity. Posterior to the dorsal fin the dolphin's spine rose into a very pronounced hump. This individual did not appear to have any difficulties swimming or keeping up with the group.

Two different bottlenose dolphins with apparent spinal deformities were observed on more than one occasion near Killary Harbour, Co Galway (53º37'N, 9º54'W) during 2001 and 2002 (Simon Ingram, *pers. comm*.). A malformed dolphin has also been observed in a group of three dolphins, travelling past salmon fish cages in Mannin Bay, Co Galway (53˚ 28'N, 10˚ 05'W) on 25 and 30 May 2005 (Saul Joyce, *pers. comm*.) approximately 40km from Killary Harbour. The group included what appeared to be an adult and calf. The malformed dolphin was a little smaller than the adult but was a much paler colour and had no difficulty keeping up with the other dolphins. It is likely that these observations all refer to the same dolphin and is also probable that this is the same dolphin as that observed in Galway Bay.

Although probably not uncommon, malformites such as those described here have not been reported before in Ireland. A recent review (Berghan, J. and Visser, I.N. *op.cit*.) would classify the spinal deformities described in Ireland as kyphoscoliosis (backward and lateral curvature of the vertebral column).

There are no published records from Britain, yet scoliosis has been recorded on a number of occasions. A living bottlenose dolphin with vertebral deformities has been frequently observed along the southwest coasts of England. It was first observed in October 1991 as a neonate with a severe deformity of its dorsal fin, which was bent through nearly 90 degrees (Nick Tregenza, *pers. comm*). Two stranded bottlenose dolphins (a female calf measuring 165cm in length in 1993; and an adult female in 1998) with scoliosis have been recovered from the Moray Firth, north-east Scotland. The latter was only 260cm in length, which compares with a normal adult length of 320-330cm, demonstrating the amount of curvature of the spine (Bob Reid, *pers. comm*.). Scoliosis has been observed in bottlenose dolphins stranded in separate incidences in the Thames (Paul Jepson, *pers. comm*.). One with mild spondylosis (spinal osteoarthritis leading to partial or complete bony fusion) in 1999 and a case of mild kyphoscoliosis in 2001.

Vertebral column malformities have been associated with a diverse range of causative factors. Physical abnormalities in belugas *Delphinapterus leucas* (Pallas) from the St Lawrence estuary, Canada, were tentatively linked to high levels of organochlorines found in their tissues. Stress or exertion is also considered a potential causative factor along with spondylodiscitis as a result of a bacterial infection (Berghan and Visser *op.cit.*). Congenital malformities have also been reported and are the most likely cause in those described here (Paul Jepson, *pers. comm*.). They are likely to be hereditary and genetic studies may be revealing, although samples would be difficult to obtain.

The longevity of malformed dolphins is largely unknown. The dolphin off south-west England was first reported as a neonate in 1991 and is now adult. It was still observed up to 2003 with a visible twist to its spine. There are also further records of bottlenose dolphins seen alive with scoliosis in the Moray Firth, Scotland (Ben Wilson, *pers. comm*.). A bottlenose dolphin in Sarasota Bay, Florida with scoliosis in the caudal peduncle region has been observed for the last 20 years (Berghan and Visser *op.cit.*) but longevity is probably determined by the severity of the malformity. Given the severity of the scoliosis in the Shannon estuary dolphin it is unlikely this dolphin survived weaning, however the dolphin reported from Galway Bay might have survived for a number of years.

We encourage observers to report incidences of vertebral column malformities in dolphins in Ireland so as to determine the extent of this condition. Records of malformed dolphins could give an insight into the movements of bottlenose dolphins in Irish waters as they are relatively easily recognised individuals.

We would like to thank Deirdre Noonan of Widervision for obtaining video footage of the dolphin in the Shannon estuary and Dr Don Cotton for considerably improving this note.

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Note published in the Irish Naturalists' Journal

O'Brien, J., Berrow, S.D. (2006) Seaweed ingestion by a bottlenose dolphin *Tursiops truncatus*. *Irish Naturalists' Journal*, 28(8):338.

Seaweed ingestion by Bottlenose dolphin (*Tursiops truncatus*)

On 22 April 2005 one of the authors (SB) received a report from Marion Broderick of a dolphin apparently in distress at An Poll Mór near Kilronan on Inishmór in the Aran Islands, Co Galway (L 878 084). Local fishermen reported that they had observed the dolphin in the bay apparently driving fish towards the shore. What is presumed to be the same dolphin live stranded the next day, and was re-floated, but was found dead on the same beach a few hours later. The site was visited by JO'B on 26 April and the animal was identified as a male (penis slightly extruded) bottlenose dolphin *Tursiops truncatus* (Montagu, 1821), measuring 3.4m in length. Further identification features included a short stubby beak with a tooth count of 20-22 teeth in each jaw, and all uniform grey colouration fading to a white belly. A post mortem examination was carried out and the stomach and intestines were recovered and stored frozen.

Upon removal of these organs we immediately noticed a large amount (300x200x200mm) of undigested seaweed *Himanthalia elongate* (L.) S.F.Gray found tightly compacted throughout the dolphins oesophagus and into the main stomach. We also recovered a small plastic bag (with the writing 'Pick n' Mix' still visible) measuring (200x150mm) and canvas measuring (100x120mm) from the main stomach. All stomachs and intestines were washed through with water and 36 fish otoliths were recovered. Attempts to identify fish species using Härkönen (1986, *Guide to the otoliths of the bony fishes of the Northeast Atlantic*, Danbiu ApS, Hellerup. 256 pp) proved impossible because all otoliths were corroded due to digestion and could only be determined as being from either pollock *Pollachius pollachius,* whiting *Merlanguis merlangus* or saith *Pollachius virens*.

Small pieces of seaweed have been very occasionally recovered from the stomach of stranded cetaceans in the UK and Ireland (Paul Jepson *pers. comms*., Emer Rogan *pers. comms*) but there are no published reports of such a vast amount of seaweed recovered from a dolphins' stomach. An emaciated harbour porpoise *Phocoena phocoena* (L. 1758) that live stranded on the Dutch coast regurgitated 31g of undigested bladder wrack *Fucus vesiculosus* along with the remains of a plastic bag, banana peel, polychaete worm tubes and some fishing line (Kastelein, R.A. & Lavaleije, M.S.S. 1992, *Aquatic Mammals* 18.2:40-46). They suggested that the seaweed might have been eaten in the same way that terrestrial carnivores eat vegetation to induce vomiting. They also suggested that in this case, hunger and stress might have driven the porpoise to consume whatever it encountered. Kastelein (*pers. comm*.) also carried out a post-mortem on a trained harbour porpoise that died in captivity due to dislodging of the larynx by seaweed. This porpoise was restrained in a seapen and had access to the seabed. Its stomach and oesophagus was packed full of *Ascophyllum nodosum* (L.) Le Jolis but it had also consumed fish presented by its trainers. He has observed porpoises pulling individual strands of seaweed off the sea bed and moving them in and out of its mouth across its tongue. If the porpoise had swallowed each piece afterwards this may explain its full stomach. Kastelein (*pers. comm*.) has also recovered seaweed from the stomach of live stranded White-beaked dolphins *Lagenorhynchus albirostris* Gray 1846. The bottlenose dolphins stranded at An Poll Mór was not emaciated and had no external lesions and the cause of death is not known. However ingesting of so much seaweed is considered unusual behaviour and may have contributed to its death.

The only other published record of a prey item recovered from a bottlenose dolphin in Ireland involved a Dogfish *Scyliorhinus canicula* L. which was found wedged into its oesophagus apparently choking it to death (Nash, R. 1974 *Irish Naturalists' Journal* 18:121-122.). Santos *et al*., (2001, *J. Mar. Biol. Ass. U.K*, 81, 873-878) reported that cod *Gadus morhua,* saithe *Pollachius virens* and whiting *Merlangius merlangus* were the most important prey species in the diet of bottlenose dolphins around the Scottish coast.

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Humpback whale *Megaptera novaengliae*

A whale was observed off Inch in Dingle Bay, Co Kerry (52º 06'N, 10º 03'W) by Jonathan Smith on 14 July 2006 among a group of bottlenose dolphins *Tursiops truncatus*. The whale was confirmed as a humpback whale from its bushy blow, humpbacked appearance and long white pectoral fins by Nick Massett. Jonathan Smith filmed the whale as part of a documentary for the BBC. The whale was small, estimated to be around 6-7m in length, and had a number of long white scars on its tailstock posterior to the dorsal fin.

On 15 July Mick O'Connell observed a whale breaching near Beginish Island in Blasket Sound, Co Kerry (52º 07'N, 10º 29'W) at 10:00am. The whale was confirmed as a humpback whale from its long white pectoral fins. It was thought to be a juvenile due to its small size and most likely the same whale seen the previous day about 35km to the east. That evening Nick Massett also observed a juvenile humpback in Blasket Sound.

On 21 July 2006 a small baleen whale was found washed up at Baile na hAbhainn, near Inverin, Co Galway (53º 14'N, 9º 29'W) by Rory Thynne. Joanne O'Brien visited the site on 23 July and identified it as a humpback whale from its long white pectoral fins. It was a male (penis slightly extruded) measured 6.0m in length and was in very good condition with most of its skin intact. Post-mortem examination by SB and JO'B found no food remains in the stomach but around 1.5 litres of fluid and a piece of clear plastic measuring 300 x 150mm in size. Samples were taken to determine whether the fluid was milk. One barnacle *Coronula reginae* remained on the whales throat but at least 4 others had already been removed. A sample of skin was removed for genetic analysis.

Jonathan Smith provided a digital grab of the dorsal surface of the tail flukes from the underwater footage he took of the humpback whale in Dingle Bay. The trailing edge of the fluke was very irregular and had two-square shaped notches, one at the centre of the tail flukes and one approximately 150mm to the right. This image was compared to the fluke of the stranded whale in Inverin and confirmed that it was the same whale filmed in Dingle Bay. After a news item broadcast on TG4 on 23 July, local fisherman Mickie Conlon from Spiddal reported that he had observed a small whale with long white pectoral fins off Inverin on 17 July 2006. It is likely that this was the same whale stranded at Inverin, which means the whale swam the 150km from the Blaskets Islands in a maximum of 36-48 hours.

Humpback whales in the North Atlantic are born in low latitudes during the winter and are 4.0-4.6m at birth and 8-10m at independence (Clapham, P.J., Wetmore, S.E., Smith, T.D. and Mead, J.G. 1999 *Journal of Cetacean Research and Management* **1(2):** 141-146). Therefore it is likely that this whale had not weaned and was still dependant on its mother. No adult whale was reported during sightings on 14-15 July so it is probable that this humpback whale calf either became separated from its mother or the mother had died.

Although frequently sighted in Irish waters (IWDG data www.iwdg.ie/sightings) this is only the sixth stranding record of this species. This event however is not unprecedented. A young humpback whale calf, 6.7m in length, was observed swimming alone in Kinsale harbour, Co Cork in June 1992 before being found stranded 6 weeks later in August at Tralong Bay, Co Cork (Smiddy, P. and Berrow, S. 1992 *Irish Naturalists' Journal* 24(4): 162.

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