CETACEANS IN IRISH WATERS: A REVIEW OF RECENT RESEARCH

Joanne O'Brien, Simon Berrow, David McGrath and Peter Evans

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 Act 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 paper, we review historical and recent research on cetaceans in Irish waters (within the EEZ) 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 and 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.

Joanne O'Brien (corresponding author; email: joanne.obrien@gmit.ie); David McGrath, Department of Life Sciences, Galway–Mayo Institute of Technology, Dublin Road, Galway; Simon Berrow, Irish Whale and Dolphin Group, Merchants Quay, Kilrush, Co. Clare; Peter Evans, SeaWatch Foundation, 11 Jersey Road, Oxford 0X4 4RT, UK.

Cite as follows: O'Brien, Joanne, Berrow, Simon, McGrath, David and Evans, Peter 2009 Cetaceans in Irish waters: A review of recent research. *Biology and Environment: Proceedings of the Royal Irish Academy* **109**B, 63–88. DOI: 10.3318/BIOE.2009.109.2.63.

Received 13 December 2007. Accepted 29 October 2008. Published 30 July 2009.

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. Numbers of cetacean-related publications have been consistently increasing since 1976 (Fig. 1). There has been an increase in national and international legal obligations for the protection of cetaceans and their habitats. Ireland has recently submitted the first conservation assessment of cetaceans under the EU Habitats Directive (NPWS 2008). For the 18 species (not including vagrants) that 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 paper, we review the current knowledge of cetacean ecology and research carried out to date in Irish waters. The overall aim of this review is 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 paper.

LEGISLATION

There is a range of legislative instruments in Ireland aimed at protecting and managing 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, and (iii) all right whales. The 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 no. 15, 2005) under a Statutory Instrument for correct procedures when encountering whales and dolphins, dictating *inter alia* that boats should not get closer than 100 metres and should maintain a speed of less than 7 knots.

Ireland signed the Bern Convention on the Conservation of European Wildlife and Natural Habitats (1979), which offers protection to cetacean species. While this legally binding agreement did not extend the legal protection beyond that afforded by the Wildlife Act, it acted as a forerunner to more wide-ranging legislation. The protection of cetaceans was further extended

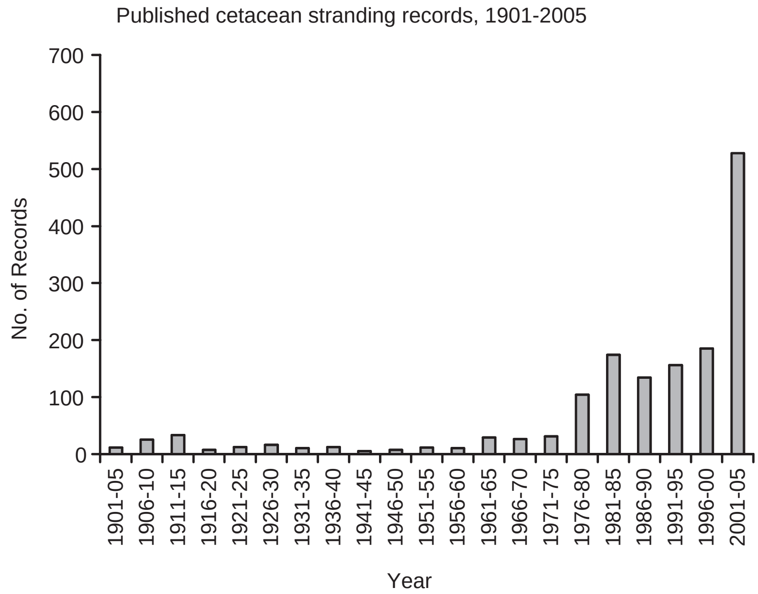

Fig. 1—Number of published cetacean stranding records from 1901 to 2005 (Source: Berrow *et al*. 2005a).

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) (Fig. 2). This legislation also requires Ireland to undertake surveillance, to form management plans and to 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 Community. 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 Sea and North Sea). The area covered by ACOBANS 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 the monitoring of by-catch rate in a range of gill-net and trawl fisheries.

HISTORICAL RECORDS

Prior to the ratification 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 (Blake family 1995), 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

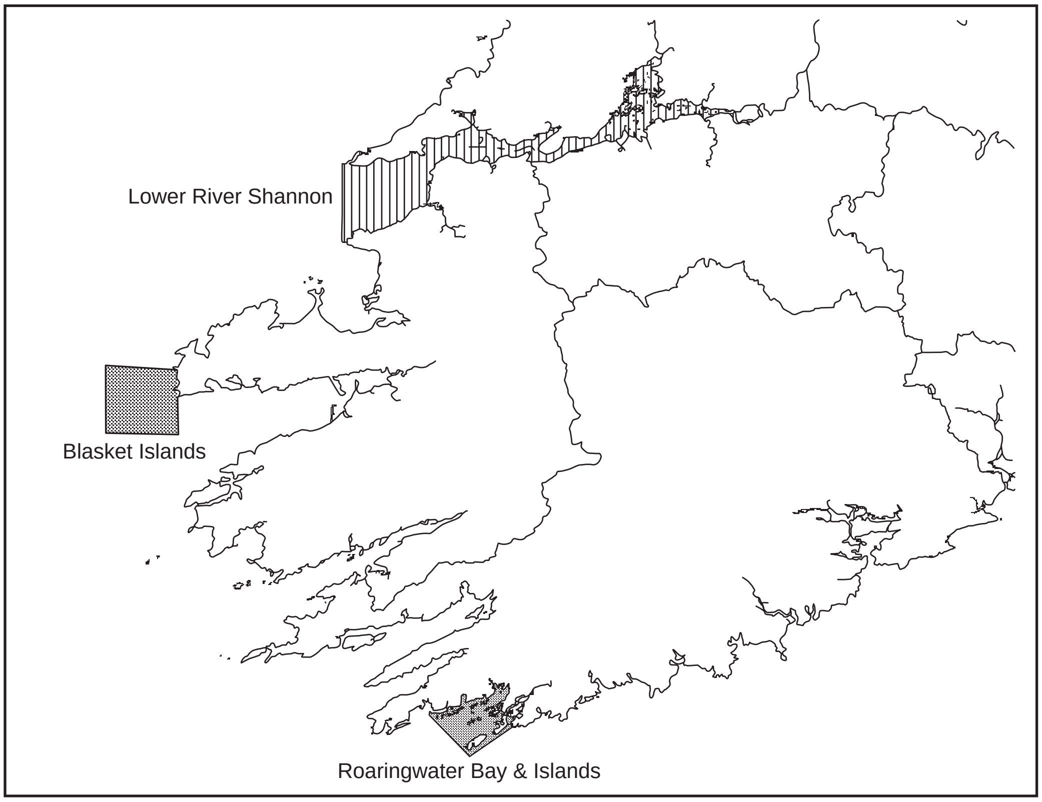

Fig. 2—Cetacean cSACs, Lower River Shannon (Bottlenose dolphin), Blasket Islands (Harbour porpoise), Roaringwater Bay and Islands (Harbour porpoise).

History Museum in London (Harmer 1914–1927; Fraser 1934; 1946; 1953; 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*, and 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 eighteenth 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 County Mayo, and during this period at least 894 whales were killed within a 95–100km radius of the stations. Most of these were fin whales, but 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—it is thought that these species were already 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, which were recorded incidentally. Locations such as Cape Clear Bird Observatory reported cetacean sightings on a regular basis, and this data was 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)) were sighted offshore and harbour porpoises were sighted near-shore, 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 1570 sighting records of 20,994 individuals collected between 1958 and 1978 from British and Irish waters, which showed the highest overall concentrations 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 southern Cork and Waterford; bottlenose dolphins from Bantry Bay, the Shannon Estuary, Galway and Ballinakill Bays; common dolphins and pilot whales from west of the Kerry coast, and killer whales from 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; where they allow for the application of pre-designed sampling regime, 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 mark–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 whale (*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 *et al.* 2002a; Berrow 1993). Berrow *et al.* (2002a) compiled a similar list of species to that described above by reviewing 2851 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 County Dublin, bottlenose dolphin in the Shannon Estuary and common dolphins and minke whale off County Clare, although coverage remained patchy. Berrow *et al.* (2005a) reviewed 3689 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 County Cork westwards and northwards to County 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 Seabirds At Sea surveys of the UK Nature Conservancy Council (later to become the Joint Nature Conservation Committee). 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 harbour porpoise (coefficient of variation, CV = 0.34), 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 9106 individual cetaceans of thirteen species were recorded during 37,563km 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 during this survey 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); blue whale (1 individual); Cuvier's beaked whale (1 individual); Sowerby's *Mesoplodon bidens* (Sowerby 1804) (1 individual); 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 *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 3167km was 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), 6 of minke whale (eight individuals), one of 2 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 RV *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 were observed, including 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 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) survey 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 1195 minke whales (CV = 0.49), and 833 *Lagenorhynchus* species (Atlantic white-sided dolphins and white-beaked dolphins) (CV = 1.02) were recorded during 2974km 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 among the lowest recorded in the Europe-wide survey, and only one-quarter of the highest reported density recorded in the North Sea (0.78).

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 2356km of survey effort using the double platform technique, 126 cetacean encounters were recorded with 8 baleen whale and 7 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 5490 (CV = 0.43) and common dolphins at 4496 (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 2900km of line transect effort, 222 encounters of common dolphins were made, generating abundance estimates of 1186 (CV = 0.41) in 2004, 1644 (CV = 0.27) in 2005, and 2166 (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 abundance 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 (5370; 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 1073 (Celtic Sea, CV = 0.89), 2222 (Atlantic coastal Ireland, CV = 0.84) and 1719 (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, where CI denotes confidence interval) 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

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.

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 RV *Celtic Explorer* and RV *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-engined Cessna flying at an average height of 500m, and a velocity of between 100–120mph to locate large baleen whales along the south coast. They found aerial surveying to be a successful method for locating cetacean, 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 101 Squadron (formerly the Maritime Squadron). Aerial surveys may provide a fast, effective way of utilising weather windows, which are often rare. Although this may be particularly useful for the west coast of Ireland, where favourable sea conditions may be limited, especially during winter months, there is little experience of and expertise in aerial surveys of this nature in Ireland.

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 it into a central database. Whale-watching vessels are also very useful platforms: these have been used particularly 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 was carried out in a consistent and uniform way (Berrow *et al.* 2005a; 2005b). There has been a marked increase in the number of reported strandings since the 1970s (Fig. 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 because rehabilitation facilities are not available. Consequently, animals are either re-floated, euthanised or left to die. In recent years, dolphins not suitable for re-floating have occasionally been euthanised (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; Gould *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. The 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 in order to reduce potential competition for prey. In contrast to the records for sperm whales, Murphy (2004) analysed common dolphin stranding records between 1901–2003 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 relate 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, this 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 genetic analysis and to assess contaminant loads. Some of these topics can only be investigated through the provision of these biological samples. Of the 100–150 stranded animals reported every year (Fig. 2), many of 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 as 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 is much less susceptible to increasing sea states. However, it is dependant 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 twenty days at sea, concentrating along the edge of the continental shelf off County 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 through acoustic detections. 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 14,479km. 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.* 2007). 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 suggests certain whistle types are associated with certain behaviour types. Hickey *et al.* (2009) compared 1182 whistle types between the Shannon Estuary and Cardigan Bay in Wales and found that of the 32 distinct whistle types observed, 8 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 regional distinct areas or dialect.

Ansmann *et al.* (2007) analysed 1835 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 9kHz 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 southern and western 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 whales and humpback whales along the southern and western 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.* 2009) and leatherback turtles (Doyle *et al.* 2008) and could be used for tracking cetaceans, provided that 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 being 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, thereby 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), population structure of bottlenose dolphins in the Shannon Estuary (S.N Ingram, pers. comm.) 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-whales, fin whales 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), while 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 southern 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 is obliged to designate SACs for both species; however, 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).

Harbour porpoise

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 north-east Atlantic (Santos and Pierce 2003).

Common dolphin

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 cephalopods prey, common dolphins fed primarily on *Gonatus*, *Histioteuthis* spp, *Toderopsis, Loligo forbesi* and the common octopus, *Eledone cirrhosa.* 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 south-west 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 north-east Atlantic (Evans 1994; Hassani *et al.* 1997).

Atlantic white-sided dolphin

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 their 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.

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)

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 that had also ingested a large quantity of seaweed. Otholiths could only be identified as either pollock, whiting or saith due to their degenerated 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 north-west County 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 fourteen stranded animals examined, nine 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, *Trisopterus* 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 Roches point, Co. Cork.

Pygmy sperm whale

Notes on the diet of pygmy sperm whales stranded in Ireland suggests 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 of the cephalopod species in the family *Histioteuthidae*, which were also numerically the most important. Other cephalopod species found in the stomach included *Mastigoteuthis scmidti*, *Taonius pavo, Galiteuthis armata*, *Teuthowenia megalops*, *Histioteuthis bonnellii* and *Haliphron atlanticus*.

In conclusion, the diet of harbour porpoise and common dolphin in Irish waters is typical for this species in other parts of the north-east Atlantic (Evans 1994; Hassani *et al.* 1997; Santos and Pierce 2003), while the diet of striped dolphin was found to be comparable with that in the Mediterranean Sea (Würtz and Marrale 1993) and Japanese waters (Miyazaki *et al.* 1973).

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 the species 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 indicated 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 categorised individuals into different reproductive stages by using characteristics of their gonadal morphology. They found that sexually mature individuals were 195–223cm in length and 8–28 years of age, while 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 nineteen Atlantic white-sided dolphins live-stranded in County 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 have been reported with foetuses at advanced stages of development (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)). Sexually mature male Atlantic white-sided dolphins (Bruton 1985) and female Cuviers 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 County 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 were used to investigate population structure around the UK and adjacent waters (Walton 1997). The author showed there were significant differences 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 County Mayo. He showed that genetic relatedness occurred between at least some adults and that 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.

Genetic studies have also been used for species identification. Two strandings of beaked whales in County 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 County 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) and 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 malformations observed in bottlenose dolphins off Counties Clare and Galway. Although probably not uncommon, malformations such as those described here have not been reported before in Ireland. They are most likely to be inherited congenital malformations. 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. Internal parasites 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 parasite-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 County 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,* was recorded 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 with 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 whales and humpback whales off the south and west coasts of Ireland demonstrated high site fidelity and inter-annual consistency. Of twelve identifiable fin whales, two have been re-sighted over a two-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 dolphins' 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 (1995) 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 1991) 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 2200 harbour porpoises and 230 common dolphins were killed annually by bottom set gill nets 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 (long-finned pilot whale, common, Atlantic white-sided, white-beaked and bottlenose dolphins) 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 north-east Atlantic in 1996 and 1998. Clearly, incidental capture in fishing nets is one of the most immediate threats to cetaceans in Irish waters. Nevertheless, not all fisheries experience cetacean by-catch but fisheries need to be monitored to determine which have the greatest

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 and 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, M. (1988), O'Riordan, C.E. (1972)

*Species on Annex II of the Habitats Directive.
By = Bycatch, Po = Pollution, Ha = Habitat degradation, So = Sound disturbance, Ss = Ship strikes.

impact and what mitigation measures can be developed.

Acoustic deterrents have been developed by Bord Iascaigh Mhara (BIM) in order to mitigate dolphin by-catch in pelagic trawls (Bord Iascaigh Mhara 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 in the 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.

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 suggests that radio-nuclide levels are low in harbour porpoises in the Irish Sea (Berrow *et al.* 1998a), while 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 the average for 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 demonstrates 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. 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 tropic 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 County 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 (no. 15, 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 similar studies are being conducted extensively in the seas around Northern Europe (Evans and Nice 1996). Seismic surveys utilise airgun arrays to produce sounds to map the seabed: broadband source levels of 248–255dB re 1μPa-m, zero to peak are typical of a full scale array (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. The NPWS has 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 (MMOs) 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 (2–10kHz 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). There are a number of deep water canyons west of Ireland off the edge of the continental shelf (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 1980s, there has been a general warming trend of 0.3°C 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; changes to community structure; and increased 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 distributions 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. 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 upwellings 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 RV *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.

As harbour porpoises and bottlenose dolphins are listed under Annex II of the EU Habitats Directive, the NPWS is 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. All of these cSACs are located in the south-west of the country. Harbour porpoises frequent all Irish coastal waters and the absence of an SAC off the south, east and north-west coasts means that not all the representative habitat in Ireland for these species is represented. Future research should attempt to identify sites for future designation. NPWS is 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 been explored (Leeney 2005; Berrow *et al.* 2009). 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 whales and humpback whales, occurring off the south and west coast of Ireland (Berrow *et al.* 2002). 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. 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, perhaps by exploring alarm calls that these animals themselves make in the wild. Alternative fishing methods should also be trailed, such as 'fish potting', since such techniques are more environmentally friendly.

Cetaceans and fishermen are also in potential competition for resources. There is relatively very 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 needs 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 constructions. 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 communicating; and 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.

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 1980s, sea surface temperatures in north-western Europe have risen at a rate of *c.* 1°C 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, affecting prey distribution, abundance and migration patterns, community structure and susceptibility to disease and contaminants. A cetacean's ability to adapt to the above changes is largely unknown. Climate change is an issue of serious concern because a number of species likely to be affected are already listed as endangered or vulnerable according to their Red List category (Simmonds and Isaac 2007; IUCN 2008). Of the 24 cetacean species found in Irish waters, five are listed as endangered or vulnerable under the IUCN Red List update, 2008 (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 we address a number of the information gaps highlighted in this review and seek to collaborate with cetaceans projects throughout Europe to ensure all cetacean species attain favourable conservation status.

ACKNOWLEDGEMENTS

This review compiled as part of a PhD thesis by Joanne O'Brien and funded by the National Parks and Wildlife Service of the Department of Environment, Heritage and Local Government. We would like to thank Dr Emer Rogan of UCC and Brendan McHugh of the Marine Institute for providing a number of references and Dr Oliver O'Cadhla (UCC) and Michéal Ó Cinnéide for their comments on earlier drafts.

REFERENCES

Andersen, L.W. 2003 Harbour porpoises (*Phocoena phocoena*) in the North Atlantic: distribution and genetic population structure. In T. Haug, G. Desports, G. Víkingsson and L. Witting (eds), *Harbour porpoises in the North Atlantic*, 11–30. NAMMCO Scientific Publications Vol. 5. Tromsø, Norway. The North Atlantic Marine Mammal Commission.

Anguliar de Soto, N., Rogan, E., O Cadhla, O., Gordon, J.C.D., Mackey, M. and Connolly, N. 2004 Cetaceans and seabirds of Ireland's Atlantic margin. Volume III—Acoustic surveys for cetaceans. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porcupine Studies Group project P/15 and Offshore Support Group (OSG) project 99/38.

Ansmann, I.C., Goold, J.C., Evans, P.G.H., Simmonds, M. and Keith, S.G. 2007 Variation in the whistle characteristics of short-beaked common dolphins, *Delphinus delphis*, at two locations around the British Isles. *Journal of Marine Biological Association of the UK* **87**, 19–26.

Berrow, S. 1991 Common porpoise *Phocoena phocoena* (L.). *Irish Naturalists' Journal* **23** (12), 496.

Berrow, S. 1993 Constant effort of cetacean sighting survey of Ireland. *Irish Naturalists' Journal* **24** (8), 344.

Berrow, S.D. 2001 Biological diversity of cetaceans (whales, dolphin and porpoises) in Irish waters. In J.D. Nunn (ed.), *Marine biodiversity in Ireland and adjacent waters. Proceedings of a conference 26–27 April, 2001*, 115–119. Belfast. Ulster Museum.

Berrow, S.D. and Holmes, B. 1999 Tour boats and dolphins: a note on quantifying the activities of whale watching boats in the Shannon Estuary, Ireland. *Journal of Cetacean Research and Management* **1** (2), 199–200.

Berrow, S.D. and O'Brien, J. 2005a Sperm whale *Physeter macrocephalus* L. calf, live stranded in Co. Clare. *Irish Naturalists' Journal* **28** (10), 40–1.

Berrow, S.D. and O'Brien, J. 2005b Scoliosis in bottlenose dolphins *Tursiops truncatus* in Ireland and Britain. *Irish Naturalists' Journal* **28** (5), 219–20.

Berrow, S.D. and Rogan, E. 1995 Stomach contents of harbour porpoise and dolphins in Irish waters. *European Research on Cetaceans* **9**, 179–81.

Berrow, S.D. and Rogan, E. 1997 Cetaceans stranded on the Irish coast, 1901–1995. *Mammal Review* **27** (1), 51–76.

Berrow, S.D. and Rogan, E. 1998 Incidental capture of cetaceans in Irish waters. *Irish Naturalists' Journal* **26** (1/2), 22–31.

Berrow, S.D. and Stark, D. 1990 White-sided dolphin *Lagenorhynchus acutus* (Gray). *Irish Naturalists' Journal* **23** (8), 334.

Berrow, S.D., Evans, P.G.H. and Sheldrick, M.C. 1993 An analysis of sperm whale *Physeter macrocephalus* (L.) stranding and sighting data from Britain and Ireland. *Journal of Zoology* (London) **230**, 333–7.

Berrow, S.D., Holmes, B. and Kiely, O. 1996 Distribution and abundance of bottle-nosed dolphins *Tursiops truncatus* (Montagu) in the Shannon Estuary, Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* **96**B (1), 1–9.

Berrow, S.D., Long, S.C., McGarry, A.J., Pollard, D. and Rogan, E. 1998a Radionuclides (Cs-137 and K-40) in harbour porpoises *Phocoena phocoena* L. from British and Irish waters. *Marine Pollution Bulletin* **36** (8), 569–76.

Berrow, S.D., O'Neill, M. and Brogan, D. 1998b Discarding practices and marine mammal bycatch in the Celtic Sea Herring Fishery. *Biology and Environment: Proceedings of the Royal Irish Academy* **108**, 1–8.

Berrow, S.D., Whooley, P. and Ferriss, S. 2002a *Irish Whale and Dolphin Group cetacean sighting review (1991–2001)*, 1–34. Kilrush, Co. Clare. Irish Whale and Dolphin Group.

Berrow, S., Dalebout, M. and Conroy, J. 2002b Cuviers' beaked whale (*Ziphius cavirostris*). *Irish Naturalists' Journal* **27** (4), 168–9.

Berrow, S.D., McHugh, B., Glynn, D., McGovern, E., Parsons, K., Baird, R.W. and Hooker, S.K. 2002c Organochlorine concentrations in resident bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary, Ireland. *Marine Pollution Bulletin* **44**, 1296–313.

Berrow, S.D., Oliver, G., Roden, C. and Whooley, P. 2003 Large whale survey off the south coast of Ireland. A final report to the Heritage Council. Grant App. 1229.

Berrow, S.D., Whooley, P. and Wall, D. 2005a ISCOPE-Irish Scheme for cetacean observation and public education. Final report 2003–2005. Irish Whale and Dolphin Group.

Berrow, S.D., Wall, D. and Rogan, E. 2005b *Recording stranded cetaceans in Ireland. Stranding Networks Workshop Proceedings*. La Rochelle, 2–7 April. La Rochelle, France. European Cetacean Society.

Berrow, S.D., O'Brien, J. and Holmes, B. 2006a Whistle production by bottlenose dolphins *Tursiops truncatus* in the Shannon Estuary. *Irish Naturalists' Journal* **28** (5), 208–13.

Berrow, S.D., O'Brien, J. and Massett, N. 2006b Humpback whale *Megaptera novaeangliae*. *Irish Naturalists' Journal* **28** (2), 339–40.

Berrow, S.D., Leeney, R., O'Brien, J., McGrath, D. and Cosgrove, R. 2006c Evaluation of pelagic trawl pingers and their effect on the behaviour of common dolphins *Delphinus delphis*. Report to Bord Iascaigh Mhara.

Berrow, S.D., O'Brien, J., McGrath, D. and O'Connor, I. 2009 Abundance estimate and acoustic monitoring of harbour porpoise *Phocoena phocoena* in the Blasket Islands' Candidate Special Area of Conservation. *Biology and Environment*: *Proceedings of the Royal Irish Academy* **109B**, 35–46.

Blake, family 1995 *Letters from the Irish highlands of Connemara by the Blake family of Renvyle House 1823/1824*; introduction by Kevin Whelan. Clifden. Gibbons Publications.

Boelens, R., Gray, J. and Parsons, A. 2004 Review and Evaluation of marine environmental impact indicators and their applications in Ireland. NDP Marine RTDI desk study series. Marine Institute Galway, DK/01/006.

Bord Iascaigh Mhara 2004 *Report on the development of prototype cetacean deterrent systems for the albacore tuna pair pelagic fishery 2002–2003, 1–11.* Bord Iascaigh Mhara (BIM) Report no. 2.04. Dun Laoghaire. Bord Iascaigh Mhara.

Brereton, T., Wall, D., Cermeno, P., Vasquez, A., Curtis, D. and Williams, A. 2001 Cetacean monitoring in north-west European waters. The Atlantic Research Coalition. Available at http://www.iwdg.ie/downloads/ARC%202001%20Report.pdf (22 May 2008)

Brophy, J.T. 2003 The diet of the common dolphin (*Delphinus delphis* L.) in Irish waters. Unpublished MSc thesis, National University of Ireland, Cork.

Bruton, T. 1985 Euphrosyne dolphin *Stenella coeruleolaba* (Meyen). *Irish Naturalists' Journal* **21** (12), 538–40.

Bruton, T. and Berrow, S. 1994 Records from the Irish Whale and Dolphin Group. *Irish Naturalists' Journa*l, **24** (12), 511–12.

Bruton, T. and Rogan, E. 1997 Records from the Irish Whale and Dolphin Group. *Irish Naturalists' Journal* **25** (11/12), 447–8.

Caurant, F., Aubail, A., Lahaye, V., Van Canneyt, O., Rogan, E., López, A., Addink, M., Chaurland, C., Robert, M. and Bustamante, P. 2006 Lead contamination of small cetaceans in European waters—the use of stable isotopes for identifying the sources of lead exposure. *Marine Environmental Research* **62**, 131–48.

Charif, R.A., Clapham, P.J. and Clark, C.W. 2001 Acoustic detections of singing humpback whales in deep waters off the British Isles. *Marine Mammal Science* **17** (4), 751–68.

Clark, C.W. and Charif, R.A. 1998 *Acoustic monitoring of large whales to the west of Britain and Ireland using bottom-mounted hydrophone arrays, October 1996–September 1997.* JNCC Report no.

281. Peterborough. Joint Nature Conservation Committee.

Cotton, D.C.F. and Murphy, S. 2004 Cuvier's beaked whale *Ziphius cavirostris* Cuvier, in Co. Sligo. *Irish Natralists' Journal* **27** (9), 364–5.

Couperus, A.S. 1995 Interactions between Dutch midwater trawl and Atlantic white-sided dolphins (*Lagenorhynchus acutus*) southwest of Ireland. *Journal of Northwest Atlantic Fishery Science* **22**, 209–18.

Cox, T.M., Ragen, T.J., Read, A.J., Vos, E., Baird, R.W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L., D'Amico, A., D'Spain, G., Fernandez, A., Finneran, J., Gentry, R., Gerth, W., Gulland, F., Hilderbrand, J., Houser, D., Hullar, T., Jepson, P.D., Ketten, D., MacLeod, C.D., Miller, P., Moore, S., Mountain, D.C., Palka, D., Ponganis, P., Rommel, S., Rowels, T., Taylor, B., Tyack, P., Wartzok, D., Gisiner, R., Mead, J. and Benner, L. 2006 Understanding the impacts of anthropogenic sound on beaked whales. *Journal of Cetacean Research and Management* **7** (3), 177–87.

Cronin, M. and Mackey, M. 2002 Cetaceans and seabirds in waters over the Hatton-Rockall region. Cruise report to the Geological Survey of Ireland. Available at http://cmrc.ucc.ie/publications/reports/Petrov_02_Report.pdf (22 May 2009).

Cronin, M.A., Zuur, A.F., Rogan, E. and McConnell, B.J. 2009 Using mobile phone telemetry to investigate the haul-out behaviour of harbour seals *Phoca vitulina vitulina*. Endangered Species Research (Preprint 2009, doi: 10.3354/esr00170) http://www.intres.com/articles/esr2008/theme/Tracking/TMVpp6.pdf).

Doyle, T.K., Houghton, J.D.R., O'Suilleabhain, P.F., Hobson, V.J., Marnell, F., Davenport, J. and Hays, G.C. 2008 Leatherback turtles satellite-tagged in European waters. *Endangered Species Research* **4**, 23–31.

Duke, S. 2003 The population and social structure of the harbour porpoise from around the coasts of Iceland and Ireland. Unpublished PhD thesis, University College Dublin.

Dunne, S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Venkata Ratnam, J., Semmler, T., Sweeney, C., Varghese, S. and Wang, S. 2008 *Ireland in a warmer world; scientific predictions of the Irish climate in the twenty-first century.* Dublin. Community Climate Change Consortium for Ireland (C4I). ISBN: 9 780952 123255. Available at http://www.c4i.ie/docs/IrelandinaWarmerWorld.pdf (27 May 2009).

EEC 1992 Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal L206 (22.7.1992), 7–50.

Englund, A., Ingram, S. and Rogan, E. 2007 Population status report for bottlenose dolphins using the lower River Shannon SAC, 2006–2007. Final report to the National Parks and Wildlife Service, 1–35.

Evans, P.G.H. 1976 An analysis of sightings of Cetacea in British waters. *Mammal Review* **6**, 5–14.

Evans, P.G.H. 1980 Cetaceans in British waters. *Mammal Review* **10**, 1–52.

Evans, P.G.H. 1981 Whale and seabird cruise N.E. Atlantic Summer 1980. Sponsored by The Mammal Society and Seabird Group.

Evans, P.G.H. 1988 Killer whales (*Orcinus orca*) in British and Irish waters. *Rit Fiskideildar* **11**, 42–54.

Evans, P.G.H. 1991 Whales, dolphins and porpoises: order Cetacea. In G.B. Corbet and S. Harris (eds), *Handbook of British Mammals*, 299–350. London. Blackwell.

Evans, P.G.H. 1992 Status review of cetaceans in British and Irish Waters. Report to UK Department of the Environment. Oxford, Sea Watch Foundation.

Evans, W.E. 1994 *Common dolphin, white-bellied porpoise Delphinus delphis Linnaeus, 1758.* Handbook of Marine Mammals no. 5. London. Academic Press.

Evans, P.G.H. 1997 Ecology of sperm whales (*Physeter macrocephalus*) in the eastern North Atlantic, with special reference to sightings and strandings records from the British Isles. In T.G. Jacques and R.H. Lambertsen (eds), *Sperm whale deaths in the North Sea science and management*. Bulletin de L'Institut Royal des Sciences Naturelles de Belgique. *Biologie* **67** (suppl.), 37–46.

Evans, P.G.H. 1998 Biology of cetaceans of the northeast Atlantic (in relation to seismic energy). Proceedings of the Seismic and Marine Mammal Workshop, June 23–25, 1998, London, UK. Available at http://www.bape.gouv.qc.ca/sections/mandats/sismiques/documents/DD19.pdf.

Evans, P.G.H. and Boran, J.R. 1995 Earthwatch cetacean surveys in the Irish Sea, Summer 1995. Report to Earthwatch. Sea Watch Foundation, Oxford.

Evans, P.G.H. and Hammond, P.S. 2004 Monitoring cetaceans in European waters. *Mammal Review* **34** (1), 131–56.

Evans, P.G.H. and Miller, L. 2004 *Active sonar and cetaceans*. Proceedings of Workshop held at the ECS 17th Annual Conference, Las Palmas, Gran Canaria, 8th March 2003, 1–84. Kiel, Germany. European Cetacean Society.

Evans, P.G.H. and Nice, H. 1996 Review of the effects of underwater sound generated by seismic surveys on cetaceans. Report to UKOOA. Sea Watch Foundation, Sussex.

Evans, P.G.H. and Scanlan, G. 1989 Historical review of cetaceans in British and Irish waters. Report to the Greenpeace Environmental Trust. UK Mammal Society Cetacean Group, Oxford.

Evans, P.G.H. and Scanlan, G. 1990 Historical status changes of cetaceans in British and Irish waters. In P.G.H. Evans and C. Smeenk (eds), *European research on cetaceans—3*, 51–57. Leiden, Holland. European Cetacean Society.

Evans, P.G.H. and Wang, J. 2002 Re-examination of distribution data for the harbour porpoise around Wales and the UK with a view to site selection for this species. Report for Countryside Council for Wales.

Evans, P.G.H., Harding, S., Tyler, G. and Hall, S. 1986 Analysis of cetaceans sightings in the British Isles, 1958–1985. Report to the Nature Conservancy Council, Peterborough, UK Mammal Society Cetacean Group.

Evans P.G.H., Anderwald, P. and Baines, M.E. 2003 UK cetacean status review. Report to English Nature and Countryside Council for Wales. Sea Watch Foundation, Oxford.

Evans, P.G.H., Baines, M.E. and Ansmann, I. 2007 Common dolphin abundance survey, Celtic Deep, 2004–06. Report to Countryside Council for Wales. Sea Watch Foundation, Oxford.

Fairley, J.S. 1981 *Irish whales and whaling*. Belfast. Blackstaff Press.

Fraser, F.C. 1934 *Report on Cetacea stranded on the British coasts from 1927 to 1932*. Cetacea report no. 11. London. British Museum (Natural History).

Fraser, F.C. 1946 *Report on Cetacea stranded on the British coasts from 1933 to 1937*. Cetacea report no. 12. London. British Museum (Natural History).

Fraser, F.C. 1953 *Report on Cetacea stranded on the British coasts from 1938 to 1947*. Cetacea report no. 13. London. British Museum (Natural History).

Fraser, F.C. 1974 *Report on Cetacea stranded on the British coasts from 1948 to 1966*. Cetacea report no. 14. London. British Museum (Natural History).

Gassner, I. and Rogan, E. 1997 Twin pregnancy in a Risso's dolphin (*Grampus griseus*). European Cetacean Society, 11th Annual Meeting of the European Cetacean Society, Stralsund, Germany, 10–12 March.

Glanville, E., Bartlett, P. and Berrow, S.D. 2003 Common dolphin *Delphinus delphis* L. *Irish Naturalists' Journal* **27** (6), 241–2.

Goold, J.C. 1999 Acoustic assessment of populations of common dolphin, *Delphinus delphis*, off the west Wales coast, with perspectives from satellite infra-red imagery. *Journal of the Marine Biological Association of the UK* **76**, 811–20.

Goold, J.C., Whitehead, H. and Reid, R.J. 2002 North Atlantic sperm whale, *Physeter macrocephalus* strandings on the coastlines of the British Isles and Eastern Canada. *Canadian Field-Naturalist* **116** (3), 371–88.

Gordon, J., Berrow, S.D., Rogan, E. and Fennelly, S. 1999 Acoustic and visual survey of cetaceans off the Mullet Peninsula, Co. Mayo. *Irish Naturalists' Journal* **26** (7/8), 251–9.

Gresson, R.A.R. 1966 Pilot whales, *Globiocephala melaena* (Triall) stranded at Cloghane, Co. Kerry. *Irish Naturalist' Journal* **15** (6), 163–6.

Gresson, R.A.R. 1968 White-sided dolphins, *Lagenorhynchus acutus* (Gray) stranded at Ventry Harbour, Co. Kerry. *Irish Naturalists' Journal* **16**, 19–20.

Hammond, P.S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jorgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. and Oien, N. 2002 Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* **39**, 361–76.

Harmer, S.F. 1914–27 *Report(s) on cetacean strandings on the British coasts from (1913–1926)*. British Museum (Natural History) **1–10**.

Hassani, S., Antoine, L. and Ridoux, V. 1997 Diets of albacore, *Thynnus alalunga*, and dolphins, *Delphinus delphis* and *Stenella coeruleoalba,* caught in the northeast Atlantic albacore drift-net fishery: a progress report. *Journal of Northwest Atlantic Fishery Science*, 119–23.

Henry, W. 1739 Hints towards a natural and typographical history of the countys Sligo, Donegal, Fermanagh and Lough Erne, Public Record Office, Dublin. Ms M2533 (cited from Fairley 1981).

Hickey, R.B., Berrow, S.D. and Goold, J.C. 2008 Towards a bottlenose dolphin whistle ethogram from the Shannon Estuary, Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* **109B**, 89–94.

Hoyt, E. 2000 *Whale watching 2000, Worldwide tourism numbers, expenditures and expanding socioeconomic benefits*. Chippenham, Wiltshire. Whale and Dolphin Conservation Society, UK**.**

Ingram, S.D. 2000 The ecology and conservation of bottlenose dolphins in the Shannon Estuary, Ireland. Unpublished PhD thesis, University College Cork.

Ingram, S., Englund, A. and Rogan, E. 2001 An extensive survey of bottlenose dolphins (*Tursiops truncatus*) on the west coast of Ireland. Final report to the Heritage Council (Ireland) WLD/2001/42.

Ingram, S.N. and Rogan, E. 2002a Identifying critical areas and habitat preferences of bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary and selected areas of west-coast of Ireland. Report to the National Parks and Wildlife Service**.**

Ingram, S.N. and Rogan, E. 2002b Identifying critical areas and habitat preferences of bottlenose dolphins (*Tursiops truncatus*). *Marine Ecology Progress Series* **244**, 247–55.

Ingram, S. and Rogan, E. 2003 Estimating abundance, site fidelity and ranging patterns of bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary and selected areas of the west-coast of Ireland. Report to the National Parks and Wildlife Service.

Ingram, S.N., Englund, A. and Rogan, E. 2003 Habitat use, abundance and site-fidelity of bottlenose dolphins (*Tursiops truncatus*) in Connemara coastal waters, Co. Galway. Heritage Council Wildlife Grant final report no. 12314.

Ingram, S.N., Englund, A. and Rogan, E. 2004 Methods of best practice for the use of T-POD passive acoustic detectors for cetacean research in Irish waters. Report to the Heritage Council, Ireland.

IUCN 2008 Cetacean update of the 2008 IUCN Red List of Threatened Species. http://www.iucnredlist.org/wnew/news#b5167.

IWC 1996 Report of the sub-committee on small cetaceans. *Report of the International Whaling Commission* **46**, 160–79.

IWDG 1995 *Face to face with a beaked whale; Guidelines for the welfare of live stranded cetaceans*. Kilrush, Co. Clare. Irish Whale and Dolphin Group.

Jepson, P.D., Bennett, P.M., Deaville, R., Allchin, C.R., Baker, J.R. and Law, R. 2005 Relationships between polychlorinated biphenyls and health status in harbour porpoises (*Phocoena phocoena*) stranded in the United Kingdom. *Environmental Toxicology and Chemistry*, **24** (1), 238–48.

Keane, I., Kelly, T.C. and Rogan, E. 1996 Parasites associated with the cranial sinuses of a group of 19 white-sided dolphins that mass stranded in Killala Bay, Ireland. *Proceedings from the 10th Annual European Cetacean Society Conference, Portugal, 1996.* Kiel, Germany. European Cetacean Society.

Learmonth, J.A., Macleod, C.D., Santos, M.B., Pierce, G.J., Crick, H.Q.P. and Robinson, R.A. 2006 Potential effects of climate change on marine mammals. *Oceanography and Marine Biology: An Annual Review* 44, 431–64.

Leeney, R.H., Berrow, S.D., McGrath, D., O'Brien, J., Cosgrove, R. and Godley, B.J. 2006 Effects of pingers on the behaviour of bottlenose dolphins. *Journal of the Marine Biological Association of the UK* **86**, 5467/1–5.

Leeney, R.H. 2005 Critical habitats of a protected species: distribution of harbour porpoises in relation to tide, time and boat traffic. Unpublished PhD thesis, University College Dublin.

Leopold, M.F., Wolf, P.A. and Van de Meer, J. 1992 The elusive harbour porpoise exposed, strip transect counts off southwestern, Ireland. *Netherlands Journal of Sea Research* **29** (4), 395–402.

Mackey, M., Viney, E. and Viney, M. 2001 Pygmy sperm whale *Kogia breviceps* (de Blainville). *Irish Naturalists' Journal* **26** (12), 476.

MacLeod, C.D. 2000 Review of the distribution of *Mesoplodon* species (order Cetacea, family Ziphiidae) in the North Atlantic. *Mammal Review* **30** (1), 1–8.

MacLeod, C.D., Pierce, G.J. and Santos, M.B. 2004 Geographic and temporal variations in strandings of beaked whales (Ziphiidae) on the coasts of the UK and the Republic of Ireland for 1800–2002. *Journal of Cetacean Research and Management* **6** (1), 79–86.

Mannion, S. 1991 *Ireland's friendly dolphin*. Dingle. Brandon Book Publishers.

McHugh, B., Law, R.J., Allchin, C.R., Rogan, E., Murphy, S., Barry Foley, M., Glynn, D. and McGovern, E. 2007 Bioaccumulation and enantiomeric profiling of organochlorine pesticides and persistent organic pollutants in the killer whale (*Orcinus orca*) from British and Irish waters. *Marine Pollution Bulletin* **54**, 1724–31.

McKenzie, C., Rogan, E., Reid, R.J. and Wells, D.E. 1998 Concentrations and patterns of organic contaminants in Atlantic white-sided dolphins (*Lagenorhynchus acutus*) from the Irish and Scottish coastal waters. *Environmental Pollution* **98**, 15–27.

McNally, K. 1976 *The sunfish hunt*. Belfast. Blackstaff Press.

Mirimin, L., Coughlan, J., Rogan, E. and Cross, T. 2005 Social structure and relatedness in the Atlantic white-sided dolphin (*Lagenorhynchus acutus* Gray, 1828). *European research on cetaceans, Proceedings of the nineteenth annual conference of the European Cetacean Society, La Rochelle, France, 2–7 April, 2005.* Kiel, Germany. European Cetacean Society.

Miyazaki, N., Kusaka, T. and Nishiwaki, M. 1973 Food of *Stenella coeruleoalba*. *Scientific Reports of the Whales Research Institute* **25**, 265–75.

Murphy, S. and Rogan, E. 2002 Records from the Irish Whale and Dolphin Group, 2000–2001. *Irish Naturalists' Journal* **27**, 357–64.

Murphy, S. 2004 Biology and ecology of the short beaked common dolphin (*Delphinus delphis*) in the north-east Atlantic. Unpublished PhD thesis, National University Ireland, University College Cork.

Murphy, S., Collet, A. and Rogan, E. 2005a Mating strategy in the male common dolphin (*Delphinus delphis*): what gonadal analysis tells us. *Journal of Mammalogy* **86** (6), 1247–58.

Murphy, S., Mirimin, L., Englund, A. and Mackey, M. 2005b Evidence of a violent interaction between *Delphinus delphis* L. and *Tursiops truncatus* (Montagu). *Irish Naturalists' Journal* **28** (1), 42–3.

Murphy, S., Herman, J.S., Pierce, G.J., Rogan, E. and Kitchener, A.C. 2006 Taxonomic status and geographical cranial variation of common dolphins (*Delphinus*) in the eastern North Atlantic. *Marine Mammal Science* **22**, 573–99.

Nadarajah, C., Rogan, E. and Kely, T.C. 1996 Incidence of *Anisakis simplex* (Rudolphi, 1809, Det. Krabbe, 1878) in common dolphins (*Delphinus delphis* L.). *Proceedings from the 10th Annual European Cetacean Society Conference, Portugal, 1996.* Kiel, Germany. European Cetacean Society.

Nash, R. 1974 Notes on some stranded Cetacea from Ulster. *Irish Naturalist' Journal* **18**, 121–2.

Newell, R.G., Merne, O.J. and Evans, P.G.H. 1969 B.O.U. supported survey of seabirds off S.W. Ireland, August 1968. *Ibis* **111**, 279–80.

Nixon, E. 1991 PCBs in marine mammals from Irish coastal waters. *Irish Chemical News* **7**, 311–38.

Northridge, S., Tasker, M.L., Webb, A. and Williams, J.M. 1995 Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhynchus albirosris* Gray), and minke whale (*Balaenoptera acutorostrata* Lacepede) around the British Isles. *ICES Journal of Marine Science* **52**, 55–66.

NPWS 2007 Mitigating measures for the protection of marine mammals during acoustic seafloor surveys within Irish Waters. National Parks and Wildlife Service. Department of Environment, Heritage and Local Government.

NPWS 2008 The status of EU protected habitats and species in Ireland. Conservation status in Ireland of habitats and species listed in the European Council Directive on the Conservation of Habitats, Flora And Fauna 92/43/EEC. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government.

O'Brien, J. and Berrow, S.D. 2006 Seaweed ingestion by a bottlenose dolphin. *Irish Naturalists' Journal* **28**(8), 338–9.

O'Brien, J., McGrath, D. and Berrow, S. 2006 Bottlenose dolphins and harbour porpoises in Galway Bay and North Connemara. *Proceedings from the 20th Annual European Cetacean Society Conference, Poland, 2006*. Kiel, Germany. European Cetacean Society.

O'Cadhla, O., Burt, M.L., Borchers, D.L. and Rogan, E. 2001 Summer distribution and abundance of cetaceans in western Irish waters and the Rockall Trough. Paper SC/53/O15 presented to the International Whaling Commission Scientific Committee, July 2001, London.

O'Cadhla, O., Englund, A., Philpott, E., Mackey, M. and Ingram, S. 2003 Marine mammal monitoring in the waters of Broadhaven Bay and northwest Mayo: 2001–2002. Report to Enterprise Energy Ireland, Ltd.

O'Cadhla, O., Mackey, M., Aguilar de Soto, N., Rogan, E. and Connolly, N. 2004 Cetaceans and seabirds of Ireland's Atlantic margin. Volume II—Cetacean distribution and abundance. Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porcupine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38.

O'Crohan, T. 1934 *The islandman*. Dublin. Talbot Press. [In Irish, translated by R. Flower].

O'Riordan, C.E. 1972 Provisional list of Cetacea and turtles stranded or captured on the Irish coast. *Proceedings of the Royal Irish Academy* **72** (15), 253–74.

O'Riordan, C.E. 1975 Long-finned pilot whales, *Globicephala melaena,* driven ashore in Ireland, 1800–1973. *Journal of the Fisheries Research Board of Canada* **32** (7), 1101–103.

Philpott, E., Englund, A., Ingram, S. and Rogan, E. 2007 Using T-PODs to investigate the echolocation of coastal bottlenose dolphins. *Journal of Marine Biological Association, UK* **87**, 11–7.

Pierce, G.J., Santos, M.B., Murphy, S., Learmonth, J.A., Zuur, A.F., Rogan, E., Bustamante, P., Caurant, F., Lahaye, V., Ridoux, V., Zegers, B.N., Mets, A., Addink, M., Smeenk, C., Jauniaux, T., Law, R.J., Dabin, W., López, A., Alonso Farré, J.M., González, A.F., Guerra, A., Garciá-Hartmann, M., Reid, R.J., Moffat, C.F., Lockyer, C. and Boon, J.P. 2007 Bioaccumulation of persistent organic pollutants in female common dolphins (*Delphinus delphis*) and harbor porpoise (*Phocoena phocoena*) from western European seas; Geographical trends, casual factors and effects on reproduction and mortality. *Environmental Pollution* **153**, 401–15. doi:10.1016/j.envpol.2007.08.019.

Pollock, C., Reid, J.B., Webb, A. and Tasker, M.L. 1997 *The distribution of seabirds and cetaceans in the waters around Ireland*. JNCC Report no. 267. Peterborough. Joint Nature Conservation Committee.

Power, E.P. and Murphy, S. 2002 *Staphylococcus aureus* septicaemia in a killer whale. *The Veterinary Record* **150**, 819.

Quigley, D.T.G. and Flannery, K. 2002 Leucoptic harbour porpoise *Phocoena phocoena* L. *Irish Naturalists' Journal* **27** (4), 170.

Reid, J.B., Evans, P.G.H. and Northridge, S.P. 2003 *Atlas of cetacean distribution in north-west European waters*. Peterborough. Joint Nature Conservation Committee.

Richardson, J.W., Greene, C.R. Jr., Malme, C.I. and Thompson, D.H. 1995 *Marine mammals and noise*. San Diego, CA. Academic Press.

Rogan, E. and Berrow, S.D. 1996 Review of harbour porpoises *Phocoena phocoena* L. in Irish waters. *Report of the International Whaling Commission* **46**, 595–605.

Rogan, E., Baker, J.R., Jepson, P.D., Berrow, S.D. and Kiely, O. 1997 A mass stranding of white-sided dolphins *Lagenorhynchus acutus* in Ireland: biological and pathological studies. *Journal of Zoology (London)* **242**, 217–27.

Rogan, E., O'Mahony, E., Gassner, I. and Kelly, T.C. 1998 A comparative analysis of the lungworm fauna of striped (*Stenella coeruleoalba*) and common dolphin (*Delphinus delphis*). *Proceedings from the 12th Annual European Cetacean Society, Valentia, Spain, 1998*. Kiel, Germany. European Cetacean Society.

Rogan, E. and Mackey, M. 1999 Cetacean by-catch in a driftnet fishery for albacore tuna in the Celtic Sea. *Proceedings of the 13th European Cetacean*

Conference, Valentia, Spain. Kiel, Germany. European Cetacean Society.

Rogan, E. and Mackey, M. 2007 Megafauna by-catch in drift nets for albacore tuna (*Thunnus alalunga*) in the NE Atlantic. *Fisheries Research* **86** (1), 6–14. doi:10.1016/j.fishres.2007.02.013.

Rogan, E., Gassner, I., Mackey, M.J. and Berrow, S.D. 1999 A review of striped dolphins, *Stenella coeruleoalba*, in the waters around Ireland. Paper SC/49/SM40 presented to the International Whaling Commission Scientific Committee, September 1997, Bournemouth (unpublished).

Rogan, E., Kelly, T., Ingram, S. and Roycroft, D. 2003a The ecology of seabirds and marine mammals in a fluctuating marine environment. Report to the Higher Education Authority (HEA).

Rogan, E., Quinn, O. and Murphy, S. 2003b Gonadal development in the male striped dolphin *Stenella coeruleoalba*. Paper presented to ECS Conference, Las Palmas de Gran Canaria, March 2003.

Rogan, E. and Philpott, E. 2006 Passive acoustic monitoring: A tool to investigate the response of bottlenose dolphins to pingers. Paper presented to ECS Conference, Gdynia, April 2006.

Rosen, M.J., Evans, P.G.H., Boran, J.R., Bell, G. and Thomas, C. 2000 Cetacean studies in the Celtic Sea, English Channel, and SW North Sea: using training surveys for data collection. In P.G.H. Evans, E. Rogan and R. Pitt-Aiken (eds), *European research on cetaceans—13*, 383–6 European Cetacean Society. Rome, Italy.

Ryan, C. and Wilson, P. 2003 Observations on the behaviour of a pod of killer whales *Orcinus orca* L. that visited Cork Harbour in 2001. *Irish Naturalists' Journal* **27** (5), 187–91.

Santos, M.B. and Pierce, G.J. 2003 Diet of harbour porpoise (*Phocoena phocoena*) in the NE Atlantic: a review. *Oceanography and Marine Biology: Annual Review* **41**.

Santos, M.B., Berrow, S.D. and Pierce, G.J. 2006 Stomach contents of a sperm whale *Physeter macrocephalus* calf in Co. Clare (Ireland). *Irish Naturalists' Journal* **28** (7), 272–4.

Santos, M.B., Pierce, G.J., Hartmann, M.G., Smeenk, C., Addink, M.J., Kuiken, T., Reid, R.J., Patterson, I.A.P., Lordan, C., Rogan, E. and Mente, E. 2002 Additional notes on stomach contents of sperm whales *Phyester macrocephalus* stranded in the north-east Atlantic. *Journal of the Marine Biological Association of the UK* **82**, 501–7.

SCANS-II 2008 Small cetaceans in the European Atlantic and North Sea. Final Report to the European Commission under project LIFE04NAT/GB/000245. Available from SMRU, Gatty Marine Laboratory, University of St Andrews, St Andrews, Fife, KY16 8LB, UK.

Simmons, M.P. and Isaac, S.J. 2007 The impacts of climate change on marine mammals: early signs of significant problems. *Oryx* **41** (1), 19–26.

Smiddy, P. 1986a Common dolphin *Delphinus delphis* (L). *Irish Naturalists' Journal* **22**, 166.

Smiddy, P. 1986b Bottle-nosed whale *Hyperdoon ampullatus* (Forster). *Irish Naturalists' Journal* **22**, 165.

Smiddy, P. and Berrow, S.D. 1992 Humpback whale *Megaptera novaeangliae* (Borowski). *Irish Naturalists' Journal* **24** (4), 162.

Smyth, M., Berrow, S.D., Nixon, E. and Rogan, E. 2000 Polychlorinated biphenyls and organochlorines in by-caught harbour porpoises *Phocoena phocoena* and common dolphins *Delphinus delphis* from Irish coastal waters. *Biology and Environment: Proceedings of the Royal Irish Academy* **100**B (2), 85–96.

Tregenza, N.J.C., Berrow, S.D., Leaper, R. and Hammond, P.S. 1997 Harbour porpoise *Phocoena phocoena* L. bycatch in set gill nets in the Celtic Sea. *ICES Journal of Marine Science* **54**, 896–904.

Wall, D., O'Brien, J., Meade, J. and Allen, B. 2006 Summer distribution and relative abundance of cetaceans off the west coast of Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*, **106**B, 135–42.

Walton, M.J. 1997 Population structure of harbour porpoises *Phocoena phocoena* in the seas around the UK and adjacent waters. *Proceedings of the Royal Society of London* Series B **264**, 89–94.

Went, A.E.J. and O'Suilleabhain, S. 1967 Fishing for sun-fish or basking sharks in Irish waters. *Proceedings of the Royal Irish Academy* **65**C, 91–115.

Whooley, P. and Steele, P. 2006 Larne sei whale *Balaenoptera borealis*. *Irish Naturalists' Journal* **28** (8), 340.

Whooley, P., Berrow, S. and Barnes, C. 2005 Photo-identification of fin and humpback whales off the south coast of Ireland. *Proceedings of the 15th Irish Environmental Researchers' Colloquium, Environ 2005. Institute of Technology, Sligo, 28th–30th January, 2005.* Limerick, Ireland. ESAI.

Wilson, J.P.F. and Pitcher, P.J. 1979 Feeding and behaviour of a killer whale *Orcinus orca* L. in the Foyle Estuary. *Irish Naturalist' Journal* **19**, 372.

Wurtz, M. and Marrale, D. 1993 Food of striped dolphin, *Stenella coeruleoalba*, in the Ligurian Sea. *Journal of the Marine Biological Association of the UK.* **73**, 571–8.

Zegers, B.N., Mets, A., Van Brommel, R., Minkenberg, C., Hamers, T., Kamstra, J.H., Pierce, G.J. and Boon, I.P. 2005 Levels of hexabromocyclododecane in harbor porpoises and common dolphins from western European seas, with evidence for Stereoisomer-specific biotransformation by cytochrome P450. *Environmental Science and Technology* **39**, 2095–100.