Muc Mhara

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The Irish Whale and Dolphin Group

Ireland's Smallest Whale

Proceedings of the 2nd IWDG International Whale Conference

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Muc Mhara - Ireland's smallest whale

Fitzpatrick Castle Hotel,
Killiney, Co Dublin

19th - 21st September 2008

ISBN: 0-9540552-3-3

"The Irish Whale and Dolphin Group (IWDG) was established in December 1990 and is *"dedicated to the conservation of cetaceans (whales, dolphins and porpoises) in Irish waters, through study, education and interpretation."*

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Citation: IWDG (2009) Muc Mhara – Ireland's smallest whale. Proceedings of the 2nd Irish Whale and Dolphin Group International Whale Conference (Eds. Berrow, S.D. and Deegan, B.) 19th -21st September 2008, Killiney, Co. Dublin.

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INTRODUCTION: THE HABOUR PORPOISE OR MUC MHARA

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The harbour porpoise is probably the most widespread and abundant cetacean species in Irish waters. It has been recorded off all coasts and over the continental shelf (Reid *et al.* 2003). They are consistently one of the most frequently recorded species that are stranded in Ireland (Berrow and Rogan 1997). The life history of harbour porpoise in Irish waters is poorly understood, but since the establishment of the Irish Whale and Dolphin Group (IWDG) there has been a large increase in our knowledge of, and research into, cetaceans in Irish waters, including the harbour porpoise. Rogan and Berrow (1996) carried out a review of the harbour porpoise in Ireland including information on distribution, diet, reproduction and threats including fisheries and persistent pollutants.

For centuries, harbour porpoise, or muc mhara (sea-pigs), would have been very familiar to coastal communities throughout Ireland. The Annals of Ulster from 827 AD records “a slaughter of sea-hogs on the coast of Co. Louth by foreigners”, which were thought to be by Norsemen (Fairley 1981). A vertebra thought to be from a porpoise was excavated from a kitchen midden in Co. Louth (Fairley 1981), suggesting that they were eaten. The most detailed description of hunting porpoises is from the Blasket Islands where O’Crohan (1978) describes driving sea-hogs ashore in 1890, where they were killed and eaten during the winter.

Photo © Simon Berrow

Plate 1. Muc Mhara or harbour porpoise showing typical small triangular dorsal fin

Harbour porpoise are on Annex II of the EU Habitats Directive and thus member states are required to designate Special Areas of Conservation (SAC) to protect important populations and habitats. To date, two sites (The Blasket Islands and Roaringwater Bay cSACs) have been designated for harbour porpoise, but more sites must be designated and managed to fulfill Irelands’ legal obligations. Harbour porpoise, like all cetacean species, are also entitled to full protection throughout the Irish Exclusive Fisheries Zone, up to 200 nautical miles offshore. Identifying important sites with high concentrations is constrained by lack of information on their distribution and abundance. Effective management of the present cSACs and all Irish waters for harbour porpoise requires a much better understanding of their life-history and ecology.

The objective of *Muc Mhara – Irelands’ smallest whale* conference was to raise interest and awareness of the harbour porpoise and its conservation in Ireland. This was to be achieved by reviewing present knowledge on the species in Irish waters including presentations on its life-history (as determined from post-mortem examination), abundance estimates, acoustic monitoring and recent work attempting to reduce by-catch in fishing nets, which is generally perceived as one of their greatest threats. In order to learn about relevant work on harbour porpoise elsewhere, we invited the world's foremost authority on harbour porpoise, Professor Andy Read, to present current knowledge of this species from the Northwest Atlantic. One of the most exciting projects on harbour porpoise in recent years in Europe is a satellite telemetry study from Denmark where harbour porpoise recovered from pound nets were tracked for up to one year. This study has huge implications for the conservation management of the species. Apart from fishing, one of the most recent potential threats to harbour porpoise in Ireland is the predicted expansion of renewable energy. It has been predicted that Ireland could become a net exporter of renewable energy generated mainly at sea due to our high winds and huge wave and tidal energy. The relevant issues regarding renewable energy are not known, but recent work on the potential impact of tidal devices is of great relevance. We hope this conference has fulfilled its objectives by pulling together existing information from Ireland, identifying some important gaps in our knowledge and has got people talking about Muc Mhara.

This conference would only be an idea without the generous support of our sponsors. We would like to thank them for their continued support and hope that we have contributed to raising interest and awareness of the harbour porpoise - *Irelands' smallest whale.*

Plate 2. Harbour porpoise *en route*

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AN IRISH NAME FOR THE HUMBLE HARBOUR PORPOISE

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I read recently about the upcoming IWDG conference in Killiney and noted the title: Muc mhara: Ireland's smallest whale. It struck me that the Irish name for this country's commonest cetacean is now all but official (An Roinn Oideachais 1978). Certainly, the roots of both the English and Irish names do have much the same etymology. Muc mhara translates as sea-hog (feminine), while porpoise combines the Latin words, porcus and piscis to form pig-fish. The harbour porpoise (*Phocoena phocoena*) is a blunt-nosed sea-mammal with short, stocky body that resembles a pig. Nevertheless, based on the literature, it appears that in the past, muc mhara was used more widely.

After a preliminary investigation, I found quite an etymological tangle. This of course, is par for the course when it comes to common names of fauna. In the first place, there is the problem of dialect. In the second place, fewer people now speak the Irish language. As a result, standard Irish words for natural phenomena have, in some cases, been created. To make matters worse, it is often only the specialist that can be sure about the identification of a particular species. In other parts of the world, the common names of dolphins and porpoise are often interchanged (Carwardine 1995). And I have heard it said that some fishermen mistake the triangular, dorsal fin of the porpoise for that of a shark.

An examination of dictionaries and other listings reveals a number of Gaelic variants. (I have ignored those names that clearly refer to other marine creatures.) In addition to the feminine name, muc mhara (Dineen 1927), we find muc bhiorach (O'Reilly, 1864), and the masculine words, tóithín and tóithíneach (Dineen 1927, An Roinn Oideachais 1978 and Nic Pháidín 1981). By the way, muc bhiorach means 'pointed hog' and seems a rather strange equation with the porpoise. Does the name instead refer to the sharply pointed snout of the minke whale? Tóithíneach translates loosely as 'puffer', and is, presumably, linked to the 'puffing pig' of eastern Canada (Fisheries and Oceans, Canada 2007). The blow of the harbour porpoise is a sharp, puffing sound rather like a sneeze. Incidentally, in Scots Gaelic, muc steallain, or 'spouting pig' is another name. At the time, the collective name, muclach, was used as a general term for 'sea-hogs' (O'Donovan 1864).

Recently, I came across a fascinating verse in Scots Gaelic about a magical hierarchy of marine animals based on the sacred number, seven. The poem, which was collected in 1860 (Carmichael 1900), reveals that, on the Isle of Skye at least, there were two creatures with the name, muc mhara. At the time, 'sow of the sea' was an ordinary term for the whale.

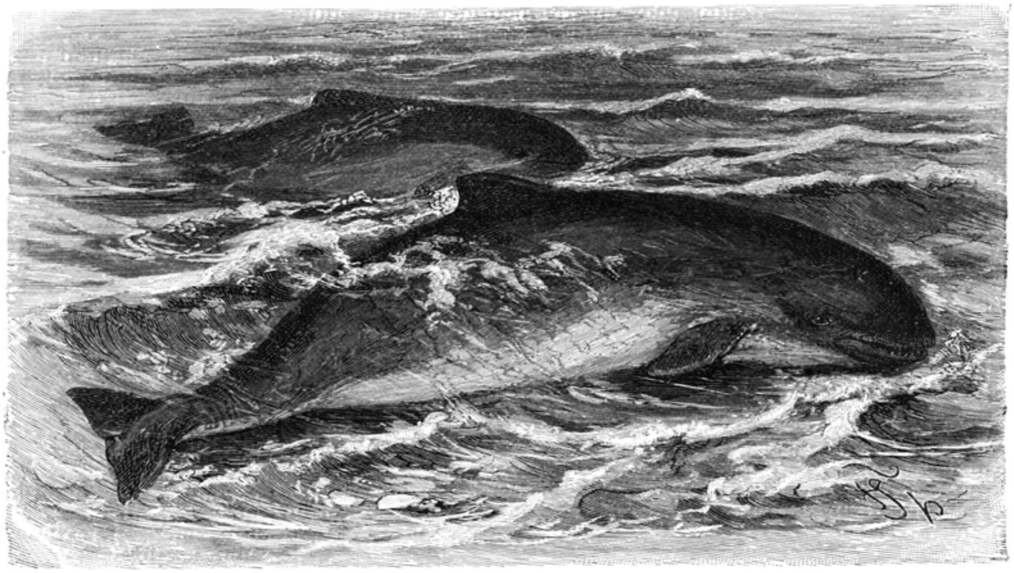
Seachd sgadain, sáth bradain;
Seachd bradain, sáth róin
Seachd róin, sáth muice mara bhig
Seachd mucan-mara beaga sáth muc mhara mhóir
Seachd mucan-mara mór sáth cionnain cró
Seachd cionnain cró sáth miol-mhóir a" chuain

Seven herrings, feast of salmon;
Seven salmon, feast of seal;
Seven seals, feast of little sow of ocean;
Seven little sows of ocean, feast of large sow of ocean;
Seven large sows of ocean, feast of cionarain-cro;
Seven cionarain-cro, feast of great beast of ocean.

My first guess would be that the 'little sows of the ocean' were porpoise, while the 'large sows of the ocean' were minke whales. Porpoise and minke whales are abundant in Scottish waters, and, as I understand it, have a similar dive sequence. Indeed, I have heard an old man from Cape Clear refer to the minke whale as a 'big porpoise' (O'Driscoll *pers. comm*.).

Cuaisín na Muice Mara, on the south coast of Cape Clear, is a place-name that is of particular interest in this respect (Beese 2002). The Irish name is probably best translated simply, as 'little inlet of the whale'. Its origin is forgotten, but it seems likely that the arrival of a whale in the small cove would certainly have had more impact than a porpoise, providing perhaps both oil and food. In any case, the current island-name for a porpoise is tóithíneach. (On the island, this word has a second, irreverent meaning because it describes someone who is overweight, no doubt, puffing as they walk along the island's steep roads.)

Here, I ask readers to make enquiries in their own area and record any local name, whether in English or Irish that has been used for the harbour porpoise. More research needs to be done on this subject but if my thesis is correct, perhaps we should we follow the Scottish precedent and upgrade the humble porpoise to muc mhara bheag? 'Tis prettier anyway.



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LIFE IN THE FAST LANE: ECOLOGY AND BEHAVIOR OF HARBOR PORPOISES IN THE GULF OF MAINE

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Photo © Ari Friedlaender.

Plate 1. A harbour porpoise surfaces in the Bay of Fundy, Canada.

Harbour porpoises are the most abundant species of cetacean off the coasts of eastern Canada and the United States. In addition, these are amongst the best-studied of all whales, dolphins and porpoises, thanks to a research program that will mark its fortieth anniversary this summer. In 1969, a new faculty member at the University in Guelph in Canada, David Gaskin, began a research program in the Bay of Fundy to study these enigmatic animals. David's work revealed some of the adaptations that allow these small marine mammals to thrive in what seems to us to be a cold, harsh and unforgiving environment. As one of David's students, I was fortunate to continue his legacy, which in turn, is now being led by two of my former students, Andrew Westgate and Heather Koopman. In this very brief article, I'll summarize some of the highlights of this long-standing research program.

One of the most fundamental questions addressed in David's early research was how these warm-blooded animals manage to stay warm in waters that would quickly stun and kill a human being. Some early studies suggested that porpoises manage to stay warm by increasing their metabolic rate (akin to turning up the thermostat in a drafty house). Perhaps not surprisingly, natural selection resulted in a much more energy-efficient solution. Much of the core body of a harbour porpoise is wrapped in a 1.5 to 2.5 cm-thick layer of lipid-rich blubber, which insulates the animal in a very effective manner. The animals do not need to turn up their metabolic furnaces simply to keep warm.

The blubber of a porpoise is comprised of fat cells suspended in a matrix of collagen fibers; up to 90% of the blubber of a healthy porpoise is made of fat. Heather Koopman's research showed that blubber is not a uniform tissue, however, and both its composition and function varies over the body surface. For example, blubber on the tail stock has more fiber and less fat; this part of the blubber functions as a biological spring, increasing the efficiency with which the flukes moves up and down, thus providing more thrust for less energy expenditure. Heather also showed that when porpoises are unable to feed, they lose fat from the blubber in their thorax and abdomen, but not from their tail, allowing them keep swimming in search of food. Eventually, of course, a starving porpoise will succumb to hypothermia or pneumonia – we see many young porpoises in this condition on the beaches of New England each spring. These starved animals have not learned to forage effectively on their own after being weaned from their mothers.

In the Gulf of Maine, porpoise reproduction is very seasonal and synchronized. Most mating takes place during a brief period in June. About six weeks later, a single embryo implants in the wall of the female's uterus and pregnancy begins. After a pregnancy of almost eleven months, the baby porpoise is born the following May, measuring about 75 cm in length and weighing 7 or 8 kg. It is remarkable that these tiny newborns are able survive in a cold ocean. Perhaps it is not surprising that they spend much of their first few months nursing and rapidly accumulate a thick coast of insulating blubber. Work by my colleague Patrik Börjesson indicates that the exact timing of reproduction varies from population to population. Porpoises in the Baltic, for example, mate and give birth much later in the year than do their counterparts in the Gulf of Maine. This likely reflects adaptation to local ecological conditions that allow individual female porpoises to give birth during seasons of plentiful food, as they must meet their own energetic needs as well as those of their nursing calf for its first few months.

In the Gulf of Maine, young porpoises start to feed on solid food by taking euphausiids, a type of small crustacean. Soon however, they join their mothers and feed on herring, which forms the majority of the diet of older porpoises during the summer months. Herring are a lipid-rich fish, which helps porpoises to meet their energetic requirements. The movements of porpoises are tightly coupled with those of their prey during the summer – when the herring appear, the porpoises are right on their tails (Lewis Carroll had it almost right).

The tight coupling between predator and prey leads some porpoises into trouble when they follow herring into weirs – large fish traps set along the shorelines of the Bay of Fundy. We worked with fishermen to develop a co-operative program in which porpoises were released safely from herring weirs by using specialized nets and placing divers in the water to capture the animals. This program had multiple benefits - saving the lives of porpoises, eliminating a nuisance for fishermen, and providing us with an opportunity to study healthy live animals. The porpoise rescue program, now run by Andrew Westgate and Heather Koopman, now releases more than 90% of the porpoises trapped in herring weirs each year.

Photo © John Wang, Grand Manan Whale and Seabird Research Station.

Plate 2. Andrew Westgate releases a harbour porpoise from a herring weir in the Bay of Fundy.

We have learned much from the porpoises we rescue from herring weirs. Our examinations are brief and a porpoise is typically back in the water a few minutes after being lifted into our research boat. This gives us just enough time to take a blood sample, measure blubber thickness with a portable ultrasound machine, and to attach a small plastic tag to its dorsal fin for later identification. We have also equipped a small number of porpoises with satellite-linked radio tags, using the same techniques as our Danish colleagues. The tags are surgically attached to the animal's dorsal fin with plastic pins that eventually break, shedding the transmitter. The tags stay on for a few months, allowing us to track the movements and behaviour of these animals from our office, via satellite. The movements of these tagged porpoises have amazed us –individuals sometimes move hundreds of kilometres in a matter of a few days. Porpoises use the entire Gulf of Maine during their travels; we believe that their mobility reflects the need to stay close to prey resources.

The porpoise rescue program is a wonderfully successful animal welfare story, but the number of animals trapped in herring weirs each year is relatively small and does not pose a significant threat to the population. Of much greater concern is the death of porpoises in gill nets set on the sea floor to catch cod and other bottom-dwelling fish. These nets are designed to entangle fish that attempt to swim through them, typically around the gills. For reasons that we still do not understand, porpoises also become entangled in gill nets, perhaps as they are chasing prey near the sea floor. A porpoises entangled in a gill net is unable to surface and breathe and will die of asphyxiation in a few minutes. This sad story is repeated hundreds of thousand times over each year in the world's oceans with many species of small cetaceans. In the early 1990s I worked with a group of scientists, fishermen and conservationists to find a way to reduce the number of porpoises dying in gill nets in the Gulf of Maine. At that time, the U.S. government estimated that approximately 2,000 porpoises were being killed each year in gill nets and there was considerable concern over the long-term sustainability of this population. Some of the fishermen we worked with suggested that it might be possible to put small sound emitters, or acoustic alarms, on the nets to make them more detectable to a porpoise. Scientists, including myself, were skeptical about the efficacy of this approach, but we agreed to conduct an experiment to determine whether the alarms were effective or not. In a tightly controlled, double-blind experiment conducted in 1994, we learned that acoustic alarms reduced the mortality of porpoises in gill nets by 90%. Acoustic alarms were quickly adopted as one of the key conservation measures in a plan to reduce the by-catch of porpoises to sustainable levels in the Gulf of Maine.

The plan was adopted in late 1998 and, by 2001, the annual mortality of porpoises in the gill net fishery had dropped to about 50 - a forty-fold reduction. Unfortunately, the alarms are relatively expensive and, as a result, unpopular with fishermen. After September 11, 2001, the U.S. Coast Guard reduced its enforcement of fisheries conservation measures and directed its efforts to counter-terrorism measures. As a result, compliance with the conservation plan (measured by onboard fisheries observers) dropped dramatically. In 2003, for example, only 20% of 217 monitored trips were in compliance with the plan. Not surprisingly, porpoise by-catch increased to almost 600 animals that year. Recently the Coast Guard has stepped up its enforcement and the fishing industry has agreed that, unless compliance increases significantly, more drastic conservation measures, such as the closure of large areas to fishing, will be necessary.

Photo © Andrew Read

Plate 3. A harbour porpoise killed in a gill net in the Gulf of Maine.

Photo © Danielle Waples

Plate 4. A fishermen retrieving a gill net equipped with an acoustic alarm.

We have learned much from our 40 years of studying these wonderful little animals. I am continually amazed at their abilities, from traversing the Gulf of Maine in a few days, to diving to the deepest portions of the Gulf (more than 200 m) in search of food. There is a tremendous amount left to learn, however, and many important conservation battles left to fight. In most areas of their range, including the waters around Ireland, we do not know how many porpoises exist, or how many are killed each year. Conservation measures will not be needed everywhere, of course, but it is certain that many problems exist undetected today. Despite the fact that I have being studying harbour porpoises for almost 30 years, I have many more questions than answers. How do porpoises recognize each other using sound, if they do not produce individually distinctive whistles like those used by many dolphins? How does their mating system work? Why do they become entangled in nets when they possess such a sophisticated system of echolocation? There is much exciting research ahead of us….

THE ECOLOGY OF HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) IN IRISH WATERS: WHAT STRANDINGS PROGRAMMES TELL US.

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Introduction

Cetacean strandings programmes (the recovery and post-mortem examination of beach-cast animals) provide important insights into the life history and ecology of cetacean species. Historically, records of cetacean strandings in Ireland were reported on an *ad-hoc* basis and published in various publications. Since 1983, records of stranded animals are recorded in the Irish Naturalists' Journal (INJ). With the establishment of the Irish Whale and Dolphin Group (IWDG) in December 1990, a more systematic approach to the reporting of stranded animals was implemented. The group publicises and encourages the reporting of strandings and these peer-reviewed strandings records are reported annually to the INJ. In parallel with the development of the IWDG, a cetacean monitoring programme was established in University College Cork. This programme was established primarily to study the ecology of small cetaceans (including the harbour porpoise (*Phocoena phocoena*)) and over the period 1993 to 2004 was funded by a number of different research programmes and funding bodies, including the Irish Heritage Council, INTERREG Ireland-Wales, National Parks and Wildlife Service (formally Dúchas) and EU 6th framework programme (BIOCET – "Bioaccumulation of Persistent Organic Pollutants in Small Cetaceans in European Waters: Transport Pathways and Impact on Reproduction" project) and all are gratefully acknowledged. Throughout this period, a number of researchers and students conducted or helped out with post-mortem examinations and I am indebted to them for their hard work and enthusiasm. The data presented here summarises some of the research output.

What can strandings programmes tell us?

Harbour porpoise are the most frequently reported stranded cetacean on the Irish coastline (Berrow and Rogan 1997) although this varies annually. Harbour porpoise have been reported stranded along the entire Irish coastline, although most strandings are from the south and west coasts. Over the period 1993 - 2004, we have examined 123 harbour porpoises and most strandings were of single individuals (in contrast to other cetaceans species, which occasionally strand in large groups). However, stranded animals are found in different levels of decomposition, varying in the extremes between skeletal remains to freshly dead individuals. This limits sampling (and the amount of information obtained) in very decomposed animals and allows a more compete post-mortem examination to be carried out on freshly stranded individuals. Sampling follows standard protocols and includes sampling for genetic analysis, a range of contaminants (e.g. lead, mercury, and persistent organic pollutants), diet, morphometrics, parasites, age and reproductive status.

Stranding patterns

The number of animals stranded and examined each year varies and the pattern of strandings for porpoises from 1993 – 2004 (which corresponds to the main sampling period) are given in Figure 1. It appears that the number of stranded harbour porpoises has increased in recent years, but this is likely as a result of an increase in the number of individuals reporting strandings, coincident with a more public profile of both the IWDG stranding programme and the research programmes. There is an approximately equal ratio of male to female animals stranding and most strandings occur in late winter – early spring, possibly suggesting an offshore movement in the summer, or more storms during winter depositing more dead animals on to beaches.

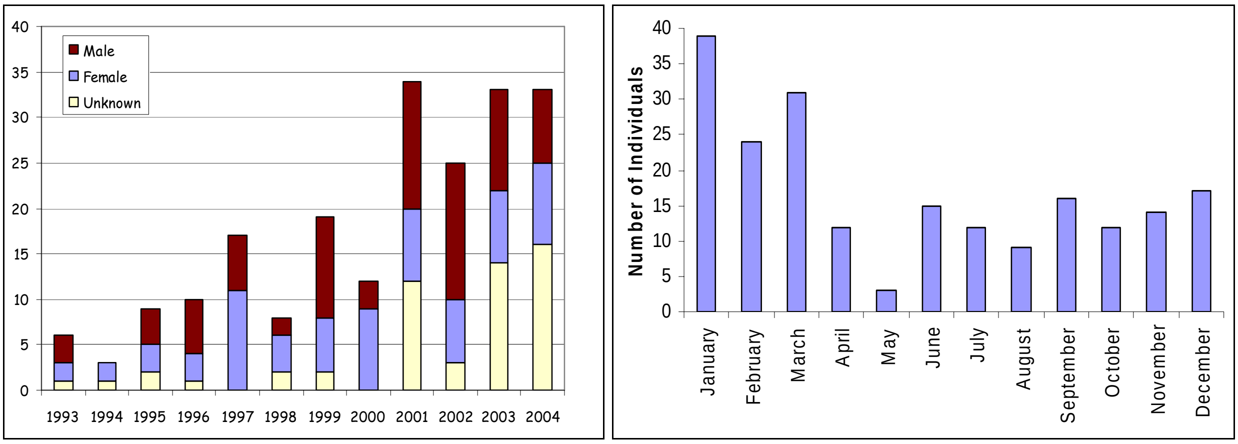

Figure 1. The number of harbour porpoises sampled per annum (1993 – 2004) and the monthly distribution of strandings

Causes of death

When post-mortem examinations are carried out, the animals are divided into broad categories, based on causes of death (when determined). These categories consist of live stranded animals, stranded (animals which died as a result of loss of condition/emaciation, pathological reasons, including diseases such as pneumonia, and parasites, trauma and not established), by-caught individuals (incidentally caught in nets) and known by-caught animals. The majority of the animals examined are young animals < 140cm (Figure 3).

A small number (4%) of animals died as a result of stranding alive and 7% were diagnosed as having died after entanglement in fishing gear. If the proportion of animals diagnosed as by-catch are calculated based on "fresh" individuals only, this increases to 11% and is consistent with findings from elsewhere in Europe. Thirteen known by-caught animals were also examined. These were animals that were recovered through on-board observer programmes and were known to have died in gillnets. By-catch has been highlighted as a problem in the Celtic Sea gillnets (following observer programmes, e.g. Tregenza *et al*. 1997) and the recent introduction of acoustics devices (pingers) on some fishing gear in this area may help to reduce this. However, by-catch of harbour porpoise in other gear types and regions has not yet been quantified.

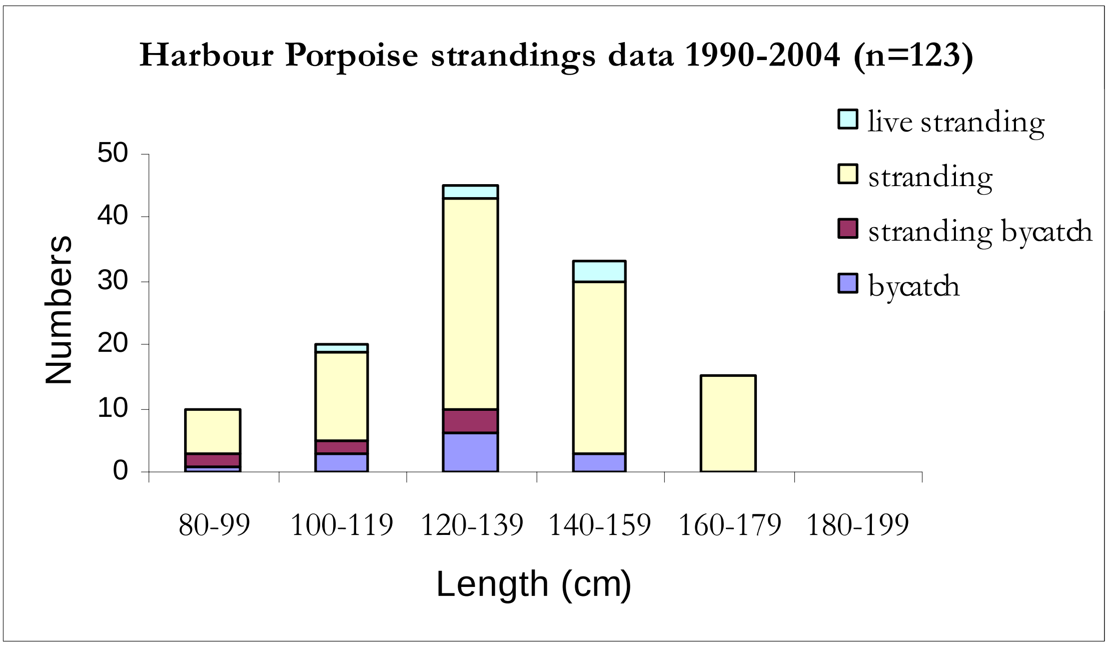

Figure 2. Length frequency distribution of porpoises by stranding category

Within the category "stranding" two harbour porpoises showed injuries consistent with injury from a bottlenose dolphin (*Tursiops truncatus*). The symptoms included blunt force trauma, broken ribs and clear evidence of rake (tooth) marks from a bottlenose dolphin interaction. Bottlenose dolphin interactions with harbour porpoises have been recorded from strandings in Scotland, Wales and the US and in Ireland. A visual account of a bottlenose dolphin-harbour porpoise interaction in Cork Harbour is given by Ryan (2008).

Life history

Toothed whales (odontocetes) can be aged by reading the Growth Layer Groups in the dentine and cementum of the teeth. Under the BIOCET project (see below) ages from harbour porpoises from stranded animals along the coastlines of a number of countries (Scotland, Ireland, Belgium, Netherlands, France, northern Spain (Galicia)) were calculated, specifically for the purpose of examining the impact of contaminants on this species. From this broader scale analysis, animals were found to range in age from neonates (< 1 yr old) up to 24yrs (in Scotland), although most individuals were < 14yrs. In addition to this, it is clear that females attain greater body length than males, and this trend increases at the southern end of this range (Figure 3). In Galicia, harbour porpoises are bigger than in more northern Europe. The age distributions are similar to elsewhere in Europe (e.g. Lockyer 1995) but differ from age analysis in the Gulf of Maine, where the maximum age was found to be 17, with most animals < 12yrs (Read and Hohn 1999).

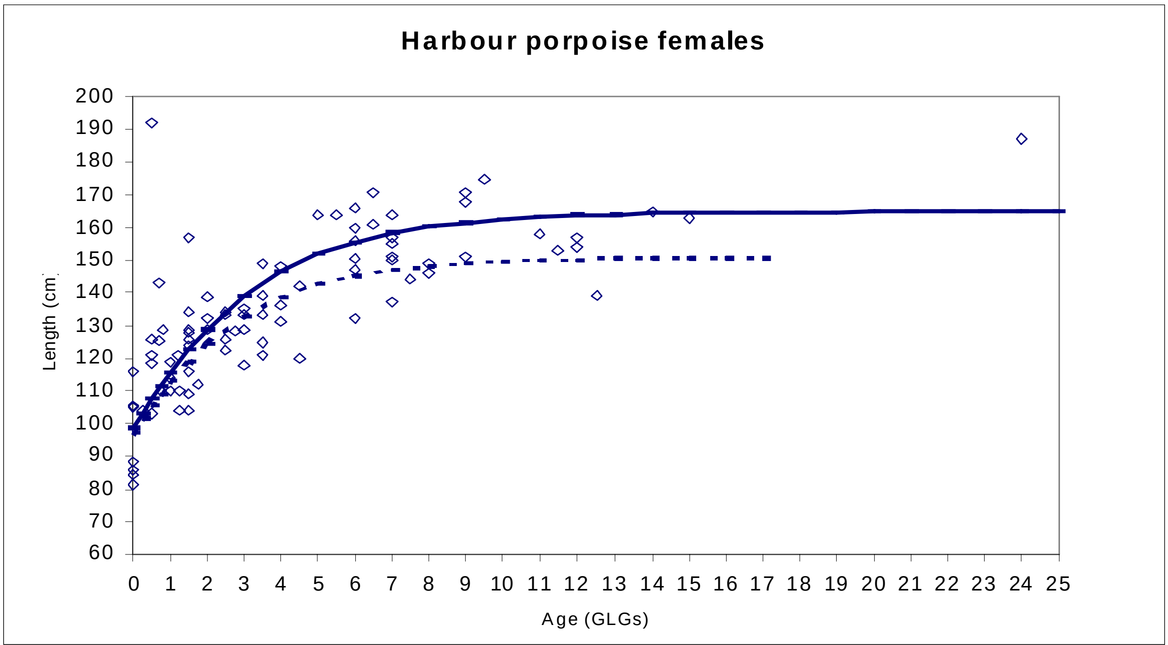

Figure 3. Age of individual harbour porpoises in BIOCET project plotted against length (cm). The dark line shows female growth curve and the dotted line shows the male growth curve (from Rogan *et al*. 2006).

Examining the reproductive tracts of males and females can provide insights as to when individuals become sexually mature. With females, ovaries are examined for *corpora* scars, as an indication of sexual maturity and examining the uterus for the presence of a foetus, combined with records of neonate mortality, help to define whether a breeding period exists. In males, testes size and, on histological examination, the presence of sperm in the lumen of the testes, provides information on sexual maturity. Age at sexual maturity (ASM) in harbour porpoises also differs between European waters and the US east coast. In the BIOCET study, females were found to be sexually mature at a body length of 142 – 156 cm, and approximately 4.5 years of age, although there is individual variation. This contrasts with information from the US east coast, where the average ASM for female harbour porpoise was 3yrs (Read and Hohn 1995). The majority of neonates (animals < 90cm) were found in May and June, suggesting that most animals give birth during this period, although this was based on a very small sample size. Males appear to mature at a body size of between 144 and 157cm. As with females, there is individual variation, with some males attaining sexual maturity at 4 yrs and some later, at 8yrs (Learmonth *et al*. 2006). These results are based on pooled data from European waters. In time, and with additional samples, it will be possible to determine more accurately, ASM on a finer regional scale, which is important, given the possible impact of contaminants on this species (see contaminants below).

Diet analysis

Diet can be determined by examining stomach contents and reconstructing diet from analysis of any remaining hard parts, such as fish otoliths (ear bones), vertebrae, jaws and cephalopod (squid and octopus) beaks. Otoliths and beaks are very useful in diet analysis as they are species specific and can be used to identify the exact prey species and when measured, can be used to re-construct the length and weight of the prey item. However, when otoliths get worn (as a result of the digestive process) it becomes difficult to differentiate between closely related species, such as Norway pout, poor cod and bib and in this analysis, these species are grouped as *Trisopterus* spp. Similarly, the otoliths of many gadoid species – e.g. haddock, saithe, pollack and whiting are difficult to distinguish with increased wearing, and in this analysis, where possible these are presented separately, but otherwise are presented as unidentified gadoid species. Analysis of 73 stomachs has shown that harbour porpoises forage primarily on fish (98%) with the remainder of the prey items comprising cephalopods and crustaceans. At least 16 different taxa have been recorded, revealing a broad generalist diet. Looking at the percentage of prey by number (i.e. how many of an individual species was present in all the stomachs) shows that species such as whiting, *Trispoterus* spp and unidentified gadoids are important. Examining the data in relation to % occurrence (how often a prey item occurs) shows that in addition to these groups, herring is also important. Fish species that occur less frequently include hake, scad, sprat, silvery pout and rocklings. Again, this is broadly similar to analyses from elsewhere in European waters. For example, in Scotland, whiting and sandeels were found to be important (Santos *et al*. 2004), and in Sweden, herring was the most important food item, with sprat and whiting varying seasonally (Borjesson and Berggren 1996). In the Gulf of Maine (US), herring comprise a high proportion of the diet in summer and autumn, with hake species and pearlsides important in autumn (Gannon *et al*. 1998), whereas in the Bay of Fundy (Canada), although there were strong inter-annual variations, herring, silver hake and cod are important (Recchia and Read 1989). It is also interesting to note, that while some of the prey items are commercially fished (e.g. whiting and herring and that some of these stocks are declining) that *Trisopterus* spp (which are not generally targeted, except Norway pout which is caught for fish meal) are very important to harbour porpoises and other marine mammal species in this region, including common dolphins (unpublished data), grey seals (McKibbon 2000) and common seals (Kavanagh *et al*. in review). One individual harbour porpoise was found with plastic in its oesophagus.

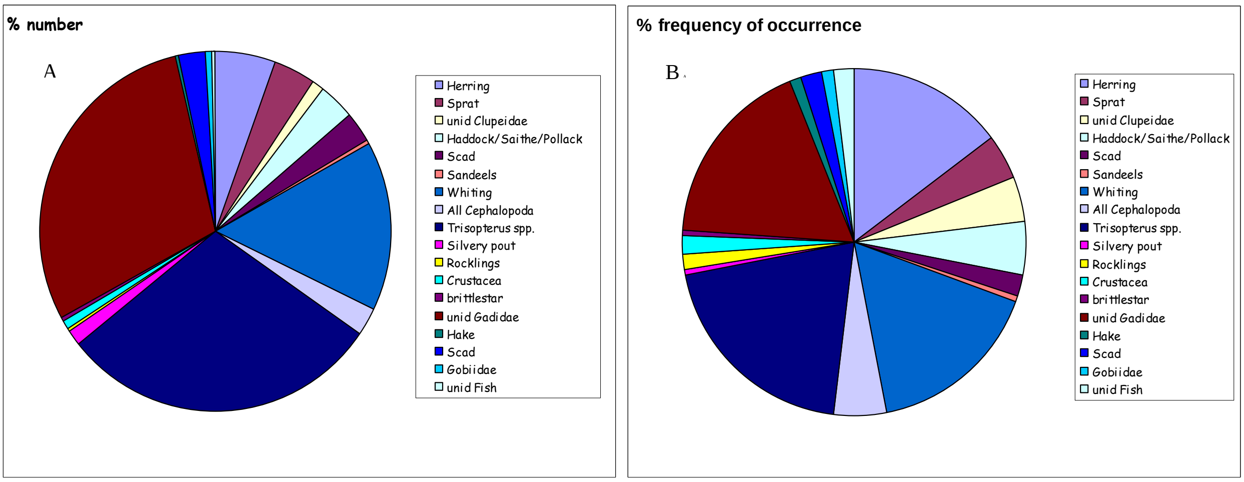

Figure 4. Proportion of different prey items in the diet of harbour porpoises by a) % number and b) % occurrence.

Contaminants
Different contaminants likely to accumulate in marine mammals through the food chain, and over sampling periods, have been examined in harbour porpoises in Ireland. These include radionuclides (Berrow *et al*. 1998), PCBs and organochlorines (Smyth *et al.* 2000). More recently, under the BIOCET project, we have had the opportunity to examine recent contaminants burdens and a broader range of contaminants to examine potential synergistic effects. Apex predators, such as harbour porpoises, are at risk from effects of contaminants such as Persistent Organic Pollutants (POPs), e.g. PCBs and dichlorodiphenylethanes (e.g. DDT), due to bioaccumulation (increasing concentration with age in individuals) and biomagnification (higher levels higher up the food chain, especially when moving from gill-breathing animals like fish and cephalopods to air-breathing animals like marine mammals). Persistent Organic Pollutants are lipophilic compounds that tend to accumulate in the lipid-rich blubber. In marine mammals, POPs enter the body almost exclusively through the diet (Pierce *et al*., 2008). Potential harmful effects of POPs include immune suppression, increased risk of infection, disease and parasite burden, and reproductive failure. Toxic elements measured in the BIOCET project included lead (Caurent *et al*. 2006) and others trace elements, e.g. cadmium, mercury, zinc (Lahaye *et al*. 2007), polychlorinated biphenyls (PCBs), and hexabromocyclododecane (HBCDs), a chemical used as a flame retardant (Zegers *et al*. 2005). In general, levels of heavy metals recorded from porpoises from all Irish coastal waters were low (when compared to levels recorded in the North Sea, for example), with the exception of two individuals which had elevated hepatic mercury levels. POPs in porpoises from the west of Ireland were recorded in lower levels than in porpoises found in the Irish Sea and these were significantly lower than POP levels in porpoises from the North Sea, where there are indications of reproductive failure in this species. HBCDs were recorded in high levels from porpoises in the Irish Sea (and northwest Scotland), which is of concern.

Stock structure
A number of studies have looked at population structure of harbour porpoises using both ecological tracers (such as caesium, Berrow *et al*. 1998) and genetic techniques (mtDNA and microsatellites). With regard to genetic sampling, skin tissue is analysed and genetic differences are inferred from examining individuals from different regions. Identifying population structure is important for management purposes, especially if by-catch limits are established on a population basis. Samples from porpoises stranded along the Irish coastline have been used for comparison with Iceland (Duke 2003), UK (Walton 1997) and on a pan-European basis (Fontaine *et al.* 2007). Although ecological data suggest that Irish Sea porpoises should be considered a separate management unit, genetic evidence (e.g. Walton 1997) suggests that there is no difference between porpoises in the Irish Sea and Celtic Sea. The discrepancy in the results is due to differences in the time scale applicability of both markers. In general terms, it takes many generations and a much longer timeframe for genetic differences to become established, whereas radiocaesium indicates residency over an individual's lifetime. On a larger spatial scale, it is clear from genetic analysis that harbour porpoises in the central and eastern North Atlantic behave as a "continuous" population that extends over a wide geographic area from Bay of Biscay northwards to Iceland and Norway (Fontaine *et al*. 2007), with isolation by distance. The degree of genetic differentiation differs, and other studies have shown small (but significant) differences between adjacent areas, such as the North Sea and Celtic Sea. These differences appear to be mediated by females, that don't range as much as males (Walton 1997). Using smaller conservation/management units for this species is therefore appropriate.

Summary
Stranding programmes can provide us with much information on life history and ecology, stock structure and health status of small cetaceans. Examining location and seasonal patterns can provide us with insights into broadscale distribution patterns. In addition, a stranding programme can serve to highlight by-catch (incidental entanglement) or disease related mortality events. The work also highlights that sustained and continued sampling effort is important to obtain sample

sizes that will allow robust and appropriate comparative analysis to be carried out. For management, it is important for example, to determine ASM, pregnancy rates and how often porpoises reproduce, to better ascertain how they would recover from a high mortality event and/or whether high contaminant burden influences reproductive output. Continuous monitoring also can show changes in contaminant levels, such as has been shown for toxic elements such as lead (which has seen a decrease in levels detected in harbour porpoises, since the introduction of unleaded petrol) and HBCDs, but also to look at more long term effects such as those resulting from climatic changes (e.g. the decadal scale North Atlantic Oscillation and how this might be reflected in changes in diet), changes in fishing practices and declining fish stocks.

Acknowledgements
I would like to acknowledge the help of a large number of people who have helped over the years: the members of the IWDG network, for reporting strandings, and in particular Mick O'Connell and Pat Smiddy, Simon Berrow (who got me into all of this), Trish Clayton, Irene Gassner, Mick Mackey, Sinéad Murphy, Evelyn Philpott, John Brophy, Eoin Browne, Dave O'Leary, Tina Rose, Ailbhe Kavanagh, Luca Mirimin, John O'Brien for help with post-mortem examinations, sampling and freezers!, the ever (odour) tolerant staff and students of the Dept. of Zoology, Ecology and Plant Science, UCC, the by-catch observers on the pinger project (Sam Shephard, Peter Rendell), James Fairley and Don Cotton, as meticulous editors of the INJ Cetacean Notes, and *inter alia*, Thijs Kuiken, Paul Jepson, Christina Lockyer, Harry Ross, John Baker, Seamus Kennedy, Rod Penrose, Bego Santos, Jen Learmonth, Graham Pierce, Sarah Duke, Thierry Jauniaux, Florence Caurant, Virginie Lahaye, Marjan Addink, Bart Zegers, Jan Boon, Michaël Fontaine, Andrew Kitchner and Jerry Herman. I would also like to acknowledge the various funding bodies contributions over the years: Heritage Council, NPWS (Dúchas), INTERREG (Ireland – Wales), DG Fish and EU 6th framework. *Go raibh míle maith agaibh go léir*.

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PASSIVE ACOUSTIC MONITORING OF THE HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) IN IRISH WATERS

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Introduction

Underwater visibility is affected by a combination of factors and even under optimum conditions is limited to a few 10's of meters (Au 2000). Harbour porpoises inhabit Irish coastal waters, where the visibility is impacted upon by strong currents, sea-state and river influences, resulting in dark turbid conditions. Their ability to echolocate enables them to overcome this obstacle and allows them to efficiently navigate and find food. Harbour porpoise echolocation signals are characterised as being narrow-band and of high frequency between 110 and 150 kHz, with a detection range (for a single fish of ingestible size) of up to 30m. Their average click duration is 2µs and mean source level of 150dB re 1µPa @ 1m (Møhl and Andersen 1973; Goodson and Sturtivant 1996; Au *et al.* 1999; Carlström 2005; Villadsgaard *et al.* 2007; Verfuß *et al.* 2007). Boat sonar and echo-sounders are the only sounds in the sea which are similar to harbour porpoise sonar, as other sounds are more broadband and have longer durations and occur at lower frequencies (Kyhn *et al.* 2008). This ability to echolocate and the characteristics associated with their click production makes the harbour porpoise an ideal candidate for passive acoustic monitoring (PAM).

The use of PAM is a very valuable tool for the exploration of fine scale habitat use by the harbour porpoise, in comparison with visual observation, which carry with it many constraints, influenced by variables such as sea state (Clarke 1982, Palka *et al*. 1996, Teilmann 2003, Evans and Hammond 2004), observer error (Young and Peace 1999), optics and height above sea level. PAM can be carried out independent of these variables and most importantly it does not negatively impact upon the animals. PAM during the present study was carried out using T-PODs. A T-POD is essentially a hydrophone, which is connected to two band pass filters, a comparator/detector circuit and a microprocessor which has memory capability to store information logged from the target species (Kahn 2006). All electronics are contained within a waterproof PVC housing and are powered by 12 lithium D-celled batteries and have 128 megabytes of memory. These devices are fully automated, and can detect harbour porpoises, dolphins and other toothed whales by recognising and logging details of echolocation click trains (www.chelonia.co.uk). The T-POD hydrophone is omni-directional in the horizon plane, while detection distances of 200m (Tougaard *et al.* 2006) and 300m to 500m (Villadsgaard *et al.* 2007) have been calculated. The dedicated software T-POD.exe is used to download the data from the logger, which identifies and classifies click trains of cetacean origin. A T-POD runs six successive scans each of 9.3 seconds duration and selects only tonal clicks from which it logs the time and duration of each click. However, sensitivities between units differ and therefore tank calibration tests are recommended prior to deployment to determine the detection threshold of each unit as detection threshold is directly related to detection range (Kyhn *et al.* 2008). In addition field calibrations are also recommended prior to employment of the devices in monitoring programmes in order to facilitate comparisons between datasets collected in different areas using multiple loggers (Dähne *et al.* 2006).

The objective of this present study was to examine the scale of habitat use by harbour porpoise on the west coast of Ireland in order to assess the suitability of two sites for future SAC designation (Galway Bay and Clew Bay). No previous acoustic monitoring was carried out in either area, but a visual dataset is available from land and vessel based observations carried out simultaneously to PAM (O'Brien *et al.* 2008a, O'Brien *et al*. 2008b).

Study areas

T-PODs were deployed at two locations in Galway Bay (Figure 1). The first site was located 3km east of Spiddal Pier within the Marine Institute's wave energy test site. The second site used for short-term deployments (May to August 2007) was located at Gleninagh, off north Clare. In Clew

Bay, T-PODs were deployed from salmon cages, at Portlee, on the eastern side of Clare Island (Figure 2).

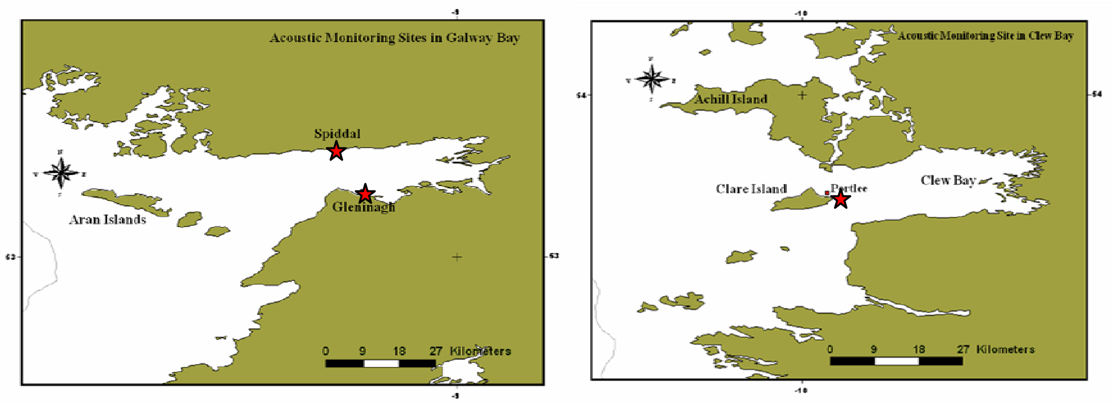

Figure 1 and 2. Location of PAM devices (T-PODs) in Galway Bay and Clew Bay

Results

T-POD's were deployed for 441 days in Galway Bay (333 days off Spiddal, and 108 days off Gleninagh) and for 234 days in Clew Bay. Harbour porpoises were detected on an average of 89% days monitored in Clew Bay and on 88% of days at Spiddal and 40% of days off Gleninagh. Although harbour porpoises were detected almost on a daily basis, the presence of these animals within the vicinity of the T-PODs was very short, ranging from 0.07 to 4.47 minutes per hour of deployment in Clew Bay, and 0.03 minutes to 1.4 minutes in Galway Bay. Seasonal variation in the harbour porpoise data from Spiddal was explored statistically. Autumn had the highest mean detection rate of Porpoise Positive Minutes (*PPM*) (24.4 *PPM*), followed by winter (20.4 *PPM*), summer (11.4 *PPM*) and spring (1.6 *PPM*). A random sample of 10 days for each of the seasons was selected, and statistical results showed a significant difference (P=0.00). *Post hoc* Mann-Whitney U-tests (using the Bonferroni correction, P-value reduced from 0.05 to 0.01) showed that spring was significantly different from autumn (P=0.00), with most detections been logged during the autumn and winter months. In Clew Bay, winter had the highest mean detection rate of *PPM* (107.4), followed by spring (24.11), autumn (15.22) and summer (9.89). A total of 9 random days from each season were chosen from the Clew Bay and a significant seasonal difference was found (P=0.004). *Post hoc* Mann-Whitney U-tests (using the Bonferroni correction, P-value reduced from 0.05 to 0.01) showed winter was significantly different from spring (P=0.006), summer (P=0.002), and autumn (P=0.008), with more porpoise detections logged over the winter months.

Discussion

The aim of the present study was to explore the presence and the fine scale habitat use by the harbour porpoise on the west coast of Ireland through static Passive Acoustic Monitoring (PAM) and to further evaluate the potential of two sites for future SAC designation. Both of these areas were the focus of simultaneous visual and acoustic monitoring, contributing to a proficient assessment of cetacean activity in both areas (O'Brien *et al.* 2008a, 2008b). The potential designation of these sites needs to be underpinned with precise scientific knowledge of activity occurring within these areas. T-PODs enabled us to remotely monitor the presence of harbour porpoise throughout the year and most importantly outside the restrictions of adverse weather conditions and darkness as imposed on visual observations. Although porpoises were detected in all seasons, statistical examination of the long-term acoustic data-set showed a significant seasonal component was present. Visual observations both ship and land-based were carried out in Galway Bay over a 24 month period and although harbour porpoises were the most frequently sighted species in the area, no seasonal trend could be detected from the visual dataset (O'Brien *et al.* 2008a). Hence PAM results from the present study suggest that temporal trends can be detected more quickly through acoustic monitoring. PAM results from Clew Bay showed harbour porpoises were acoustically detected almost daily, while during visual observations only a single porpoise was recorded on a one occasion. Acoustic data was crucial in identifying the habitat use by harbour porpoises in the area. However, there is a fundamental limitation with PAM in that data is non quantitative, i.e. no information on the numbers or densities of animals using an area can be derived from this method alone.

In order to fully appreciate the values of these acoustic results, they were compared with results derived from various other surveys carried out in Irish waters (Table 1, Berrow *et al.* 2008). An index of PPM/h^{-1} was used as a measure of acoustic activity within an area. Already designated SACs include the Blasket Islands off Co. Kerry and Roaringwater Bay, Co. Cork, hence results from these sites were used as references. Mean PPM/h^{-1} from the Blasket Islands ranged between 1.04 and 1.99, while in Roaringwater Bay values ranged between 0.23 and 3.58. Mean PPM/h^{-1} from Galway and Clew Bay are lower than the detections rates from the two reference sites. However, the number of days monitored in both Galway and Clew Bay was far greater and this lower detection rate was probably due to the seasonal component which wouldn't be detected from the shorter datasets at the two reference sites. Furthermore, the total area of Galway and Clew Bay is also far greater than the two already designated SACs.

Table 1. Acoustic results from studies carried out in Ireland; expressed PPM/h^{-1}

Year	General area	Location	Deployment duration	Mean PPM per hour	Reference
2008	Dublin: Dublin bay	Howth Head	46d	11.8	Berrow *et al.* (2008)
2008	Cork: Cork coast	Old head of Kinsale	27d	0.8	Berrow *et al.* (2008)
2008	Cork: Cork coast	Galley Head	60d	1.1	Berrow *et al.* (2008)
2008	Cork: Roaringwater Bay	Sherkin Island	20d	1.5	Berrow *et al.* (2008)
2008	Cork: Roaringwater Bay	Castlepoint	60d	0.9	Berrow *et al.* (2008)
2007	Kerry: Blasket Islands	Wildbank	29d	1.99	Berrow *et al.* (2007)
2007	Kerry: Blasket Islands	Inishtooskert	29d	1.04	Berrow *et al.* (2007)
2006-07	Galway: Galway Bay	Spiddal	333d	0.40	O'Brien *et al.* (2008)
2006-07	Mayo: Clare Island	Clare Island	234d	0.90	O'Brien *et al.* (2008)
2005	Cork: Roaringwater Bay	Calf Islands	66d	0.63	Leeney (2007)
2005	Cork: Roaringwater Bay	Sherkin Island	71d	3.58	Leeney (2007)
2005	Cork: Roaringwater Bay	Long Island	55d	0.23	Leeney (2007)

Conclusions

A number of constraints are associated with visual and acoustic monitoring. However, the combination of both methods can provide an accurate assessment of a population within an area. Acoustic monitoring provides details on the fine scale habitat use of an area, and allows for the detection of trends over short periods (such as seasonal variation, diel and tidal variation). However, without the use of visual monitoring no data can be acquired on densities and abundance, which provide a good measure of an increasing or decreasing population, as well as identification of important areas such as calving grounds. Therefore it is fundamental that both visual and acoustic monitoring be carried out to accurately assess species presence and numbers within a defined area.

Acknowledgements

Thank you to the following for their help with erecting moorings, deploying and retrieving gear in both Galway Bay and Clew Bay; Kevin MacGabhann, Oisin Naughton, Pat Nixon, Clare Murray, Carys Davies, Ian O'Connor, Charlie Brehony, Barry O'Donoghue, Stephen Comerford, Randal Counihan, Mick O'Connell, Dave Wall, Padraig McCormack and Peter McDonagh. To the Marine Institute who facilitated the establishment of moorings in the vicinity of their wave platform off Spiddal. To Sinead Doherty and Clare Island Sea Farm for allowing the deployment of T-PODs from their salmon cages. Finally I would like to thank my supervisors Dr. Simon Berrow and Dr. Dave McGrath for their continued support and guidance.

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ABUNDANCE ESTIMATES OF HARBOUR PORPOISES IN IRISH WATERS

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There are many reasons why we would wish to count harbour porpoises and estimate their population size. What is the size and status of the population? Is it increasing, decreasing or stable? What are the impacts, at the population level, of threats such as fisheries by-catch? Surveys which estimate densities can also be used to identify important areas with high concentrations of harbour porpoise. In marine protected areas such as Special Areas of Conservation (SACs) it is important to know what proportion of the population occurs within the protected area.

We have established that it is important to estimate abundance, but how do we count harbour porpoise? Harbour porpoise surveys can be acoustic or visual, but only visual surveys can provide estimates of absolute abundance. We can determine the minimum number of porpoises by directly counting those observed during a survey. Relative abundance can be determined by quantifying the amount of effort put into making an observation. This could be expressed in time (e.g. minutes spent watching) or distance (e.g. km travelled). This can provide useful data on the relative importance of a site compared to sites elsewhere or information on seasonal abundance. At present, the only way to estimate absolute abundance is from visual surveys. However acoustic techniques are being developed that could provide density estimates (Tougaard *et al.* 2006). An important constraint in calculating population abundance is population range. Harbour porpoise in Irish waters are thought to belong to an Irish/Western British Isles stock but the whole Northeast Atlantic is thought to be one population (IWC 1996). Thus any survey in Irish waters is only counting a proportion of the harbour porpoise population and immigration and emigration are very likely.

How do we estimate abundance?

Single platform line-transect methodology along pre-determined survey routes can be used to determine harbour porpoise density. A double platform methodology will provide a more accurate estimate of abundance as the proportion of sightings missed by the primary platform can be recorded however more surveyors and a large vessel are required which is not suitable for small-scale inshore surveys. When a sighting is made the position of the vessel is recorded immediately and the angle and the distance of the sighting from the vessel (in a straight line from the observer to the sighting) are also recorded. The software DISTANCE can then calculate the distance the sighting was from the track of the vessel which then goes to produce a detection function and estimate g(0), which is the density estimate (Buckland *et al.* 2001). By extrapolating the density estimate to the area surveyed an absolute abundance estimate can be calculated.

Harbour porpoise can be difficult to observe at sea unless the sea conditions are very good. There is a significant decrease in an observer's ability to detect harbour porpoise in sea-state greater than 2 but even in sea-state 2 the detectability of porpoises declines considerably (Teilman 2003) and ideally surveys should be carried out in sea-state 0 or 1. Other factors that can influence detection include the height of the observer above sea-level. The DISTANCE model requires a minimum of 40 sightings and ideally 60 sightings to provide a robust estimate. Therefore if this model is to be used, sufficient track-lines must be surveyed to accumulate this number of sightings during a survey. In a small survey area it can be difficult to accumulate this number of sightings during a single survey and data from a number of days may have to be combined. This may over-estimate abundance, especially if there are considerable changes in their distribution between surveys.

Absolute abundance surveys in Ireland

The first broad-scale dedicated harbour porpoise survey to be carried out in European waters was the SCANS (Small Cetacean Abundance in North and Baltic Seas) survey in July 1994 (Hammond *et al.* 2002). Although SCANS was not originally designed to cover Irish waters, the survey area was expanded to include the Celtic Sea due to a reported bycatch rate of 2,200 harbour porpoise per annum in the bottom-set gillnet fishery (Tregenza *et al.* 1997). The impact of this bycatch rate could not be assessed without an estimate of harbour porpoise abundance. A total of 32 harbour porpoise sightings were recorded within an area of 201,490 km^2 of the Celtic Sea. The mean group size was calculated at 1.64, which gave a density estimate of 0.180 and a coefficient of variation (CV) of 0.57. The CV is a measure of how much variability is in the estimate, the lower the CV the more accurate the estimate. This survey provided an abundance estimate of 32,280. This meant that 6.2% of the estimated abundance was caught in bottom-set gillnets each year – the highest bycatch rate of any fishery recorded at the time. In July 2005, a second survey (SCANS II) was carried out to derive abundance estimates for not only the Celtic Sea but all Irish waters including the Irish Sea. This survey suggested around 100,000 harbour porpoises occur in Irish waters (Table 1).

Table 1. Harbour porpoise abundance estimates for Irish waters from SCANS II (2008)

Location	*Area*	*Density*	*CV*	*Abundance*
Celtic Sea	197,400	0.41	0.5	80,616
Irish Sea	45,417	0.34	0.35	15,230
Coastal Ireland	31,919	0.28	0.37	10,716
Offshore shelf edge[1]	149,637	0.07	1.24	10,002

[1] one-half of the area surveyed was in Scottish waters, thus 50% of this abundance is attributed to Irish waters

The first dedicated small-scale harbour porpoise survey in Ireland was carried out in the Blasket Islands cSAC in 2007 (Berrow *et al*. In Press). Six survey days were carried out between July and September in an area of 227 km^2 and surveyed along 82 track-lines with an accumulated effort of 457 km. A total of 44 sightings were made of 102 harbour porpoises. Density estimates per day using the track-line as the sample ranged from 0.71 to 3.39 per km^2, resulting in abundance estimates of 162-769, with an overall estimate ± standard error of 303±76 (95% Confident Intervals = 186-494: CV = 0.25).

In 2008 we have carried out similar surveys for harbour porpoise at eight sites (Carnsore Point, Co Wexford, Blasket Islands cSAC Co Kerry, Donegal bay, Co Donegal North County Dublin and Dublin bay in Co Dublin, Cork coast and Roaringwater bay cSAC, Co Cork and Galway bay in Co Galway).

Results

During 37 days at sea, 475 track-lines totaling 20,662km of effort were surveyed in sea-state 2 using distance sampling. From the total of 332 sightings, 618 individual porpoises were observed. Overall densities ranged from 2.03 to 0.53 porpoise per km^2; mean group size ranged from 1.19 to 2.67 animals. The proportion of young was typically 6-8% but 14 and18% were recorded at two sites. Abundance estimates ranged from 87 to 402 porpoises depending on the density estimate and area of the site.

The number of sightings per survey varied from no harbour porpoise sightings to 48 sightings per survey day. No or very few sightings often coincided with poor sighting conditions but not always. At some sites even with excellent sea conditions only five or less sightings were recorded. Clearly as the DISTANCE model requires 40-60 sightings to provide robust estimates no estimates can be derived from these surveys. A number of the areas surveyed are small (<150km^2) and even with good densities of harbour porpoise there may not be sufficient sightings for the model to be used.

In order to demonstrate, we have used data from North County Dublin and Dublin and Galway bays. Five surveys were carried out in North County Dublin (Area: 104 km^2) with a total of 82 sightings. On 29 August, 48 sightings were made of a total 59 animals along 69 km of track-line.

This was exceptional and the density estimate at 6.99 harbour porpoise per km^2 (CV-0.12) was the highest recorded in Irish waters during any survey to date. With a mean group size of 1.38 this gave an abundance estimate of 728 (95% CI: 574-924). Dublin bay covers an area of 117 km^2 and 43 sightings have been made during four surveys to date. On 21 August 24 sightings (mean group size of 1.12) were made along 68 km of track-line providing a density estimate of 2.85 per km^2 (CV = 0.21) resulting in an abundance estimate of 332 (95% CI: 217-506).

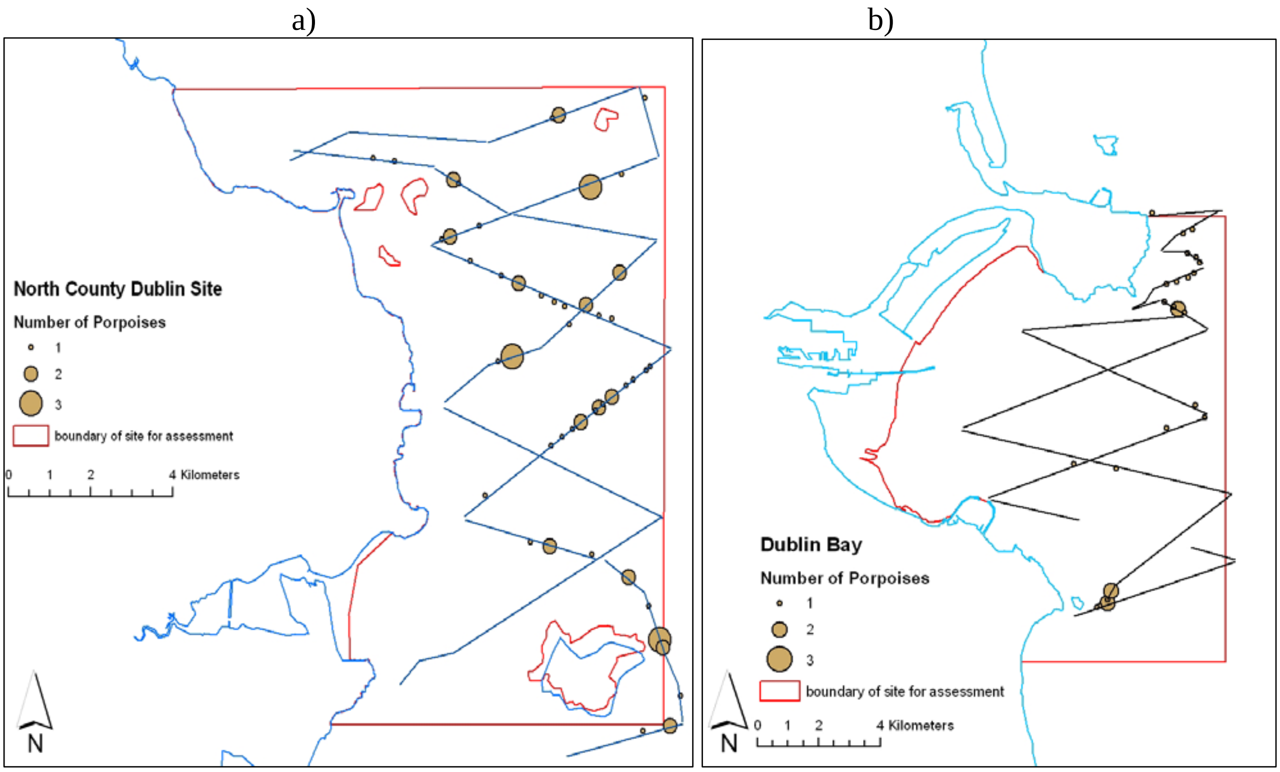

Figure 1. Harbour porpoise survey area in a) North County Dublin and b) Dublin Bay during 2008

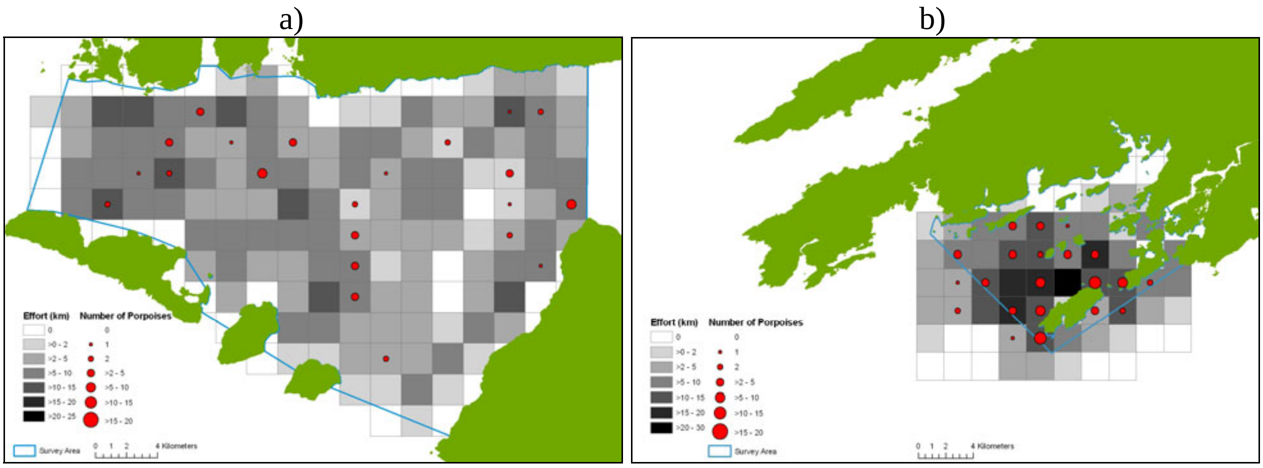

Figure 2. Harbour porpoise density maps (2km cells) for (a) Galway Bay and (b)Roaringwater Bay

If we compare these estimates to the Blasket Islands cSAC in 2007 and Galway bay in 2008 we can see that these estimates were very high suggesting the two Dublin sites provide very good habitats for harbour porpoises. The highest density in the Blasket Islands cSAC was 3.38 per km^2 but overall the density was estimated at 1.33 per km^2 (CV = 0.35) giving an abundance of 303 (133-691). In Galway bay the highest density estimate (using the day as the sample) was 1.03 per km^2 but as the site is very large (547 km^2) this gave an abundance of 573 (95% CI: 344-956).

In summary, harbour porpoise abundance can be assessed using line-transect methodology but this requires very calm seas to derive a good estimate. In order to derive robust estimates the area to be surveyed must be an appropriate spatial scale with sufficient transect lengths to obtain enough sightings (40-60) for the model DISTANCE to be used. Otherwise estimates will have too much variation to provide a suitable method for monitoring.

Densities of harbour porpoises in Dublin bay and North County Dublin were among the highest recorded in Ireland to date. This may lead to their recommendation as Special Areas of Conservation for harbour porpoises. This work is still in progress with fieldwork to be carried out until the end of September after which a full report will be prepared by the end of October.

Acknowledgements

I would like to thank the IWDG survey team of Eileen Diskin, Bojana Ferlan, Brian Glanville, Sophie Hansen, Ronan Hickey, Eugene McKeown, Dana Miller, Joanne O'Brien, Fiacc O'Brolchain, Mick O'Connell, Tracey O'Shea, Debbie Pedreschi, Conor Ryan, Dave Wall, Faith Wilson, Peter Wilson and Pádraig Whooley for their commitment to this project and Dave McGrath and Ian O'Connor at Galway-Mayo Institute of Technology for assistance with survey design and GIS. We have worked with a range of skippers (Colin Barnes, Jeff Brownlea, Willian van Dyke, Declan Kilgannon, Ruairi O'Brien, Edmund O'Byrne, Fachtna O'Driscoll, Mick Sheeran and Richard Timony) who have been extremely tolerant of late changes to plans and some early starts. The surveys in 2007 and 2008 were funded by the National Parks and Wildlife Service within the Department of Environment, Heritage and Local Government.

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SATELLITE TRACKING OF HARBOUR PORPOISES IN EUROPEAN WATERS

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Introduction

During the last century the issue of how to protect nature and manage our surroundings in a sustainable way has become widely addressed on international, national and local levels. In all EU countries, a legal framework has been, or is in the process of being, implemented to protect endangered species and habitats and prevent further negative anthropogenic influence.

The proper conservation of cetaceans depends on knowledge of several aspects of their population ecology. Ideally, information on population size, population structure, seasonal distribution, mortality rates, breeding success and movements should be available. However, this is rarely the case. For a wide ranging species such as the harbour porpoise (*Phocoena phocoena*), knowledge on distribution and movements is limited due to their small size and shy behaviour making observations at sea difficult in anything but calm weather. A recent approach in the protection of small cetaceans is the designation of marine protected areas (MPAs or Special Areas of Conservation - SACs) as described in the European Habitat Directive (92/43/EEC). This Directive requires that all EU member states must designate SACs for harbour porpoises by 2012 (European Commission 2007). The first step towards the selection and management of a protected area is identifying key habitats for harbour porpoises. Key habitat refers to those areas of a cetacean's range that represent essential factors to their life and reproduction (Hoyt 2005). For a wide ranging species such as the harbour porpoise that spend the majority of its time submerged, attaining knowledge of its key habitats is particularly difficult. This problem was addressed at a meeting convened by the European Commission in 2000 (European Commission 2001). The meeting concluded that "it is possible to identify areas representing crucial factors for the life cycles of this species". These areas should be selected on the basis of the following criteria:

1. The continuous or regular presence of the species (although subject to seasonal variations)
2. Good population density (in relation to neighbouring areas)
3. High ratio of young to adults during certain periods of the year

The current available methods for studying density and distribution of harbour porpoises are visual surveys from aircraft or boat, passive acoustic monitoring (PAM i.e. static monitoring (e.g. T-PODs) and towed arrays behind boats) and satellite telemetry. However, since surveys are limited in time and only give an instant view of the distribution and static acoustic monitoring has a limited spatial range (less than 300 m), we have used satellite tracking of porpoises to give a continuous picture of the movements of individuals. By tagging many animals, we aimed to identify key habitats for the population of harbour porpoises in the inner Danish waters throughout the year.

Materials and Methods

From 1997 to 2007, 39 harbour porpoises were tagged in the inner Danish waters (Figure 1). Porpoises were caught incidentally in pound nets and tagged within 24 hours of contact with the fisherman. Satellite transmitters were attached to the dorsal fin (see details on method in Teilmann *et al.* 2007).

The locations of satellite tagged animals are positioned according to the ARGOS system. The locations are saved and can be downloaded by the user. To remove implausible positions the raw Argos data were filtered using the SAS-program, Argos_Filter v5.0 (Dave Douglas, USGS, Alaska Science Center, Alaska, USA). To standardise data only one location per day was used in the analysis.

To localise the key habitat for harbour porpoises, kernel density utilisation grids were produced in ArcMap using the fixed kernel density estimator (Hawth's Analysis Tool: www.spatialecology.com/tools/). Smoothing factor (or bandwidth) were set to 20.000 and output cell size to 1km^2. The kernel density estimate is a nonparametric estimation that calculates the relative density distribution from all the Argos locations. By determining the smallest possible area containing user specified percentage of the positions, the kernel grid was divided in percentage volume contours from 10-90% in 10% intervals. For instance, the 90% volume contour consists of the smallest possible area containing 90% of the locations used to generate the kernel density grid. This means that the 10% contour area represents areas with highest density and the 90% contour almost the entire range of the porpoises.

Results

The lifetime of the transmitters varied from 14 days to 306 days (average=107 days). Only 5 of the 39 porpoises left the Inner Danish Waters (IDW) during their tagging period and two of these returned within the period of contact. This indicates that the porpoises in the IDW are relatively stationary and likely belong to a separate distinct porpoise population. In order to examine the two first criteria for identifying key habitats, namely 1) The continuous or regular presence of the species (although subject to seasonal variations) and 2) Good population density (in relation to neighbouring areas), the distribution of transmitted locations from harbour porpoises (1 per day) are shown in Figure 1 and the kernel density volume contours are shown in Figure 2.

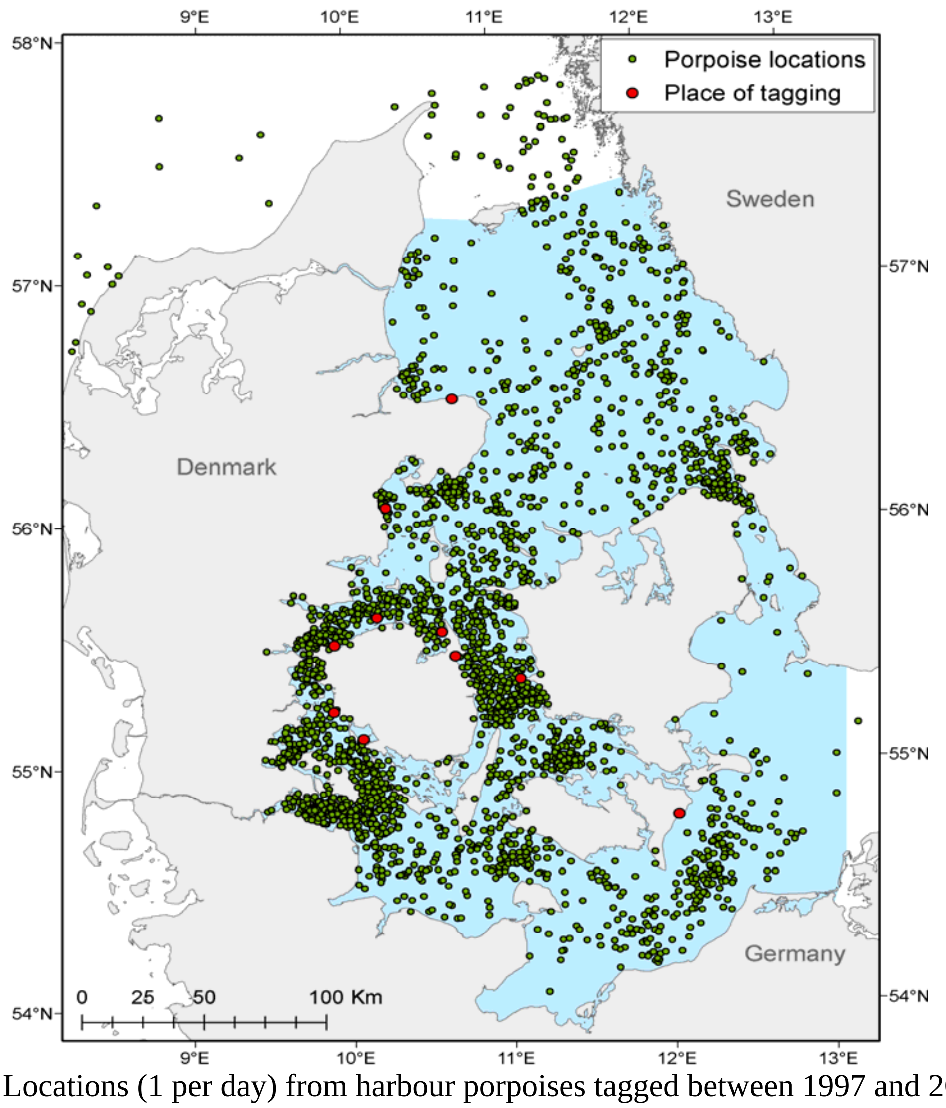

Figure. 1. Locations (1 per day) from harbour porpoises tagged between 1997 and 2007 in the Inner Danish Waters defined as the area marked in blue. Map projection universal transverse Mercator, Zone 32N, WGS84

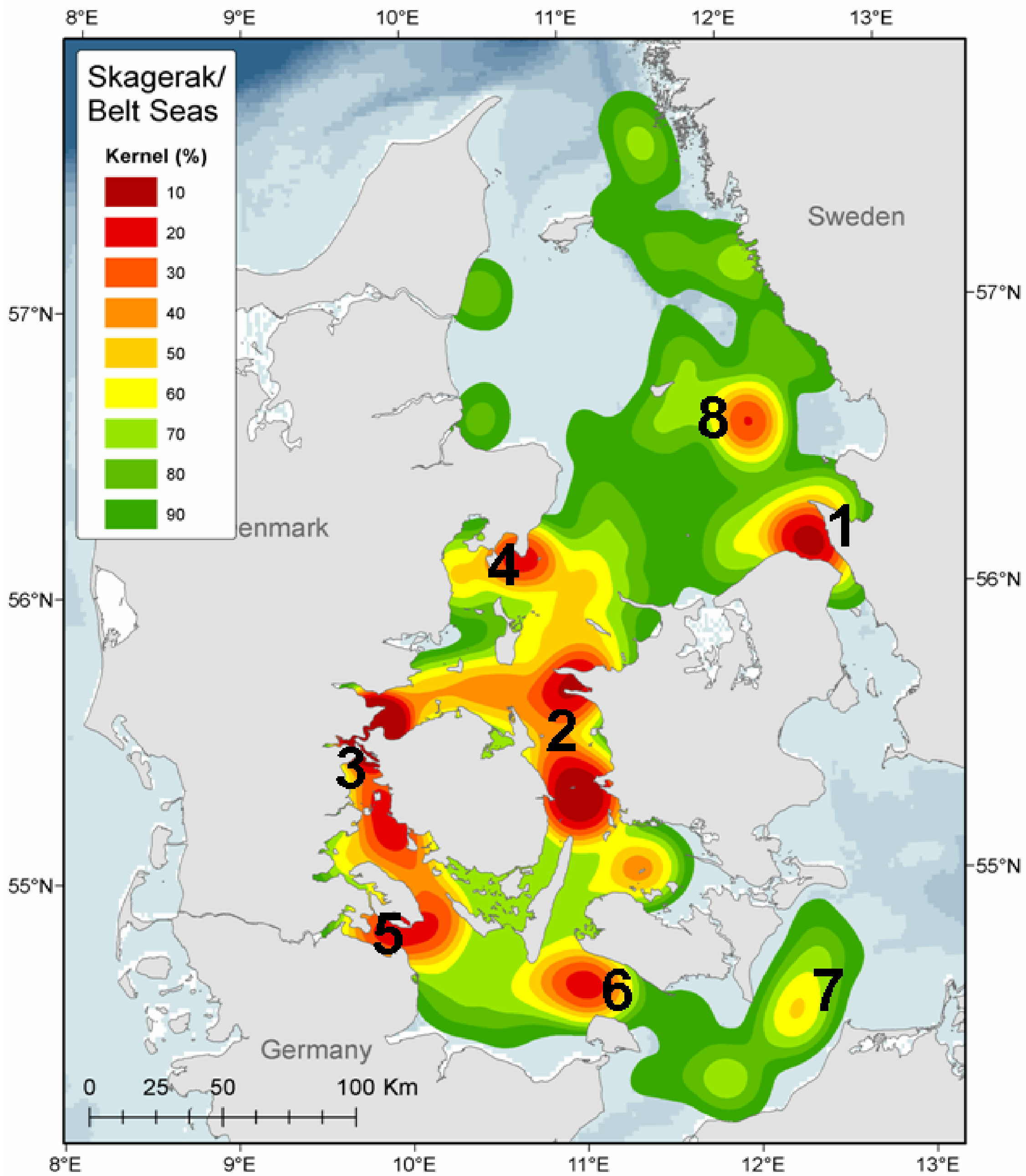

Figure 2. Kernel density distribution showing volume contours from 10% to 90% based on all locations year round. Red shown high density and green low density. Numbers refers to high density areas listed below.

Figure 2 shows that the porpoises are not evenly distributed, but gather in certain areas i.e. the key habitats. In the inner Danish waters these are 1) Northern Øresund, 2) Great Belt, 3) Little Belt, 4) Northern Samsø Belt, 5) Flensborg Fjord, 6) Fehmern Belt and to some extend 7) the Kadet Trench and 8) Store Middelgrund. Only areas based on more than two tagged porpoises were included. Figure 2 only shows the year round key habitat, but we found a seasonal variation so that the key habitats in the south are more pronounced and that e.g. are 1, the Northern Øresund is only used in the spring and summer.

To confirm the identified key habitats, acoustic ship surveys were used as an independent validation method. Six surveys were conducted every second month in 2007 (Figure 3). To evaluate the correlation between the acoustic surveys and the satellite tracking kernels we analysed the average detection rate for all surveys combined (porpoise/km) in each kernel percentage area determined by the satellite tracked porpoises (Figure 5) and found a good correlation between the high density areas defined by the two methods e.g. both method show very low density of porpoises in central Kattegat and high density in Great Belt and Northern Øresund.

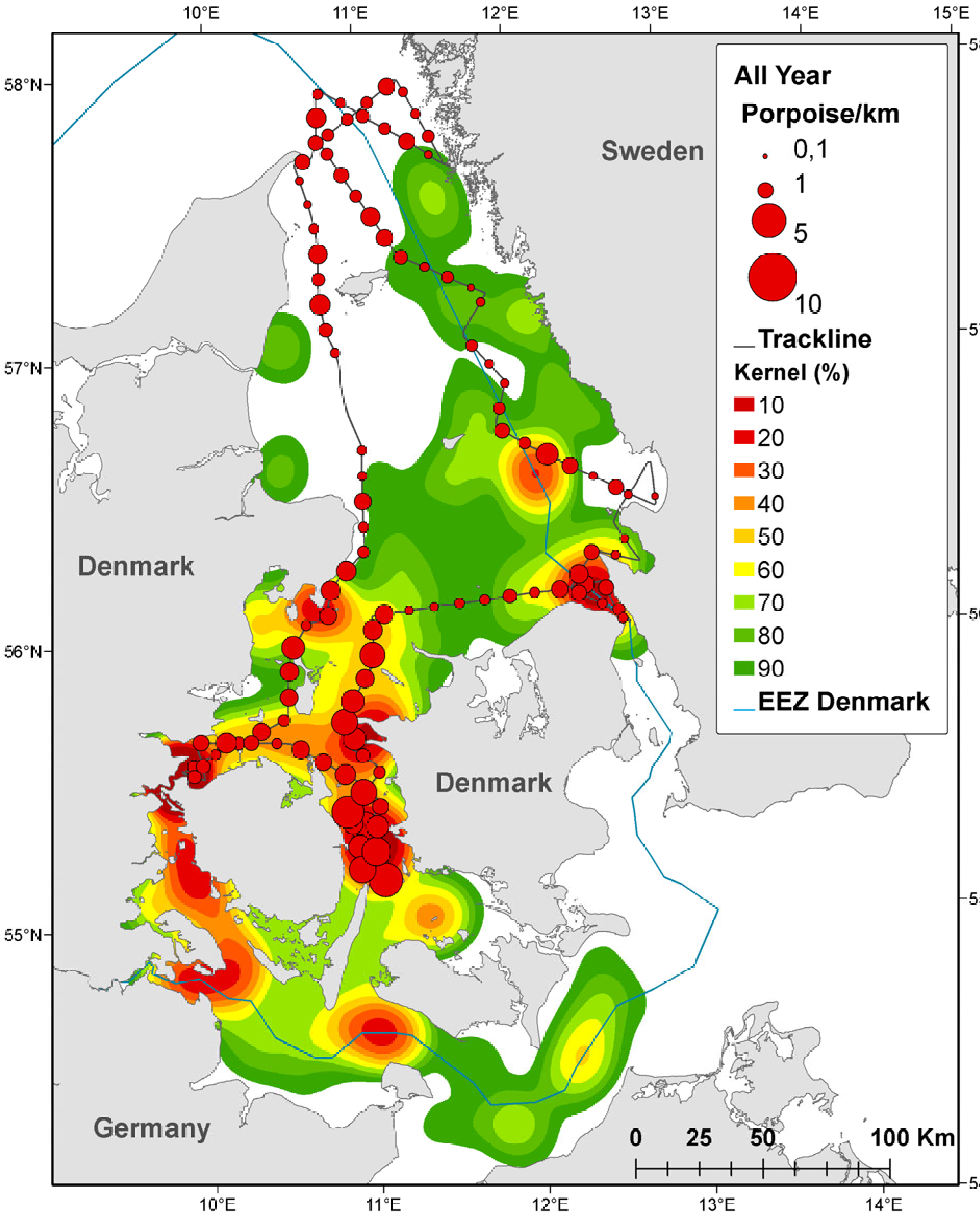

Figure 3. Map of the acoustic ship surveys showing the trackline and the detection rate in red dots. The figure shows the all year average based on all six surveys. The size of the dots corresponds to the number of detections per km calculated for every 10 km. The underlying kernel contours from the satellite tracking show the high density areas (highest density is shown in red and lowest in green).

In the Western Baltic the high density areas found by satellite telemetry was confirmed by German studies i.e. static acoustic monitoring and aerial surveys, conducted in order to identify the German SAC's for porpoises. All three methods found Flensborg Fjord, Fehmern Belt and the Kadet Trench to contain the highest densities in the Western Baltic (von Nordheim *et al.* 2006).

Conclusions

In summary, this study concluded that satellite tagging of porpoises may be used for identifying key habitats. The distribution of porpoises seems to be stabile over the years, but there are seasonal variations. The high density areas found by satellite tracking are supported by results from passive acoustic monitoring and aerial surveys in the Western Baltic and by acoustic surveys in the Belt Seas and Kattegat. For further information on the project see Teilmann *et al.* 2008.

Acknowledgements

We wish to thank the pound net fishermen and the people who volunteered during fieldwork for their invaluable contribution to the satellite tagging project. We are also thankful to the crew of "Skagerak" who carried us safely through the acoustic surveys. The study was carried out under permissions from Skov- og Naturstyrelsen (Danish Forest and Nature Agency SN 343/SN-0008) and Dyreforsøgstilsynet (Ministry of Justice 1995-101-62). The Danish Forest and Nature Agency, the Danish Institute for Fishery Research, Fjord and Bælt, University of Southern Denmark, Odense and The National Environmental Research Institute are thanked for financial support.

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A COST OF GREEN ENERGY: ARE OFFSHORE RENEWABLES: A THREAT TO PORPOISES?

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The need to reduce atmospheric carbon emissions and increase the diversity of energy supplies is driving the development of a new range of renewable energy technologies. Wind turbines, fuel crops, hydropower and solar heat/electricity generators are all maturing industries on land, but available resources and planning constraints are limiting their spread. Instead, the marine environment is becoming increasingly attractive for renewable energy resources despite the associated logistical difficulties. In the presentation I reviewed four groups of marine renewable power technologies of relevance to harbour porpoises (*Phocoena phocoena*) in northern European waters. They are (1) offshore wind (2) wave (3) tidal-stream and (4) macro-algae. While there are other sources of marine renewable power under development (osmotic potential, tidal-barrier, micro-algae and so on) they are either in their infancy or unlikely to impinge on porpoise populations.

(1) Offshore wind power: The wind turbine concept is now well established and offshore wind farms are beginning to proliferate in European coastal waters. They employ the same concept as onshore wind farms, but stronger and more reliable winds allow the construction of larger turbines delivering more consistent supply. Europe currently leads the field in offshore wind farms with the resource itself getting greater towards the north and west of Europe.

(2) Wave power: Electricity has been produced from shore-mounted generators for several years but the spread of such devices has been limited by their specialised site requirements. Offshore devices are less well established, but a number of technologies are developing fast. Many designs have been put forward ranging from surface mounted flexible pipes, funnels and buoys to subsurface buoys and pivoting panels. As with the wind resource, the energy potential is focussed towards the north and west of Europe, but it requires a lengthy fetch so the Atlantic seaboard is the most likely area for the industry’s main application.

(3) Tidal-stream power: Sub-surface water currents offer a huge potential for energy generation. Again the resource is focussed on northwestern Europe, but in more discrete areas, particularly where seabed topography forms tidal bottlenecks. As with wave power a wide range of technologies have been proposed and the majority involve a submerged multi-bladed turbine akin to wind turbine technologies. However there is far more diversity in the designs from two, three or many bladed turbines that may be either open or shielded within a duct. Other variants include a many bladed ring (e.g. OpenHydro) or a vertical turnstile type (e.g. Blue Energy). Structures may be entirely submerged or surface piercing.

(4) Macro-algae for biofuels: The idea of growing terrestrial crops to produce biofuels is well established, but there is growing political resistance to replacing conventional food-crops with fuel-crops. Locating other sources of biomass to produce biofuels is therefore desirable. One such, is using the marine environment to farm marcroalgae (seaweeds) specifically kelp species for the generation of ethanol or methane. Kelp circumvents the problems of terrestrial cropping. They are also the fastest growing large plants and contain no lignin or cellulose making them easier to digest. Furthermore Irish and Scottish coasts appear to be good places to grow them. Techniques to farm kelp on suspended ropes have been developed by the Chinese and demonstrated at very large scales. There is considerable potential for similar developments in European waters.

Despite being diverse in nature, these four classes of marine technology will have many features in common. All need anchored to the seabed. The most likely attachment techniques will be monopiles, jackets, gravity structures, conventional anchors, chains and mooring ropes. All devices will be large and have a significant presence in the marine environment. Many, particularly tidal-stream and wave devices will have moving parts in contact with the marine environment and all require boat attendance for servicing / harvesting and particularly their construction.

With these renewable energy technologies poised to enter the marine environment, are there any implications for harbour porpoises? From other marine industries, particularly oil and gas, shipping, fishing, aquaculture and aggregate extraction we know that conflicts with cetaceans do often arise and that these typically distil down to the following issues: entanglement; habitat alteration; noise; chemical pollution and collisions.

Entanglement of cetaceans in fishing nets is well known, but it is becoming increasingly apparent that entrapment in lines as simple as risers for crab/lobster pots does occur particularly for larger whales. This appears to be less common for small cetaceans particularly porpoises, but studies of habitat use by dusky and bottlenose dolphins suggest that aquaculture using suspended ropes may exclude animals from the immediate vicinity. This habitat alteration may be because of intrinsic avoidance of these structures or because such structures alter the otherwise featureless open water habitat in which these animals forage. Thus alterations in the predator prey dynamic may produce this area avoidance rather than direct entanglement concerns. The behaviour of "neophobic" harbour porpoises around such structures is unknown.

Underwater noise pollution has been a significant concern for the developing offshore wind industry. Operating turbine noise itself appears to be relatively unobtrusive and any effects are likely to be local but construction noise, on the other hand, is much more pervasive. Wind turbines are held in place by piles driven into the sea bed. The percussive noise generated by pile driving has sufficient intensity to produce auditory injury in marine mammals and their prey. Behavioural impacts at greater distances are also likely.

Unlike the oil and gas industry, renewable energy devices are unlikely to be significant sources of chemical pollution. Many devices will however, require anti-fouling and contain lubricants for machinery though these are unlikely to directly impact porpoises.

Of more direct concern are physical collisions between marine mammals and devices, particularly those with moving parts in already moving water – notably tidal-stream devices. Contrary to popular belief, collisions between marine mammals and ships are relatively frequent events and include the bow as well as propellers. Tidal-stream devices, particularly tidal turbines are different to ship's propellers as they are being passively turned by the water and taking energy from it rather than turning the water and adding energy. However, the parallel between turbine blades and the bows of ships is much stronger. Turbines are likely to be large at 12-20 meters in diameter and tip speeds are likely to range up to 12 ms^{-1}.

To investigate the magnitude of a collision threat, a model was constructed of the potential frequency of encounters between a hypothetical commercial-scale coastal development (100 turbines) and the harbour porpoise population off western Scotland (Wilson *et al.* 2007). Because cetacean responses to turbines are unknown it was assumed that they were neither attracted to nor avoided these devices. The model predicted that in a year of operation up to 1300 individuals (3 to 10% of the population) would share the same space and time as a rotating blade and thus have the potential to make physical contact. The model highlights body size as a critical factor and so collision rates for larger species may be greater still than for the porpoises. Nevertheless, were these interactions to result in mortality for porpoises it would lead to unsustainable population impacts. Thus the behavioural response of porpoises to tidal turbines is critical to whether or not collisions are going to be a significant conservation issue. At present little is known about how porpoises will respond (avoid or be attracted) to these devices.

Because tidal turbines will operate in areas of poor visibility and at night it is unlikely that visual cues will be enough for porpoises to avoid turbines. Instead the acoustic cues are more likely to be involved in device detection. Ongoing modelling work of potential device sound levels, porpoise hearing thresholds and ambient noise levels (Carter 2008) suggests that upstream acoustic detection distances and times will be highly variable and site specific ranging from hours to seconds.

In summary, several renewable energy industries are poised to move into porpoise habitat. Information on threats from existing industries gives cause for concern. The potential threats posed by marine renewables are diverse, but one of the most obvious is the potential for porpoises to collide with tidal turbines. Modelling suggests that these interactions could be common, but that the behavioural responses of porpoises to these devices will be key to whether there is significant problem.

Overall, there are many good reasons to encourage the development of the marine renewable industries described above. There is currently a fierce commercial race to develop designs that are reliable, cost effective and provide good energy yields. However, it is important that environmental concerns are not left until the eleventh hour to be dealt with. The sooner the marine mammal research and conservation communities get involved in dialogue and research with developers, the better for both energy supply and porpoise conservation.

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HARBOUR PORPOISE POPULATIONS AND PROTECTION IN AN EU CONTEXT

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This presentation concentrated on the harbour porpoise in northwestern Europe including, the distribution of populations, threats to these populations: e.g. by by-catch, ship strike, and noise, conservation measures needed to mitigate these impacts: e.g. marine protected areas and other regulations and international conservation instruments: e.g. EU legislation, the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS).

The distribution of harbour porpoise populations

There are 14 recognised populations across the North Atlantic from the Gulf of Maine to Northwest Africa and to the Black Sea (Rosel *et al.* 1999). In the ASCOBANS area, we are concerned with five distinct populations in the North Sea, in the Kattegat and adjacent waters, in the Baltic Sea, around Ireland and the western British Isles, and along the Iberian coast and in the Bay of Biscay. The density distribution (as animals sighted per standard survey hour) of the harbour porpoise between Ireland and Sweden, and from France to the Faroe Islands was first mapped on the basis of 20 years of search effort (Reid *et al.* 2003).

The two SCANS surveys in July 1994 and in July 2005 provided two detailed snapshots for an extended area. The modeling based on the survey results (extrapolated to animals per square kilometre) depicted a major shift in distribution centres within the North Sea. In 1994, SCANS-I estimated the harbour porpoise population in that area to consist of some 341,000 individuals (CV = 0.14) with about 250,000 individuals in the North Sea, 36,000 in Kattegat and adjacent waters, and 36,000 in the Celtic Sea (Hammond *et al.* 2002). No, or almost no, animals were recorded in the English Channel and in the southwestern Baltic proper. In the western Baltic proper and the adjacent Belt Sea, the German Oceanographic Museum (DMM) has been operating a net of up to 42 static acoustic monitoring stations (equipped with T-PODs) since 2002 along the German coast. These recordings provide good evidence for a seasonal pattern (in the occurrence of porpoise-positive days) indicating a southeast migration in spring and a reverse movement in autumn (Verfuß *et al.* 2007).

What are the threats to harbour porpoises in European waters?

By-catch in fishing gear, e.g. bottom-set gillnets, is the biggest anthropogenic mortality factor: Usually some 35% to 55% of beach-cast animals bear fresh net marks. In the North Sea, porpoise abundance was estimated to be 250,000 animals (SCANS-I) while about 8,000 porpoises were estimated to die as by-catch annually. At the same time, 2,200 porpoises were by-caught annually in the Celtic Sea out of a population of 36,000 (Treganza *et al.* 1997). These by-catch rates of 3% and 6%, respectively, by far exceed the 1% found to be tolerable by ASCOBANS (out of 1.7% of total anthropogenic removal) to avoid the decline of a porpoise population.

Collisions with vessels are also dangerous for cetaceans, particularly large whales. Fast ferries have proven to be particularly lethal with the great majority of collisions leading to severe injury or death at speeds of 14 knots or more. The most fatal or serious injuries are caused by large ships (80m of length or more). At 40 knots approaching a whale at 600m leads to a maximum reaction time of 30 seconds.

Underwater noise pollution from anthropogenic sources may have many impacts and comes from a large number of sources. Major sources of anthropogenic underwater noise are ship traffic, explosions, pile-driving, seismic exploration, military SONAR, and deterrent devices. Depending on the distance from the sound source, concentric impact zones can be characterised as: lethal, leading to severe physical injury, leading to hearing loss (temporary threshold shift or permanent threshold shift), leading to masking, leading to disturbance and stress, and lastly the zone of audibility (Richardson *et al.* 1995)

Two examples of current noise pollution:

1. Explosions occur frequently for military- and industry-related purposes, for example: tests of the Navy (e.g. ship shock trials, mine demolition for training purposes), destruction of dumped ammunition, pipeline construction, and the dismantling of platforms. Risk zones during the detonation of WWII ammunition (equivalent to 350 kg TNT) in Kiel Bight, Germany, were declared to be lethal underwater and/or leading to severe physical injury within a 4 km radius, leading to hearing loss (temporary threshold shift or permanent threshold shift) within a 13 km radius, and being potentially stressful within a 33 km radius (source: Schleswig-Holstein state government). All three zones contain a number of coastal SACs declared by the Schleswig-Holstein state government to protect harbour porpoises.
2. The production of wind energy has become a major offshore industry. Pile-driving during the construction of the foundations is one of the loudest non-explosive sounds made by man. The impact of the noise of operating windmills on porpoises is still unknown.

What conservation tools and mitigation measures are available?
There are already a number of examples of established <u>marine protected areas</u> for cetaceans in Europe:

- the Irish Whale and Dolphin Sanctuary (1991)
- the Pelagos Marine Sanctuary in the Ligurian Sea / Mediterranean Sea (1999)
- the 'Whale Sanctuary' in the Schleswig-Holstein Waddensea Nationalpark, German Bight / North Sea (1999)
- Special Areas of Conservation (SACs) in Wales (2004)

Binding <u>regulations</u> can help to mitigate threats to cetaceans. As an example, the E.U. Council Regulation 812/2004 of 26 April 2004 lays down measures concerning incidental catches of cetaceans in fisheries and amending Regulation (EC) No 88/98. These measures are: the use of active acoustic deterrent devices (pingers), at-sea observer schemes and the phase-out of driftnets in the Baltic Sea. The introduction of pingers into gillnets is presumed to avoid by-catch by issuing warning sounds in very high frequencies. Gillnets are of particular danger to cetaceans, because they are walls of netting which hang vertically in the water column, they are mainly of nylon since the 1960's, and they vary in mesh size, height and length depending on target catch. Under this Council Regulation, pingers have become mandatory in certain fisheries in the North Sea in August 2005, in the Celtic Sea in January 2006 and in the southwestern Baltic Sea and in the English Channel in January 2007.

Legal Instruments for the conservation of cetaceans
Legal instruments can be differentiated on global, regional and sub-regional levels into either providing incidental or targeted protection for cetaceans. On a global level, IMO Conventions, the Ramsar Convention, the Ozone Convention (Montreal Protocol) and UNFCCC (Kyoto Protocol) may provide incidental protection whereas UNCLOS, CBD, UNEP/CMS, CITES, UNESCO-WHC, and ICRW are targeted to provide protection. On a regional level, UNECE Conventions and general European Community Law may provide incidental protection whereas the Bern Convention and special European Community Laws are targeted to provide protection. On a sub-regional level, the Bonn Agreement and WSSA may provide incidental protection whereas the Barcelona Convention, the Bucharest Convention, HELCOM, OSPAR, ACCOBAMS and UNEP/ ASCOBANS are targeted to provide protection.

Relevant pieces of EC legislation are:

- Primary legal instrument to manage fisheries management (including by-catch mitigation) is the Common Fisheries Policy (CFP) (Council Reg. (EC) 2371/2002); it is to provide for coherent measures concerning conservation, management and exploitation of living aquatic resources (Article 1)
- Council Reg. (EEC) 348/81: Common rules for imports of whales or other cetacean products
- Council Reg. (EC) No. 338/97: Protection of Species of Wild Fauna and Flora by Regulating Trade Therein;
- Directive (EEC) No.79/409: "Birds Directive"
- Directive (EEC) No. 92/43: "Habitats Directive"

Birds and Habitats Directives form the NATURA 2000 Legislation:
In the Birds Directive, Article 3 and 4 ask for the creation of protected areas and classify the most suitable areas, so-called Special Protection Areas (SPAs). In the Habitats Directive, Article 3 sets up a coherent European network of Special Areas of Conservation (SACs), including SPAs under Birds Directive, under title NATURA 2000 for habitat types listed in Annex I, and for habitats of species listed in Annex II including harbour porpoise and bottlenose dolphin.

Obligations with respect to SACs (Art. 6, 12, 14, 15):

- Take necessary conservation measures;
- Prohibit deterioration of habitats and disturbance to species
- Environmental Impact Assessments for plans or projects likely to have a significant effect on the site; agreement to project, only if no adverse effect or imperative reasons of overriding public interest, in latter case compensatory measures to ensure that coherence of NATURA 2000 is protected;
- For species listed in Annex IV (including all cetaceans) a system of strict protection must be established, prohibiting the deliberate capture or killing, the deliberate disturbance, and the deliberate destruction of breeding sites or resting places;
- Monitoring system for incidental capture and killing must be established.
- If taking is unavoidable it must be compatible with favourable conservation status, indiscriminate means of capture or killing and means described in Annex VI is prohibited.

Intergovernmental organizations also provide legal instruments for the conservation of cetaceans. For example, ten countries have joined ASCOBANS so far: Belgium, Denmark, Finland, France, Germany, Lithuania, Netherlands, Poland, Sweden, and UK. The Agreement came into force in 1994 with the overall objective to achieve and maintain a favourable conservation status for small cetaceans. Its main bodies are:

- the Meeting of Parties (MOP) every three years
- the Advisory Committee (AC) meets annually
- the Jastarnia Group (for the implementation of the Baltic Porpoise Recovery Plan) meets annually, and
- the Secretariat (currently located in Bonn, Germany)
- The westward extension of the ASCOBANS area, which came into force on 3rd February 2008, now invites Ireland, Spain and Portugal to join the Agreement.

What do Contracting Parties to ASCOBANS do to protect small cetaceans?
Obligations: Parties are expected to cooperate to achieve a favourable conservation status, apply conservation and management measures prescribed in the Conservation and Management Plan and report annually on the implementation

A Conservation and Management Plan usually asks for:

- Habitat conservation and management;
- Surveys and research;
- Establishment of a system for retrieving by-catch and stranded specimens,
- Research and provision of information in an international database;
- Adoption of appropriate legislation (prohibition of taking, obligation to release live catches);
- Information and education work

Achievements: Over the years ASCOBANS has adopted various resolutions and initiated practical activities:

- Resolutions on incidental take: Res. Mop. 3/3, Mop. 5/5): Reduce by-catch to below level of "unacceptable interaction" = (in the short term) total anthropogenic removal of no more than 1.7%; Precautionary objective of reducing by-catch to less than 1% of the best population estimate, ultimately to zero;
- Resolutions on other issues such as disturbance, research, education, etc.;
- Working group on pollution;
- Various workshops, most recently on selection criteria for cetacean MPAs and on wind farms and marine mammals (both jointly with ECS) as well as on cetacean population genetics (jointly with HELCOM);
- Participation in SCANS;
- Conservation Plan for North Sea harbour porpoises is under development;
- Recovery Plan for Baltic Harbour Porpoises ("Jastarnia Plan"), 2002

The recovery plan for the Baltic Sea harbour porpoise also known as the "Jastarnia Plan" (2002) asks for:

- Immediate precautionary measures to reduce by-catch to fewer than **two** individuals per year through the reduction of fishing effort (drift nets, bottom set nets, recovery of ghost nets), the change from harmful to less harmful fishing gear, the introduction of pingers as short-term measure only (2-3 years), and the compilation of data on fishing effort
- Research to improve knowledge in key subject areas;
- Development of more refined (quantitative) recovery targets as new information on population and threats becomes available
- Establishment of protected areas;
- Education and awareness-raising;
- Establishment of the "Jastarnia Group" (4 meetings to date);
- Periodic re-evaluation (currently taking place)

What support does ASCOBANS provide to help protect small cetaceans ?
The community of Parties provides through the ASCOBANS bodies:

- A transfer of knowledge and scientific expertise (e.g. in scientific workshop, frequently also in collaboration with other international expert bodies);
- Advice on monitoring and conservation needs (e.g. under the Habitats Directive);
- Preparation of regional conservation plans to aid the protection of biodiversity;
- External advice on common conservation problems from invited experts or commissioned advisors;
- Representation of conservation issues at other international fora;
- Support of local research projects relevant to the conservation of small cetaceans;
- Common grounds to meet and discuss conservation matters with non-governmental organisations.

Acknowledgements
Finally, I like to acknowledge the support of Steven Benjamins, Petra Deimer, Peter Evans, Sven Koschinski, Alice Mackay, Fabian Ritter, Rüdiger Strempel, the Sea Mammal Research Unit (SMRU) in St. Andrews, Scotland, and, last but not least, the German Oceanographic Museum (DMM) in Stralsund, Germany.

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ASSESSMENT OF ACOUSTIC DETERRENT DEVICES 'PINGERS' AND PORPOISE BY CATCH RATES IN IRISH GILLNET FISHERIES IN THE CELTIC SEA

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Introduction

A gillnet can be described as a sheet of multi or monofilament meshes suspended between a buoyant head rope and a weighted footrope on the sea bed. In 2005, approximately 20 Irish gillnet vessels operated off the south coast, primarily targeting hake and cod. A tangle net is a type of gillnet with relatively large meshes which hang loosely and these are used in Ireland on a more sporadic basis than gillnets to catch flatfish, monkfish and crawfish. One of the advantages of gillnets is that they are size selective in that juvenile or undersize fish are too small to become enmeshed and simply swim through the net. However, larger non targeted species such as harbour porpoises (*Phocoena phocoena*) can occasionally get entangled and become an unwanted by-catch and extensive research has been carried out to try and prevent this. Acoustic devices known as 'pingers' which emit relatively low frequency signals and can be attached to nets, have been proven to greatly reduce porpoise by-catch in gillnets and they are now legally required on gillnets deployed by Irish vessels of 12m or over in the Celtic Sea (S.I 274 of 2007). However, prior to their introduction it was important to establish that these devices were robust enough to endure harsh working conditions, were safe and easy to use, and were not prohibitively expensive to deploy and maintain.

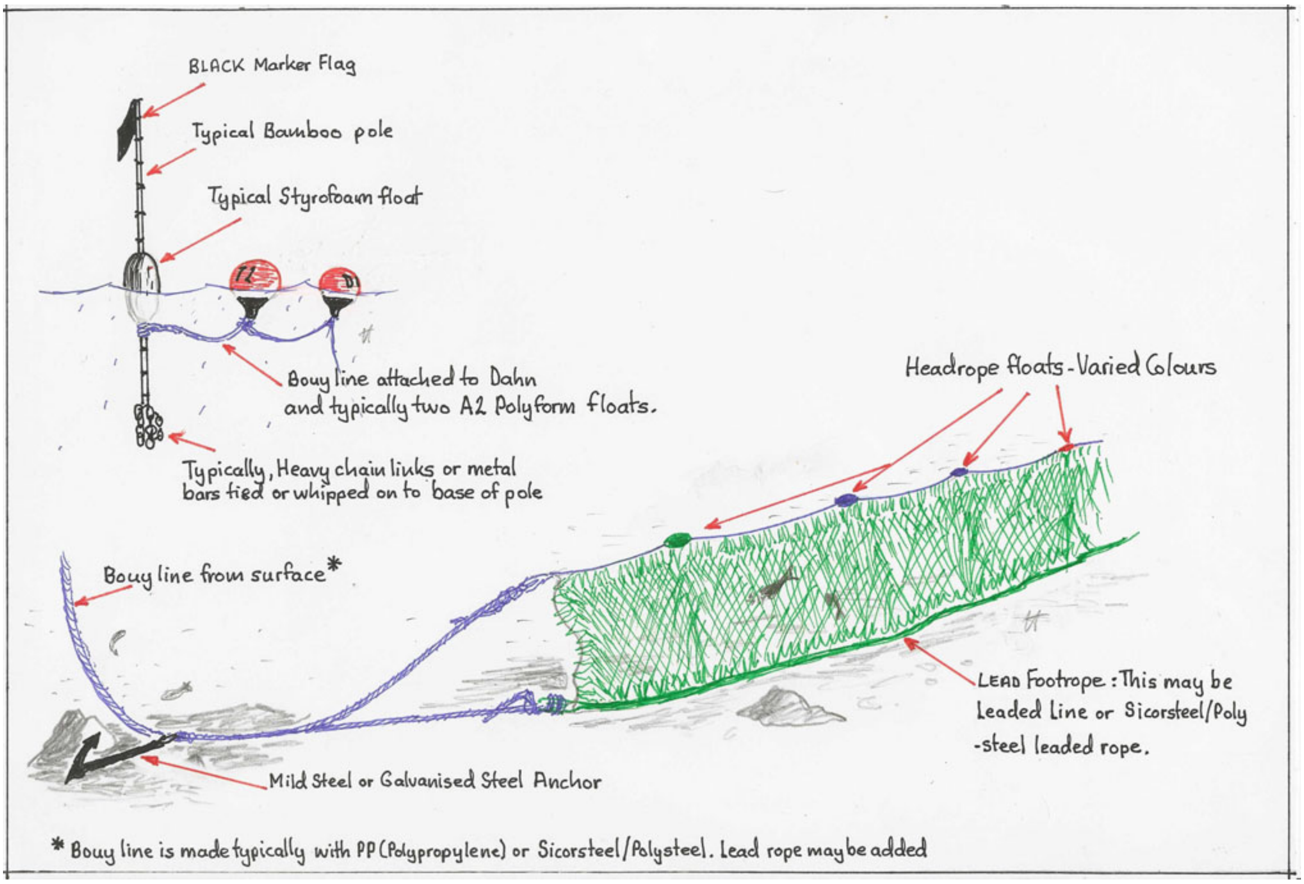

Figure 1. A typical Irish bottom set gillnet. Drawing by Myles Mulligan, BIM

Technical assessment

BIM therefore carried out a series of trials on commercial fishing vessels aimed at assessing the practical implications of using these devices and addressing problems which arose during the trials. Four models made by different manufacturers were assessed in terms of their impact on fishing operations, functionality, durability, and cost.

Key problems encountered during the trials were:

- In tangle nets 34% of pingers regardless of model type became tangled in the gear during hauling.
- Net flaking machines which are used to store nets onboard were frequently blocked up.
- Tangling of the gear slowed up operations and safety issues arose when fishermen were obliged to climb up high to the net flaker to undo blockages.
- Pingers suffered heavy collisions on vessel structures during fishing operations which resulted in various degrees of damage to pinger models.
- When tested acoustically at the end of the trials, none of the pingers were 100% reliable with more than half the units of one particular model not working.
- Three out of four of the pingers tested were negatively buoyant and this would naturally cause the head rope in tanglenets to sink.
- One model used lithium batteries which can be extremely dangerous if they come into contact with seawater and major problems were encountered when some of these pingers ruptured during fishing operations.

Solutions

BIM addressed these issues by developing a modified attachment system which consisted of mounting individual pinger units between floats in bait bag tubing and attaching the customised device at the interface between sheets of netting known as the 'joins'. The addition of net floats reduced the impact of heavy collisions thereby improving the durability of pingers and also assisted in keeping the head rope of tanglenets buoyant. The modified system was also larger than the meshes in tanglenets and this combined with the mounting of devices at the net joins, greatly reduced tangling of pingers in the fishing gear. Contact was subsequently made with pinger manufacturers to discuss the results of the trials and two of the companies have since improved their moulding processes in order to boost pinger durability and prevent contact of lithium batteries with seawater.

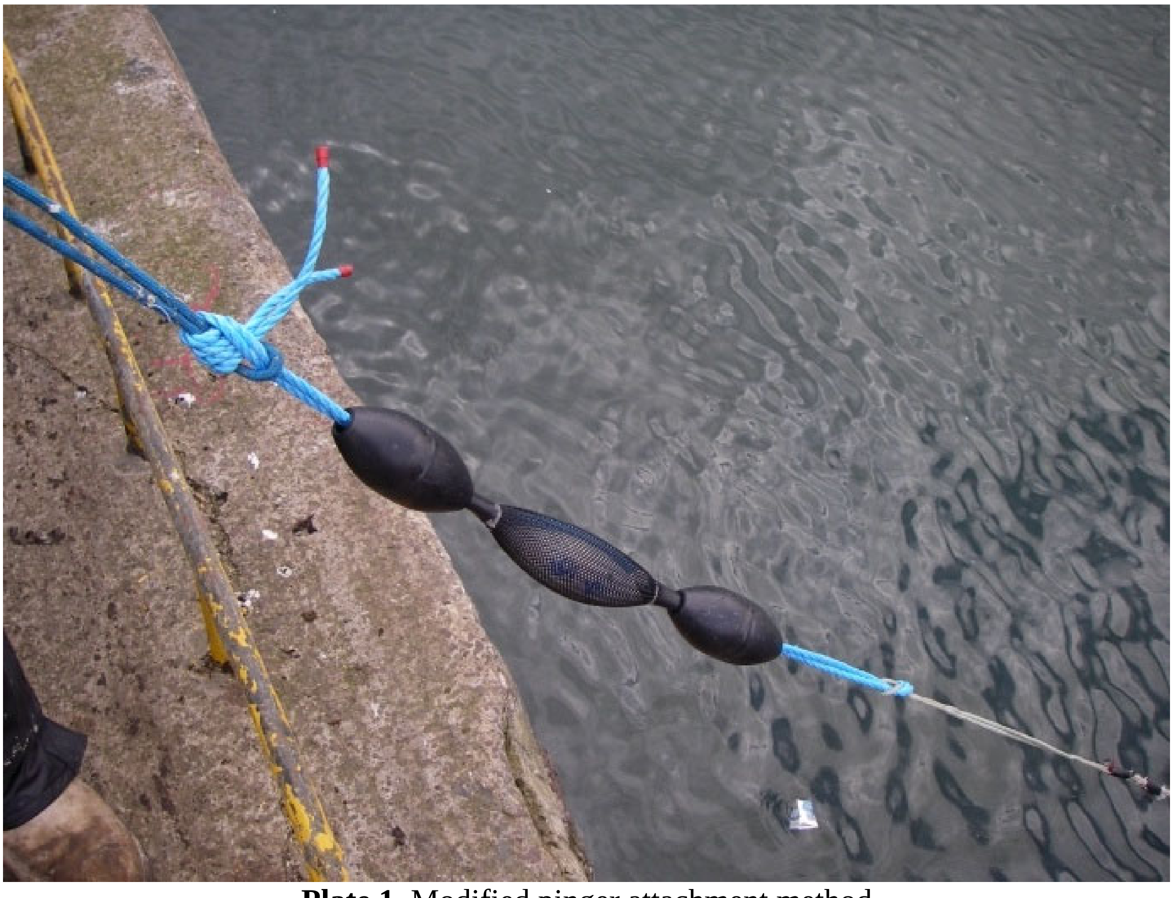

Plate 1. Modified pinger attachment method

Pinger spacing
Next BIM set out to establish what number of pingers would be required on fishing gear. European legislation required pingers to be deployed at a maximum spacing of 200m, but the maximum effective spacing had yet to be determined and the sound characteristics of specific pinger models suggested that the spacing could be higher. The advantages of using less pingers include reductions in pollution from lost or damaged pingers, noise pollution and associated potential porpoise habitat limitation, and of course cost and handling for fishermen. Further trials on fishing vessels were carried out and by-catch rates in nets with pingers deployed at 200m, 600m and in control hauls with no pingers attached were compared. Aquamark 100 pingers supplied by Aquatech in the UK were deployed according to these categories on individual strings or stations of gear approximately 4 km in length and careful watch was maintained when hauling gear to check for porpoise by-catch. As by-catch rates were low, the data were supplemented with control hauls from the pinger assessment trials during 2005 in order to take advantage of incidences of porpoise by-catch and to boost the power of analyses.

Spacing results
A total of 152 hauls/stations measuring 637km were carried out over 13 trips to sea for a total by-catch of 7 porpoises. No porpoises were caught in 27 stations with 600m spacing or in 22 stations with 200m so these groups were obviously not statistically different. A total of 7 porpoises were caught in 103 control stations but this group was not statistically different from either of the groups with pingers (Two sided Fishers exact chi squared test: P = 0.27). So although it appears that pingers do work at higher spacings, due to relatively low levels of porpoise by-catch it was not possible to scientifically prove this in Irish waters. A similar trial was carried in 2006 by the Danish Institute for Fisheries Research (DIFRES), in the Danish North Sea hake fishery where higher porpoise by-catch rates produced clear and conclusive results. A 100% reduction in porpoise by-catch rates was observed in nets with 455m spacing and a 78% reduction in by-catch in nets with 585m spacing with no significant difference between pinger spacing groups (Larsen and Krog 2007). Based on the research carried out by BIM and DIFRES the Irish government issued a derogation in June 2007 permitting an increase in the maximum spacing from 200m to 500m.

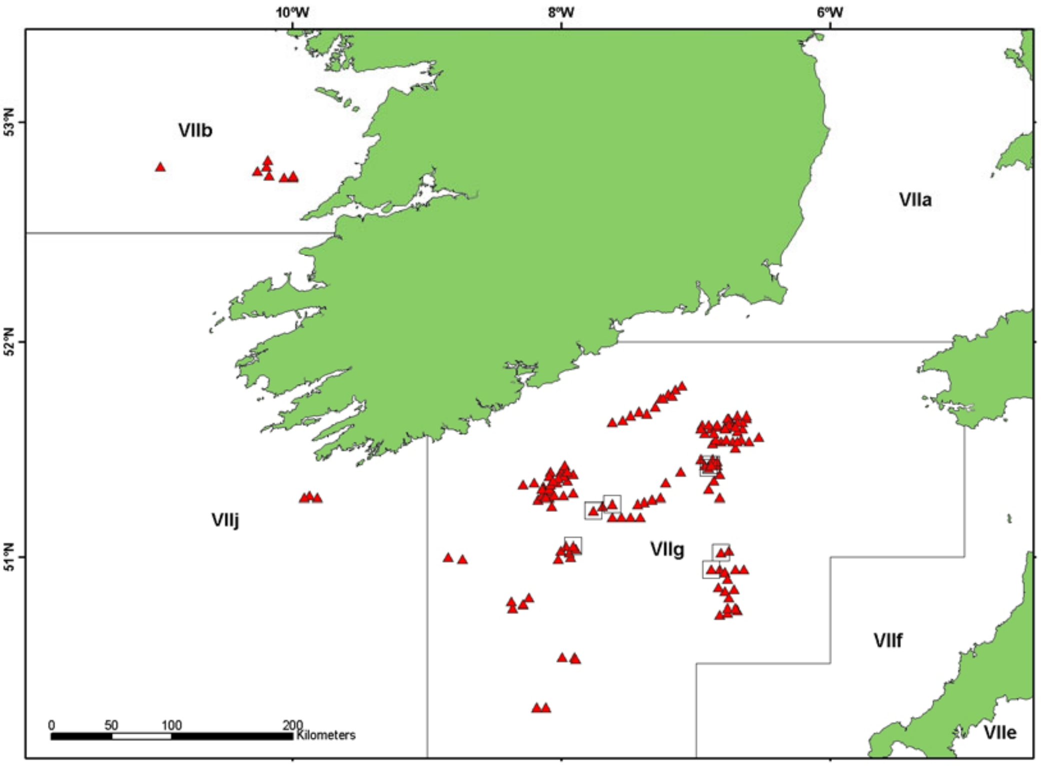

Figure 2. Position of 152 hauls used in pinger spacing analysis. Porpoise by-catch points are represented by clear squares.

Porpoise by-catch estimates

Data collected from the pinger assessment and spacing studies where pingers were not used, were used to update estimates of porpoise by-catch by Irish gillnet vessels in the Celtic Sea prior to the wide scale introduction of pingers. By-catch rates were compared with other studies in the Celtic and North Seas, and the total porpoise by-catch and impact on the population were estimated.

The results may be summarised as follows. A total observed porpoise by-catch rate of 7.94 animals per 10^4 km.h (gear length x period of immersion) was obtained for Irish vessels operating in the Celtic Sea between 2005 and 2007, which was slightly higher than an observed rate of $7.02*10^4$ km.h in an earlier study conducted from 1992 to 1994 (Tregenza *et al*. 1997). With the exception of winter when no observations were made during the recent study, a consistent seasonal trend in by-catch rates was observed between the two studies, with a peak occurring between March and May each year. However, the peak during the recent study was 2.2 times higher than the peak reported from 1992 – 1994. The observed porpoise by-catch rate during the peak season of July to September 2006 (Larsen and Krog 2007) was approximately 7 times higher than the peak in the Celtic Sea in the recent study.

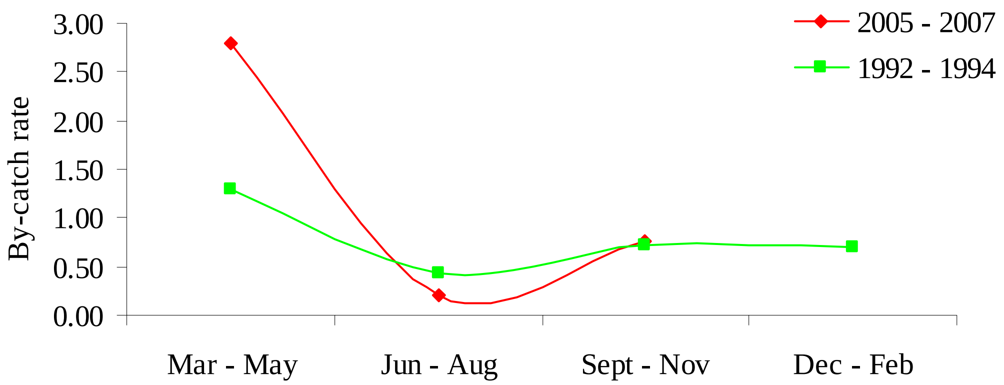

Figure 3. Comparison of seasonal porpoise by-catch rates (porpoises/1000 km.h) on Irish vessels in the Celtic Sea

Total estimates of porpoise by-catch were extrapolated from observed porpoise by-catch rates using national landings data provided by the Department of Agriculture, Fisheries and Food (DAFF). Based on days fished, an estimated 355 porpoises (± 247, C.V 34%) were taken as by-catch by Irish gillnet vessels in the Celtic Sea in 2006. This is 4.2 times lower than an estimated by-catch of 1497 (± 931, C.V 32%) porpoises in the Celtic Sea in 1993 (Tregenza *et al*. 1997). This decrease can be attributed to a major drop in fishing effort; 4,277 trips by Irish gillnet vessels in the Celtic Sea were reported in 1993, compared to 444 trips in 2006. The 2006 Irish by-catch estimate equates to 0.44% of the total estimated abundance of harbour porpoises in the Celtic Sea (SCANS-II, 2008). The introduction of legislation in 2007 requiring all gillnet vessels of 12m or over to use pingers, should result in further reductions to the impact of fishing on the Celtic Sea porpoise population.

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HARBOUR PORPOISE CONSERVATION IN THE REPUBLIC OF IRELAND

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National Parks and Wildlife Service (NPWS) of the Department of the Environment, Heritage and Local Government is the statutory body responsible for nature conservation in Ireland. The principal functions of NPWS include *inter alia* co-ordinating the implementation of Irish and European legislation, and international agreements relating to wildlife conservation. It also has the primary role in collecting and collating data relating to the conservation status of harbour porpoise to ensure effective management.

Cetaceans have had some protection in Irish waters since the Whale Fisheries Act, 1937 which limited the whales that could be targeted by commercial fisheries. In 1976, the introduction of the Wildlife Act made it an offence to hunt, injure or wilfully interfere with, or destroy, the breeding place of all cetaceans. In 1991, the Irish Government declared all Irish waters a whale and dolphin sanctuary with the purpose of prohibiting all forms of hunting or capture of these species. The amendment to the Wildlife Act in 2000 further made it an offence to interfere with the resting place of cetaceans.

In addition to national legislation, Ireland must also implement European Community law. Council Directive 92/43/EEC, more commonly known as the Habitats Directive, has a major role in protecting harbour porpoise in Irish waters. This Directive was framed to provide a common conservation strategy for threatened species and habitats on a Community wide basis. One of the principal methods of achieving this objective is to designate protected areas called Special Areas of Conservation (SAC) for habitats and species (including harbour porpoise). According to Article 6 of the Directive, developments within or adjacent to those designated sites must be assessed to ensure there is unlikely to be an impact on listed habitats or species. Where the likelihood of an adverse impact can not be excluded, permission for such applications must only be granted if there is over-riding health and safety or socioeconomic reasons. Under Article 12 of the Directive, all species of cetacean are afforded a strict level of protection in the Irish Exclusive Economic Zone. The Directive requires that the protection afforded to harbour porpoise and conservation status of this species are monitored both within and outside designated areas. Every six years, the information collected from this monitoring forms an Article 17 report on the status of this species from each Member State. Article 18 of this Directive also requires that research is undertaken in order to fulfil the mandated conservation requirements. This legislation has been transposed into Irish law by the European Communities (Natural Habitats) Regulations (SI 94/1997).

Several other legal instruments and international agreements are relevant to harbour porpoise conservation in Ireland. A recent European regulation (Council Regulation (812/2004)) has been designed to reduce the level of by-catch of small cetaceans in fishing gear. It requires the use of acoustic deterrent devices (pingers) on some vessels and provides for the monitoring and reporting of by-catch to the European Commission. The Convention on International Trade in Endangered Species (CITES), transposed into European law by Council Regulation (EC) No. 338/97 and into Irish law by the Wildlife (Amendment) Act 2000, limited or prohibited the trade of cetacean specimens and products. The Convention on Migratory Species, or Bonn Convention, protects species considered to have an unfavourable conservation status and encourages regional co-operation between signatory states. Migratory species that need or would significantly benefit from international co-operation are listed in Appendix II of the Convention (including harbour porpoise). The Convention on Biological Diversity (CBD) requires Parties to integrate as far as possible and as appropriate the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans and programmes. The OSPAR Convention for the Protection of the Marine Environment of the Northeast Atlantic (1992) seeks to provide a framework to protect the quality of the marine environment and certain threatened species including harbour porpoise. Ireland is also a member of the International Whaling Commission, which currently prohibits commercial whaling.

Through the objectives and goals of these agreements and legislation NPWS seeks to conserve harbour porpoise. Currently there are two sites designated as Special Areas of Conservation for this species; Blasket Islands and Roaringwater Bay and Islands candidate SACs. The guidance provided by the Commission on site selection for harbour porpoise suggests that the proposed area should be used for residence, breeding, reproducing or seasonally (European Commission, 2007). The proportion of a national resource may also be used as guidance. Category A sites would hold 100% to 15%, Category B from 15% to 2% and Category C from 2% to 0%. Proposed designated sites should also be large enough to support the population and should represent the range of habitats used by the target species throughout a jurisdiction.

During 2007, NPWS submitted a report on the conservation status of harbour porpoise to the European Commission (NPWS 2008). This report collated the available information from a range of sources. The population of porpoises within the Exclusive Economic Zone was calculated to be approximately 111,560 individuals derived from SCANS II (Hammond and Macleod 2006). This represented approximately one-third of the north-east Atlantic population. Although it was thought that the population was relatively stable there were a number of pressures that could be identified as potentially impacting on the population. The main threats to the species were identified as by-catch, pollution, over-fishing and habitat degradation. Harbour porpoise were identified as primarily a coastal species, but they were not limited in where they ranged through the marine jurisdiction. Therefore, the potential range of the species extended over the entire Irish Exclusive Economic Zone. Since the pressures were considered to have an insignificant effect on the population status at existing levels and there was no indication that these pressures would increase it was judged that the future prospects for the species were favourable. Overall the conservation status of harbour porpoise was judged to be favourable. However, it is clear that greater effort is required to provide data sufficient to report during the next six-year cycle.

During 2008, NPWS commissioned a series of surveys for harbour porpoise. Both the Blasket Islands and Roaringwater Bay and Islands cSACs were assessed to derive an abundance estimate (Figure 1). Four other sites were assessed using single-platform randomised-transect boat surveys and static acoustic devices (T-POD). These were North County Dublin, Dublin Bay, Cork Coast (from the Old Head of Kinsale to Galley Head) and outer Galway Bay (Figure 2). Two other sites, Carnsore Point and Donegal Bay, were assessed using only transect methods. The results of these surveys will be used to inform on the status of harbour porpoise in coastal waters. NPWS is also funding other projects focussed at least partly on harbour porpoise. These include the Policy Recommendations from Cetacean Acoustics, Survey and Tracking (PReCAST) funded jointly by NPWS and the Irish Marine Institute. This broad project will provide information relating to amongst others inshore acoustic surveys for harbour porpoise, offshore surveys and will advance current knowledge relating to habitat requirements for cetaceans. NPWS is also funding a PhD focussed on small cetaceans along the western seaboard. This project is aimed at assessing sites as potential SACs and possible monitoring techniques. NPWS jointly funds the Irish Scheme for Cetacean Observation and Public Education (ISCOPE) which on an all-Ireland basis collects and collates both casual and focused data relating to cetacean observations in both the inshore and offshore areas. The NPWS has also been involved in funding two international offshore surveys for small cetaceans, SCANS II (small cetaceans in the European Atlantic and North Sea) and CODA (Cetacean Offshore Distribution and Abundance).

In the near future, NPWS will receive the results of the 2008 harbour porpoise surveys. These data will be used to assess whether survey sites may be suitable for designation and to place the existing designated areas in both a national and international context. Special Area of Conservation designations for harbour porpoise clearly have a role in protecting this species. However, the protections afforded outside of those areas are also comprehensive. Qualification as a European level site for the conservation of this species is not the only mechanism available in the future. Sites that were not judged to be suitable for SAC status could be designated as Natural Heritage Areas under the Wildlife (Amendment) Act 2000. The European Commission recently communicated to the Irish Government that its conservation measures for cetaceans were inadequate. To address the issues raised, a number of actions have been taken including commissioning a Cetacean Action Plan for all 24 species known from Irish waters. This plan will address the current level of knowledge relating to those species, list the threats and formulate specific actions to counteract those pressures. It is very likely that specific actions will be highlighted that will address acknowledged threats to the harbour porpoise population. The first Article 17 submission to the European Commission found that harbour porpoise were at a favourable conservation status. However, to ensure that this continues, ongoing collection of data on the marine environment is required. That submission highlighted that for some species of cetacean very little information was available. Although recently there has been a significant increase in survey effort specific to harbour porpoise, it is clear that further data are required to ensure the future conservation of this species. In particular, more data are required on habitat requirements, ecological data and population trends. Data must also be collected on the pressures experienced by this species so that specific responses can be formulated to limit or negate them.

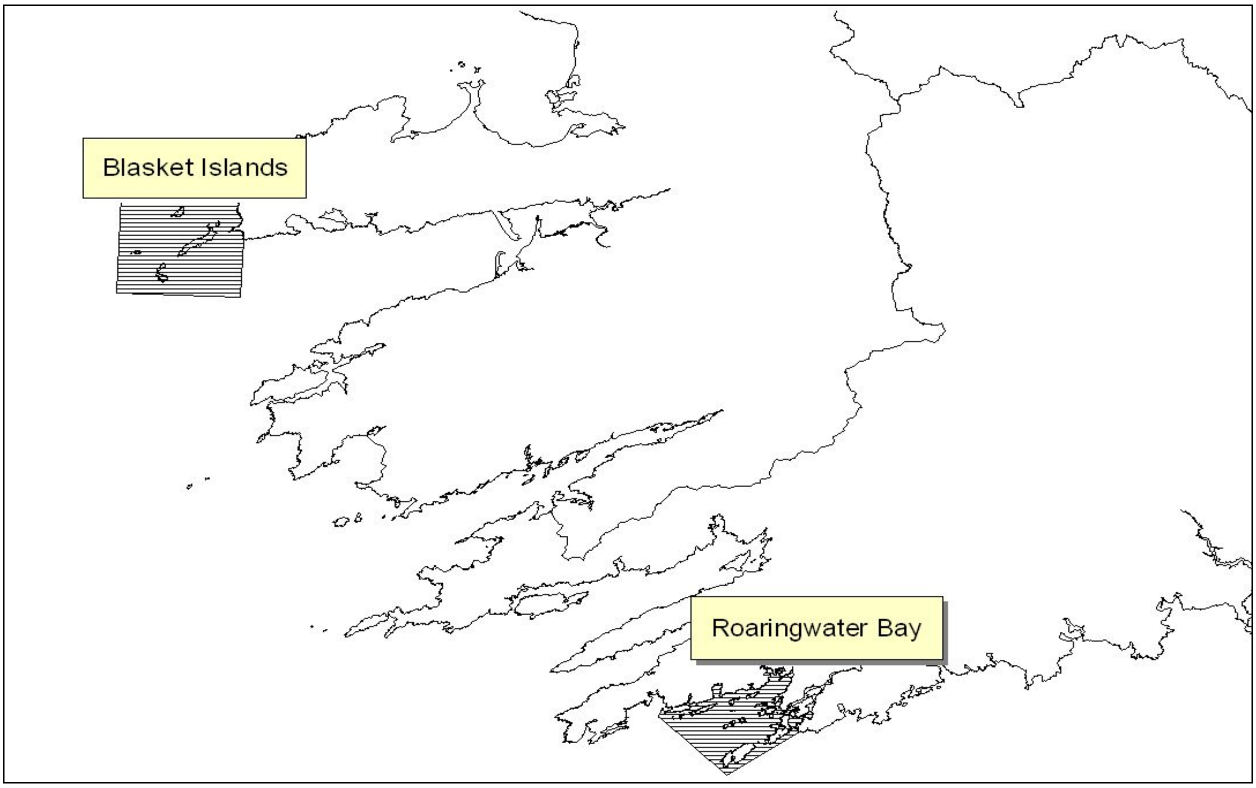

Figure 1. Special Areas of Conservation currently designated for harbour porpoise (*Phocoena phocoena*) in Ireland

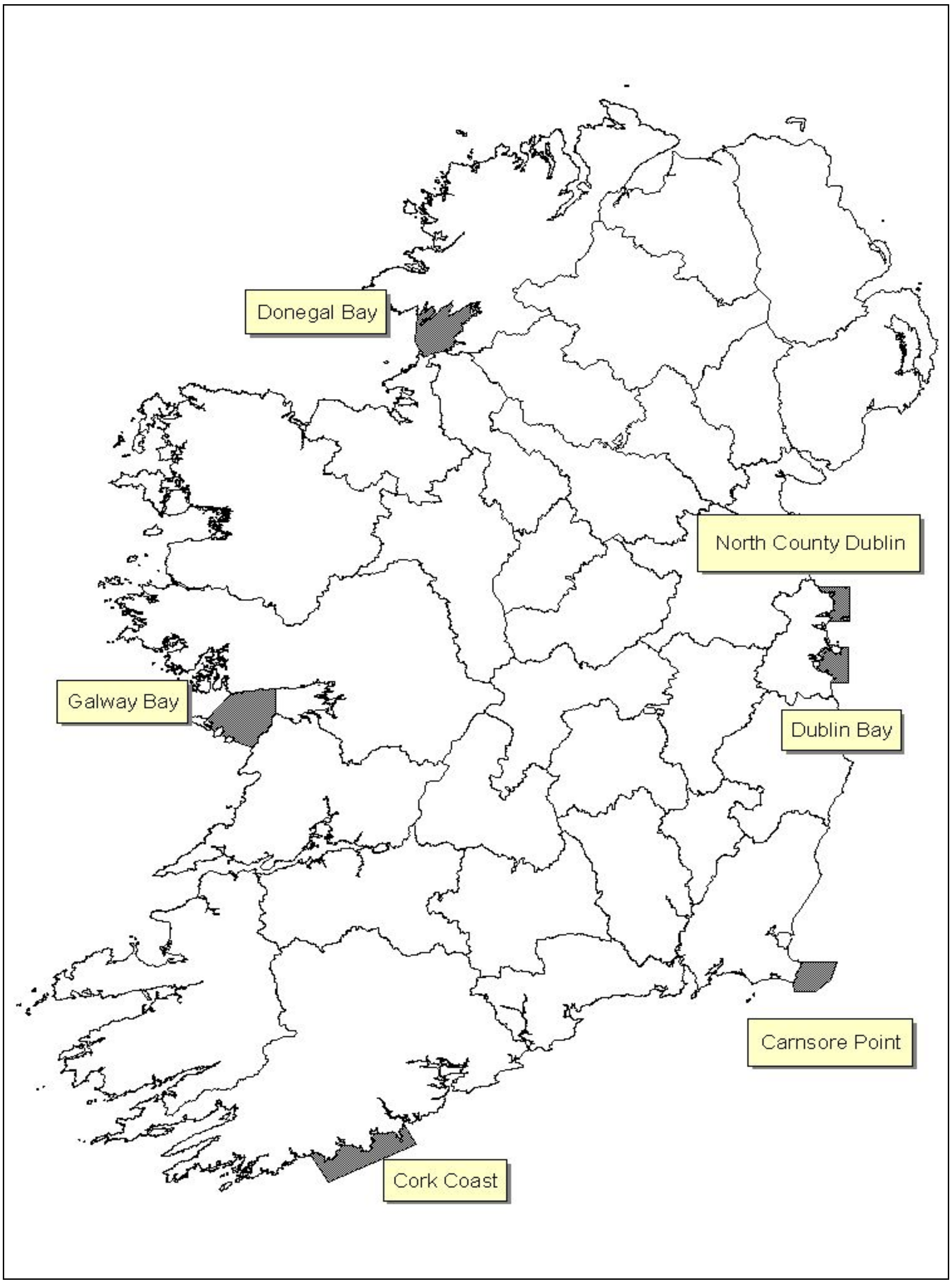

Figure 2. Sites surveyed for harbour porpoise during 2008

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European legislation is available to download on URL: http://eur-lex.europa.eu/en/index.htm

APPENDIX 1. ATTENDEES OF THE 2ND IWDG INTERNATIONAL WHALE CONFERENCE MUC MHARA IRELAND'S SMALLEST WHALE

Malcolm G	Barradell
Jenni	Barrett
Frances	Bermingham
Simon	Berrow
Stefan	Brager
John	Brophy
Lorraine	Bull
Brendan	Burgess
Gary	Burrows
Patricia	Byrne
Richard	Collins
Ronan	Cosgrove
Caroline	Curtis
Helen	Doyle
Peter	Dunne
Mike	Fagan
Vanessa	Fagan-Vanhorn
Shay	Fennelly
Bojana	Ferjana
Jennifer	Firth
Jacqueline	Forde
Kay	Foster
Graeme	Glennon
Josephine	Glynn
Bernard	Goggin
Patrick	Graham
Karen	Greene
Eithne	Griffin
Lisa	Groth
Sophie	Hansen
Neill	Harmey
Ronan	Hickey
Kate	Hockley
Frankie	Hogan
Catherine	Hooper
Henry	Horrell
Eamonn	Kelly
Iwona	Kuklik
David	Lyons
Sinead	Lyons
Barbara	Maciejewska
Andrew	Malcolm
Aileen	Mc Carthy
Kevin	Mc Cormick
Keith	Mc Grane
Emma	McLaughlin
Sam	Meyler
Rosemary	Muir
Angela	Murphy

Sinead	Murphy
Vincent	Murphy
Mick	O' Connell
Cliona	O'Brien
Joanne	O'Brien
Fiacc	O'Brolchain
Barry	O'Donoghue
Kate	O'Donovan
Conal	O'Flanagan
Christian	Osthoff
Andy	Read
Cillian	Roden
Emer	Rogan
Conor	Ryan
Robert	Shearman
Elizabeth	Sides
Krzysztof	Skora
Sabine	Springer
Hauke	Steinberg
Raymond	Stephens
Signe	Sveegaard
Ann	Trimble
Peter	Tyndall
Padraig	Whooley
David	Williams
Ben	Wilson
Faith	Wilson
Peter	Wilson
Claire	Youdale

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

dlr
Comhairle Contae County Council

Marine Institute
Foras na Mara

NDP
National Development Plan 2007 - 2013

An Chomhairle Oidhreachta
The Heritage Council

epa
Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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ISBN:0-9540552-3-3