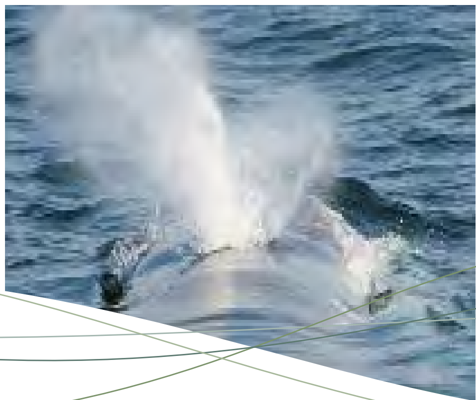
Marine Research Sub-Programme
(NDP 2007–'13) Series

Sea Change
Casadh na Taoide

Marine Mammals and Megafauna in Irish Waters - Behaviour, Distribution and Habitat Use. *Final Summary Report*

Project-based Award



Lead Partner: Galway Mayo Institute of Technology

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1. Assist existing, and largely indigenous, marine sub-sectors to improve their overall competitiveness and engage in activity that adds value to their outputs by utilising knowledge and technology arising from research.
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4. Increase the marine sector's competitiveness and stimulate the commercialisation of the marine resource in a manner that ensures its sustainability and protects marine biodiversity and ecosystems.
5. Strengthen the economic, social and cultural base of marine dependant regional/rural communities.

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Marine Research Sub-Programme 2007-2013

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Marine Mammals and Megafauna in Irish Waters - Behaviour, Distribution, and Habitat Use

(PBA/ME/07/005(02))

Lead Partner: Galway-Mayo Institute of Technology

Project Partners: Irish Whale and Dolphin Group

Author(s): Berrow, S.D., O'Brien, J., O'Connor, I., McGrath, D. and Wall, D.

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Disclaimer

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1. Introduction

Irish waters are internationally important for cetaceans (whales, dolphins and porpoises), with 24 species recorded to date (Berrow, 2001). These range from the harbour porpoise, the smallest species in European waters, to the blue whale, the largest animal to ever have lived on Earth. Some species are relatively abundant and widespread while others are extremely rare and have never been sighted in Irish waters, only known from carcasses stranded on the Irish coast. At least 12 cetacean species are thought to calve within the Irish Exclusive Economic Zone (EEZ)[1] (Berrow, 2001). Marine mammals, including cetaceans and seals, represent almost 50% of the Irish native mammal fauna, and thus Ireland has a significant conservation obligation towards them and their habitats. In 1991 the Irish government recognised the importance of Ireland for cetaceans by declaring all Irish waters within the EEZ a whale and dolphin sanctuary (Rogan and Berrow, 1995).

This diversity of cetacean species in Ireland reflects the range of marine habitats, which extend to 200 nautical miles (nmls) (370km) offshore and comprise an area of 453,000km^2. This is a little over six times the area of the land of Ireland. These habitats range from shallow continental shelf waters to shelf slopes, deep-water canyons, offshore banks, carbonate mounds, and associated deep water reef systems and abyssal waters.

1.1. Legal Framework

All cetaceans and their habitats are protected under Irish and international law. The Wildlife Act[2] and Wildlife (Amendment) Act[3] entitle all cetaceans and their habitats up to 12nmls from the coast to full protection, including from disturbance and wilful interference. All cetacean species occur on Annex IV of the EU Habitats Directive[4], and are thus entitled to strict protection, including: prevention of deliberate capture or killing; prevention of deliberate disturbance; prevention of deterioration of breeding or resting sites; and prevention of capture for sale. There is also a requirement to monitor the incidental capture or killing of these species. Two species, the harbour porpoise and bottlenose dolphin, are on Annex II which requires the designation of Special Areas of Conservation (SACs) to protect a representative range of their habitats. To-date, two candidate SACs have been designated for the harbour porpoise, Roaringwater Bay, Co Cork and the Blasket Islands, Co Kerry, and one for the

[1] EEZ: a seazone in which a state has special rights over the exploration and use of marine resources.
[2] Wildlife Act (1976)
[3] Wildlife (Amendment) Act (2000)
[4] Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora

bottlenose dolphin, the Lower River Shannon. The European Court of Justice (ECJ) ruled in February 2009 that the Irish government had failed to 'put in place a comprehensive, adequate, ongoing monitoring programme for cetaceans that could enable a system of strict protection for those species to be devised'.

Under Article 17 of the Habitats Directive, each member state must report on the status of all species and habitats listed under the Habitats Directive which occur within the state. The first reporting round was completed in 2007 and covered the period 2000–2007. A conservation assessment requires information on range, habitat, population, and future prospects. The conservation assessments for cetacean species were considered very inadequate due to a significant lack of data on range, habitat, and population estimates for nearly all cetacean species in Irish waters. The next reporting round will be completed in 2013, and the National Parks and Wildlife Service (NPWS) must ensure that available data are adequate to make a proper conservation assessment, at least for the most abundant and widespread species.

In December 2009, the National Parks and Wildlife Service (NPWS) published its Conservation Plan for Cetaceans in Irish Waters[5]. This plan lists 41 actions. These include: conducting further research to determine the distribution, relative abundance, and habitat preferences of cetaceans (Action 1); identifying breeding ecology, movements, and migration routes (Action 2); devising a programme to effectively monitor cetaceans inside and outside designated areas (Action 3); encouraging the development of passive acoustic monitoring (Action 4); exploring the possibility of using static acoustic monitoring to provide data for monitoring cetaceans (Action 9); including cetacean surveys on fisheries cruises to collect information on the possible relationships between fish and cetacean abundance (Action 18); and carrying out spatial monitoring using GIS to explore the relationship between cetacean distribution and fisheries (Action 19).

The Irish government also has legal obligations to protect cetaceans and other marine megafauna, and their habitats under a range of other legislation. These include the Convention on the Conservation of Migratory Species[6] (Bern Convention) and the Convention on the Conservation of European Wildlife and Natural Habitats[7] (Bonn Convention). Under the OSPAR Convention[8], Ireland is obliged to address recommendations on the protection and

[5] Conservation Plan for Cetaceans in Irish Waters (2009). Department of Environment, Heritage and Local Government.
[6] Convention on the Conservation of Migratory Species of Wild Animals (1979)
[7] Convention on the Conservation of European Wildlife and Natural Habitats (1979)
[8] Convention for the Protection of the Marine Environment of the North-East Atlantic (1992)

conservation of species, habitats, and ecosystems that make it not only relevant to marine mammals and turtles but also to basking sharks.

The National Biodiversity Data Centre recently established a marine mammal database. The data collected during this project will be used for this database in order to make the data available for a range of assessments, including Environmental Impact Assessments, Strategic Environmental Assessments and Appropriate Assessments.

Amendments to the EU Common Fisheries Policy require an Ecosystem Approach to Fisheries Management (EAFM). This requires data on the predators as well as the fish prey, and the drivers linking the different ecological systems. This presents a great challenge and member states are exploring how such an approach can be implemented.

The development of a sustainable marine tourism industry has been identified as a national priority by both the Marine Institute and Fáilte Ireland. While marine wildlife tourism has great potential as a high spend product for peripheral coastal regions, the species targeted are usually protected and populations often depleted through over-exploitation. Information on the distribution, abundance and status of these species is essential for responsible development of this resource.

1.2. Marine Mammals and Megafauna in Irish Waters

The research termed *Marine Mammals and Megafauna in Irish Waters – behaviour, distribution and habitat use* attempted to address some of these issues. The project was delivered under six Work Packages. Work Package 1 attempted to increase coverage of offshore waters using platforms of opportunity (both ship and aircraft) to map the distribution and relative abundance of marine megafauna within the EEZ, and to provide recommendations on how best to meet monitoring obligations for these species. Work Package 2 attempts to develop static and passive acoustic monitoring techniques in order to use these techniques to monitor Annex II species within SACs. Under Work Package 3, we intended to develop experience and capacity in the biotelemetry of marine megafauna through satellite tracking of fin whales (*Balaenoptera physalus*). In Work Package 4, results from eight years of cetacean and other marine megafauna surveys concurrent with the Celtic Sea Herring Survey organised by the Marine Institute were used to create a GIS in order to explore ecosystem links.

Thus, the deliverables under this project will provide data which could be used to address a wide range of issues, and will contribute to developing policy advice on meeting Ireland's statutory obligations.

2. Monitoring Spatial and Temporal Habitat Use and Abundance of Cetaceans

2.1. Cetacean Line-Transect Surveys

Boat-based line transect surveys were conducted on board platforms of opportunity (vessels used as survey platforms but not chartered for this purpose) with the aim of providing baseline data from which to map the distribution and relative abundance of cetaceans within the Irish EEZ. As recent similar projects such as ISCOPE (Berrow *et al,* 2002; 2010) had provided good survey coverage of the Irish Sea, surveys under PReCAST targeted Ireland's offshore Atlantic waters during the present study. In order to identify areas and seasons where coverage was poor, a gap analysis was carried out (Wall, 2005) to inform survey design and identify the most appropriate survey platforms. The data collected would then be used to populate the Marine Mammal Database (stored at the National Biodiversity Data Centre) to prepare an atlas of cetacean distribution and relative abundance for Irish waters, and to assess the temporal use of marine habitats by cetaceans in Irish waters.

A single marine mammal observer conducted visual survey effort from research vessels and naval service vessels between March 2008 and January 2011. Observer effort focused on a 90 degree arc ahead of the ship. However, sightings located up to 90 degrees to port and starboard were also included. Surveyors scanned the area by eye and using binoculars (typically with 10X40 or 8X50 magnification). Bearings to sightings were measured using an angle board, and distances were estimated with the aid of a range-finding stick (Heinemann, 1981).

Environmental data were recorded every 15 minutes using Logger 2000 software (IFAW, 2000). Sightings were also recorded using Logger 2000. Automated position data were obtained through a laptop computer linked to a USB GPS receiver. The survey effort was conducted up to Beaufort sea-state 6 and in moderate to good visibility. Sightings were identified to species level where possible, with species identifications being graded as definite, probable or possible. Where species identification could not be confirmed, sightings were downgraded according to criteria established by the Irish Whale and Dolphin Group (IWDG) (Berrow *et al,* 2010). Sightings of seals, basking sharks, turtles and other species of interest were also recorded.

Twelve vessels from eight host institutions and five different countries were used for the ship-based survey effort. Vessels were sourced either through direct contact with the host institution or by utilising the EU Foreign Vessel Observer Scheme administered by the Marine Institute. The majority of vessels utilised were engaged in fisheries surveys. However, vessels conducting oceanographic surveys, naval patrols, dedicated cetacean surveys, ROV surveys and geological surveys were also used.

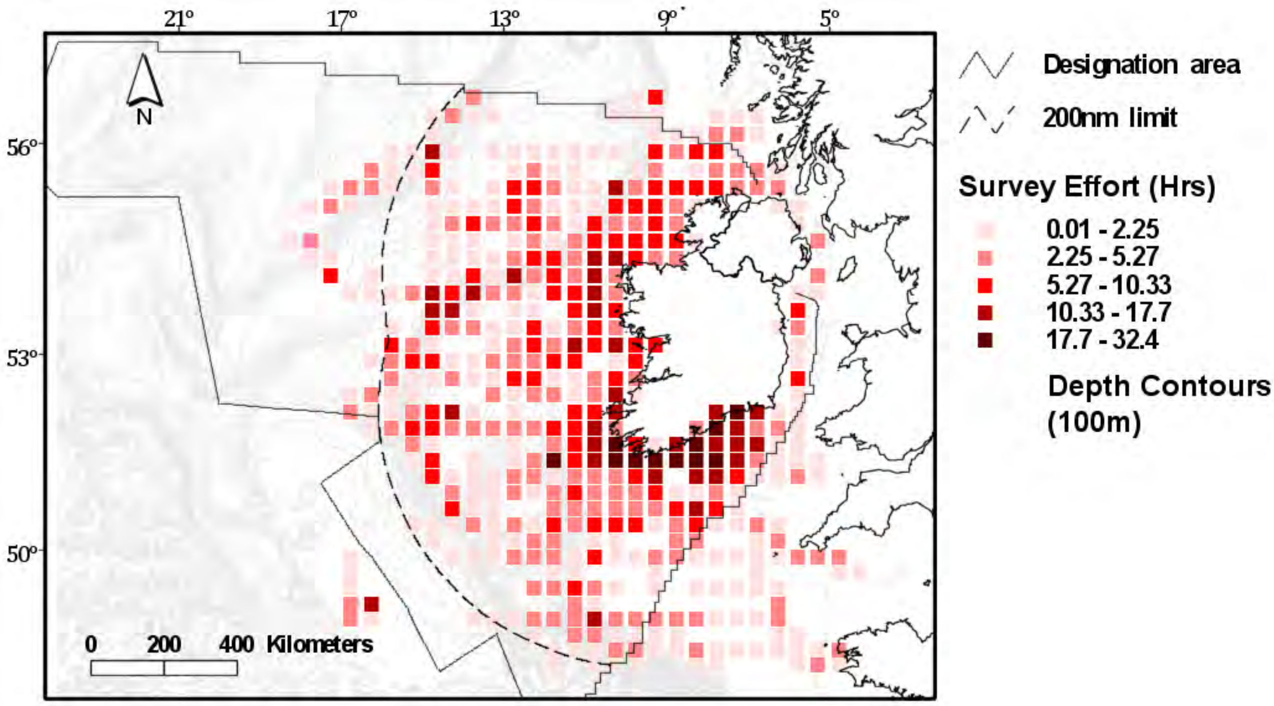

Figure 2.1: Total survey effort (on-effort hours) for all sea states (0-6) and all seasons per ¼ ICES Statistical Rectangle from March 2008 to January 2011

From March 2008 to January 2011, 585 days-at-sea were completed within the Irish EEZ and in adjacent EU waters, involving the collection of 2,366 hours of visual survey effort (Fig. 2.1). A total of 1,392 sightings of 12,995 individual cetaceans were recorded. These included sightings of rarely encountered species such as blue whale and Sowerby's beaked whale. Short-beaked common dolphin was the most abundant and widespread cetacean species encountered over the Irish continental shelf, while long-finned pilot whale was the most abundant and widespread cetacean in deep water habitats (200m+). The most frequently encountered baleen whale was the fin whale, which was seasonally abundant off the south coast and on the northwest shelf slopes. Sperm whales were frequently encountered on the shelf slopes and in deeper waters, and are possibly the most widespread and abundant large whale species in the deep water habitats of the Irish EEZ.

Evidence of calving (indicated by the presence of calves or juveniles in a group) was recorded for eight species (fin whale, sperm whale, pilot whale, Risso's dolphin, bottlenose dolphin, common dolphin, harbour porpoise, and unidentified beaked whale). In the case of fin and sperm whales, one juvenile was recorded in each case. However, these species are not thought to calve in Irish waters. Comparison with past data sets indicated an increase in sightings of humpback whales, fin whales and beaked whales, although increases may be a product of differing survey methods and/or survey areas. The data also suggest a decrease in sightings of cold water species such as white-beaked and Atlantic white-sided dolphins. Sightings of two seal species were recorded, with the grey seal accounting for 95% of seal sightings. Seven sightings of basking sharks and three sightings of leatherback turtles were also recorded. A sighting of a blue whale foraging along the shelf edge was confirmed by photographic images (Wall *et al,* 2009).

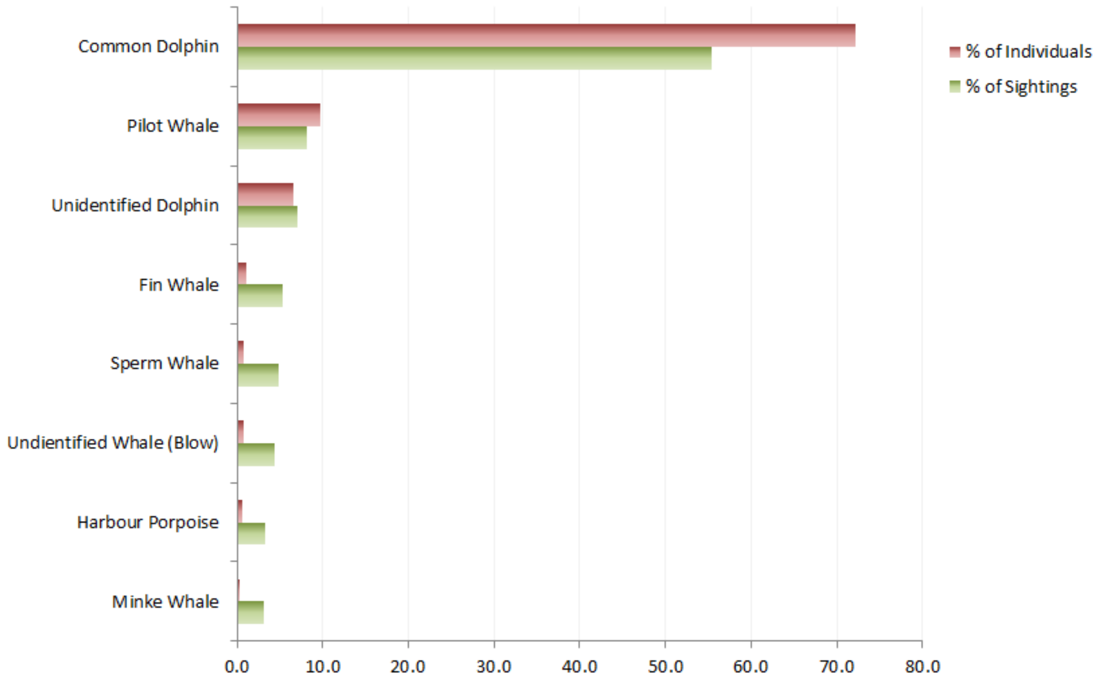

Figure 2.2a: Percentage of all sightings and all individuals accounted for by the six most commonly encountered cetacean species recorded during PReCAST line transect surveys

Of the 17 cetacean species recorded during the survey, sufficient data were collected to enable maps of seasonal distribution and relative abundance to be prepared for seven: fin whale, minke whale, sperm whale, long-finned pilot whale, bottlenose dolphin, short-beaked common dolphin, and harbour porpoise. For all other species a single distribution and relative abundance map, combining data from all seasons, was prepared. Species distribution and relative abundance maps are available in the technical report (Wall *et al*, 2012).

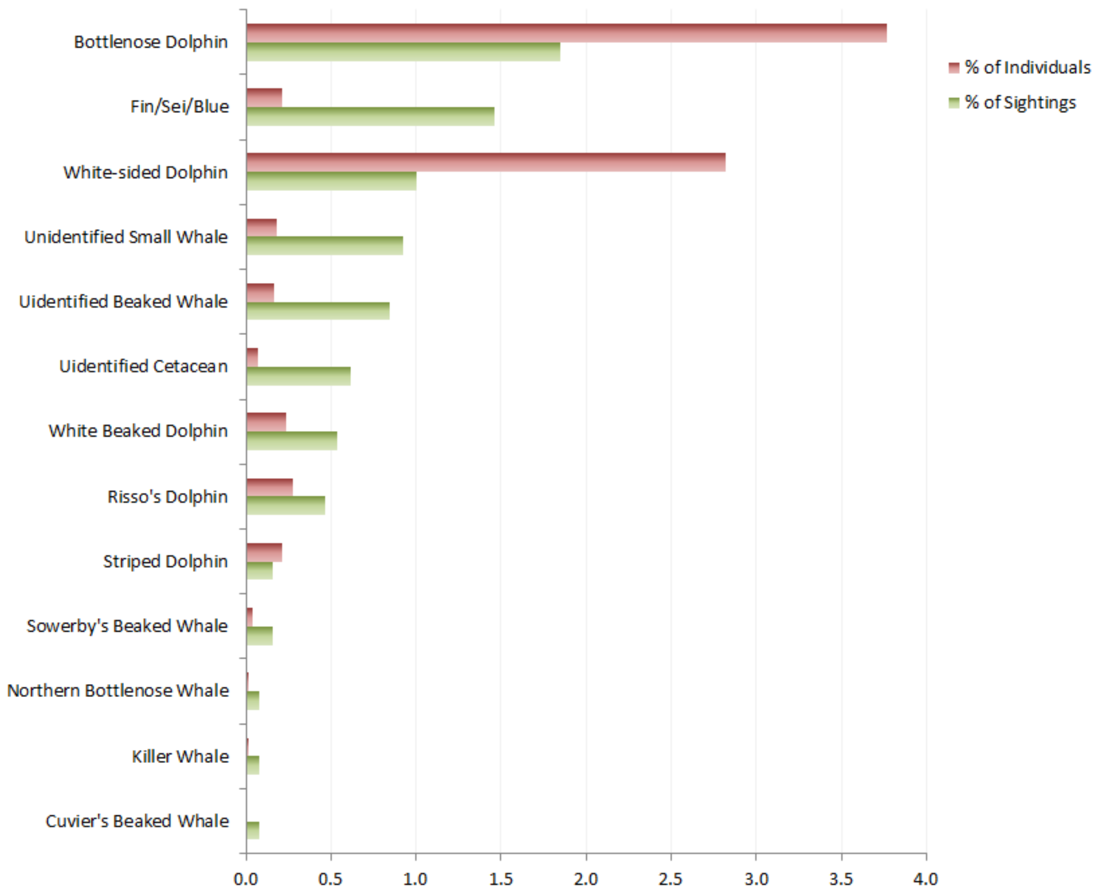

Figure 2.2b: Percentage of all sightings and all individuals accounted for by all other cetacean species recorded during PReCAST line transect surveys (NB: note difference in scale of x-axis)

Three of the species for which seasonal data were available (fin whale, minke whale and common dolphin) showed strong seasonal changes in habitat use (distribution) and abundance. For minke and fin whales a temporal (time-related) absence from the Irish EEZ was apparent.

2.2. Cetacean Aerial Surveys

Two observers accompanied Air Corps Maritime Squadron patrol flights within the Irish EEZ. Patrols were conducted on board one of the Maritime Squadron's two Casa CN 235 Maritime Patrol Aircraft. One observer, positioned in the cockpit, recorded positional and environmental data using the aircraft's cockpit instrument gauges. This observer also opportunistically recorded sightings through the aircrafts cockpit windows. The second observer surveyed for cetaceans from one of the aircraft's two bubble windows. Due to the difficulty in detecting cetaceans at the surface when wave clutter is present, aerial surveys were conducted only when sea conditions were forecast at sea state two or less. Survey effort focused from an angle of 10 degrees from vertical to 45 degrees from vertical. Sightings made by the bubble window observer were logged using a Garmin™ 72 handheld GPS unit. This unit also recorded the altitude of the aircraft at the time each sighting was made.

A total of 53.3 hours of visual survey effort were conducted between May 2008 and June 2011 during 16 patrol flights with the Maritime Squadron (Figure 2.3). Surveys were conducted in all seasons, with the greatest amount of effort and widest geographic coverage achieved in spring and summer. A total of 89 sightings were recorded of eight different cetacean species, totalling 866 individuals.

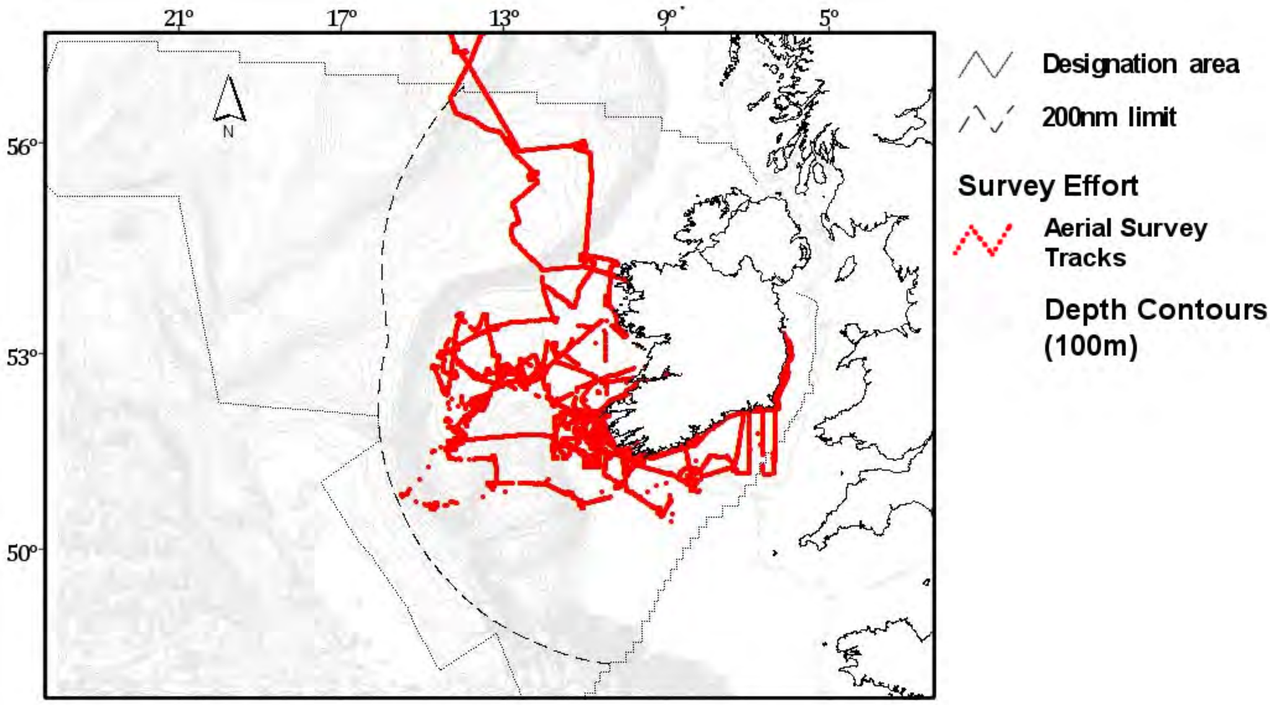

Figure 2.3: Aerial survey effort logged between May 2008 and June 2011

Typically, aerial cetacean surveys are carried out along a fixed-width strip of water below or to one side of the aircraft. To achieve this with any degree of accuracy, the speed and altitude of the aircraft should ideally be constant. Where the speed and altitude of the aircraft are variable (as with platforms of opportunity), a high accuracy of data collection is required to allow survey effort falling within pre-defined survey parameters to be calculated. If enhanced automated position, altitude and speed data can be collected using available technologies, and perhaps linked to automated HD digital video collection at a reasonable cost, the Maritime Squadron CASA Patrol Aircraft may offer an effective and productive means of surveying cetaceans, seabirds and other marine megafauna within the Irish EEZ.

2.3. Dedicated Cetacean Surveys

Two dedicated, multi-disciplinary surveys targeting slope and canyon habitats off the west coast of Ireland were undertaken on board the *RV Celtic Explorer*. '*Cetaceans on the Frontier I*' was carried out in August 2009 and '*Cetaceans on the Frontier II*' between February and March 2010. The surveys involved collaborators from seven different institutions collecting data on a range of species and within a range of parameters, from cetaceans and seabirds to oceanography and plankton sampling. Eighty-nine cetacean sightings of at least seven cetacean species, totaling 772 individuals, were recorded on the first survey and 94 sightings of at least five cetacean species, totaling 750 individuals, were recorded on the second survey.

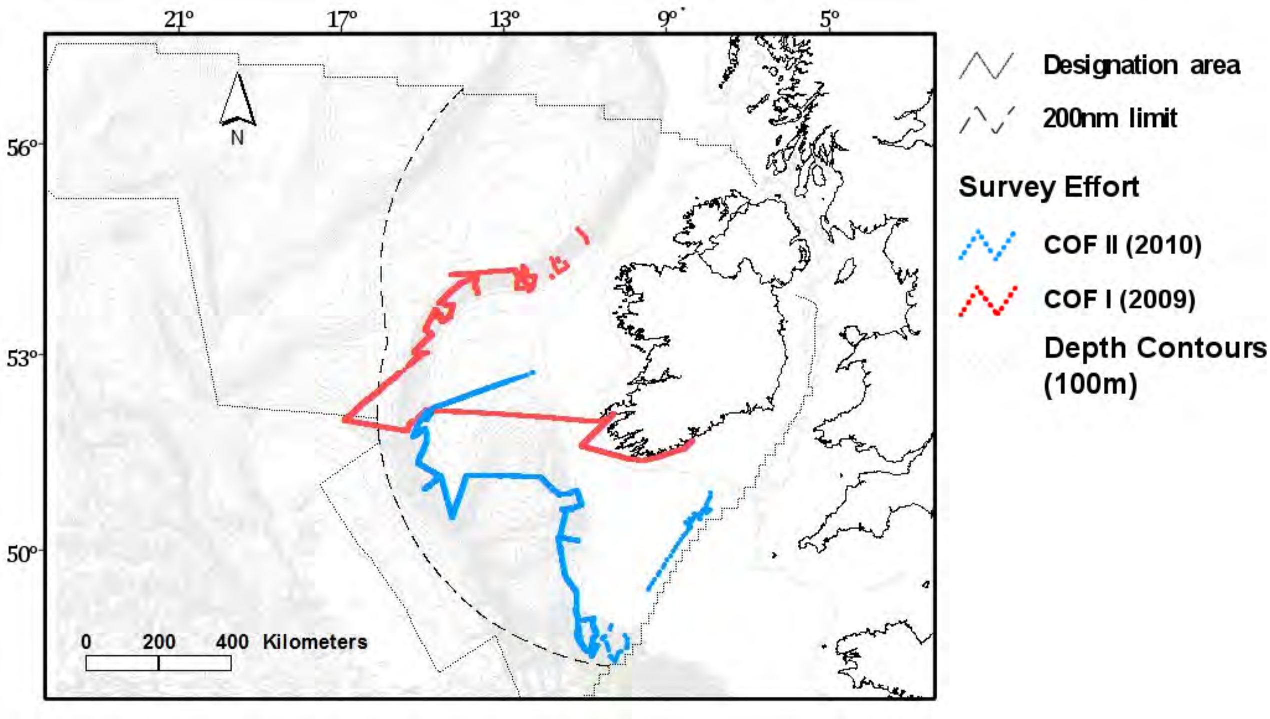

Figure 2.4: Survey effort during Cetaceans on the Frontier (COF) Cruises I and II

Species recorded included fin whale, sperm whale, northern bottlenose whale, long-finned pilot whale, killer whale, bottlenose dolphin, common dolphin, and striped dolphin. Common dolphins were the most commonly encountered and abundant species recorded during both surveys. A large group of bottlenose dolphins, in excess of 200 individuals, was encountered on the 26 August 2009 on the northwest slopes of the Irish shelf, and this was the largest confirmed group of bottlenose dolphins recorded to date in Irish waters. The majority of sightings during the second survey were made over the Whittard Canyon system, with common dolphins also being commonly encountered in small groups over the Celtic Shelf. Maps of the distribution of sightings recorded during these surveys are presented in the technical report (Wall et al, 2012). Poor weather conditions during both surveys prevented estimates of absolute abundance being conducted.

2.4. Impact of Present Study on Coverage: Updated Gap Analysis

The Gap Analysis carried out by Wall (2005) was updated to assess the impact of the present study. Effort was calculated as hours of survey effort conducted. Survey effort conducted outside of the Irish EEZ and Northern Irish territorial waters was not included in the Gap Analysis. The Irish Declared Area was broken down into survey zones suitable for the planning of surveys of cetacean relative abundance and distribution, based on the working areas of naval and scientific vessels, marine habitat types, and extent of geographical coverage likely to be achieved during any one survey. Survey effort was assigned to survey areas using GIS Software, and maps showing seasonal survey effort and seasonal geographic coverage per survey area were prepared.

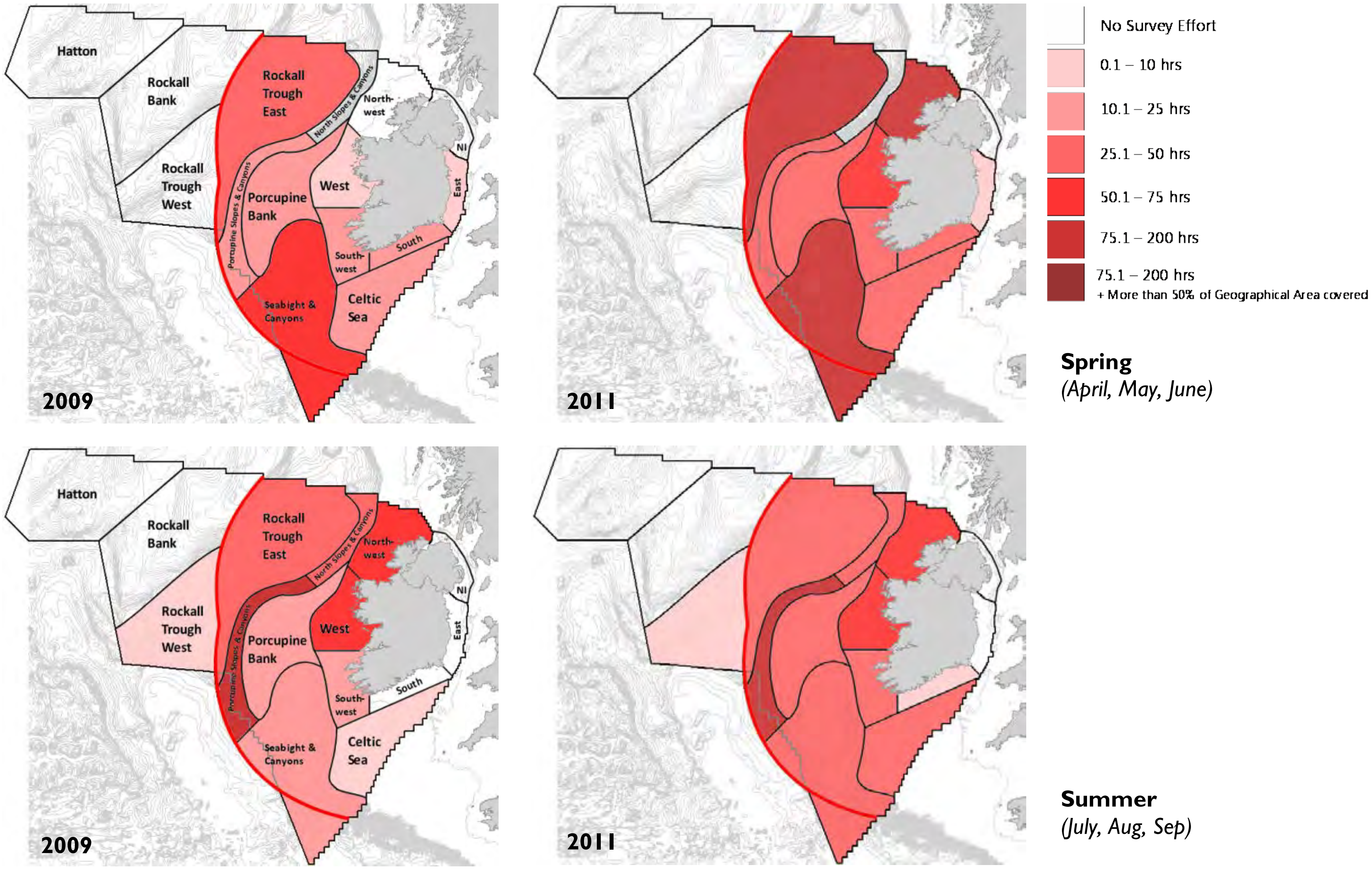

Figure 2.5a: Maps showing the increase in accumulated survey coverage (hours of survey effort) allocated to the 15 survey zones between spring/summer 2009 and spring/summer 2011

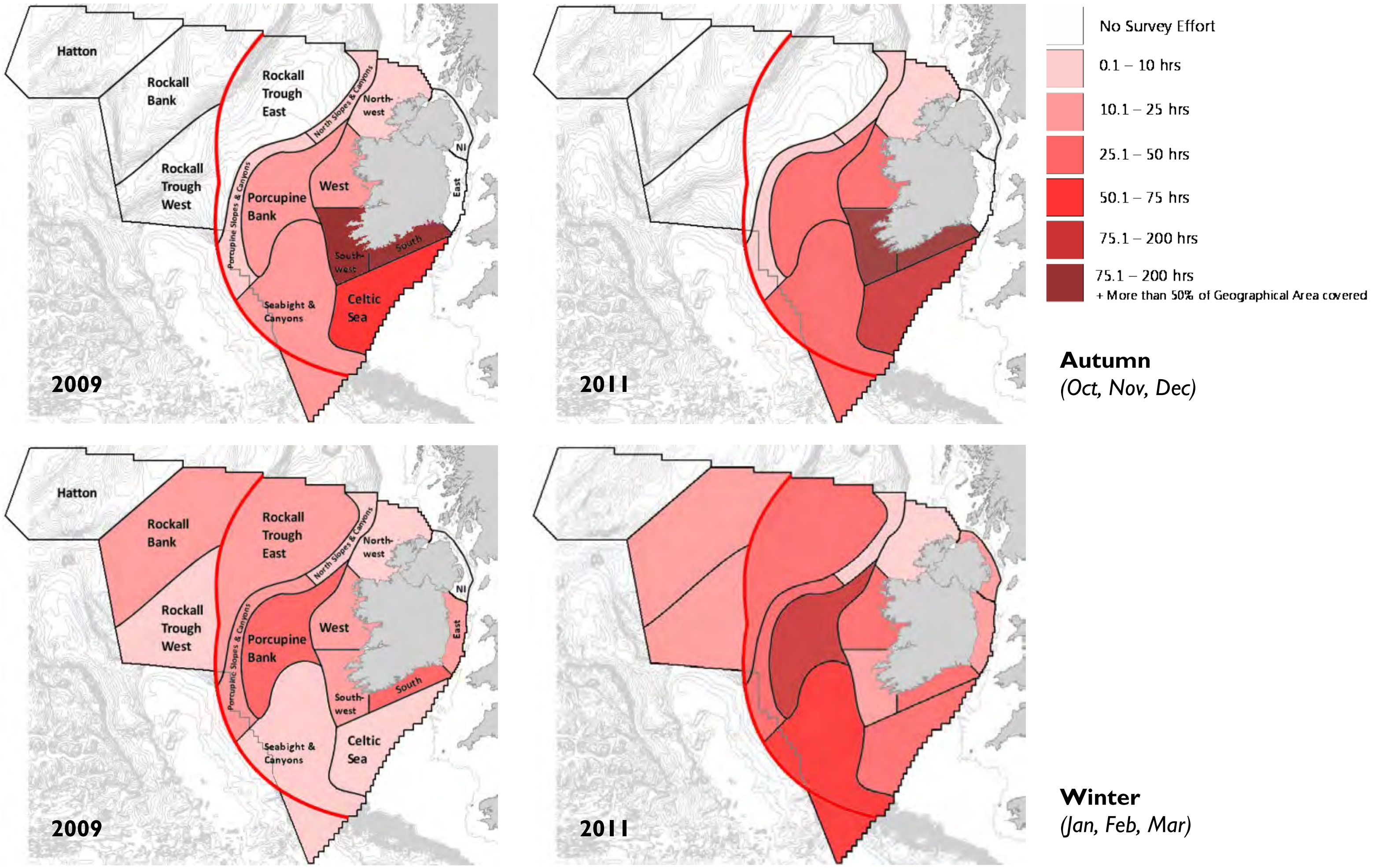

Figure 2.5b: Maps showing the increase in accumulated survey coverage (hours of survey effort) allocated to the 15 survey zones between autumn/winter 2009 and autumn/winter 2011

2.5. Assessment of the Use of Airborne Radar for Detecting Cetaceans

The number of sightings which were detected first by radar was low with only three confirmed detections. In discussion with the Air Corps radar operators, radar detections of cetaceans were most likely to occur in very calm sea states (Beaufort 2 or less) when objects such as buoys were also detectable. Larger groups of animals were more likely to be detected than smaller groups because in large groups, some proportion of the animals are always at the surface whereas small groups or individuals only offer an intermittent radar signal. Both large whales and groups of dolphins were detected by the radar and a maximum detection range of 2,500m was recorded for one large rorqual. It is doubtful that radar could be used to survey for cetaceans in anything but the calmest sea states, when there is no swell.

2.6. Assessment of the Occurrence of Bottlenose Dolphins in Offshore Habitats

An assessment of the use of offshore habitats by bottlenose dolphins was conducted, summarising what is known of their offshore distribution and habitat preferences in Irish waters. Offshore bottlenose dolphins appeared to show a discernible preference for continental slope habitat in contrast to the reported preferences for coastal and estuarine habitats exhibited by inshore dolphins. This study and the results of previous studies indicate that although bottlenose dolphins occur regularly in offshore habitats, they are at relatively low population densities and likely to be highly mobile. Data from dorsal fin photo-identification, when coupled with the latest published data on Irish bottlenose dolphin population genetics and distribution data from visual surveys, suggests that an offshore ecotype of bottlenose dolphin may exist within the Irish EEZ. The probable presence of an offshore population of bottlenose dolphins within the Irish EEZ warrants further targeted survey effort, incorporating genetic sampling, acoustic recording, and photo-identification studies.

2.7. Assessment of the Timing and Use of the Rockall Trough Migration Corridor by Large Rorquals

The seasonal use of Irish coastal and offshore habitats as foraging and migratory areas for large rorquals (baleen whales) was assessed. Data on the monthly distribution of large rorquals within the Irish EEZ collected during PReCAST was limited by the distribution of survey effort. However, a pattern of large rorqual distribution was evident from the data (figure 10.2). Large rorquals appeared to be generally absent from the Irish EEZ during March, April and May.

From June through to January, large rorquals were detected in the deeper waters of the Irish Shelf edge, the slopes of the Porcupine Bank and the Rockall Trough. Particularly high densities were recorded along the edge of the Irish Shelf and the Porcupine Bank in August and September. However, a lack of survey effort in shelf slope habitats in October, November, and December did not allow for assessment of densities along the shelf edge in these months. This is largely in agreement with Chariff *et al* (2001 & 2009), who reported blue and fin whales detected acoustically by the US military SOSUS hydrophone array from June through March, with migrating fin whales moving south along the western shelf slopes from August to February and blue whales from July to January.

The majority of large rorquals recorded off the south coast and along the shelf edge during PReCAST were fin whales. Humpbacks were present in far fewer numbers and most sightings were recorded off the south coast. On two occasions, single humpback whales were recorded over the Porcupine Bank. Only one sighting of a blue whale was confirmed, over the northwest slopes of the Porcupine Bank.

Little is known of the relationship between migratory large rorquals, which occur annually along the Irish shelf slopes, and the animals which forage in waters off the south coast each autumn and winter. Further research is required to define the relationship between the two events and to identify which Atlantic populations the large rorquals occurring in Irish waters belong to.

2.8. Discussion

This is the fifth large cetacean dataset to be collected in Irish waters and only the third multi-seasonal and multi-annual data set. A number of different methodologies have been used to gather cetacean data in Irish waters, including European Seabirds at Sea (ESAS) surveys (Reid *et al,* 2003), Petroleum Infrastructure Programme (PIP) surveys (O'Cadhla *et al,* 2004), SCANS-II, and CODA (Hammond *et al,* 2006; 2011). It is not clear how differing survey methods may have affected the detection rates for different cetacean species. Reid *et al* (2003) and O'Cadhla *et al* (2004) employed European Seabirds at Sea (ESAS) survey methods, which are designed primarily for seabird surveying and *'significantly reduced the observer's likelihood of detecting cetaceans outside the relatively narrow field-of-view on one side of the moving vessel'* (O'Cadhla *et al,* 2004). Hammond *et al,* (2006; 2011) used double-platform distance sampling to derive density and absolute abundance estimates in 2005 and 2007. However, both surveys covered only the single month of July.

Detection distance data for cetacean sightings collected during the present study indicate that adherence to a 300m survey box will lead to significant under recording of species which actively avoid survey vessels (e.g. offshore bottlenose dolphins) and whale blows, which tend to show against the horizon. A possible example of the effects of the two differing survey methods is in the low numbers of fin and sperm whales detected by O'Cadhla *et al* (2004) compared to those detected during the present study. One must, therefore, be cautious when assuming apparent increases in the occurrence of certain species when comparing data collected by different survey methods, unless that increase is supported by other data, for example, if the apparent increase in fin whale occurrence is in agreement with increased sightings of this species off the south coast of Ireland (Whooley *et al*, 2011), and indications of fin whale stock recovery are evident in some North Atlantic populations during the last stock assessment in 2006 (Reilly *et al*, 2008).

The problems encountered in comparing cetacean distribution and abundance data collected by different survey methods could be reduced in future by agreeing a standard methodology for European cetacean surveys. The Atlantic Research Coalition (ARC) has progressed this issue through working to standardise line transect survey methods conducted by researchers on commercial ferries in northwest European waters (Brereton *et al,* 2009).

2.9. Priorities for Future Cetacean Monitoring on board Platforms of Opportunity

The availability and suitability of platforms of opportunity operating within the Irish EEZ from 2009 to 2011 was analysed with a view to assessing the potential for future cetacean monitoring effort using such platforms. Between January 2009 and December 2011, some 3,019 survey days were scheduled by Irish and foreign research vessels for surveys conducted partially or completely within the Irish EEZ. To provide a monitoring programme within the framework of the requirement for reporting to the EU on the favourable conservation status of Irish cetacean species, no single survey or survey method will provide robust data on all cetacean species in Irish waters.

In an effort to prioritise surveys to be targeted by ongoing visual cetacean survey effort, platform suitability was prioritised based on a number of factors, including predicted visual survey hours achievable per day at sea, survey geographical and seasonal coverage, habitat types targeted and data value enhancement from concurrent data collection by the host survey. Priority one surveys included surveys providing wide geographic coverage along fixed transects and were repeated annually (or triennially), e.g. the southwest herring acoustic survey and mackerel egg surveys. Priority two surveys provided reasonable spatial coverage of habitats in seasons outside of those covered by the priority one surveys, e.g. the Irish groundfish and deepwater surveys. Priority three surveys targeted specific habitats, species or temporal periods which were difficult to achieve using other surveys, e.g. deepwater canyon surveys and one-off surveys offering wide spatial coverage. Additional survey effort for the purposes of filling data gaps may be achieved using other platform types, such as naval service patrols. In addition to the use of platforms of opportunity, targeted dedicated visual and acoustic surveys of specific species and habitats will be required to achieve specific conservation or monitoring goals.

Protocols for the collection and storage of visual cetacean survey data from ships and aircraft of opportunity were developed based on survey experience, scientific best practice, and ensuring compatibility with European data sets and data storage protocols.

Overall, the results show a high level of diversity of cetacean species and in the spatial and temporal use of offshore marine habitats by cetacean and megafauna species in Irish waters. The use of platforms of opportunity provided a highly cost-effective means of surveying a wide geographical area and of obtaining seasonal information on the abundance and distribution of cetaceans within the Irish EEZ. The collection of cetacean data alongside oceanographic, fisheries, and habitat data enhanced the value of the data collected. Multidisciplinary data collection also allowed for current and future analysis of spatial and temporal use of marine habitats by cetaceans in terms of the physical, chemical, and biological characteristics of those habitats and is highly compatible with an ecosystems approach to managing marine resources such as fish stocks.

3. Developing Acoustic Monitoring Techniques

Cetaceans live in an acoustic world and increasingly acoustic techniques are being developed to determine their distribution and behaviour. Visual survey methods are strongly influenced by light, weather conditions and sea state, especially for species such as the harbour porpoise or deep diving species like beaked whales. Increasingly, acoustics are used as an alternative to, or simultaneously with, visual methods for monitoring cetacean species or important habitats. Several areas have been the target of seasonal acoustic monitoring on the west, south and east coasts of Ireland (O'Cadhla *et al,* 2003; Ingram *et al,* 2004; Englund *et al,* 2006; Coleman *et al,* 2008; Berrow *et al,* 2008; Berrow *et al,* 2009a), but only a few studies have focused on an area for more than six consecutive months. These include O'Brien (2009), who focused on a single site in both Galway Bay and Clew Bay, and Anderwald *et al* (2011), who have been continuously monitoring Broadhaven Bay in Co Mayo since 2009.

This study aimed to assess acoustic monitoring techniques as a means of addressing monitoring obligations under the EU Habitats Directive for Annex II species (harbour porpoise and bottlenose dolphin). The use of biosonar by porpoises and dolphins has been extensively studied (Au, 1993), and it has been shown that porpoise and dolphin sonar characteristics differ greatly from each other, making it possible to differentiate between these species. Bottlenose dolphins have peak frequencies at 70kHz but unlike harbour porpoises, they do not constantly echolocate. Three commercially available Static Acoustic Monitoring (SAM) devices were compared and assessed for their suitability during inshore long-term SAM programmes. Static Acoustic Monitoring is so named as it is deployed in a stationary location and left for a period of time to monitor the surrounding environment. Three sites were monitored acoustically for two years to create a dataset from which monitoring indices could be derived. Additionally, the first deployments of Deep C-PODs, a unit capable of deployment to depths of 2000m, were done in offshore waters. Passive Acoustic Monitoring (PAM) was carried out from platforms of opportunity and was also assessed for its suitability in detecting cetaceans. PAM is carried out from moving vessels, and differs from SAM in that sense. Similar equipment can be used to carry out the two types of deployments (SAM and PAM) but results are different in that different spatial scales can be monitored. Protocols of best practice for SAM and PAM were developed.

3.1. Assessment of SAM devices

Three commercially available SAM units were assessed: T-PODs and C-PODs, both manufactured by Chelonia, and AQUAclick, made by Aquatec Group Ltd. Both manufacturers are UK based. All three units are fully automated, static, passive systems which can detect porpoises, dolphins, and other toothed (odontocete) whales by recognising the trains of echolocation clicks. Although SAM, once deployed, is independent of weather conditions and thus ensures high quality temporal data, the units only operate at a small spatial scale and, at present, cannot reliably distinguish between dolphin species.

Figure 3.1: T-POD, C-POD and AQUAclick SAM units

When using SAM DEVICES, there are a number of issues to consider which can influence their effectiveness. This includes handling of equipment, deployment methods and duration, downloading, analysis, and available software and reliability.

The most immediate issue is deployment, and a number of problems were encountered with moorings during the study, including damage, theft, and reliability of acoustic releases, mooring malfunction, and adverse weather. Five mooring designs were used during the present study: i) light-weight moorings, ii) heavy-weight moorings, iii) bottom-mounted acoustic releases (AR), iv) existing structures such as jetties, and v) already established moorings, including a wave platform device and navigational buoys. Light-weight moorings deployed coastally are vulnerable to disturbance and interference. However, with regular maintenance, these moorings can last year round in sheltered inshore environments that have a low fishing intensity. Heavy moorings were deployed at two locations in the Blasket Islands cSAC due to the exposed nature of this site. These moorings were deployed in February and equipment was due to be serviced in May but, when this was attempted, it was discovered that the pulley system design had snagged. Divers were brought on site to retrieve gear but all equipment was missing from both moorings. The mooring choice shifted to Acoustic Release Arrays after this episode in order to reduce drag on the array and not highlight the arrays position through eliminating the need for a surface marker. The use of a wave energy platform was used successfully as were more permanent structures such as jetties. The most successful mooring types used during the present project were existing structures and acoustic releases. All units were moored in the same manner and were robust enough to survive all environmental conditions.

Where servicing of SAM devices had to take place at sea, C-PODs proved to be the easiest to handle, as only an SD card and battery had to be changed. TPODs and AQUAclicks need to be down-loaded in a controlled environment, as internal components are exposed and units can take hours to download. Additionally, AQUAclicks need to recharged in the lab and, therefore, replacement units are required when servicing.

Chelonia Ltd, manufacturers of C-POD and T-POD units, provide extraction and analytical software. This software can extract click trains per minute, hour or day, as required, It can process a long deployment of 150 days in around three hours. AQUA*view* software for AQUAclicks does not include a detection algorithm and thus can only extract click data.

If multiple units are involved in a monitoring programme, it is good practice to keep an accurate record of their deployment history. These should include location, deployment duration, depth, accompanying units if deployed, average file size from deployment, as well as results from field calibrations and analysis, as this will help to identify less efficient units.

Monitoring was carried out in the only candidate Special Area of Conservation (cSAC) for bottlenose dolphins in Ireland, the Lower River Shannon cSAC, and one of the two cSACs for harbour porpoises (Blasket Islands cSAC) (Fig. 3.2). Only bottlenose dolphins occur in the Lower River Shannon which excludes the possibility of harbour porpoise detections. In addition, Galway Bay was also monitored as both harbour porpoise and bottlenose dolphins are known to use this site.

3.1.1. Calibration of SAM devices

Variation in sensitivity between SAM units is known to occur and can have a large influence on data analysis and interpretation. Therefore, calibration is highly recommended in long-term monitoring programmes. Neither the T-PODS nor AQUAclicks were rigorously calibrated prior to supply. C-PODs are calibrated to a standard prior to dispatch and do not require further tank calibration. However, calibration in the field is recommended. We carried out a number of field calibration trials in Galway Bay and the Shannon Estuary in order to assess differences in PAM device sensitivity. A total of nine trials were carried out using 27 individual C-PODs, four T-PODs and three AQUAclicks.

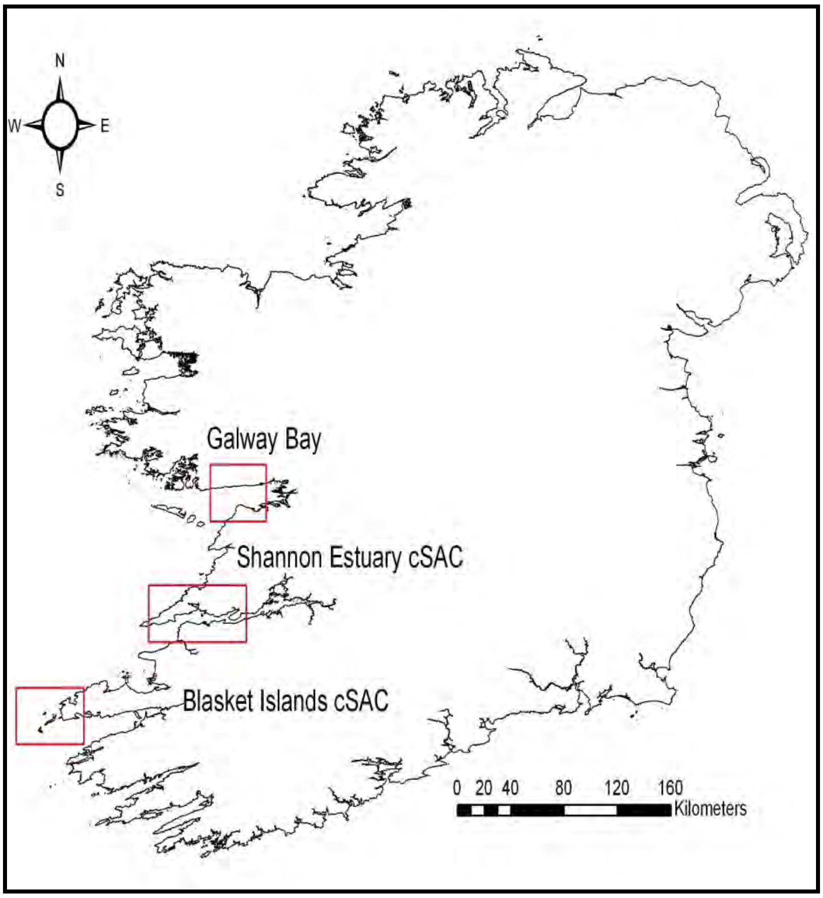

Figure 3.2: Areas where SAM was carried out on the west coast of Ireland

Results from the first calibration in Galway Bay showed that all C-PODs performed very similarly, while there was some deviation in the T-POD data (Fig. 3.3). The AQUAclick data had no reflection of either the C-POD or T-POD data, and the units only have a battery life of around 14 days, whereas a C-POD can last for up to 150 days. Additionally, AQUAclick data extraction had to be done by eye so extraction parameters could not be generated to facilitate a comparison with C-PODs. AQUAclicks were subsequently excluded from the study. The majority of C-PODs performed within a margin of error of 20% (Fig. 3.4). It is recommended that field trials be sufficient to monitor C-POD performance and to identify outliers that may need to be re-calibrated. Field calibrations are also necessary when introducing new units to an existing study, and calibrations should be carried out every 12 months as it is likely that C-PODs may lose sensitivity over time. It is also recommended that field trials should involve a minimum of three units at a time to assist data interpretation.

In order to assess the effectiveness of T-PODs and C-PODs, simultaneous deployment of units was carried out at Moneypoint in the Lower River Shannon cSAC and in Galway Bay. A total of 189 days were compared from Spiddal in Galway Bay, where, on average, C-PODs detected seven times more DPMs that the T-POD. A similar comparison was carried out on the Moneypoint data to assess inter device performance for dolphin detections. A total of 154 days were compared at the site, and results showed that, on average, C-PODs detected four times more DPMs than T-PODs.

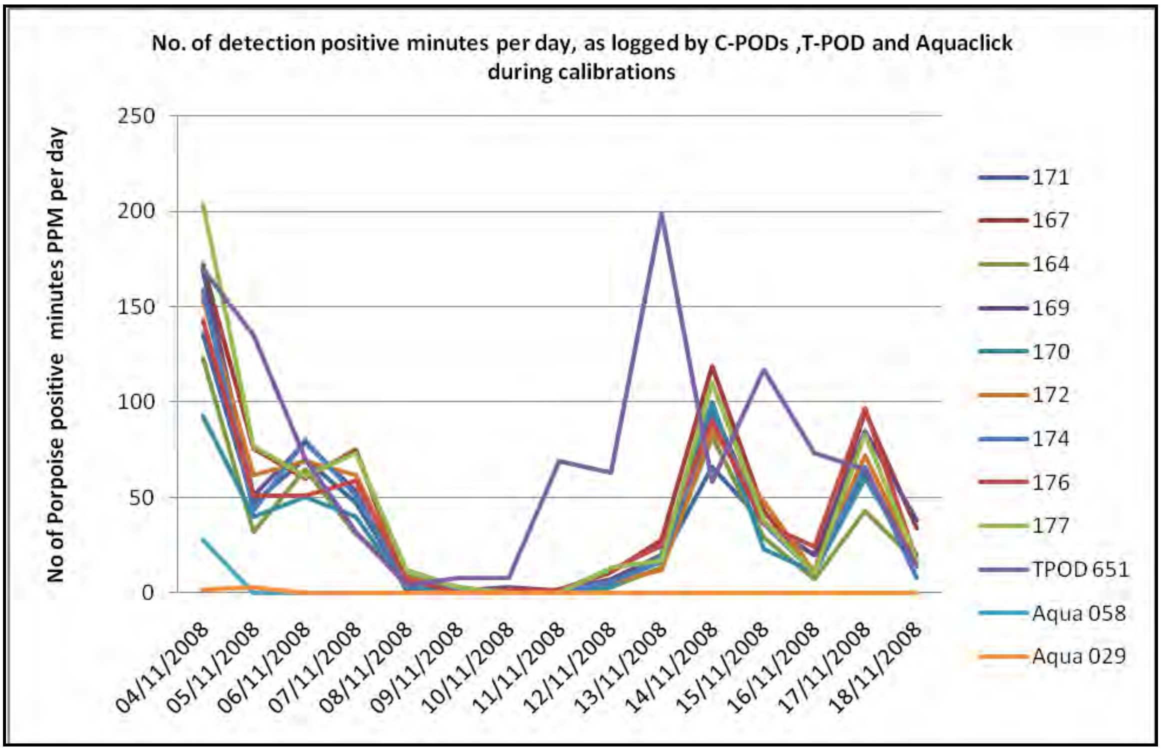

Figure 3.3: Results from calibration trial in Galway Bay using C-POD, T-POD and AQUAclicks

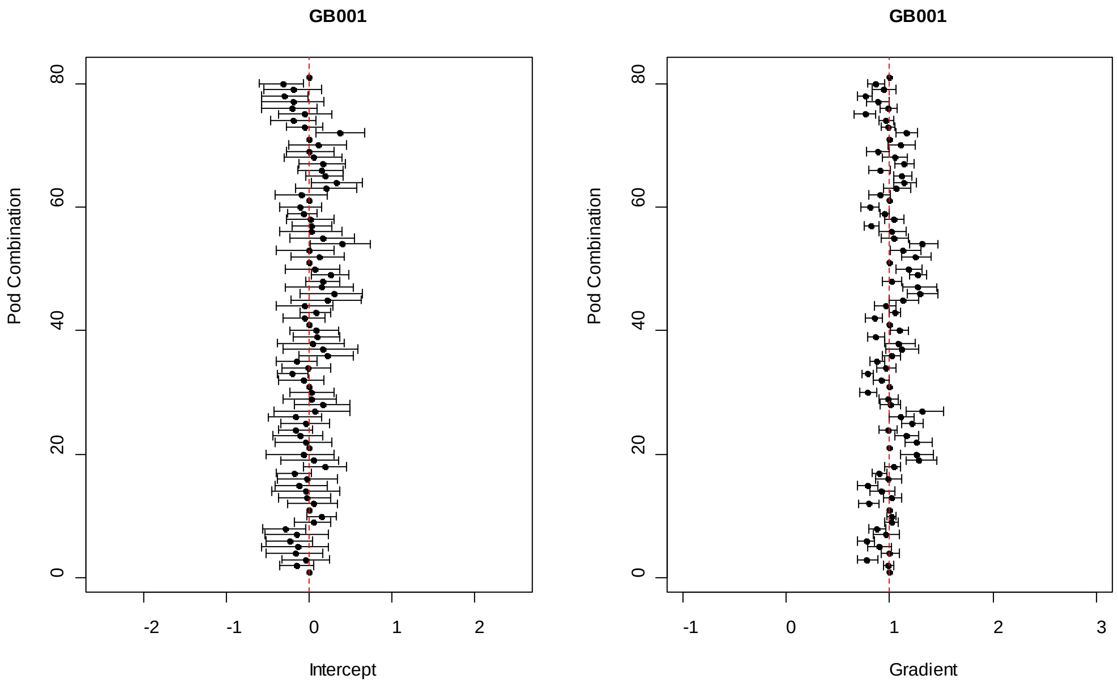

Figure 3.4: Centipede plot for each C-POD in a calibration trial. Red dotted lines indicate deviation from the null model that both pods are performing the same

3.1.2. Estimation of detection range

If SAM is to be used to monitor cetaceans and inform conservation management, it is essential to determine the detection range of the equipment. Trials were carried out at two locations to determine the detection range of two acoustic devices, C-POD and T-POD, for both harbour porpoises and bottlenose dolphins. Land-based theodolite tracking was carried out and animal positions were mapped using Cyclops Tracker. During 39 hours of observations from Black Head in Galway Bay, 36 harbour porpoise groups were tracked, of which 81% were detected on the C-POD and 50% on the T-POD. Minimum detection distances for C-POD ranged from 20 to 431m, with 97% of groups detected within 400m. The T-POD detection distances ranged from 110 to 454m, with 83% of groups detected within 400m. A second analytical technique used 50 harbour porpoise acoustic matches with the C-POD and 27 matches with the T-POD. The maximum distance that a visual observation corresponded to an acoustic detection was 441m ± 42m (92% <400m) for the C-POD and 534.3m ± 42m (59 % < 400m) for the T-POD.

During 47 hours of visual observations in the Shannon Estuary, a total of 30 bottlenose dolphin groups were tracked at distances ranging from 48 to 6,732m from the SAM equipment, of which 23% were detected on the C-POD. The minimum detection distances ranged from 83 to 284m. A second analytical technique recorded a minimum detection distance of 798m ± 61m, with 75% of groups recorded within 400m.

Limited spatial coverage can be overcome with the deployment of many units within an area to achieve a more even spatial coverage. If multiple units can be used in a programme, the strategic placing of moorings could enable the tracking of movements.

3.1.3. Long-term static acoustic monitoring

Long term datasets of up to two years were to be collected acoustically to explore the occurrence of small cetaceans at three sites (two candidate SACs) on the west coast of Ireland. The efficacy of SAM and its potential as a monitoring technique was addressed as well as exploring the feasibility of an acoustic monitoring index of activity at a site. Long-term SAM was carried between January 2009 and February 2011, which are the longest acoustic datasets collected to date from cetacean cSACs in Ireland. Results for all sites are shown in Table 3.1. Harbour porpoises were the most frequently detected species in Galway Bay and the Blasket Islands, and bottlenose dolphins were the only species recorded in the Lower River Shannon cSAC. At the Wave Energy Test Site off Spiddal in Galway Bay, a total of 572 days were monitored, with harbour porpoise detected on between 92% (T-POD) and 95% (C-POD) of days while dolphins were rarely recorded (4%). In the Lower River Shannon cSAC, C-PODs were deployed off Foynes Island for a total of 591 days, with dolphins recorded on 41% (C-POD) of days, and at Moneypoint for 641 days, with dolphins detected on 73% of days. In the Blasket Islands cSAC, C-PODs were deployed for 264 days off Inishtooskert, 289 days off Wild Bank and 52 days off the Gob at Great Blasket. Harbour porpoises were detected on 89% of days off Inishtooskert, on 76% of days off Wild Bank and on 94% of days off the Gob.

Table 3.1: Results of C-POD deployments from all sites along the west coast

C-POD deployments											
				NBHF	NBHF	NBHF	NBHF	Dolphin	Dolphin	Dolphin	Dolphin
Location	Total Days	Total Hours	Total Min	DPD	Total DPM	% DPD	% DPM	DPD	Total DPM	% DPD	% DPM
Spiddal	572	13664	819840	541	27902	94.58	3.40	24	125	4.218	0.02
Inishtooskert	264	6296	377760	236	3930	89.394	1.04	64	181	24.242	0.05
Wild Bank	289	6874	412440	221	2097	76.471	0.51	46	252	15.917	0.06
The GOB	52	1213	72780	49	3015	94.231	4.14	2	2	3.846	0.003
Moneypoint	641	15308	918480	103	235	25.741	0.03	466	4010	72.699	0.44
Foynes	591	14062	843720	46	69	7.797	0.01	244	1158	41.356	0.14

The percentage of minutes with detections during all minutes monitored (%DPM) was the most effective monitoring index of activity across sites and factors. This index can be generated across various temporal scales and, therefore, can be used to compare activity between sites. The highest index for harbour porpoise was recorded in Galway Bay (3.4), while the Blasket Islands ranged between 0.51 and 4.14 (Inishtooskert and the Gob). However, the deployment at the Gob was only for two months. For bottlenose dolphins, Moneypoint (0.44) had a higher overall index than Foynes Island (0.14).

3.1.4. Habitat use as determined through SAM

Investigating patterns of cetacean presence over seasonal scales, diel cycles, and tidal patterns is important to ensure successful monitoring of a protected species. Data were extracted as the number of hours with detections during the monitoring period (Detection Positive Hours - DPH). Data were categorized into season, diel, tidal phase, and tidal cycle. Season was categorized as spring, summer, autumn, and winter. Diel cycle was split into four phases and tidal phase was classified according to the phases of the moon.

All four variables were found to significantly affect the presence of bottlenose dolphins off Moneypoint in the Lower River Shannon cSAC. Tidal cycle had the greatest influence, with the highest proportion of detections occurring during an ebbing tide and at slack low tide. Seasonal differences in bottlenose dolphin presence were also found to be significant, with a higher detection rate in winter and summer than both autumn and spring. Significant variance in DPH across diel cycle was attributed to a higher level of detections during the night and in the morning during spring tides in comparison to neap tides. A similar pattern was found off Foynes Island, with a peak in detections during spring which gradually decreased throughout summer and autumn, with winter showing the lowest detections. Diel cycle was also found to be significant, with higher detections during the night and morning and lower detections during the day and evening. In contrast to Moneypoint, detections were greater during neap tide, which was attributed to a drop in detections during slack high water. In Galway Bay, there was a peak in harbour porpoise occurrence during autumn and winter in 2009 and winter in 2010. The night and morning phases had a greater level of harbour porpoise detection. There was a significant drop in detections during slack low water in 2009 but a slightly higher level of detections during an ebbing tide in 2010. No data were collected in October 2010, which is thought to have influenced these apparent in-seasonal patterns. In the Blaskets Islands, cSAC data could not be analysed by year due to gaps in the dataset caused by equipment theft, so all data were pooled. Season and diel were both found to significantly affect harbour porpoise detections, with a peak during autumn and winter and during the day, and a decrease throughout evening, night, and morning.

Seasonal as well as temporal trends, such as diel and tidal influences, can be detected through SAM more readily than through visual methods. SAM can be used to predict times of the year when abundance is high, as reflected by increased detections, and visual surveys should focus on this period.

3.1.5. Behaviour as determined through SAM

SAM can be used to assess behaviour by some cetacean species, such as foraging, approach behaviour, and communication. Different species of odontocetes that echolocate have different characteristics associated with their click production, such as click duration, Inter-Click-Interval (ICI), frequency, source level, and range, that enable researchers to identify specific species and behaviours (Au, 1993). Feeding buzzes and click bursts have been described in many odontocete species (Leeney *et al,* 2011 [Heaviside's dolphin]; Herzing, 2000 [bottlenose dolphin]; Miller *et al,* 1995 (narwhal; *Monodon monoceros*)). Variation in ICI has been used as an indicator of certain behaviours in cetaceans (Wahlberg, 2002; Carlström, 2005; Koschinsksi *et al,* 2008; Akamastu *et al,* 2010; Leeney *et al,* 2011).

A total of 144,216 click trains were recorded in Galway Bay, with a mean number of clicks per train of 15, 175.5 clicks per second and a frequency of 130.7kHz. Most click trains (41%) were categorised as foraging, suggesting the site at Spiddal was an important foraging area. There was little variation in foraging clicks between season, diel, tidal cycle, and phase, but foraging clicks did peak during the winter months. C-PODs were deployed for 605 days in the Blasket Islands sites, during which 38,398 NBHF click trains were extracted for analyses. The data were analysed separately, according to site, in order to assess fine-scale differences in site usage. Three variables were found to significantly affect the level of foraging behaviour of harbour porpoise at Inishtooskert and at Wild Bank. At Inishtooskert, diel was shown to be the most significant variable, with a peak in feeding buzzes during the day and morning phases. Tidal cycle also significantly affected the level of feeding buzzes, with a predicted rise in foraging click trains during a flooding tide. Seasonal peaks in foraging were also observed during the autumn. At Wild Bank, both seasonal and diel were the most significant variables, with a peak in predicted rise in feeding buzzes during the summer, evening and night-time phases. At the Gob, diel was the most significant variable, with a predicted peak in feeding buzzes during the night-time phase. At Moneypoint, a total of 14,169 dolphin click trains were recorded, with a mean of 14.5 clicks per train, 37.5 clicks per second and a frequency of

72.6kHz. Of these click trains, 7% were classified as foraging with no peaks across season, suggesting Moneypoint was an important foraging area throughout the year. At Foynes Island, 9.4% were classified as foraging, with a substantial peak in foraging clicks during autumn.

3.2. Passive Acoustic Monitoring (PAM)

Acoustic monitoring can detect cetaceans which are beyond visual detection and which operate during darkness and in high sea states. PAM was carried out using a towed hydrophone array, consisting of a 200m cable with two hydrophone elements. The hydrophone connects to a buffer box which ran through a laptop computer, connected to a soundcard. This allowed detection of high frequency echolocation clicks outside the capability of a standard computer soundcard. Detection software used included PAMGUARD, which is a fusion of the IFAW and Ishmael software. It has applications such as click detectors, tonal whistle detectors and the capability to calculate bearings on maps, record a track log, as well as having a spectrogram viewer, detection energy display, and built-in filters.

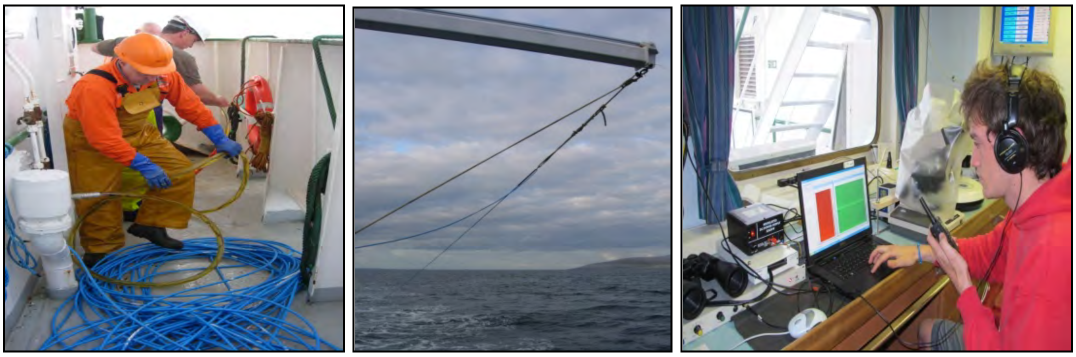

Figure 3.5: Towed hydrophone deployment and real-time monitoring

PAM was carried out on board R.V. *Celtic Explorer* travelling at an average speed of seven to 10 Knots. PAM surveys were usually carried out concurrently to visual surveys. Six PAM surveys were carried out, of which two were on dedicated cetacean cruises. A total of 533 hours of acoustic effort was collected over 55 days. Up to 300 visual sightings were collected by visual observers during the six surveys, of which 51 occurred simultaneously with acoustic data. Only acoustic detections with simultaneous visual sightings were used to assess the effectiveness of PAM. The low level of matches between simultaneous visual and acoustic surveys was most likely due to animals not vocalising or echolocating or perhaps being beyond the detection range of the PAM equipment.

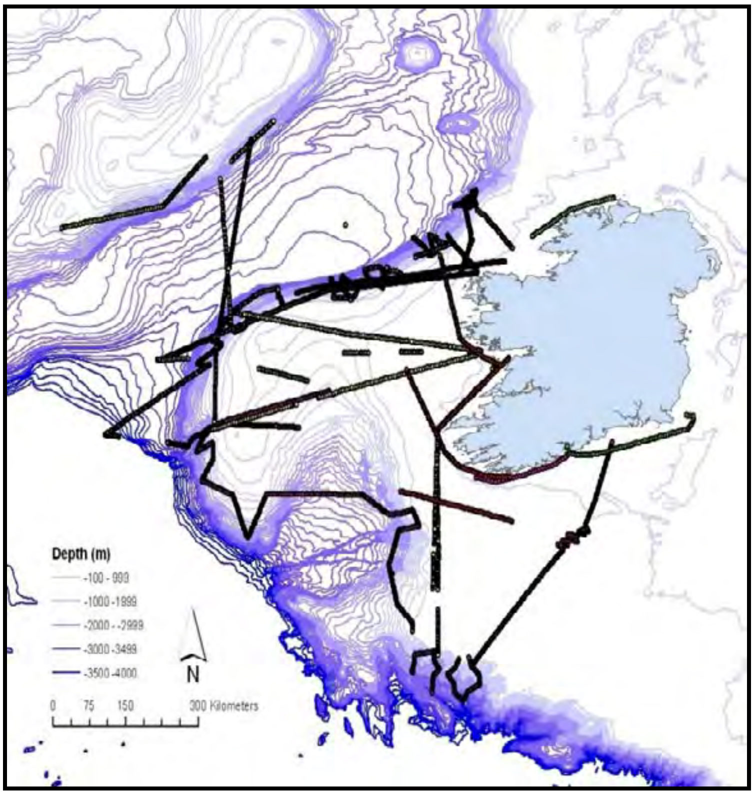

Figure 3.6: Map showing the total PAM effort carried out from the R.V. Celtic Explorer

A total of 422 acoustic encounters were identified, of which 99 were identified to species level, namely sperm whale, harbour porpoise, and long-finned pilot whale. As with visual data, acoustic detections can be plotted to determine species distribution. Species identification can prove difficult, and there is no information on abundance. It is recommended than an observer, or PAM operator, be always assigned to acoustic collection. This facilitates ease of identification of detections but also assists in species identification and analyses. It is also recommend that PAM analyses be carried out by a trained observer, as results from the automated setting of the PAMGUARD software have a very high rate of false positives, especially for whistle detection.

3.3. Best Practice for SAM and PAM

If SAM is to be used as a means to fulfil obligations under the EU Habitats Directive and to report on "Favourable Conservation Status" (FCS) for a species, then a number of factors need to be considered. The target species in an area needs to be identified and the SAM sampling strategy determined. We recommend that the area to be monitored should be stratified into pre-defined geographical grids during the planning stage. The minimum number of units to be deployed in a small inshore study area should be four to ensure that statistically robust data can be collected.

We recommended C-PODs for SAM because both C-PODs and T-PODs functioned well over long periods while the AQUAclick only worked for 14 days. AQUAclicks require servicing every 14 days, adding additional cost to a project and increasing the likelihood of gaps in a dataset due to adverse weather preventing recovery and deployment. The battery life of a C-POD is long at approximately five months while T-PODs lasted, on average, three months. The biggest gap in long-term SAM in the Shannon Estuary was due to equipment failure, where on two successive deployments the data failed to read to the SD card. This was the only problem encountered with C-PODs over the duration. However, T-PODs malfunctioned on a number of occasions and could not always be successfully downloaded. C-POD and T-POD deployments were carried out simultaneously in Moneypoint and Galway Bay to assess differences between devices. C-PODs recorded 39% more DPM than T-PODs for harbour porpoise and 29% for dolphins. The results would suggest that previous datasets collected at these sites using T-PODs would need to be converted if they were to be compared with C-POD data. Where T-POD data has been collected at other sites, we would recommend that a trial simultaneous deployment of both devices be carried out so to assess the differences between the two for specific sites and species. T-PODs are no longer manufactured but there are many still available for use.

3.4. Monitoring Index for Favourable Conservation Status

We recommend the use of %DPMs as a monitoring index. This index can, therefore, be used to compare data between sites even when the number of samples (hours monitored) from different areas is unbalanced over various temporal scales. It also serves to compare with other short-term studies where time scales do not extend beyond a few months but an index can be generated for, for example, a month and compared accordingly. This index will also allow for comparison with T-PODs data. The monitoring index could serve as an effective monitoring indicator of changes in the presence of odontocetes in an area over time and inform management of changes. A baseline, or reference dataset, will need to be collected for an area, probably in the region of two years before this monitoring index can be used to its full potential, or used to evaluate a site on an annual basis.

4. Biotelemetry of Marine Megafauna in Irish Waters

Biotelemetry is the transmission of information from biological organisms through the atmosphere by radio waves (Mech and Barber, 2002). This information may be physiological or behavioural. Signals originating from within an animal can also be monitored, amplified and stored or transmitted. Biotelemetry can also encompass measurements of animal activity, for example, dive depth, duration, and profile or sound generation. A broader definition would encompass the use of devices that record environmental variables such as salinity and temperature while attached to an animal. Finally, and perhaps more relevant to the current study, the use of devices that permit the recording and transmitting of the position of an animal are also included under the umbrella term of biotelemetry, though this may be more appropriately termed tracking.

Although biotelemetry is a relatively new technique in Ireland, it has been used on a range of species, including common and grey seals, tuna, sunfish, basking and blue sharks and otters. These studies have revealed unique insights into many aspects of their ecology. To date, there has been no biotelemetry study of cetaceans in Ireland. As part of the present project, we were requested to carry out research that will contribute to best practice in the use of biotelemetry for the monitoring of cetaceans in Irish waters. This was to be achieved by carrying out a review of biotelemetry of marine megafauna in Irish waters and to gain practical experience by attempting to satellite tag fin whales in the Celtic Sea. The latter data would also contribute to the work on ecosystem links in the Celtic Sea (Chapter 5).

4.1. Review of Biotelemetry of Marine Megafauna in Ireland

A number of reviews on the use of telemetry for marine mammals (Costa, 1993; Stone and Kraus, 1998; Mate *et al,* 20007; Weller, 2008; Godley and Wilson, 2008; Bograd *et al,* 2010) and sharks (Simms, 2010) have recently been carried out. This present study aims to summarise recent knowledge in the use of biotelemetry for tracking cetaceans such as whales, dolphins, and porpoises and other marine megafauna, as relevant to Ireland.

A number of techniques and tag types are available for biotelemetry (Table 4.1). Radio-telemetry involves the use of High Frequency (HF) and VHF (Very High Frequency) radio-waves to transmit a signal from a tag to a receiver. The conventional GPS satellite tag, which enables tracking over a huge global range, has recently been refined by incorporating a Fastloc or GSM facility to address some constraints concerning data transfer or time required to send positional data. Some tags (SLTDR and SDR) include data on depth to reconstruct dive profiles. Archival (PAT) tags are used on fish (e.g. sharks, tuna) that are not clear of the surface to transmit positional data.

Table 4.1: Summary of tags available for biotelemetry

Technique	Tag type	Benefits	Constraints
Radio-telemetry	HF/VHF	Wide range of potential study species, cost effective	Restricted range
Satellite telemetry	Global Positioning System (GPS)	Huge range to track highly mobile species	Expensive, limited data transfer via satellite
	Fastloc GPS	More precise positional data as it requires study animal to be at surface for very short period	Additional expense on top of GPS tag
	Pop-up Archival Tags (PAT)	Tracks animals not at water surface	Not real time tracking. Resolution of positional data poor as track reconstructed
	Satellite-Dive-Recorders (SDR)	Includes data on depth, water temperature	Additional cost of tag
	Satellite-Linked Time-Depth-Recorders (SLTDR)	Includes data on depth, water temperature	Additional cost of tag
	Satellite Relay Data Loggers (SRDL)	Includes data on depth, water temperature and speed	Additional cost of tag
	Conductivity-Temperature-Depth SRDL	Includes data on salinity (conductivity) and temperature as well as depth	Additional cost of tag
GSM Phone Tags	Global Systems for Mobile Communication (GSM) Phone tag	Large data-set recovered, long battery life as energy efficient	Requires study animal to come ashore or occur coastally

Radio-telemetry of marine megafauna is very limited. Early tracking of odontocetes used radio tags bolted through the dorsal fin or attached via a harness. Although animals had to be captured to have tags attached, the authors reported no reaction to the tag. These studies showed considerable movement of harbour porpoises of up to 15 to 20km per day and the first dive duration data from belugas. Radio tags are still frequently used on other biologging tags, such as Time-Depth-Recorders (Panigada *et al,* 1999) and DTAGs (Johnson and Tyack, 2003), to assist locating and tracking tags which have detached from the study animal but not for transmitting data.

Most biotelemetry of marine megafauna is now carried out using satellite telemetry, which allows researchers to track far-ranging animals such as marine animals. Satellite telemetry utilises a platform transmitter terminal (PTT) attached to an animal. It sends an ultra high frequency (401.650 MHz) signal to satellites. The satellites calculate the animal's location based on the Doppler Effect and relay this information to receiving/interpreting sites on the ground. Satellite telemetry gives researchers greater location accuracy and decreases invasiveness to animals when compared with VHF telemetry. Data are available without recapturing your animal, which are transmitted via the Argos satellite system, although tags are usually not recovered. Argos then provides the geographical position of the tag based on these transmissions. Satellite telemetry can be achieved with a wide variety of tags from Platform Terminal Transmitters (PTT), Fastloc GPS or Pop-up Archival tags.

Each telemetry system has its advantages and disadvantages. Within each system, there are also options to specifically tailor the telemetry packages to the researcher's unique needs. If funding for a study is low or if a large number of animals are to be studied for long periods, VHF telemetry is probably the only option. However, VHF telemetry is generally more labour intensive and provides a less accurate estimate of position. Although satellite telemetry is more expensive than VHF tracking, in some cases it may be the only option, for example, for far ranging species such as offshore marine mammals.

The use and analysis of biotelemetry data can be problematical and differs between tag types. GPS data points are usually serially correlated, whereas with standard radio-tracking, they often are not, depending on their time intervals. Thus, data points from the same individual are not necessarily independent of each other. This issue is not confined to telemetry data but typical of time-series data where the correlation (relationship) between observations and the same values at a fixed time interval can later result in residual error terms when observations of the same variable at different times are correlated (related). There is a wide selection of analytical techniques used to address this issue, ranging from regression to quasi-least square analysis.

4.2. Effects of Biotelemetry

Devices used to track marine animals have been attached by a variety of methods, including glued or suction-cupped to the study animal, attached via a harness or a tether, or bolted through body parts or implanted into the body. The importance of the effect of tagging in a study may depend upon the objectives of the study. Many of the usual behaviours which may be associated with tagging, such as increased dive times or movement away from the tag site, last only for a short time, and some workers recommend that data should not be considered reliable until after at least one week of acclimatization to the tag.

Table 4.2: Types of attachment for a variety of tags

Attachment technique	Example of species tracked	Benefits	Constraints	References
Harness	Turtles, pinnipeds, seabirds	Long term deployment	Increased drag	Doyle *et al* (2008)
Tethered to anchors	Large and medium whales, sharks	Tag large animals	Potential for infection	Baird *et al* (2010) Gore *et al* (2008)
Bolted	Large and medium odontocetes	Long deployment	Catch and handle animal, infection, stress	Mate *et al* (1995) Martin and da Silva (1998)
Suction cups	Medium-sized cetaceans	Skin not broken	Short attachment duration, close approach	Johnston and Tyack (2003)
Glue	Pinnipeds, turtles, birds	Hydrodynamically efficient, cost effective	Catch and handle animal	Fossette *et al* (2008) Cronin and McConnell (2008)
Implantation	Otters	Track small, hydrodynamic species	Very invasive, capture and handle animal	Mech and Barber (2002)

Regardless of which telemetry system is selected, potential effects on an animal's health and normal behaviour must be considered whenever an animal is handled or tagged. It is to the researcher's advantage to minimize these effects since the goal of radio-tracking is to obtain data most closely reflecting the animals' natural behaviours (Mech and Barber, 2002).

4.3. Relevant Research using Biotelemetry of Marine Megafauna

The diving behaviour of cetaceans is impossible to study without the aid of electronic devices (Teilmann *et al,* 2004). For short-term studies, suction cup tags have been used for attachment of tags (Schneider *et al,* 1998), but to follow animals for days or months, the tag needs to be attached more permanently. On large cetaceans, the tag can be attached to an anchor fired into the tissue. For small cetaceans, the animals may be caught or live stranded and the tag attached by means of pins through the dorsal fin. In recent years there has been a huge increase in the use of satellite-telemetry for recovering data on the diving, foraging behaviour and orientation of cetaceans.

Seals are popular subjects for tagging as they can be easily caught on their breeding or haul-out sites. Grey seals have been tracked by satellite since the mid 1980s and in Ireland since 2004. Seals are now frequently used as autonomous ocean profilers and have been fitted with a wide range of different tags including TDRs, salinity and temperature loggers and even cameras. For example, Costa *et al,* (2008) used crabeater seals to supplement traditional oceanographic sampling methods to investigate the physical properties of the sea. Seal-derived temperature measurements provided broader space and time resolution than was possible using any other currently available oceanographic sampling method.

The basking shark was one of the first large marine animals to be fitted with a satellite tag. In 1982, Priede (1984) tracked a basking shark in the Firth of Clyde, Scotland for 17 days using a Platform Transmitter Terminal (PTT) satellite tag and the ARGOS network. Since 2001, basking sharks have been fitted with satellite tags on both sides of the Atlantic.

Early telemetry of adult leatherback turtles was carried out using Time-depth-Recorders attached by harnesses to on gravid females on St. Croix, US Virgin Islands, in the Caribbean, as access at the nesting beaches was very easy. Doyle *et al* (2008) tagged two turtles caught in surface drift nets off the Dingle peninsula, Co Kerry, in 2005 and 2006 with Satellite Relay Data Loggers (SRDL). The reconstructed tracks showed that the female turtle was tracked for 375 days and travelled a total of 4,500km and the male turtle, 3,900km, in 233 days of tracking. The male turtle performed the deepest dives ever recorded by a reptile (1,280m) while south of the Cape Verde Islands.

Atlantic bluefin tuna are true ocean roamers and in 2003, Bord Iascaigh Mhara deployed two tags on bluefin tuna caught by hook-and-line off Donegal. The data showed that both fish remained off Donegal for just over a month before moving west, first to the continental shelf and then to the mid Atlantic Ridge. One tag "popped up" east of the Bahamas while the second was recovered west of Portugal. In 2008, the Marine Institute tagged three individual porbeagle sharks using archival pop-up tags. The tags were programmed to detach after 122 days. One tag popped-up between Morocco and Madeira, indicating a southerly migration of over 2,400 km in four months. The second shark tagged stayed in the oceanic waters around the shelf edge west of Ireland and the third migrated southwards to the Bay of Biscay (Saunders *et al,* 2011).

The ocean sunfish is the largest bony fish in the world. One fish tagged off Co Kerry travelled 959 km from the tagging site to southwest England in 54 days. The sunfish occurs mainly in shallow water, with only 2% of recorded time spent below 200m (Sims *et al,* 2009).

O'Neill *et al* (2008) fitted radio transmitters to 11 otters trapped in Roaringwater Bay, Co Cork, and de Jongh *et al* (2010) carried out a pilot study to explore the use of GPS GSM transmitters to determine range sizes and diel activity.

4.4. Best Practice Guidelines

Over the last 20 years, the range of species tracked and devices deployed has expanded rapidly. Cooke (2008) explored the ethical and legal issues surrounding the telemetry of endangered species. Most studies using biotelemetry on endangered or protected species require permission from the relevant licensing authority, and this enables authorities to ensure standards are maintained by including conditions on the licence. This usually requires an assessment of the impact of the activity and encourages the development and testing of tagging techniques. It is in the interest of all concerned that the device does not adversely affect the individual and that the relative benefits of the research outweigh any potential short-term costs. Therefore, these benefits should be demonstrated if best practice is to be followed. As the number of studies using biotelemetry increases exponentially, the impact on tagged individuals is likely to decrease as tag design improves.

A recent review of tag design for cetacean telemetry was published following a workshop held in 2009 (Anon, 2009). The workshop recommended establishing screening criteria for animal selection, based on size, condition, mother-calf pairs etc, and recommended avoiding tagging animals in poor condition or the more vulnerable age classes. It also promoted the use of photo-ID to assess the potential tag effects through re-sighting data. In terms of tag design, it recommended integrating electronic components to minimise tag size and improve hydrodynamic performance. The use of experienced tagging teams in the field should reduce impact on the tagged individual and justify the sample size before conducting research.

There are currently no published best practice guidelines for biotelemetry of cetaceans, and best practice guidelines may not be available and/or may not be obvious (Anon, 2009; Andrews, 2011).

4.5. Biotelemetry of Marine Megafauna

We had hoped to place satellite tags on fin whales off the south coast of Ireland using SPOT five PTT tags for real-time tracking. These tags were to be tethered via anchors embedded in muscle underlying the blubber to maximise deployment duration. As satellite tracking of cetaceans is an invasive technique and all cetacean species are entitled to strict protection in Ireland, a licence was required from the National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht to place satellite tags on cetaceans.

Following our license application, the department raised concerns about the invasive nature of the tagging technique and their responsibility to provide strict protection to all cetacean species and their habitats. Due to licensing constraints, no attempt was made to carry out biotelemetry on cetaceans during this project.

We obtained additional funding to attach satellite tags on basking sharks. On 14 July 2008, two MK10 Archival Tags were deployed on single basking sharks off Slea Head, Co Kerry. The satellite tags were deployed with an extendable pole at the base of the sharks' dorsal fins and held in the shark with an anchor deployed just below the skin. The satellite tag was attached to the anchor with a short tether and programmed to detach from the shark after 215 days. A tag deployed on a 7m male was received on 21 February from the Celtic Sea, ending a deployment period of 222 days. A signal from Shark B, an 8m shark of unknown gender, was received on 1 January 2010 around 150 km offshore of Co Clare, a deployment period of 170 days.

Some of the data from both tags were corrupted so only indicative maps of the sharks' movements could be plotted. Both sharks remained on the continental shelf for most of the tagging period. One shark spent most of its time in the Irish and Celtic Seas, with evidence of a southerly movement in the winter to the west coast of France. Movements of Shark B were more constrained, remaining off the southwest coast for the whole period, with locations recorded off the shelf edge and in the Porcupine Bight. These data were presented to an ICES Elasmobranch Working Group (Berrow and Johnston, 2010).

4.6. Additional Information

In the original Work Package, biopsy sampling and photo-identification of fin and humpbacks whales was proposed as ancillary projects to biotelemetry. These data would add value to telemetry data by identifying the gender of tagged individuals (biopsy sampling) and long-term monitoring of the individual, including the potential impact of tagging (photo-ID). Images of fin and humpback whales were submitted to the IWDG photo-ID catalogues. Matches were sought with the North Atlantic Fin and Humpback Whale catalogues held by Allied Whale in Bar Harbour, Maine, in the US, but no matches to any other sites in the North Atlantic could be made. A paper (Whooley *et al,* 2010) was published using data from the fin whale catalogue. This showed a high re-sighting rate and site fidelity along the south coast. During this project we obtained tissue samples from 11 fin whales and from three humpback whales and these samples are currently being analysed as part of a PhD study of baleen whales in Irish waters at the Galway-Mayo Institute of Technology.

4.7. Recommendations

Licensing restrictions during the present study constrained the use of this technique on cetaceans. The issues raised during this project must be addressed by researchers in the future if this technique is to be licensed in Ireland.

We recommend that if biotelemetry of cetaceans is to be licensed in Ireland, photo-identification and biopsy sampling of individuals to be tagged should accompany all attempts under a best-practice environment. The information obtained from the addition of photo-identification and biopsy will help interpret the biotelemetry data and assess potential impact.

5. Ecosystem Links and Habitat Use Between Cetaceans and Fisheries in the Celtic Sea

The seasonal occurrence of cetaceans, including fin, humpback and minke whales, as well as common dolphins off the south coast of Ireland, has been recorded in some detail since 1999 (Berrow *et al,* 2002; 2010, Whooley *et al,* 2003). Research into the presence of fin and humpback whales in the region strongly suggests that the whales utilise this habitat predominantly for feeding (Berrow *et al,* 2003; 2005; O'Donnell et al, 2004-2009). Fin whales and common dolphins also show a strong seasonal aspect to their use of this foraging habitat (Wall and Murray, 2009).

Numerical modelling provides a method to investigate the relationships between variables (in this case cetacean abundance and distribution) and covariates, biological or environmental variables. The dynamic nature of marine environments requires a flexible analysis to allow for a complex range of variables and model structures (Redfern *et al,* 2006). Ingram *et al* (2007) reported on the role of environmental variables on minke and fin whales by using generalized linear models (GLM) and generalized additive models (GAM). Mapping of data on geographical information systems (GIS) can help to indicate patterns in distribution and habitat preference, as was reported by Firestone *et al* (2008) in a study of North Atlantic right whale migration. The current study examined the aggregations of cetaceans, especially baleen whales (fin whale, humpback whale and minke whale) and common dolphins off the south coast of Ireland by using GIS and GLM to explore the ecosystem links that may be driving this activity.

Cetacean visual line transect data were collected during the Celtic Sea Herring Acoustic survey on board the research vessel *R.V. Celtic Explorer*, operated by the Marine Institute. These surveys were conducted annually between 2004 and 2009 during October (with the exception of 2004, when the survey took place from mid-November to mid-December) over a 21-day period, targeting spawning and pre-spawning herring.

Acoustic data used to calculate the relative abundance of shoaling fish species were continuously collected by a calibrated split beam Simrad scientific echo sounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8m below the sea surface. Nautical Area Scattering Coefficient (NASC) values, which are a relative measure of biomass, were assigned to specific fish schools or scattering layers, based on visual recognition and trawl

composition. The main schooling fish species encountered over the six years were herring (*Clupea harengus*), sprat (*Sprattus sprattus*), pilchard (*Sardina pilchardus*) and mackerel (*Scomber scombrus*). Herring and sprat were consistently encountered each year and, therefore, were chosen to be used in the analysis of this study.
Remotely sensed sea surface chlorophyll *a* data was obtained from the SeaWIFS archive at the Goddard Space Flight Centre (GSFC). Their processed data was used for chlorophyll *a* and concentrations are presented as $mg.m^{-3}$.

A total of 126 days of survey effort was conducted over the study period (2004-2009). Approximately 8,399km of survey transects were covered from close inshore to a maximum distance of 145km offshore. Eight species of cetaceans (common dolphin, fin whale, humpback whale and minke whale) and four schooling fish species were identified in the study area (O'Donnell *et al,* 2004-2009).

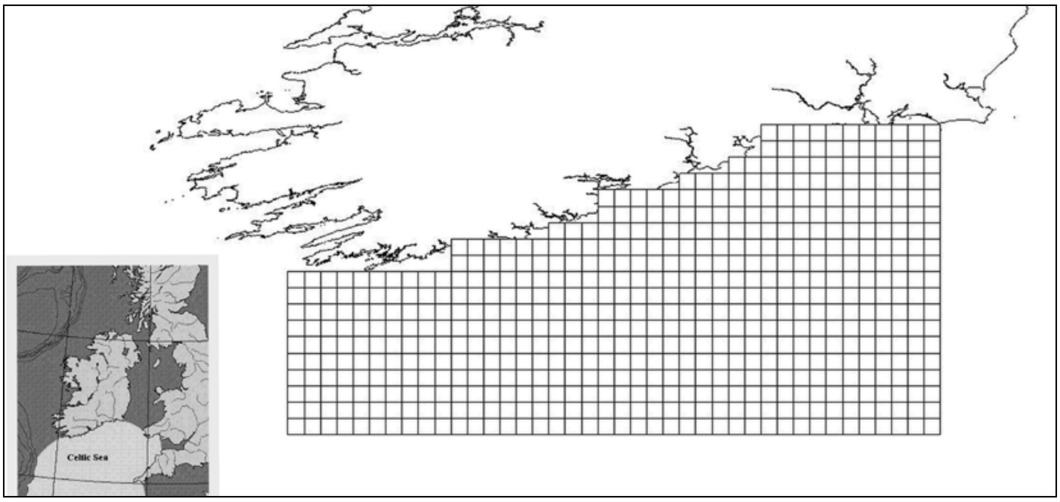

Figure 5.1: The study area in the Celtic Sea is shown, divided into 9x9km grid cells

Common dolphins were the most abundant and commonly observed cetacean species throughout the survey period, with a total of 142 sightings, comprising 5,401 individuals. GIS mapping of common dolphin distribution (Fig. 5.3) shows a wide dispersal throughout the study area. Baleen whale on-effort sightings were less common, with a total of 42 sightings, comprising 99 individuals (Fig. 5.4) Fin whales were the most abundant of the baleen whales recorded over the six-year period (72 individuals), followed by minke whales (24 individuals) and humpback whales (two individuals). Plotting of baleen whale sightings using ArcGIS showed a clumped, inshore distribution (Fig. 5.4).

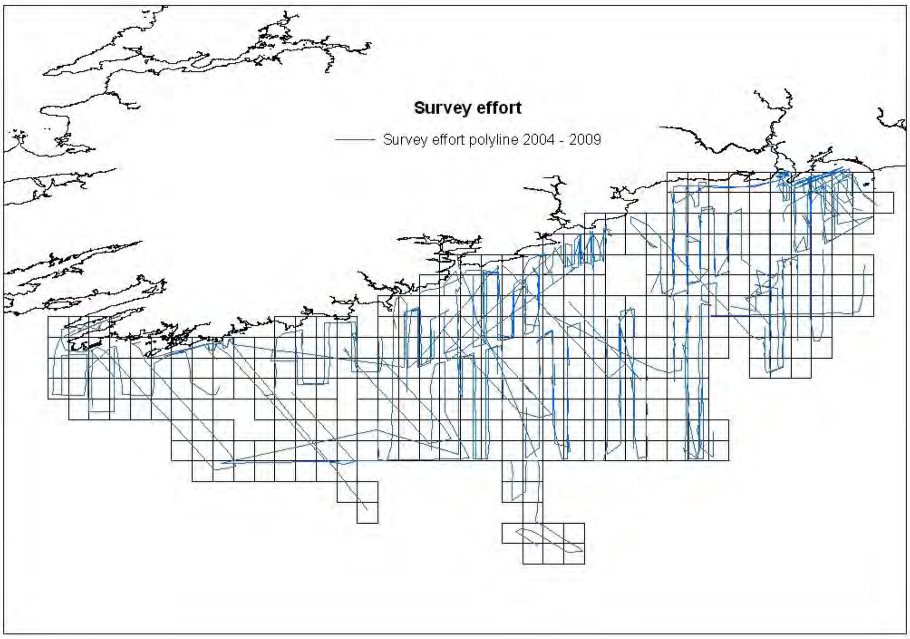

Figure 5.2: Combined track line of the Celtic Sea herring acoustic surveys from 2004 to 2009

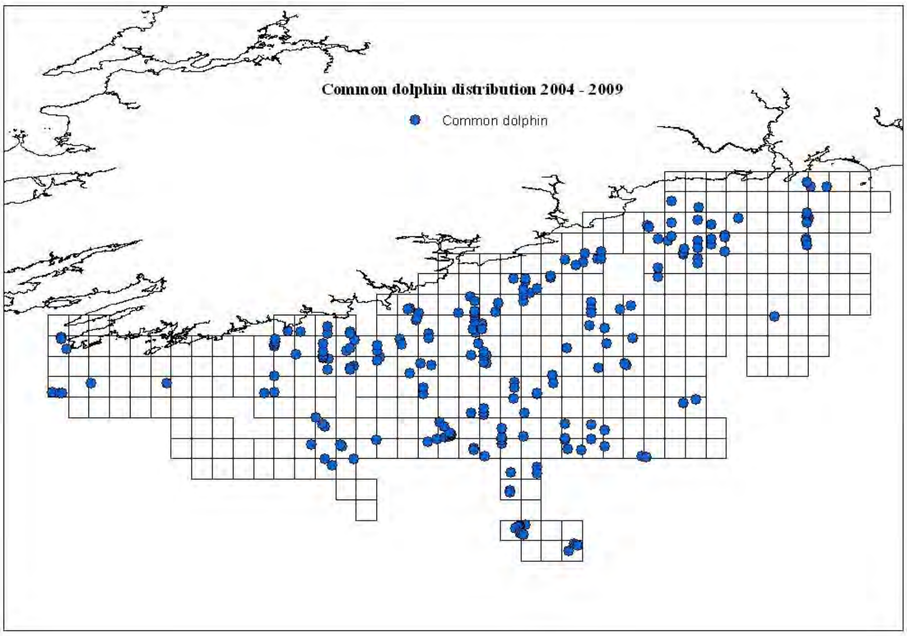

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Figure 5.3: Distribution of common dolphins throughout the study area from 2004 to 2009

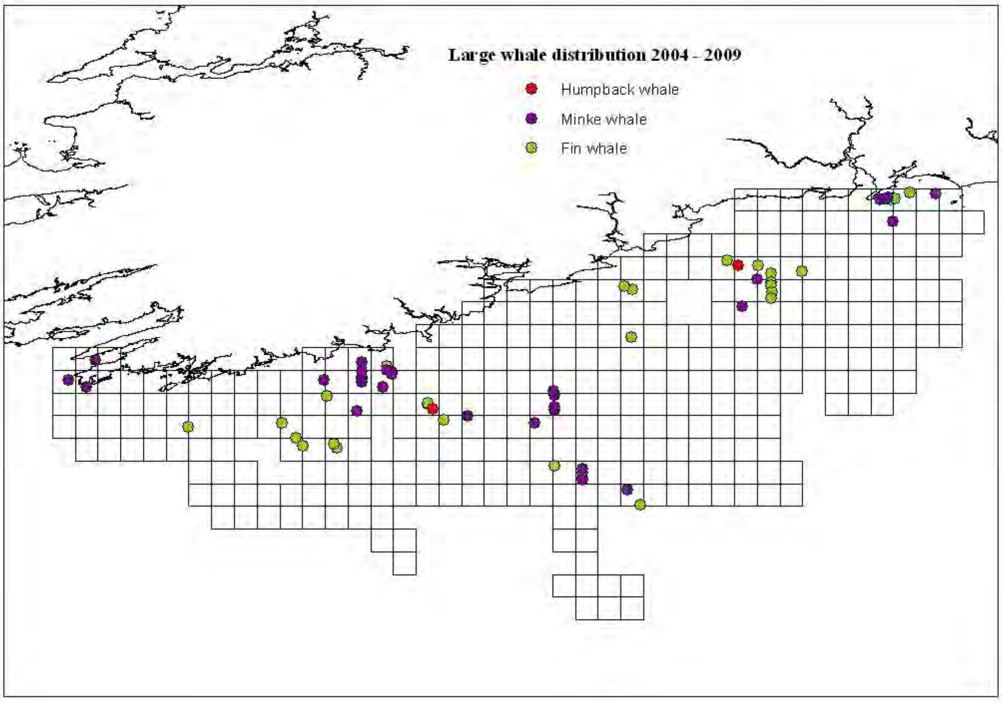

Figure 5.4: Distribution of baleen whales throughout the study area from 2004 to 2009

The presence of baleen whales was strongly and negatively correlated with distance from the shore and autumn chlorophyll *a*. Yearly comparisons of the overlap between interpolated NASC scores and cetacean distribution (using the disaggregated data from the pooled dataset) were done to provide a greater insight into the distribution of prey species within the study area on a temporal basis. In all bar one instance (Baleen Whales & Sprat, 2007), the tests failed to reject the null hypothesis of independence, indicating that there was no significant direct overlap. This is consistent across all three tests. Similar results were obtained for combined herring or sprat presence/absence.

5.1. Conclusions

This Work Package represents the first attempt to integrate the Marine Institute's fisheries data with simultaneously collected cetacean distribution data in the Celtic Sea. The scale of variation in the distribution of pelagic schooling fish and the difficulty in obtaining simultaneous cetacean distribution data represented significant challenges in the mathematical exploration of the relationships between the distributions of this predator- prey combination. Nevertheless, the data used in these analyses are the most comprehensive of their type in Ireland.

Based on a year by year analysis of the distribution of cetaceans and pelagic schooling fish in the Celtic Sea, no statistically significant link between the variables was detected. The results of this Work Package have raised questions concerning how best to represent the distribution of the predators and prey within the study area based on the data available, and also led to the development of further research cruises looking at small-scale patterns of distribution of pelagic schooling fish and cetaceans in the Celtic Sea.

Notwithstanding the lack of statistically significant links between the variables, the field observations and the data used in this work suggest that the study area appears to be an important seasonal foraging habitat for both baleen whales and common dolphins.

6. Recommendations

The following main recommendations are made from this project presented under each Work Package.

6.1. Offshore Surveys

The use of cetacean surveys on platforms of opportunity can be used to monitor cetaceans and we recommend targeting those surveys which provide good spatial coverage of offshore habitats for future survey effort. These include the Celtic Sea and Northwest Herring Surveys and the Blue Whiting and Mackerel Egg Surveys. Demersal trawl surveys, which provide reasonable spatial coverage of habitats in seasons outside of those covered by the priority surveys above, should also receive high priority for future survey effort. Cetacean monitoring programmes should collect sufficient data to enable seasonal changes in species abundance and distribution to be assessed. In addition to using platforms of opportunity, dedicated surveys of specific cetacean species and habitats should be used to contribute to defined conservation and monitoring goals.

Species specific detection distances recorded during PReCAST raised issues regarding the appropriateness of using incidental cetacean sightings during seabird surveys as a method of monitoring cetacean species. In view of the ongoing use of ESAS survey methods for cetacean monitoring and the amalgamation of data sets using dedicated cetacean survey methods and seabird survey methods, robust and independent scientific assessment of cetacean detection rates by dedicated line transect survey methods should be conducted. Data on differences in observer sighting detection rates indicate a need for the establishment and use of an experienced, and preferably calibrated, marine mammal observer panel for conducting monitoring contracts in Irish waters.

The feasibility of fitting a GPS position and altitude data logging system on board the two Air Corps Maritime Squadron CASA CN 235 aircraft should be examined. Trained cetacean observers should be available for deployment on board Air Corps patrol flights for the rapid assessment of incidents such as oil spills.

Due to the conservation importance of bottlenose dolphins and recent evidence of a genetically discrete offshore population in Ireland, further study of offshore bottlenose dolphins and their habitat within the Irish EEZ is recommended. Sightings and strandings data collected within the past five to six years suggests a northward contraction in the range of white-beaked dolphins in Irish waters, and we recommend their status should be re-assessed. In light of the increasing numbers of humpback and fin whales using inshore waters off the south coast of Ireland as a seasonal foraging ground, the identification by genetic or other means of the stock from which Irish humpback and fin whales originate should be determined.

A copy of all future cetacean survey and monitoring data funded by the State, and a copy of all past publicly funded cetacean survey data should be lodged with the National Biodiversity Data Centre.

6.2. Acoustic Monitoring

Extensive field trials and long term deployment of SAM devices during this study has shown that the C-POD is an effective SAM device for monitoring small odontocetes. However, field calibration of all SAM devices, prior to deployment, is recommended in order to facilitate comparisons within and between datasets collected using multiple loggers. A number of deployment methods were used and we recommend acoustic releases for deployment and recovery of devices in exposed sites, or those with potential for interference. Permanent structures (e.g. jetties), from which devices can be suspended, are also very useful and recommended if available at the study site.

In order to facilitate restricted stratified random sampling design, a minimum of four SAM units should be used for monitoring. During the planning stage, we recommend that the number of SAM devices purchased for a study should be twice the number of sampling sites. This is in order to minimise gaps in the dataset through loss or damage of devices and to facilitate changing over devices in the field.

When conducting PAM surveys, dedicated and trained operators should be assigned to acoustic collection. A combination of visual and acoustic techniques is recommended for effective monitoring during offshore surveys.

Analysis of acoustic data should be standardised. We recommend the proportion of minutes with detections during all minutes monitored (%DPM) as the most effective monitoring index of activity across sites and factors.

6.3. Biotelemetry

Although biotelemetry is a relatively new technique in Ireland, it has been used on a range of species, including common and grey seals, tuna, sunfish, basking and blue sharks and otters. These studies have revealed unique insights into many aspects of their ecology. To date, there has been no biotelemetry study of a cetacean in Ireland. Licensing restrictions during the present study constrained the use of this technique on cetaceans.

Attachment methods vary depending on the target species and the questions to be asked, but if invasive techniques are to be licensed in Ireland, an impact assessment should be carried out and the latest studies should be reviewed. There are no best practice guidelines available for biotelemetry of cetaceans so researchers are recommended to use the most recent techniques available. If biotelemetry of cetaceans was to be licensed in Ireland, ancillary data (e.g. photo identification and biopsy sampling of individuals) should accompany all attempts under a best-practice environment. The information obtained from these data will help interpret the results of biotelemetry and assess potential impact.

6.4. Ecosystem Links

The link between predators and pelagic fish was difficult to characterise given the nature of the data and the highly mobile behaviour of both cetaceans and pelagic fish. The 'snap-shot' nature of the Celtic Sea herring survey restricts the ability of the data to describe the overall distribution of predators and prey within the ecosystem. Therefore, we recommend additional coverage of the annual Celtic Sea Herring Survey, which will require continued facilitation by the Marine Institute's Fisheries Science Services of marine mammal observers during the Celtic Sea herring surveys. In addition, small scale (spatially) surveys examining patterns in prey and predator distribution within the Celtic Sea are recommended to better describe their movement and behaviour, which can be incorporated into a broad-scale theoretical movement model.

Further research that provides insight into the origins, distribution, and abundance of cetaceans and their prey in the Celtic Sea is required. The incorporation of this information into considerations concerning the management of the Celtic Sea herring stocks is recommended.

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8. Appendix I: List of Scientific Names and Authorities

Marine Mammals

Harbour porpoise *Phocoena phocoena* (L.)

Short-beaked common dolphin *Delphinus delphis* L.

Bottlenose dolphin *Tursiops truncatus* (Montagu)

White-sided dolphin *Lagenorhynchus acutus* (Gray)

White-beaked dolphin *Lagenorhynchus albirostris* (Gray)

Risso's dolphin *Grampus griseus* Cuvier

Striped dolphin *Stenella coeruleoalba* (Meyen)

Killer whale *Orcinus orca* (L.)

Beluga *Delphinapterus leucas* (Pallas)

Long-finned pilot whale *Globicephala melas* (Traill)

Sowerby's beaked whale *Mesoplodon bidens* (Sowerby)

Cuvier's beaked whale *Ziphius cavirostreis* Cuvier

Bottlenose whale *Hyperoodon ampullatus* (Forster)

Minke whale *Balaenoptera acutorostrata* Lacépède

Fin whale *Balaenoptera physalus* L.

Humpback whale *Megaptera novaengliae* (Borowski)

Grey seal *Halichoerus grypus* (Fabricius)

Common seal *Phoca vitulina* L.

Crabeater seal *Lobodon carcinophagus* (Hombron & Jacquinot)

Fish

Bluefin tuna *Thunnus thynnus* L.

Herring *Clupea harengus* L.

Sprat *Sprattus sprattus* (Girgensohn)

Ocean Sunfish *Mola mola* L.

Basking shark *Cetorhinus maximus* (Gunnerus)

Porbeagle *Lamna nasus* (Bonnaterre)

Other

Otter *Luta lutra* L.

Leatherback turtle *Dermochelys coriacea* (Vandelli)

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