

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



# Marine Mammals and Megafauna in Irish Waters - Behaviour, Distribution and Habitat Use. *Biotelemetry of Marine Megafauna in Irish Waters*

Project-based Award



Lead Partner: Irish Whale and Dolphin Group



An Roinn  
Ealaíon, Oidhreachta agus Gaeltachta  
Department of  
Arts, Heritage and the Gaeltacht



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# Marine Research Sub-Programme 2007–2013

## *Project-based Award*

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### ***Marine Mammals and Megafauna in Irish Waters - Behaviour, Distribution and Habitat Use*** (PBA/ME/07/005(02))

#### **WP3 Biotelemetry of Marine Megafauna in Irish Waters**

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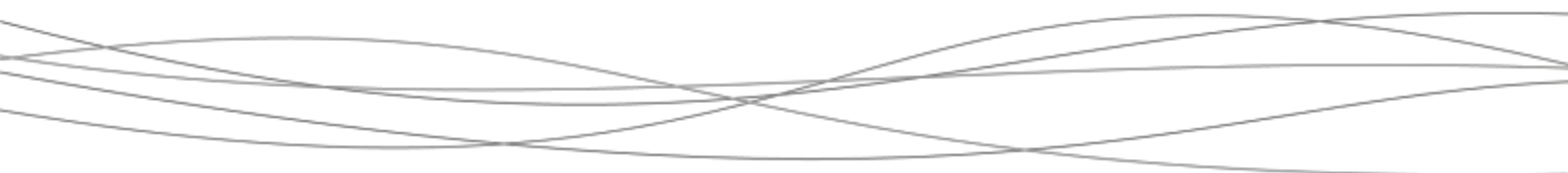
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## PREFACE

### 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)<sup>1</sup> (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<sup>2</sup>. 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.

### Legal framework

All cetaceans and their habitats are protected under Irish and international law. The Wildlife Act<sup>2</sup> and Wildlife (Amendment) Act<sup>3</sup> entitle all cetaceans and their habitats up to 12nmls from the coast to full protection, including from disturbance and willful interference. All cetacean species occur on Annex IV of the EU Habitats Directive<sup>4</sup>, 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

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<sup>1</sup> EEZ: a seazone in which a state has special rights over the exploration and use of marine resources.

<sup>2</sup> Wildlife Act (1976)

<sup>3</sup> Wildlife (Amendment) Act (2000)

<sup>4</sup> Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora

porpoise – Roaringwater Bay, Co Cork, and the Blasket Islands, Co Kerry – and one for the 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<sup>5</sup>. 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<sup>6</sup> (Bern Convention) and the Convention on the Conservation of European Wildlife and Natural Habitats<sup>7</sup> (Bonn Convention). Under the

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<sup>5</sup> Conservation Plan for Cetaceans in Irish Waters (2009). Department of Environment, Heritage and Local Government.

<sup>6</sup> Convention on the Conservation of Migratory Species of Wild Animals (1979)

<sup>7</sup> Convention on the Conservation of European Wildlife and Natural Habitats (1979)



OSPAR Convention<sup>8</sup>, Ireland is obliged to address recommendations on the protection and 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.

## **Marine Mammals and Megafauna in Irish Waters – behaviour, distribution and habitat use**

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

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<sup>8</sup> Convention for the Protection of the Marine Environment of the North-East Atlantic (1992)

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.

## EXECUTIVE SUMMARY

Biotelemetry is the transmission of information from biological organisms through the atmosphere by radio waves. Biotelemetry encompass a wide range of devices that can record environmental variables while attached to an animal, such as depth, salinity and temperature, while permitting the recording and transmitting of the position of an animal, commonly referred to as tracking.

Biotelemetry has been shown to be a very powerful technique for studying the movements, behaviour and habitat use by many species of marine megafauna. Recent tagging studies in Ireland have shown that significant potential exists for the use of this technique within the Irish EEZ and beyond. The use of this technique is still relatively underdeveloped and there has been no attempt in Ireland to carry out biotelemetry on any cetacean species.

A review of biotelemetry, with reference to relevant species in Ireland, is presented. This shows that the use of this technique has expanded rapidly since the 1990s, with a wide variety of species now studied. The range of equipment and technology available is also expanding rapidly, with new and upgraded tags appearing regularly. Although a number of marine species have been tagged and tracked in Ireland, these studies were generally of short duration or involved small numbers of individuals. However, these studies have shown that tracking marine megafauna in Ireland can be successful and that there is great potential for biotelemetry. There are currently no general guidelines with respect to biotelemetry on best practice available but a number of reviews do make recommendations depending on the species and technique to be used.

All attempts to carry out biotelemetry in Ireland must be licensed as all species of marine mammals and some other species of marine megafauna are legally protected. Some biotelemetry of marine mammals (e.g. seals) has been licensed in Ireland but invasive tagging techniques, such as that proposed for use on cetaceans, are not currently permitted primarily due to concerns of the impact of the technique on individuals.

As part of this project, two basking sharks were successfully tracked for nine months using PAT archival satellite tags. This showed that sharks remained within Irish and UK waters during the tracking period and did not exhibit any long-distance movements or deep dives.



# I. REVIEW OF BIOTELEMETRY

## 1.1. Introduction

Biotelemetry is the transmission of information from biological organisms through the atmosphere by radio waves. 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, e.g. dive depth, duration and profile or noise 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'.

The use of biotelemetry has revolutionized the study of wild animals and its use has increased considerably in recent years (Mech and Barber, 2002). The potential for gaining new information with this technique is almost unlimited. Historically, it involved the live-capture of animals and usually the attachment of a collar or other device to them. Thus the potential for disturbance or significant interference was great. However, for larger animals, tags can increasingly be deployed remotely, thus avoiding handling individuals, which for many species would not be possible.

A number of reviews on the use of telemetry for marine mammals (Costa, 1993; Stone and Kraus, 1998; Hooker and Baird, 2001; Reid *et al*, 2003; Godley and Wilson, 2008; Bograd *et al*, 2010) and sharks (Simms, 2010) have recently been carried out. This current review aims to summarise recent knowledge in the use of biotelemetry for tracking cetaceans – whales, dolphins and porpoises – and other marine megafauna, as relevant to Ireland. It will include a description of techniques available and an assessment of the advantages and constraints of these techniques. It will also include an outline of the use of telemetry technology for the collection of physical oceanographic (e.g. temperature, salinity) and behavioural data (e.g. diving and foraging). A summary of recent relevant research on each marine group of interest in Ireland will assist in identifying those methods that may be suitable for use in Irish waters and provide information on best practice.

## 1.2. Biotelemetry Techniques

A number of techniques and tag types are available (Table I). 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 at the surface to transmit positional data.

**Table I:** Summary of tags available for bio-telemetry

Technique	Tag type	Benefits	Constraints
Radio-telemetry	HF/VHF	Wide range of potential study species, cheap	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	Additionally expensive 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

### 1.2.1. Radio-telemetry

Radio tracking is the monitoring of the movements or behaviour of animals remotely through the transmission of radio waves to a receiver via a transmitter attached to the study animal. The technique has been used to study wild animals, from bats to butterflies, since the 1960s (Cochran and Lord 1963). It brought two new advantages to wildlife research: the ability to

identify individual animals and the ability to locate each animal when desired. These advantages led to the wide application of radio tracking, which has been used to study animals as varied as snakes, crayfish, dolphins, tigers and elephants, and in most countries (Mech and Barber, 2002).

In addition to more straightforward applications such as movement/home range analysis and mortality studies, radio-telemetry has proved useful in examining many diverse topics, including disease transmission, scent marking, predation and co-evolution, vocalizations, socio-ecology and breeding behaviour, sleep characteristics, physiological studies of heart rate, respiration rate, body temperature and nest egg condition (see Mech and Barber, 2002). Advances in radio tracking included very high frequency (VHF) telemetry, which now enable researchers to determine whether an animal is active or resting. Microphone-containing transmitters allow researchers to listen to a creature's vocalizations and ambient sounds.

The transmission range of HF/VHF tags is limited (10s of km), but receivers can be automated and are able to scan a range of frequency to determine whether a tag is in range. For example, a receiver near a nest or resting site can log whether an individual is present.

Radio-telemetry of marine megafauna is very limited. Early tracking of odontocetes used radio-tags bolted through the dorsal fin (Leatherwood and Ljungblad, 1979; Read and Gaskin, 1985) or attached via a harness (Frost *et al*, 1985). Although animals had to be captured to have tags attached, the authors reported no reaction to the tag. The data showed considerable movement of harbour porpoises (*Phocoena phocoena*), up to 15 to 20km per day, and the first dive duration data from belugas (*Deplinaptuus leucas*) (Frost *et al*, 1985). Retention time on belugas was limited to a maximum of 22 days. This was thought to be caused by excessive drag from the harness. Most biotelemetry of marine megafauna is now carried out using satellite telemetry, although radio-tags are frequently used on other biologging tags such as Time-Depth-Recorders (Panigada *et al*, 1999) and DTAGs (Johnson and Tyack, 2003) to assist in locating and tracking tags which have detached from the study animal but not for transmitting data.

Current VHF transmitters, which are fully waterproofed for use on aquatic species, have a life span of three to four years and weigh as little as 100g (Sirtrack VSH227A tag). They are attached to the animal with glue or via a harness. They currently cost between \$100 and \$200 per tag.

### 1.2.2. Satellite telemetry

Satellite telemetry utilizes a platform transmitter terminal (PTT) attached to an animal. The PTT 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. This allows researchers to track far-ranging animals such as marine animals that previously were too difficult to track using the relatively shorter range of the VHF system.

Satellite telemetry manifests itself in many forms, from Platform Terminal Transmitters (PTT) to Fastloc GPS to Pop-up Archival tags. Satellite telemetry gives researchers greater location accuracy and decreases invasiveness to animals when compared with VHF telemetry. Data are available without recapturing your animal. The data are transmitted via the Argos satellite system, though tags are usually not recovered. Argos then provides the geographical position of the tag based on these transmissions.

The main suppliers of these tags are Wildlife Computers ([www.wildlifecomputers.com](http://www.wildlifecomputers.com)), Sirtrack ([www.sirtrack.com](http://www.sirtrack.com)) and the Sea Mammal Research Unit ([www.smru.st-and.ac.uk/Instrumentation](http://www.smru.st-and.ac.uk/Instrumentation)). Most satellite tags cost between \$3,000 and \$5,000.

#### 1.2.2.1 GPS tags

Global Positioning System (GPS) tracking of animals is the latest major development in wildlife telemetry. A GPS receiver is used to calculate and record the animal's location, and the time and the date at programmed intervals, based on signals it receives from three or more satellites. It then stores these data in the telemetry unit for later retrieval (after recovering the device) or remote downloading, for example, via a satellite.



Examples of marine GPS tags and SPOT tags from Wildlife Computers



Global Positioning System (GPS) tracking allows the researcher to obtain data on animal location in all weather as frequently as every minute or as infrequently as once per week, with potential accuracy found to be within five metres (Moen *et al.* 1996). While GPS units afford increased accuracy, their longevity is much less than that of conventional VHF units. VHF units for wolf-sized animals usually last about four years, whereas current GPS units rarely last longer than one year. Although GPS tracking can be expensive on a per data point basis or for large, expensive studies, its costs can be cheaper than for conventional VHF radio tracking (Mech and Barber, 2002). This is because for a given unit of researcher labour, GPS radio tracking can gather many more location data.

For mobile marine species, GPS tags are the only option. A number of manufacturers supply position only tags (e.g. Wildlife Computers SPOT tags). The new generation of tags incorporate a number of additional functions, including temperature, wet/dry sensor that limits transmissions to when the tag is at the surface or the animal is hauled out and duty-cycling by day or month to extend battery life. These include Satellite-Dive-Recorders (SDR) and Satellite-Linked Time-Depth-Recorders (SLTDR), which allow dive times and depth profiles to be recorded. The latest tag is called a Conductivity-Temperature-Depth SRDL (CTD-SRDL) tag, which collect real-time oceanographic data (Boehme *et al.*, 2009). The smallest tag weighs just 30g, which is ideal for use on birds but has also been used on seals, turtles and small cetaceans.

Battery life can limit the duration a tag will transmit for and also influences the size of the tag. The larger/heavier tags contain bigger batteries and thus transmit for longer periods, but their size/weight may increase the impact of the tag on the animal.

#### 1.2.2.2 Fastloc GPS

Wildlife Computers Ltd. has incorporated Fastloc™ technology into an Argos-linked data recording tag in order to create a Fast-GPS tag. This tag addresses the difficulties inherent in deploying traditional GPS receivers on free-ranging marine animals which spend very little time at the surface. The ability to achieve highly accurate GPS locations, while requiring the tag antenna to be above the surface for less than one second, represents a major step forward in the ability to track marine animals. The Fast-GPS tag (Mk10-AF) acquires the GPS signal snapshots, which can be completed in 0.008 seconds, and archives them along with depth and temperature data. On subsequent surfacing of the tag, a percentage of the summarized data and Fast-GPS snapshots is transmitted via the Argos system. Should the Mk10-AF tag be recovered, it yields the full archive of all Fast-GPS snapshots and sampled data.



A Fastloc GPS tag FIG and F2G from Sirtrack designed to be glued directly onto the study animal



A Fastloc GPS tag F4G and F4H from Sirtrack designed to be attached to a harness

Fastloc GPS tags can be glued onto the study animal or attached via a harness

### 1.2.2.3 GPS phone tag

The GPS phone tag combines GPS geo-locations with efficient data transfer using the GSM (Global Systems for Mobile Communication) mobile phone network and have been developed. For species that come ashore and within GSM range (e.g. seals), the entire data-set can be relayed via the GSM network. Visits ashore may be infrequent as up to six months data can be stored on the tag. GSM data-relays offer very high data bandwidth and are over 100 times more energy efficient than Argos.



GPS phone tag from SMRU instrumentation

### 1.2.2.4 Archival tags

Archival tags are designed to collect and record data on the swimming behaviour of marine animals. Between the various tags available, you can sample depth, environmental temperature, velocity, heart rate, stomach temperature and light level. Light level can be used for determining geographic location on a coarse scale. Time is implicitly encoded with the stored data. Data are stored in the tag, which either is downloaded on retrieval or detaches from the animal after a predetermined period.

For fish and other animals that do not remain at the surface for long periods of time, a specialized transmitting tag called the Pop-up Archival Transmitting (PAT) tag has been developed. The PAT collects and stores data on depth, water temperature and the timing of the setting of the sun throughout its deployment. It releases itself from the animal after a pre-determined period and floats to the surface on a user-specified date. As with traditional satellite tags, the PAT utilizes the Argos system for relaying summaries of the data collected. However, the data are transmitted at the end of the deployment when the tag detaches from the subject animal on a user-specified date.



PAT Archival tag from Wildlife Computers, used on basking sharks

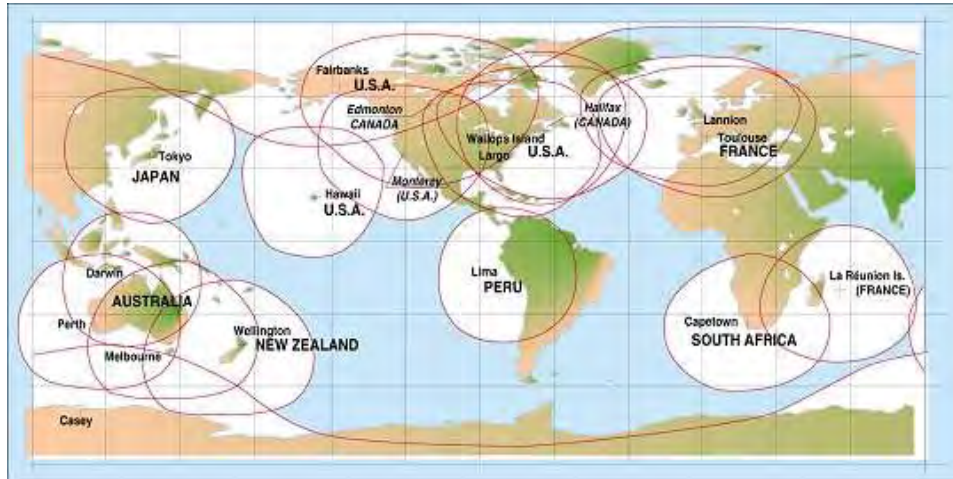
Since PAT tags can yield data without the animal being recaptured, they offer an independent means of tracking a target species. In addition, a full archival record is maintained in its memory. Thus should the PAT be recovered, the full dataset can be retrieved with the same detail as can be collected by a conventional archival tag. A surprising number of PAT tags have been recovered by beachcombers and fisheries personnel. Tagging species which return to known locations increases the chances of tag recovery.

The PAT tag is attached to the animal through an anchor deployed under the skin and attached via a tether or through sewing a tether through the animals' dorsal or other fin. PAT tags have been widely used on a range of large fish species, including elasmobranches.

### ***1.2.3. Argos Satellite System***

The Argos system consists of data acquisition and relay equipment attached to the NOAA low-orbiting weather satellites and ground-based receivers and data processing systems. With more than 8,000 platforms active worldwide, Argos has become the benchmark system for global environmental observation and monitoring.

Each transmitter continually sends short messages, which the satellites relay to ground. Processing centres then use the messages to work out the transmitter's location, with an accuracy of up to 150 metres. Messages can also contain up to 32 measurements from any sensors in use, including sea surface temperature, wind speed or the animal's heart rate.



**Figure 1:** Argos processing centres and coverage worldwide

The Argos satellite equipment records the transmissions from transmitting tags and later downloads these data back to Earth. Service Argos, the organisation which administers the Argos system, then processes these data and determines the tag's position. The data and the Argos-calculated locations of the tag can be sent via the internet or downloaded monthly on a CD. Signals from the Northeast Atlantic are received in the French centre of Lannion (also a Global Processing Centre) and processed in Toulouse, and coverage is good (Fig. 1).

Transmitting tags have an antenna that must be wholly above the surface of the water for transmissions to occur. Each transmission takes approximately 0.5 to 1.0 second. An Argos satellite must receive at least four transmissions during a pass over a tag in order to calculate the tag's location. The Argos system was originally one-way. That is, the tag did not know if a transmission was received by the satellite or not. Therefore, many transmissions had to be sent to increase the chance that at least four were received by an orbiting satellite during a pass. Satellite pass durations vary between 5 and 20 minutes, and Argos dictates that a tag may not transmit any faster than once every 45 seconds. Since 2002 Argos has developed a two-way system where transmitters will receive messages from satellites. Typical applications for this two-way communication include changing a sensor data sampling rate or saving battery time by having the transmitter switch itself on only when it knows a satellite is near.

To assign a class of location accuracy, the Argos processing centres need four messages from a transmitter during a pass. Optimally, the four messages should be spread approximately equally over the pass. There must be messages on each side of the point of inflection, i.e. where the satellite is closest to the transmitter in the middle of the pass. Knowing the position and movement of the satellite, the transmit frequency, the receive frequencies (and times), and the altitude of the platform, two geometrically determined positions can be calculated. The “theoretical” Doppler curve for these two locations is compared with the measured Doppler curve to refine the position and provide quality control. Other plausibility checks employed to further enhance quality control include the stability of the transmitter, change in position since the last location, and anticipated velocity.

Location accuracy (class designation) is determined using all the parameters in the calculation: spread of messages during the pass, pass duration, angular separation from ground track, least-squares residual of the Doppler measurement, and platform velocity. Standard locations (a minimum of four messages) comprise Classes 3, 2, 1, and 0 (Table 2). Class 0 locations have failed certain quality control checks. Thus there is no upper limit on their accuracy. These locations are available upon request and are usually used in the event of a transmitter problem. Classes A, B and Z have less than four messages.

**Table 2:** Location accuracy from the Argos system

Class	Estimated accuracy in latitude and longitude
3	$\leq 150\text{m}$
2	$150\text{m} < \text{accuracy} < 350\text{m}$
1	$350\text{m} < \text{accuracy} < 1000\text{m}$
0	$> 1000\text{m}$
A	No estimate of location accuracy
B	No estimate of location accuracy
Z	(Invalid locations)

Satellite tags have been deployed on many marine animals, including seals and sea lions, sea turtles, cetaceans, penguins, polar bears and fish. Marine mammals and sea turtles are good study animals because they spend enough time at the surface breathing to allow sufficient

transmissions to be made. Marine animals presently account for around 5% of total uses of the Argos system.

### **1.3. Determining Which Telemetry System to Use**

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. However, some generalizations apply when deciding which type of telemetry is most appropriate for a particular study (Mech and Barber, 2002).

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. Furthermore, VHF units can be used on virtually any animal, whereas satellite and GPS telemetry units are often heavier and thus limited to medium-to-large mammals. However, VHF telemetry is generally more labour-intensive and provides a less accurate estimate of position. The costs of increased labour and transportation and the researcher's flexibility about data quality must be considered. While VHF is not as accurate as GPS telemetry, it can be combined with direct observations for finer-scale studies.

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. Satellite telemetry, as with conventional VHF telemetry, is not usually an appropriate method for fine-scale habitat studies (Rempel *et al*, 1995). GPS telemetry is the most spatially accurate form of telemetry and can be used with reasonable confidence for relatively fine-scale habitat studies. A principal advantage of GPS units is the number of locations acquired per animal. For example, in a 30-day period, 2,880 locations per animal can be acquired with a GPS unit programmed for 15-minute fixes. Satellite telemetry may be more cost-effective than radio-telemetry in certain situations. For example, on a cost/data-point basis, conventional VHF telemetry was estimated to be 43 times more expensive than satellite telemetry (five-year study; ten animals; one location per day) (Fancy *et al*, 1989).

#### ***1.3.1. Data analysis and interpretation***

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 is typical of time-series data where the relationship between observations and the same values at

a fixed time interval later, can result in residual errors. There are a wide range of analytical techniques used to address this issue, from regression to quasi-least square analysis (Shultz and Chiganty, 1998).

Studies based on GPS tracking generally track a small number of individual animals because of the expense per GPS unit. Each unit may provide a very large data-set but if the animals themselves are considered the study unit, this reduced sample size can cause data-analysis problems when generalizing about a population as data are spatio-temporally auto-correlated. The data are often also unbalanced, which provides presence-only data of potentially behaviourally complex animals (Aarts *et al*, 2008). However, providing researchers are aware of these biases during analysis and care is taken in interpreting the results, studies where only a small number of individuals are tagged can still provide insights into a species behaviour which completely revises long-held theories on movements and behaviour (e.g. basking sharks).

Kernel analysis is a type of principal component analysis where linear operations (track-lines) are reproduced in a kernel Hilbert space and non-linear mapping is frequently used to identify high-use areas (Matthiopoulos, 2002). Johnson *et al* (2008) proposed a continuous random walk model for animal telemetry data which allows data that have been non-uniformly collected over time to be modelled. Aarts *et al* (2008) reviewed the evolution of regression models for the analysis of space use and habitat preference and outlined the essential features of a framework that emerges naturally from these foundations. They applied this framework to data from satellite-tagged grey seals from the east coast of Scotland and concluded that flexible empirical models can capture the environmental relationships that shape population distributions.

#### **1.4. 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, bolted through body parts or implanted into the body (Table 3). Such methods vary in their ease of application, attachment duration and potential effect on the subject animal. Adverse effects from capturing and radio-tagging terrestrial animals can range from short to long-term and from apparently tolerable to severe or fatal (Mech and Barber, 2002). Severe to fatal effects are restricted to smaller species (Birgham, 1989) which are generally associated with radio and not satellite tracking. Effects on marine megafauna are generally considered short-term though lesions associated with tagging may persist for several years (Weller, 2008).

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 (maximum one to two weeks, White and Garrott (1990)). Therefore, some workers recommend that data should not be considered reliable until after at least one week of acclimation to the tag. Conceivably, radio signals themselves could have some ill effect on the animal wearing a collar. However, the effective radiated power from VHF transmitters is so low that this possibility seems highly unlikely. Although the radiated power of Platform Terminal Transmitters (PTT) is several orders higher than for conventional animal-tracking transmitters, there have been no findings of detrimental effects to the animal (e.g. Taillade, 1992).

**Table 3:** 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 <i>et al.</i> (2008),
Tethered to anchors	Large and medium whales, sharks	Tag large animals	Potential for infection	Baird <i>et al.</i> (2010) Gore <i>et al.</i> (2008)
Bolted	Large and medium odontocetes	Long deployment	Catch and handle animal, infection, stress	Mate <i>et al.</i> (1995; 1996) Martin and da Silva (1998)
Suction cups	Medium-sized cetaceans	Skin not broken	Short attachment duration, close approach	Johnston and Tyack (1996)
Glue	Pinnipeds, turtles, birds	Hydrodynamically efficient, cheap	Catch and handle animal	Fossette <i>et al.</i> (2008)
Implantation	Otters	Track small, hydrodynamic species	Very invasive, capture and handle animal	Mech and Barber (2002) Reid <i>et al.</i> (1986)

### Glueing

This is the simplest method of attachment, and is effective for species with long hair or feathers that can be easily captured and handled. Tags are often attached to a strap which is glued to the animal, thus allowing easy detachment of the tag by the researcher. The strap will drop off during moulting.

### Harnesses

Harnesses are widely used for seabirds, sea turtles and seals, species that can be relatively easily caught and handled for attachment of the harness. Recently Fossette *et al.* (2008) suggested harnesses may have potential impact on individual turtles during long-term



deployments, associated with increased drag, and suggested transmitters stuck directly onto the carapace reduced hydrodynamic impact and reduced stress.

#### Suction cups

Suction cups have been used to attach a wide variety of transmitters, but generally TDRs or DTAGs are used as these only require short duration attachments (hours) to collect useful data. Suction cups are not used for tracking studies which require a longer duration deployment. Stone *et al* (1994) developed a suction cupped radio-transmitter for endangered Hector's dolphins (*Cephalorhynchus hectori*). They obtained deployments from 2 to 18 hours and provided data on surfacing intervals. The maximum deployment using suction cups on a large cetacean is three days for a fin whale (Hooker and Baird, 2001).

While the actual suction cups on which the transmitters are attached will have little or no effect on the study animal, the attachment process does have the potential to disturb or cause damage. Suction cups may be attached via a long pole, which allows the suction cup attachment to be lowered onto the study animal (e.g. Johnston and Tyack, 1993).

#### Bolting and surgical implanting of tags

Bolting and surgical implanting of tags into an animal requires capture and handling. This can result in additional trauma caused by surgery, and possibly requires recapture to administer follow-up care. Early studies of dolphins used plastic pins (Dieldrin) to bolt satellite tags onto the dorsal fin as this was the part of the dolphin that became clear of the water on surfacing and provided a surface on which the tag could remain upright thus facilitating data transmission to overhead satellites (e.g. Mate *et al*, 1993; 1995). No long-term reaction to satellite tags bolted onto river dolphins (*Inia geoffrensis*) was reported over periods of years after attachment (Martin and da Silva, 1998).

Sirtrack have recently developed a new tag, KiwiSat 202, which attaches to the trailing edge of the dorsal fins of animals such as dolphin and whales. The tag has a single point of attachment; however, the animal still needs to be captured to attach the tag.

Surgically implanted transmitters such as subcutaneous transmitters, abdominal transmitters or rumen transmitters are generally restricted to radio-telemetry studies of terrestrial animals (Mech and Barber, 2002). However, several studies using implanted tags found no lasting negative impacts from the implant or the surgical procedure. Reid *et al* (1986) concluded that

implants did not affect the reproductive cycle in river otters. Copulation, embryonic and foetal development, and lactation behaviours were all normal in surgically implanted river otters.

#### Tethered to anchors

Most studies using remote attachment of transmitters involve firing anchors into the study animal to which the tag is attached. The tag is usually deployed with a crossbow (e.g. Baird *et al*, 2010) when tagging large or medium-sized cetaceans, and this method is considered the most successful when using a penetrating barb attachment (Hooker and Baird, 2001). Watkins *et al* (1993) used a shotgun to deploy tags into sperm whales (*Physeter macrocephalus*). Heide-Jorgensen *et al* (2001a) have developed a system which uses compressed air. The Air Rocket Transmitter System (ARTS) uses a converted air driven line thrower which works as a long-barrelled gun and only requires a scuba tank with a DIN coupling. In this attachment, method barbs are fired into the animal to hold the tag. Barbs may be subcutaneous or sub-blubber.

For deployment of satellite tags (PAT) on pelagic sharks, a simple pole with the anchor pushed through the shark's skin just below its dorsal fin have been used when the shark is on or near the surface (e.g. Gore *et al*, 2008).

Studies on the impacts of tagging on cetaceans date back to the late 1970s (e.g. Watkins (1981). Weller (2008) was recently commissioned by the US Marine Mammal Commission to review the effect of tagging on large cetaceans to inform the Western Gray Whale Advisory Panel, which is considering the advisability of tagging studies on this critically endangered species. Evaluating the effects of tagging on large whales has been difficult due to the large-scale movements of these animals and the difficulty of locating and observing them at sea after they have been tagged. There is no actual evidence on the potential physical or physiological effects of tagging although Weller (2008) points out that large whales have survived attacks by predators, ship strikes, entanglement and the subcutaneous implantation of tags (e.g. Discovery tags), harpoons and bomb lances. Healing responses to penetrating wounds are also poorly understood and most information on wound healing is based on dolphins. The normal progression of wound healing is disrupted when an implanted tag remains in place. Full healing cannot occur as percutaneous tags keep the wound at least partially open, unlike for implanted tags which become permanently encapsulated within the body (Weller 2008). A number of studies have examined tag sites to explore their effect. Watkins *et al* (1981) observed no infection of humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*) and brydes whales (*Balaenoptera edeni*) 16 to 18 days after tagging. Mate *et al* (2007) re-sighted 40 of 430 whales tagged between 1990 and 2005 and although some whales exhibited varying

levels of swelling or scarring at the tag site, none was in poor health. Quinn *et al.* (1999) reviewed 55 tags deployed on 49 whales between 1988 and 1997. A total of 48 (87%) of the tag sites were classified and 60% of tagged whales exhibited some swelling, with a few persisting for up to seven years.

Several studies have described the behavioural reaction to tagging. Generally they indicate the reactions are frequently unnoticeable or mild and return to “normal” in a short period, though long-term impacts are hard to record. More pronounced reactions have been reported, including vigorous swimming, underwater exhalation, breaching and group disaffiliation (Weller 2008). The need for close approach in order to tag whales makes it difficult to distinguish this impact from the impact of the actual tagging. Certain activities such as boat handling, tag attachment and photo-identification should be carried out by experienced personnel in order to reduce the amount of disturbance. Three studies have explored long-term effects of tagging: re-sighting rates of tagged versus un-tagged North Atlantic right whales were the same, six of the seven southern right whales (*Eubalaena australis*) tagged off South Africa were observed the following year with calves and exhibited calving intervals similar to untagged whales. Of the seven humpback whales tagged between 1976 and 1978, all were re-sighted over a 17-year period with five re-sighted over a 30-year period. These suggest no long-term effects of tagging. Follow up direct observation of tagged individuals should be an integral component of any research plan, including information pre-tagging for comparison (Weller, 2008). Watkins and Tack (1991) explored the reaction of sperm whales to tagging with implanted tags and described relatively mild reactions consistent with similar studies of baleen whales.

Since the inception of tagging studies on large whales, a variety of tag designs and attachment methods have been used. The depth to which a tag penetrates has been the subject of much discussion. The poor structural stability of blubber allowed significant tag movement to occur, resulting in premature detachment but also reducing healing potential. Deeper penetration into the muscle reduces tag movement and increases longevity of attachment but may increase the chances of systemic infections. Practices such as sterilization of tag components and use of tapered bladed cutting tips may minimize the introduction of bacteria etc into the wound (Weller 2008). The use of antibiotics is still contentious and Weller (2008) reported participants at a recent workshop could not reach consensus on their use. The use of highly miniaturised tags in the future should alleviate some of the physical and behavioural concerns surrounding the use of implanted tags.

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 instrumented. 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).

## 1.5. Relevant Research Studies using Biotelemetry

### 1.5.1. Cetaceans

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. Initial radio tags were developed in the 1960s by Woods Hole Oceanographic Institute in the US and adapted to satellite telemetry in the 1990s (Wartzok and Maiefski, 2001). In recent years, there has been a huge increase in the use of satellite-telemetry for recovering data on diving, foraging behaviour and orientation of cetaceans.

#### 1.5.1.1 Large cetaceans

To date six species of Mysticete or baleen whale have been recorded in Irish waters, including the relatively small minke whale (*Balaenoptera acutorostrata*). Some of these species are seasonally abundant (minke, humpback and fin whale) while others are migratory (blue *Balaenoptera musculus* and sei whale *Balaenoptera borealis*) or very rare (northern right whale *Eubalaena glacialis*).

Many species of large whale have been tracked with radio and satellite tags in the northeast Atlantic. Fin whales have been tracked with both radio-telemetry (Watkins *et al*, 1984) and satellite telemetry off Iceland (Watkins *et al*, 1996), and in the Mediterranean (Mouillot and Viale, 2001). Blue whales have been tracked for 22 days in the Atlantic (Heide-Jørgensen *et al*, 2001a) via a Telonics ST-15 tag deployed from an Air Rocket Transmitter System (ARTS), and humpback whales have been tracked in the south Atlantic using SPOT satellite tags deployed from an eight-metre long fibre glass pole (Zerbini *et al*, 2006; Dalla Rosa *et al*, 2008). The minke whale is the smallest species of baleen whale and was first tagged in 1994 off northern Norway (Heide-Jørgensen *et al*, 2001b).

Sperm whales, the largest odontocete species, have been the subject of a number of studies, especially on diving behaviour (Watkins *et al*, 1993). These studies showed sperm whales dive to over 2,000m water depth.

**Table 3: Biotelemetry studies of large whales in European waters**

Species	Year and Location	Tag type	Longevity	Reference
Fin whale	1984: Iceland	30 MHz radio tag	10 days	Watkins <i>et al</i> , 1984
Fin whale	1994: Iceland	PTT via crossbow	45 days	Watkins <i>et al</i> , 1996
Minke whale	1994: Iceland			Nordoy <i>et al</i> , 1994
Minke whale	1994 and 1999: Iceland/Norway	PTT via crossbow and ARTS	31-19 days	Heide-Jørgensen <i>et al</i> , 2001b
Fin whale	1991: Mediterranean Sea	PTT via small harpoon	42 days	Mouillot and Viale, 2001
Fin whale	1998: Mediterranean Sea	TDR with VHF transmitter	Up to 8 hrs	Panigada <i>et al</i> , 1999
Sperm whale	1998: Azores	PTT via crossbow	2-4 days	Lars Kleivane
Fin whale	1998-2002: Mediterranean Sea	VHF transmitter and TDR	Up to 6 hrs	Panigada <i>et al</i> , 2003
Humpback whale	2000-2001: Greenland	ST-15	32-77 days	Heide-Jørgensen <i>et al</i> , 2003
Blue whale	2005: Azores	SPOT tags (PTT) via ARTS		Lars Kleivane
Sei whale	2005: Azores	SPOT tags (PTT) via ARTS	69 days	Lars Kleivane

#### 1.5.1.2 Small cetaceans

There are 18 species of odontocete (toothed whales) recorded in Irish waters, of which five species are beaked whales (family Ziiphiidae) and one species, the sperm whale, which is usually considered a large cetacean. Radio-telemetry has been used to study small cetaceans since the 1960s (Evans, 1971; Perrin *et al*, 1979) and satellite telemetry since the 1980s (Tanaka, 1987; Mate, 1989). In Europe, satellite telemetry of small cetaceans is limited to an ongoing study of harbour porpoises in Denmark.

One of the first species to be tracked using biotelemetry was one of the smallest of the cetaceans, the harbour porpoise. Gaskin *et al* (1975) demonstrated that radio tracking could be successfully applied to harbour porpoises in the Bay of Fundy. However, as transmitters were considered too large to be carried by this species, it was not until 1981 that Read and Gaskin (1985) carried out a more detailed study. Harbour porpoises were captured in herring weirs with seine nets and a Telenics TR2 radio-transmitter attached to their dorsal fin with two bolts. The duration of radio contact ranged from 0.30 to 22.4 days, with a mean of 5.1 days. During these periods, porpoises were estimated to travel 15-20km in a 24-hour period. An Atlantic spotted dolphin (*Stenella frontalis*) was tracked using radio-telemetry by Leatherwood and Ljungblad (1979), who bolted a radio-transmitter onto the dorsal fin of a live-stranded dolphin which was subsequently refloated.

One of the main species of small cetacean involved in early biotelemetry studies was the bottlenose dolphin (*Tursiops truncatus*). Mate *et al* (1995) used a Telonics ST-6 satellite tag to monitor the movements and dive behaviour of an adult dolphin for 25 days during which the dolphin moved at least 581km and made 63,922 dives. The tag was attached to a moulded plastic saddle which, in turn, was attached on the dorsal fin with five plastic pins. These were designed to break and detach the saddle if the saddle or tag became entangled. The dolphin was captured using an encircling net in shallow water off Tampa Bay, Florida.

To facilitate access to small cetaceans, stranded and rehabilitated dolphins and porpoises have been tracked on release. An Atlantic spotted dolphin that had been stranded and rehabilitated was fitted with a time depth recorder (SLTDR) in 1995 off Texas, in the US (Davies *et al*, 1996). The satellite-linked, time-depth recorder (Wildlife Computers SLTDR) tag was attached to a saddle, which had been moulded from polyethylene thermoplastic and lined with neoprene rubber to prevent skin abrasion, fitted over the animals dorsal fin and was held by three Delrin pins with magnesium nuts designed to dissolve in about three weeks after deployment. During 23.7 days of transmission, the dolphin moved 1,711km, ranging along a 300km stretch of coast line at a mean of 72km per day. A total of 15,506 dives were recorded for dive depth and 16,547 for dive duration (Davis *et al*, 1996). Similarly an Atlantic white-sided dolphin (*Lagenorhynchus acutus*), live stranded in Massachusetts in the US, was rehabilitated and fitted with a satellite transmitter, bolted onto its dorsal fin, providing the first data on movements and dive behaviour of this species (Mate *et al*, 1993). The dolphin was tracked for six days, during which time it travelled 309km and provided data on 4,036 dives.

A number of species have been fitted with TDR/VHF tags attached with suction cups. Hooker and Baird (1999) made 84 attempts to tag bottlenose whales (*Hyperoodon ampullatus*) in the Gully off Nova Scotia, with five successful deployments remaining attached for a maximum of 28 hours. This was the first diving data on northern bottlenose whales and the first such data on any species within the family Ziphiidae. Similar studies using suction-cup attachments have been carried out on pan-tropical spotted dolphins (Baird *et al*, 2001), short-finned pilot whales (*Globicephala macrorhynchus*) (Baird *et al*, 2002), Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales (Baird *et al*, 2006) off the Hawaii Islands in the Pacific. Suction cups have also successfully been used to attach radio tags remotely on Hector's dolphins in New Zealand and Dall's porpoises (*Phocoenoides dalli*) in British Columbia. Stone *et al* (1994) deployed tags on three Hector's dolphins off the Banks Peninsula, in New Zealand, using a pole on bow-riding individuals. Deployments lasted from 30 and 60 minutes to four to 18 hours. Hanson and Baird (1998) made 15 tagging attempts on Dall's porpoises off British Columbia in the US, with three successful deployments, of which one remained attached for 41 minutes. Both studies reported short-term reactions such as flinch and high-speed swimming.

Deploying tags with darts designed to penetrate the connective tissue in the dorsal fin have been used for tagging false killer whales (*Pseudorca crassidens*) (Baird *et al*, 2010) and Blainville's beaked whales (Schorr *et al*, 2010) in Hawaii. These resulted in up to 76 and 71 days of tracking data respectively.

Within European waters, the most extensive biotelemetry study of a species of small cetacean was a satellite telemetry study of harbour porpoises. Teilmann *et al* (2004) tagged 14 harbour porpoises with Satellite-Dive-Recorders (Wildlife Computers SDR-T10). In addition, Teilmann *et al* (2008) reported on the results of 63 harbour porpoise satellite tracked during the period 1997 to 2007 to identify high density areas to support conservation management. The porpoises were all unintentionally trapped in pound nets throughout the Danish Baltic and eastern Skagerrak. Satellite tags were attached to the dorsal fin with two or three bolts with iron nuts, designed to fall off after around one year. Tags were deployed in all months on both male and female animals but mainly were young animals (87%) as these were more likely to be caught in pound nets. Tags were fitted with salt-water switches so tags were only active when clear of the water and had a repetition rate of 45 seconds. The number of days with satellite contact ranged from 14 to 130, with average duration lasting within 96% of battery life, indicating it was the battery that was the limiting factor rather than attachment. The overall average number of dives was 34 per hour, with no significant difference between April to

August but higher in October and November. The maximum dive depth ranged from 6 to 132m, with the most frequent between 14 and 32m. Four female-calf pairs were tagged during a study by Teilmann *et al* (2004), providing a unique insight into the behaviour of two related animals. The female spent more time diving than the calf, which made more frequent but shorter duration dives. Satellite tracking data when combined with acoustic and aerial surveys provided a basis for describing 16 management units, which could be ranked in order of importance for harbour porpoises (Teilmann *et al*, 2008). Recently Sveegaard *et al*, (2011) combined acoustic data from the Kattegat with satellite telemetry data and showed a high level of agreement in identifying those areas with elevated densities, which are thus suitable for designation as Marine Protected Areas.

**Table 4:** Biotelemetry studies of small cetaceans in European waters

Tag type	Year and Location	Tag type	Longevity	Reference
Harbour porpoise	1997-1999: Denmark	Satellite Dive Recorders, bolted through dorsal fin		Teilmann <i>et al</i> , 2004
Harbour porpoise	1997-2007: Denmark	Satellite Dive Recorders, bolted through dorsal fin	14-130 days	Teilmann <i>et al</i> , 2008

### 1.5.2. Seals

Two seal species breed in Ireland: the grey (*Halichoerus grypus*) and common or harbour seal (*Phoca vitulina*). Grey seals are widespread along the east and west coasts of Ireland (O’Cadhla *et al*, 2008) while common seals are more localised, with breeding colonies in the southwest, west and northwest (Cronin *et al*. 2010).

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 (e.g. McConnell, 1986; Hill *et al*, 1987; Stewart *et al*, 1989). 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 (Hooker and Boyd, 2003; Hooker *et al*, 2007) and even cameras (Heaslip and Hooker, 2008). For example, Costa *et al* (2008) used crabeater seal (*Lobodon carcinophagus*) to supplement traditional oceanographic sampling methods for investigating 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.



**Figure 2:** Track of grey seal (“Bran”) released in Co Dublin in June 1999

In Ireland common seal pups were tracked using VHF telemetry in Co Down (Wilson, 1999a; 1999b; Wilson *et al*, 1999a; 1999b). These studies showed that during the first three weeks, pups stayed local to the tagging site but then ranged further afield. The first satellite telemetry of a seal in Ireland was carried out by the Irish Seal Sanctuary, which tracked a young grey seal post-release in June 1999 from Co Dublin to Co Wexford, and then north to Co Down over a period of 20 days (Fig. 2). The seal was fitted with a PTT stuck on the top of its head.

The largest biotelemetry study of seals in Ireland was conducted on common seals in the Kenmare River, Co Kerry. A feasibility study of the effectiveness of using the mobile phone tag was carried out during 2004 and 2005 when ten common seals were tagged with an earlier prototype of the tag (Cronin and McConnell, 2008). The GSM telemetry system proved effective at obtaining information on haul-out behaviour and provided crude movement information that was less labour intensive than VHF telemetry. After this pilot study, harbour seals were tagged during 2006 and 2007 with a hybrid GPS tag system called Fastloc (Cronin, 2007). The significant advantage of this system is that the required data capture requires less

than half a second at the surface. This opens up the possibility of very frequent and accurate positions being acquired at sea. The location, dive and haul-out records are stored onboard the tag. The tag uses GSM (mobile phone) technology, which contains a mobile phone modem. When the seal comes within range of the coastal GSM zone (up to about 20km from the coast) after a period of days, weeks or even months offshore, the records are sent ashore to a dedicated computer via a data link call.

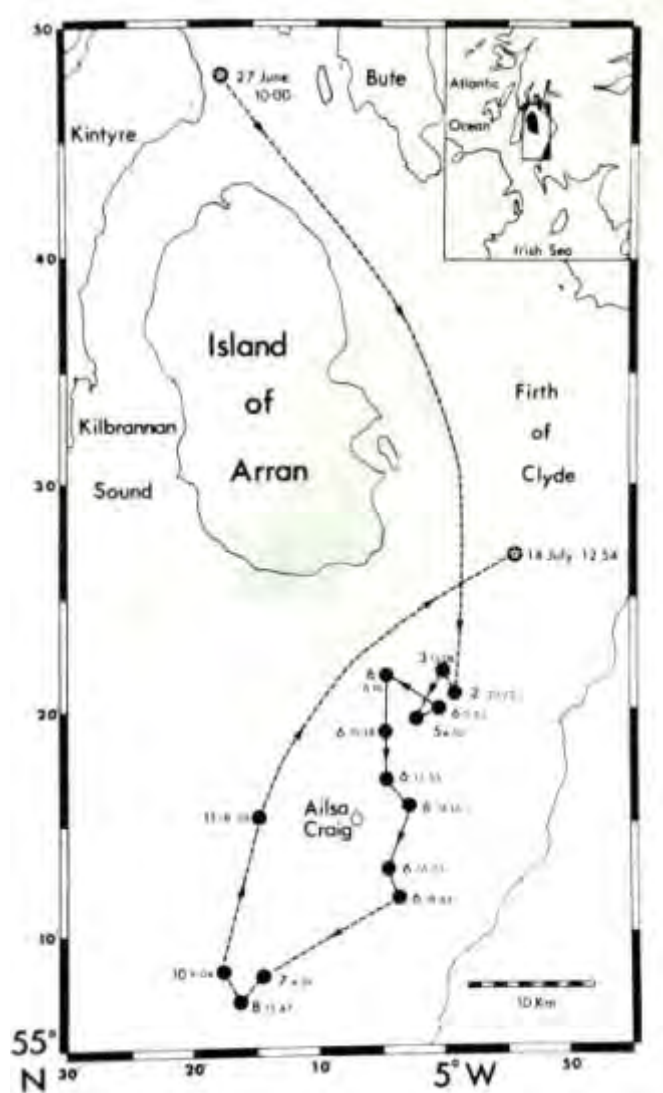
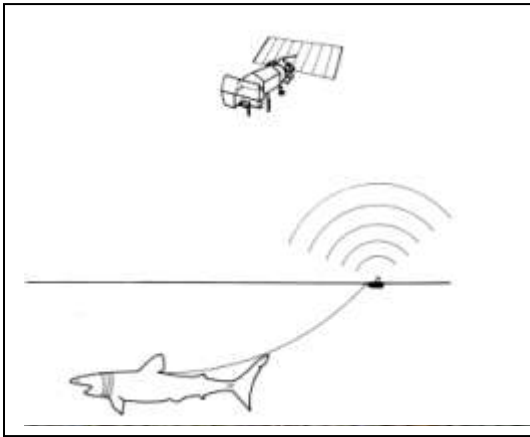
Satellite tracking of grey seals in the Blasket Islands, Co Kerry, using Fastloc GPS and GSM tags is ongoing. It was planned to tag 12 seals between 2008 and 2010, and early results have shown extensive movements from Co Kerry to Scotland, with half the seals tagged travelling these distances. Telemetry data has also been used to investigate the haul-out behaviour of harbour seals in southwest Ireland (Cronin *et al*, 2010).

McMahon *et al* (2008) deployed TDRs and PTTs on 124 elephant seals (*Mirounga leonine*) on Macquarie Island in the Indian Ocean. Tags were attached to seals prior to the moult and deployed for between 70 and 280 days. They showed that deployment of tracking devices and telemetry did not affect the at-sea mass gain by elephant seals even after multiple deployments on the same individuals.

### ***1.5.3. Basking sharks***

Basking sharks have an important historical significance in Ireland as part of a seasonal but important subsistence fishery in the 18<sup>th</sup> and 19<sup>th</sup> century from Co Donegal to Waterford, but especially in Connemara (McNally, 1976). Basking shark is frequently observed on the sea surface from May to September each year. This behaviour is thought to be associated with sea-surface temperatures (Berrow and Heardman, 1994).

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. The tag was contained within a pressure proof package and towed 10m from the shark (Fig. 3). Once the tag submerged below 5m, a pressure switch inactivated the transmitter to save battery life.



**Figure 3:** Tagging system tag and track of first basking shark satellite telemetry in 1982

Since 2001 basking sharks have been fitted with satellite tags on both sides of the Atlantic. In the UK, Sims *et al* (2003) fitted archival tags to 20 basking sharks off Cornwall and southwest Scotland. Data were received from seven (35%) of these. It was assumed that the remaining tags malfunctioned because they failed to relay data to satellites at or soon after pop-up time. The working tags provided 964 days (74 to 229 days per tag) of data covering a minimum distance of 16,754km (1,616 to 3,421km per tag). The PAT tags were able to record depth, water temperature and light level, and were programmed to “pop-off” after a pre-programmed period. The track was re-constructed using maximal rate of change in light intensity to estimate the local time of midnight or midday for longitude and sea-surface temperature for latitude. The best-fit sea-surface temperature from remote-sensing sea-surface temperature (SST) images was used compared to archival data after correcting for

cloud cover. The accuracy of the latitude and longitude position was estimated from 1-173km. These measurements and parameters have been used on each subsequent satellite telemetry study using PAT tags on basking sharks.

Sims *et al* (2003), using PAT archival tags, showed that basking sharks off southwest England and Scotland undertook extensive horizontal and vertical movements associated with the continental shelf and shelf edge throughout the year. This contradicted a long held hypothesis that basking sharks in the northeast Atlantic formed discrete stocks and hibernated during the winter when plankton densities were at a minimum. The results from this single satellite telemetry study completely changed the contemporary perception of the ecology of this familiar species. In the US, Skomal *et al* (2004) tagged a female shark with a PAT tag and obtained data for 71 days in which it travelled 800km, confirming that basking sharks associate with the continental shelf and shelf edge and remain active through the autumn. This corroborated the study by Sims *et al* (2003). A further revelation was presented by Gore *et al* (2008), who tracked a large female basking shark with a PAT archival satellite tag from the Isle of Man in the Irish Sea to Newfoundland, a distance of 9,589km in 82 days. This was the first evidence of a transatlantic movement, linking European and American populations.

The power of satellite and archival tagging in challenging our understanding of the ecology of large marine megafauna is demonstrated by the work of Sims on basking sharks. Although PAT tags are designed to archive data and transmit these data via the Argos satellite system once detached from the shark, additional data can also be downloaded from the tag if it can be recovered. Using the data from the 20 sharks tagged in 2001/2002, papers have been produced on spatial distribution (Southall *et al*, 2005), foraging ecology (Sims *et al*, 2005, 2006a) and energetics (Sims *et al*, 2006b), and there has been an attempt to use the data to explore the usefulness of protected status within UK territorial waters (Southall *et al*, 2006). Interestingly, data from satellite telemetry was also used to assess the accuracy of dedicated visual sighting surveys for basking sharks and public sighting schemes (Southall *et al*, 2005). They showed that surface sightings data did identify areas of high densities or “hot-spots” but tag geo-locations identified other areas where sharks spent considerable periods of time but were not identified from sighting surveys. This has implications for abundance estimates based on surface sightings.

The preferred method of attachment for most studies has been to use darts to anchor the tag either through the dorsal fin (Sims *et al*. 2003) or, intra-muscularly, just below the dorsal fin (Skomal *et al*, 2004, Gore *et al*, 2008). These have been deployed using a pole from a boat

(Sims *et al*, 2003, Gore *et al*, 2008) or by divers (Skomal *et al*, 2004). The tag is tethered to the anchor with monofilament line of various lengths from short (<50mm and 200m, Gore *et al*, 2008; Skomal *et al*, 2004) to long 1.8m tethers (Sims *et al*, 2003). Sims *et al* (2003) used the known length of the tether trailing behind the shark to estimate the total body length of the shark.

**Table 5: Biotelemetry studies of basking sharks in European waters**

Tag type	Year and Location	Attachment	Longevity	Reference
PAT archival	2001: Cornwall and Scotland	Dart with 1.8m tether	52-198 days	Sims <i>et al</i> , 2003
PAT archival	2001/2002: Cornwall and Scotland	Dart with 1.8m tether	74-229 days	Sims <i>et al</i> , 2006a Southall <i>et al</i> , 2006
PAT archival	2001: Massachusetts, US	Dart with 200mm leader	70 days	Skomal <i>et al</i> , 2004
PAT archival	2005-2010: Isle of Man	Dart with nylon leader	41-82 days	Gore <i>et al</i> , 2008, Manx Wildlife Trust
PAT archival	2009 and 2010: Isle of Man and Brittany	Dart with nylon leader	5-245 days	Stéphan <i>et al</i> , 2011

The accuracy of positional data from archival tags was tested by Wilson *et al* (2007) on whale sharks (*Rhincodon typus*) using multiple tagging of the same shark. Their findings supported the use of archival tag data to reconstruct the large-scale movements of marine animals. There have been no studies assessing the impact of tagging on basking sharks in the short or long-term.

#### 1.5.4. Marine Turtles

Five of the seven species of marine turtle have been recorded in Ireland, with the leatherback turtle (*Dermochelys coriacea*) by far the most frequently recorded (King and Berrow, 2010). Leatherback turtles are now recognized as a regular annual visitor to Irish waters. Records date back to the early 1900s (O’Riordan, 1972). The breeding beaches from where turtles in Irish waters originate is not known but large nesting colonies occur in the Caribbean, especially in French Guiana, and off West Africa.

**Table 6:** Biotelemetry studies of marine turtles in European waters

Tag type	Year and Location	Tag type	Longevity	Reference
Satellite Relay data Loggers (SRDL)	2005: Co Kerry	Harness	375	Doyle <i>et al</i> , 2008
Satellite Relay data Loggers	2006: Co Kerry	Glued directly onto carapace	233	Doyle <i>et al</i> , 2008

Early telemetry of adult leatherback turtles was carried out using Time-depth-Recorders attached by harnesses on gravid females on St. Croix, US Virgin Islands, in the Caribbean, as access at the nesting beaches was very easy (Ekert *et al*, 1989). Leatherback turtles have also been captured and tagged at sea off Nova Scotia, US, through the use of hoop-nets (James *et al*, 2005). Satellite-telemetry using Platform Terminal Transmitters attached to a harness around the turtle has been very successful in recording long movements of up to 7,000km in the north Atlantic (Hays *et al*, 2004; Hughes *et al*, 1998). These data have been used to identify migration routes and high use habitats, thus helping to assess threats to turtles at sea such as that caused by fishery interactions (e.g. Hays *et al*, 2004; James *et al*, 2005).

The first attempt to tag turtles in Ireland was carried out by Doyle *et al* (2008). They tagged two turtles which were caught in surface drift-nets off the Dingle peninsula, Co Kerry, in 2005 (female) and 2006 (male) (Fig. 4). Satellite Relay Data Loggers (SRDL) from the Sea Mammal Research Unit (UK) were used. These tags relay data on dive records, including speed and physical data such as sea temperature. The turtle caught in 2005 was removed to a local aquarium where it was fitted with a flexible harness to which the tag was attached (Myers and Hays, 2006). The turtle captured in 2006 was removed to shallow water and a SRDL was attached with cable ties directly via three holes drilled through the anterior part of the turtle's carapace. 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. The male turtle performed the deepest dives ever recorded by a reptile (1,280m) while south of the Cape Verde Islands.



**Figure 4:** Tracks of two leatherback turtles satellite tracked from the Dingle peninsula, Co Kerry

The use of harnesses for attached satellite tags to turtles has recently been reported to have potential welfare implications during long-term deployment (Troëng *et al*, 2006). Fossette *et al* (2008) proposed attaching tags directly to the carapace and showed more high quality uplinks were obtained than from harness-tagged turtles. This was attributed to a reduction in hydrodynamic constraints.

### 1.5.5. Others

#### 1.5.5.1 Tuna

Atlantic bluefin tuna (*Thunnus thynnus*) are one of the most enigmatic of marine megafauna in the sea and are true ocean roamers. While they have a widespread distribution from Newfoundland to the Canary Islands, significantly large numbers of Atlantic bluefin have been recently recorded in Irish waters within six miles of the coast. In 2003 Bord Iascaigh Mhara (BIM) established a tagging project in conjunction with scientists from Stanford University in the US and a charter skipper from the Irish Big Game Fishing Association. The aim of the tagging project was to investigate the movements of bluefin tuna through Irish waters and beyond. Six bluefin (over 135kg) were tagged and released during the first two years of the programme. The tags were PAT archival tags, designed to detach from the fish at a programmed date and time. The buoyant tag floats to the surface and transmits the stored data via satellite to the end user. Information on depth, associated water temperature and light



levels was collected. These data were correlated with sea surface temperature data to provide geographical positions, enabling maps of fish movement or migration to be created. So far two electronic tags have been recovered successfully. The tags were carried by two individual bluefin tuna caught by hook-and-line by the same vessel at exactly the same time 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 continued swimming west and after six months the tag “popped up” east of the Bahamas. The second moved east from the mid-Atlantic and after seven months the tag was recovered west of Portugal.

#### 1.5.5.2 Porbeagle and blue shark

Porbeagle (*Lamna nasus*) and blue shark (*Prionace glauca*) are both important species of shark in Ireland from a commercial fishing and sports angling perspective.

In 2008 a study of porbeagles around Ireland using archival pop-up tags was started by the Marine Institute. Three porbeagles were tagged with PAT (Archival Pop-up Tags) in September. The sharks were caught using rod and line and were brought onboard for body-length measurement and tagging. Each tag was attached via a short nylon tether to a small dart at the base of dorsal fin. Tags were able to measure water temperature, depth and ambient light levels, which can all be used to calculate the shark’s position. The tags were programmed to detach after 122 days. The tag from Shark 1 popped up between the western coast of Morocco and the island of Madeira, indicating a southerly migration of over 2,400 km in a four-month period. This shark traveled mainly along the shelf edge to the northwest Bay of Biscay, where it stayed for about 30 days before heading south in more open waters. Shark 2 stayed in the oceanic waters around the shelf edge west of Ireland and Shark 3 also migrated southwards from the tagging site to the Celtic Sea and to the northwest area of the Bay of Biscay, where it stayed until the tag detached (Saunders *et al*, 2011).

The results indicate that porbeagles live in oceanic waters close to the shelf edge during the winter time, and that they may undertake long-distance migrations to regions further south. The Bay of Biscay and the west coast of Ireland seem to be ‘hotspots’ for porbeagles and this may be due to increased food sources (e.g. mackerel and blue whiting) in these regions. The results also indicated that porbeagles often occupy and traverse areas that are fished intensively by pelagic tuna and billfish fisheries.

Recently two blue sharks were tagged with PAT archival tags off southwest Ireland (Tom Doyle *pers. comm.*), with one tag recovered to date.



### 1.5.5.3 Sunfish

The ocean sunfish (*Mola mola*) is the largest bony fish in the world. It is usually associated with warm temperate water but is being increasingly reported in Irish waters (Houghton *et al*, 2006). Despite its size and unmistakable appearance, little is known about its biology. Sims *et al* (2009a) tracked three sunfish with pop-off PAT tags. One fish tagged off Co Kerry travelled 959 km of the tagging site to southwest England in 54 days. The sunfish occurred mainly in shallow water, with only 2% of recorded time below 200m. Sims *et al* (2009b) have developed a method of tracking sunfish in real time using Fastloc GPS and PTT tags attached to the fish via a long (1.5m) tether. The tag was attached to a float, allowing the PTT to communicate with the ARGOS satellite system when the sunfish was near the surface.

### 1.5.5.4 Otter

The European otter (*Lutra lutra*) occurs throughout Ireland, including along the coast, and biotelemetry studies were carried out by O'Neill *et al* (2008), who fitted radio transmitters to 11 otters, and de Jongh *et al* (2010), who carried out a pilot study to explore the use of GPS GSM transmitters to determine range sizes and diel activity. They placed Teiltracker GPS GSM transmitters on seven otters trapped in Roaringwater Bay, Co Cork.

## 1.6. Best Practice Guidelines

Over the last 20 years, the range of species tracked and devices deployed has expanded rapidly. The journal *Endangered Species Research* has become a very useful source of information on biotelemetry, not only for studies on individual species, but for reviews and for facilitating discussion on developments and best practice. Recent special issues of *Endangered Species Research* (e.g. Godley and Wilson, 2008) review many of the issues relating to using biotelemetry for conservation, technological advances and ethical considerations.

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 license. This usually requires an assessment of the impact of the activity and encourages the development and testing of tagging techniques.

One of the assumptions of telemetry is that the tagging activity and presence of the device do not adversely affect the individual (Cooke, 2008). Another assumption is that the relative benefits of the research outweigh any potential short-term costs to the individual or population. This inevitably drives the use of the best available technology and tagging methodology, and thus minimises further any potential impacts. There has been an explosion of studies that compare and contrast different tagging techniques with the purpose of minimising the impact (Cooke, 2008). 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, this 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 (Cooke, 2008). In addition, data analysis and filtering is improving, resulting in more results being obtained from each deployment. As experience grows, best practice on how to increase efficiency while minimising the impact on the target animals should develop in parallel. Many species being tracked and tagged are endangered, with populations depleted following over exploitation or habitat loss. Telemetry provide a very efficient tool for reliably assessing mortality rates in wild populations, especially wide-ranging or cryptic species, or those that occupy environments poorly accessible by humans (e.g. offshore) (Cooke, 2008). Estimates of population size and status often use Population Viability Analysis to determine conservation status. Many studies of endangered species have used biotelemetry data to inform metrics used in these analyses. Telemetry has also been used to locate breeding sites of endangered species, enabling researchers to collect data on reproductive potential. Biotelemetry is also an effective tool for determining movements, occupancy and habitat associations of endangered species (Cooke, 2008). Hart and Hyrenbach (2010) reviewed trends in tracking studies and recommended future tracking studies should determine the energetic demands that different tags place on instrumented animals.

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 the research.

Remotely deployed tagging techniques should consider a stop plate to prevent deeper penetration and the appropriately sized barb for the target species. For studies which involve handling animals during tagging, basic health measurements should be taken, including blood collection, morphometrics and skin samples for genetics (Anon, 2009).

If biotelemetry is to be carried out, all efforts must be taken to minimise the burden of the transmitter and the attachment/implantation on the individuals. There are a number of syntheses that provide telemetry practitioners with guidance for minimising the impact, though these guidelines are constantly updated as research provides new information. Tag design is a particular area which is developing rapidly and as tag size and weight decreases, the potential impact also declines.

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).

Recently Andrews (2011) has started preparing such a document to inform researchers and regulatory staff and to promote training opportunities. For large whales, Weller (2008) is considered a good review of the issues.



## 2. BIOTELEMETRY OF MARINE MEGAFUNA

### 2.1. Licensing Issues and Constraints

We had hoped to place satellite tags on fin whales off the south coast of Ireland using SPOT 5 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. The Department wanted to monitor the outcome of less-invasive, suction-cupping attachment techniques before licensing sub-blubber anchoring. We decided not to attempt to attach satellite tags with suction cups due to the high risk of tag loss and the limited tracking data a successful attempt would provide, given that studies elsewhere have shown tags tend to remain on the whale for a period of only hours.

The Department also noted that it would not be possible to determine gender, age, reproductive status or health, and, therefore, that researchers would not be able to adequately assess risk to the individual before tagging. The Department also required an assessment of the long-term number of individual fin whales that would require tagging to provide population scale answers and were concerned that the proposed sample size of five whales would only provide data on the individuals and not the population.

As part of the licence application, we consulted with ten marine wildlife tour operators along the south coast who we identified as key stakeholders. Concerns were expressed by one stakeholder regarding the potential impact on the whales and their population.

Due to licensing constraints, no attempt was made to carry out biotelemetry on cetaceans during this project.

## 2.2. Satellite Tracking of Basking Sharks

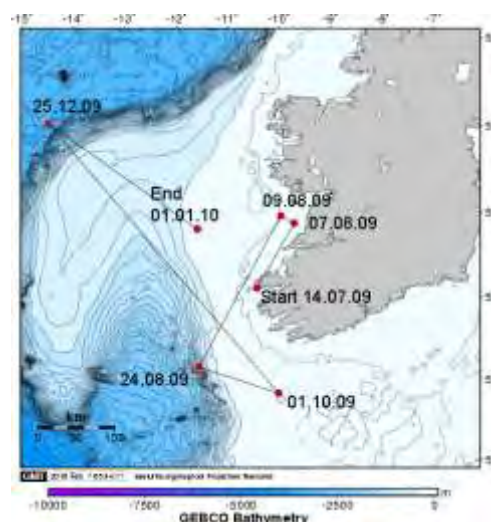
We obtained additional funding to attach satellite tags on basking sharks. This small study was carried out in collaboration with Mauvis Gore at Marine Conservation International in Scotland, and Jackie and Graham Hall from the Manx Basking Shark Watch in the Isle of Man. The satellite tags were funded by Galway-Mayo Institute of Technology and Crossing-the-line Films, which was producing a wildlife film documentary on migration called *Wild Journeys* for RTE television.

Historically, knowledge concerning the distribution and relative abundance of basking sharks in Ireland was based on surface sightings data (e.g. Berrow and Heardman, 1994). On 14 July 2008, two MK10 Archival Tags manufactured by Wildlife Computers were deployed on single basking sharks off Sleah Head, Co Kerry. The satellite tags were deployed with an extendable pole at the base of the sharks' dorsal fin. Each tag was 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 (seven months) at 1300 GMT. The tag also recorded time at temperature: 3, 4, 7, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 20+ °C and time at depth: 0, 20, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1000+ m. These settings were the same as tags used for deployment in the Isle of Man and southwest Scotland in 2009 to facilitate direct comparison of data (see Gore *et al* (2008) for details of data analysis).

A signal from tag A (7m male, Tag No. 08A0612) was received by the Argos system from the Celtic Sea on 21 February, ending a deployment period of 222 days. A signal from the second tag B (8m, gender unknown, Tag No. 08A0613) was received on 1 January 2010 around 150 km offshore of Co Clare, a deployment period of 170 days.



**Fig 5a:** Geo-locations from Shark A



**Fig 5b:** Geo-locations from Shark B

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. Shark A spent most time in the Irish and Celtic seas, with evidence of a southerly movement in the winter to the west coast of France (Fig. 5a). Movements of Shark B were more constrained. The shark remained off the southwest coast for the whole period, with locations noted off the shelf edge and in the Porcupine Bight (Fig. 5b). Recently one tag was recovered from Orkney, Scotland, and a full dataset downloaded, but the data has not been fully analysed. The tag has been sent to Wildlife Computers for refurbishment and re-batteried for deployment in 2012.

Depth data from both sat-tags are shown in Figures 6a and 6b. The greatest depth recorded by Shark A was 144m and Shark B, 136m. This shows that although Shark B was located over deep water off the shelf edge, it was not diving to large depths. Both Shark A and B were within 8m of the surface for 10% and 6% of the time respectively. Although we cannot say whether the sharks were on the surface and thus visible from above the surface, clearly they were not feeding at great depths.

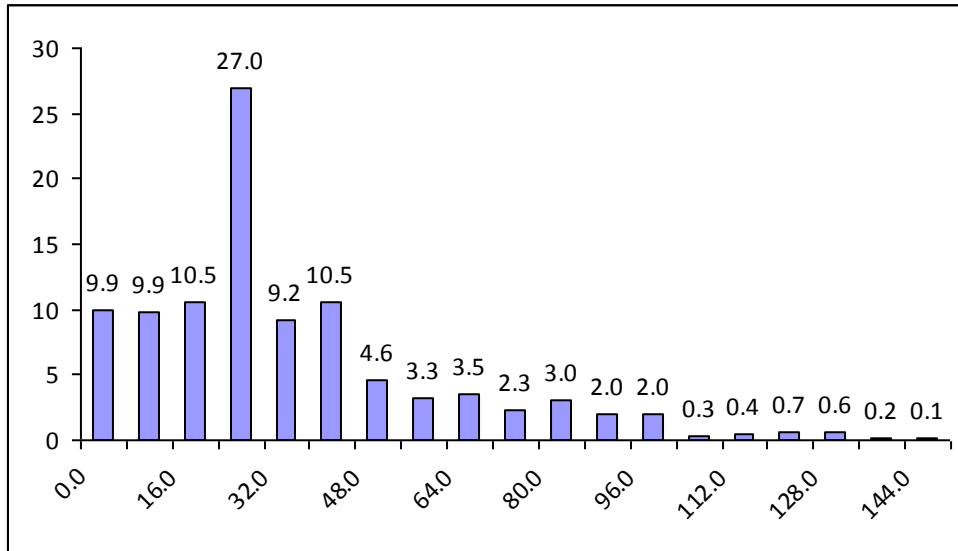


Figure 6a: Depth frequency histogram from Basking Shark A (Nos. are %)

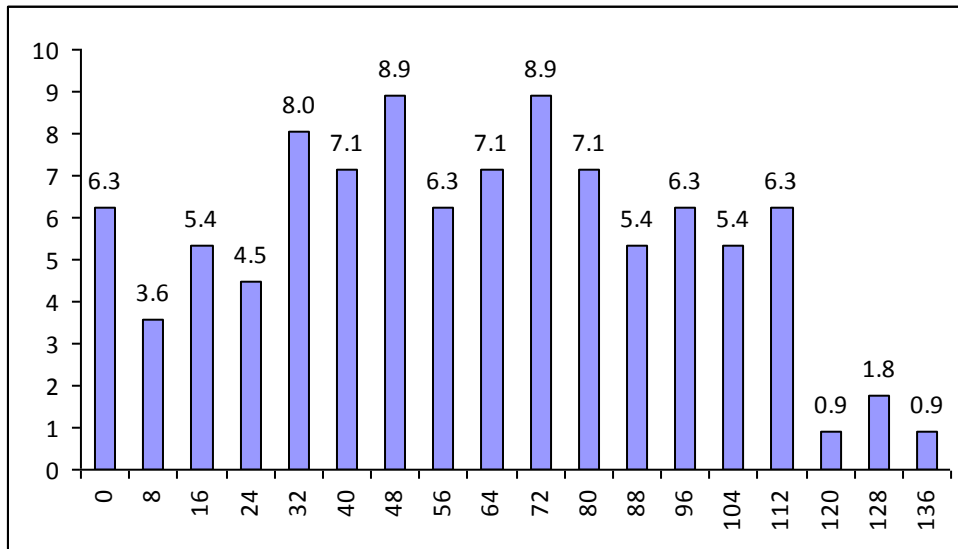


Figure 6b: Depth frequency histogram from Basking Shark B (Nos. are %)

The data from satellite-telemetry presented here is consistent with similar studies off southwest England (Sims, 2008). However, the accuracy of geo-locations derived from archival tags is poor, with resolutions as crude as within 50km<sup>2</sup>. This short study demonstrates that basking sharks are present in Irish waters throughout the winter period, and are active and have not hibernated. Depth data may provide information on the time an individual spent on the surface and thus provide potential correction factors for data from visual surveys. These data were presented to the ICES Elasmobranch Working Group (Berrow and Johnston, 2010).



### **2.3. Photo-Identification and Biopsy Sampling**

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 Irish Whale and Dolphin Group photo-ID catalogues. Matches were sought with the North Atlantic Fin and Humpback Whale catalogues held by Allied Hale in Bar Harbour, Maine, in the USA 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. A paper on humpback whale photo-identification is in preparation.

During this project, we obtained tissue samples from 11 fin whales and from three humpback whales under license from the NPWS (license nos. C76/2008; 82/2009; 113/2009; 47/2010). These samples are currently being analysed as part of a PhD study on the genetics and feeding behaviour of baleen whales in Irish waters by Conor Ryan at the Galway-Mayo Institute of Technology.



### 3. RECOMMENDATIONS

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 in the current period has 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. A workshop held during the 26<sup>th</sup> European Cetacean Society Conference in Galway in March 2012 provided an opportunity to review this technique and its application 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 asses potential impact.



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