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Marine megafauna of coastal waters of Cape Clear Island, Southern Ireland

Mořská megafauna příbřežních vod irského ostrova Cape Clear

Master thesis

Supervisor: Doc. RNDr. Adam Petrusek, Ph.D.

Prague, 2011

Declaration:

I declare this thesis is a result of my own work, except for the contribution of people stated in the acknowledgements. I properly cite all information sources used. The work contained in the thesis has not been used to obtain any other academic degree.

Prohlášení:

Prohlašuji, že jsem závěrečnou práci zpracovala samostatně a že jsem uvedla všechny použité informační zdroje a literaturu. Tato práce ani její podstatná část nebyla předložena k získání jiného nebo stejného akademického titulu.

In Prague, May 5, 2011

ACKNOWLEDGEMENTS

I would like to thank Dr Thomas K. Doyle of University College Cork, Ireland for giving me the opportunity to work at the Cape Clear Island.

Special thanks to assoc. prof. Adam Petrusek for supervising my work, many advices and big help with everything what was necessary – from help with contacting foreign turtle specialists, requests for financial support and especially for reading this thesis from the first versions and giving me advices how improve it.

Thanks to Steve Wing, his wife Mary and other friends from Cape Clear Island. Thank also to members of The Irish Whale and Dolphin Group (IWDG) for Whales and dolphin identification course. My stay at the island and the work conducted there would have been impossible without the great help I received from those people.

During my stay abroad, this project was partly supported by the National Parks & Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland; the Ministry of the Environment of the Czech Republic (through the resources of the Czech National Committee for the Cooperation with the Intergovernmental Oceanography Commission of UNESCO); Mobility Fund of the Charles University in Prague; the Czech and Slovak Ethological Society (through the Zdeněk Veselovský Prize) as well as by the Hlávka Foundation. Many thanks for this financial support, this project would have been impossible without this.

I would like to thank assoc. prof. Stano Pekár, Mgr. Petr Juračka and Mgr. Zdeněk Janovský for help with statistical analyses.

Thanks to many of my friends for correcting my English and help with figures. Thanks also to my family, especially to my sister for great support and respecting my work.

ABSTRACT

Land-based observations may contribute to an overall understanding of behaviour of large marine vertebrates and may help us understand how these animals react to climate change. I observed marine megafauna (cetaceans, Basking shark, and Sunfish) from Cape Clear Island situated in the south-west of Ireland. The study took place during the summer months (June - August 2008) because the majority of Leatherback turtles, Sunfish and other megafauna species are sighted in Irish waters in this period. Additionally to sightings, basic weather characteristics were recorded (sea state, visibility, glare and cloud cover) every day of observation.

Unfortunately, no Leatherbacks, my target species, were recorded during the study period (51 days) at Cape Clear. The reason for the turtle absence could be relatively cold and wet weather during the study period. Although no data was obtained on turtles, over 124 sightings of other megafauna were made, mostly cetaceans (five species) but also one individual Basking shark and several Sunfish. The species richness increased with time during the study period, and significantly higher number of individuals as well taxa was observed in the second month of the study when the sea surface temperature was higher. However, I did not detect a significant relationship of number of observations or megafauna species with the sea temperature itself. The recorded weather characteristics also did not have significant relationship with any of these parameters.

Additionally, detailed historical records about Leatherback turtles, Sunfish and Basking Shark sightings at the Cape Clear Island from 1971 until 2008 were collated from the Cape Clear Observatory records. This dataset contains data from 3510 days of sea observation, including the observation effort. The numbers of Leatherback turtle sightings during these years were generally low but there were two peaks in turtle abundance – the first in the period between 1989 and 1996, when around 30 turtles were observed every year, and the second in 2000, when 19 turtles were observed. However, since then the records have declining tendency. Sunfish records have overall increasing tendency. In Basking shark sightings, there are years with higher and lower number of observation, with three particularly prominent peaks – in 1977, between 1994 and 1997, and in 2007. All three species are recorded at the locality only in the months with high sea surface temperature; and, overall, the historical number of observations had a significant relationship with this climatic variable. Numbers of recorded Leatherback turtle observations were also significantly related to the North Atlantic Oscillation index. These data, although preliminary, confirm that changes in the selected megafauna species may be used as climate change indicators.

ABSTRAKT

Pozorování výskytu mořské megafauny v pobřežních vodách může přispět k lepšímu pochopení chování velkých mořských tvorů a jejich reakcí na klimatické změny. Já jsem sledovala kytovce, žraloka veliké ho, kožatky velké a měsíčníky na ostrově Cape Clear na jihozápadě Irska. Výzkum byl prováděn od června do srpna 2008, protože právě z letního období pochází nejvíce historických záznamů o pozorování želv, měsíčníků i ostatních velkých obratlovců ve sledované oblasti. Kromě výskytu druhů byly každý den zaznamenávány údaje o počasí (velikost vln, viditelnost, plocha moře ozářená sluncem a plocha oblohy pokrytá mraky).

Během výzkumu (51 dní) nebyla bohužel pozorována ani jedna kožatka velká, pravděpodobně to bylo kvůli chladnému počasí ve sledovaném období. Přesto byly ale 124x pozorovány jiné druhy megafauny - převážně kytovci (pět druhů). Byl viděn i žralok veliký a několik měsíčníků. Během sledovaného období došlo k signifikantnímu nárůstu počtu pozorování i počtu sledovaných druhů, zejména pak v druhé polovině léta, kde byla vyšší teplota mořské vody. Statistická analýza však přímý signifikantní vliv teploty povrchové vody na počet pozorování nebo druhovou diverzitu neprokázala. Ani žádná z doplňkových proměnných (údaje o počasí) ale neměla vliv ani na počet druhů, ani na celkový počet pozorování.

Kromě samotného letního výzkumu byly také digitalizovány záznamy o pozorování želv, měsíčníků a žraloků velikých shromážděné v ptačí stanici na ostrově od roku 1971 do roku 2008. Tento dataset obsahuje data z 3510 dnů pozorování moře a přidány jsou i informace o vynaloženém úsilí pozorovatelů. Počty pozorovaných kožatek velkých jsou obecně nízké, jen dvakrát došlo k jejich výraznému zvýšení – poprvé během let 1989 až 1996, kdy bylo pozorováno okolo 30 želv ročně, a podruhé v roce 2000, kdy bylo viděno 19 želv. Po tomto roce mají ale pozorování želv sestupný trend, čímž se zásadně liší od záznamů o pozorování měsíčníků vykazujících vzestupnou tendenci. V záznamech o žralocích můžeme pozorovat roky s nižšími i vyššími počty. Výrazně vyšší počty pozorování pocházejí zejména z roku 1977, z období 1994 až 1997 a z roku 2007. Všechny tři druhy mořské megafauny byly spatřovány pouze v teplých měsících, což potvrzuje i jejich signifikantně významný vztah s teplotou povrchové vody oceánu. Počet pozorování mořských želv kožatek velkých je také významně ovlivněn indexem severoatlantické oscilace (NAO). Tyto výsledky, byť ze souboru dat s omezenou vypovídací schopností, potvrzují, že změny v početnosti vybraných druhů megafauny mohou sloužit jako indikátor klimatických změn.

CONTENTS

GENERAL INTRODUCTION

Mean global air temperature has increased by approximately 0.7° C during last 100 years and it is still on the rise (IPCC 2001). There are substantial differences in temperature increase between regions. Mean Earth temperature is now approximately 14.5° C and it has not been higher at least in the last 1 300 years. There is an ongoing debate about the extent humans might have contributed to this temperature rise, but the fact is that the change of the global climate has happened. This means not only an increase in the mean global temperature but also alteration of the direction and the speed of ocean currents (IPCC 2001). Global warming can affect Earth's ecosystems enormously through these changes, which have significant impact on distribution, survival, reproduction and growth or various organisms.

There has also been a recorded increase in the temperature of global ocean surface layers. The positions of isotherms are moving towards the poles for example in the North Atlantic (McMahon & Hays 2006; Figure I-1). This warming in higher latitudes has an influence on many marine species. Those with affinities to warmer temperate waters are becoming increasingly abundant in many higher-latitude locations; accordingly, those with affinities to cold temperatures are decreasing in those locations and moving north (Stebbing 2002; Hemery et al. 2008). The movement of species area boundaries may strongly affect human activities; notably, it has a marked impact on commercial fishing in the North Sea (Perry et al. 2005).

This thesis deals with megafauna in Irish coastal waters. Climate changes also influence many of these species, including big charismatic animals such as the Leatherback sea turtle, Sunfish, Basking shark, and varieties of cetaceans. As each of them has an important role in this thesis, I will now introduce them in detail.

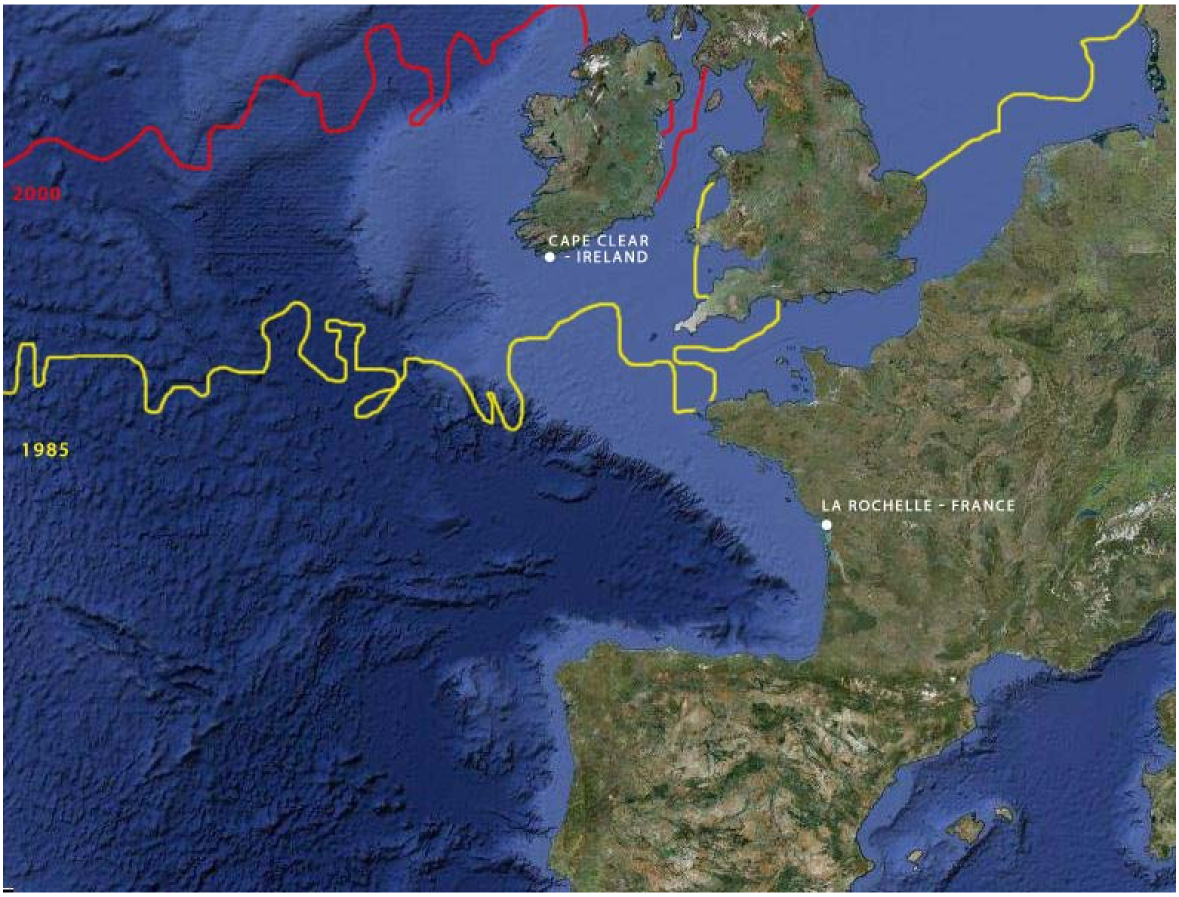


Figure I-1: Map of the north-eastern part of Atlantic Ocean (image based on Google Earth, adapted after McMahon & Hays 2006). Coloured lines demonstrate changes in mean summer sea surface temperature between August1985 and 2000; yellow line indicates 15° C isotherm in August 1985, the red one shows 15° C isotherm in August 2000. Morphology of the ocean floor, in particular position of the edge of the continental shelf, is also visible on the map. Positions of Cape Clear and La Rochelle, localities with most sightings of the Leatherback turtle in European waters, are indicated.

Leatherback sea turtle

Distribution of some megafauna species, including the Leatherback turtle (*Dermochelys coriacea*, Dermochelyidae), can be a sensitive indicator of climate change. This pelagic marine species is the largest turtle in the world (132–178 cm and 250–907 kg; James et al. 2005) and the deepest diving reptile (1280 m; Hays et al. 2004). Unfortunately, these large, long-lived animals have recently faced multiple anthropogenic hazards, which are the main reason for their rapid global population decline (more than 60 % over the past two decades; Spotila et al. 1996). The total number of nesting females of the Leatherback turtle is now estimated at less than 35 000 worldwide (Spotila et al. 1996, 2000). Accordingly, this species is listed as critically endangered by the IUCN Red List (IUCN 2004).

Leatherback turtles are also the widest ranging reptiles on the planet; they migrate over all the oceans except the Arctic and Antarctic (Hays et al. 2004). The most important long-distance movements are between the nesting beaches and the food-rich foraging areas in higher latitudes, where the turtles accumulate supplies for the migration back to breeding grounds (Rivalan et al. 2005, Figure I-2). These migrations are realized by adult turtles every 2–3 years. After coming near to nesting beach, turtles mate. During the reproduction season, female leatherbacks lay on average seven clutches; there is an interesting interval of 9–10 days between every two nesting events. Mean clutch size is 85 eggs, and approximately two months after the eggs are laid, they begin to hatch. Hatching success of Leatherback turtle clutches is low in comparison with other sea turtle species; with only 50 percent successful in an undisturbed nest (in contrast to 80-90 % in other species). As in all sea turtles, the sex of Leatherbacks is determined by temperature in the nest. At 29.5° C, the pivotal temperature for hatchlings, there is an equal proportion of males and females. At temperatures lower then 29.5° C, more hatchlings become males, while in higher temperatures most become females. Small hatchlings go from the nest straight to the ocean, and, supported by currents, swim away from the shore. They grow rapidly and between the ages of 9 and 15 years they start to reproduce at the same location as their parents. The whole life cycle of Leatherback turtle is illustrated in Figure I-2; more details are given in Spotila (2004).

Leatherback turtles are specialized predators of gelatinous zooplankton: jellyfish, siphonophores and salps (Davenport 1998). Due to the relatively low nutritional value of such prey (Houghton et al. 2006a), turtles have to consume it in great quantities, up to 200 kg/day (Duron-Dufrenne 1987). Obtaining a sufficient food supply is especially important for females, which on average lose 10.5 kg of body weight each nesting season (James et al. 2005a, b). As a consequence, 22.5 % of the leatherback distribution on feeding grounds can be explained by jellyfish aggregations (Houghton et al. 2006a).

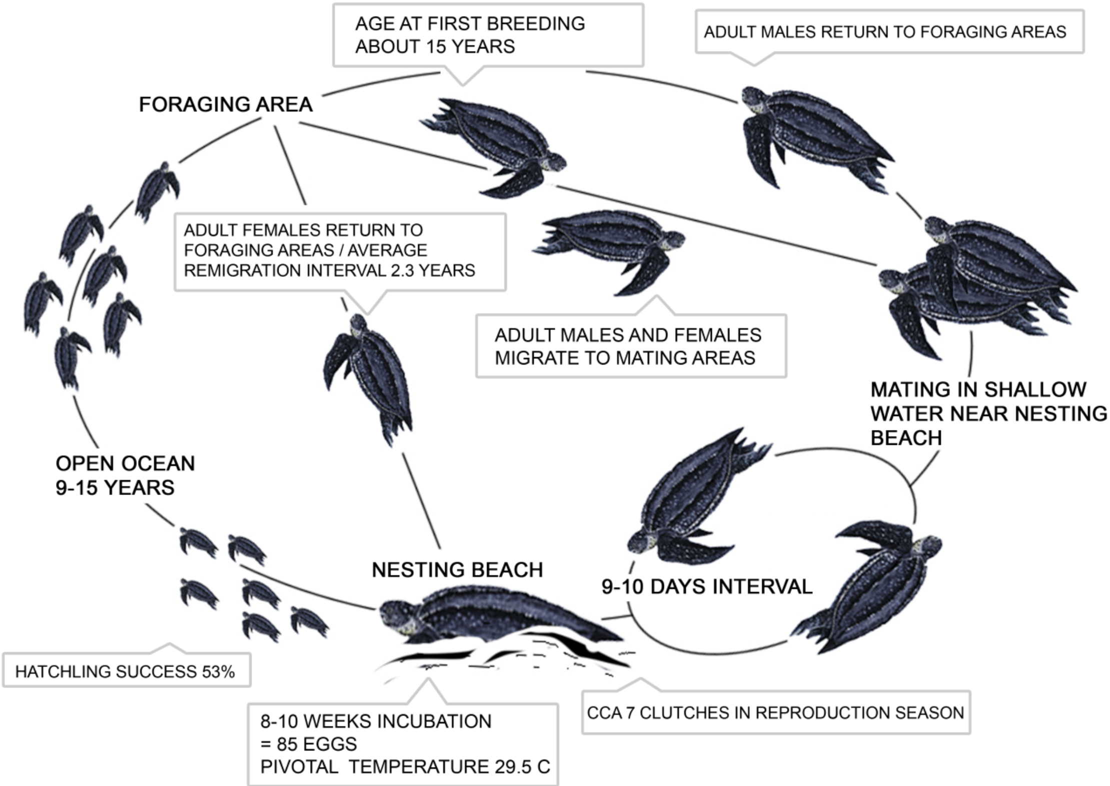


Figure I-2: Leatherback turtle life cycle (adapted from Miller 1996).

Temperature, due to exothermic nature of reptiles, is limiting the distribution of this turtle at high latitudes (James et al. 2006a, Witt et al. 2007b). The leatherback has many forms of adaptation to conserve heat. Through regional endothermy, temperature is mediated by considerable body mass, counter-current vasculature in the flippers, lipid layers and variable lipid composition and distribution. These adaptations help turtles to survive in high latitudes (Frair et al. 1972, Witt et al. 2007a). Nevertheless, McMahon & Hays (2006) claim that leatherbacks spend only 2 % time in areas with the sea surface temperatures below 15° C. This temperature can be therefore considered the thermal limit on the northerly movements of this turtle, and the change of the respective isotherm position can determine changes in leatherback distribution. This is supported by the increase of foraging range of the Leatherback turtle in the last decades, corresponding to moving summer position of the 15° C isotherm (McMahon & Hays 2006, James et al. 2006a, Witt et al. 2007a, Houghton et al. 2006a; Figure I-1). Furthermore, turtles show microhabitat selection of warm water in high latitudes (Schofield 2008).

Sunfish

In addition to leatherbacks, other species of megafauna may also serve as biological indicators of climate change in Atlantic Ocean waters (Houghton et al. 2006b). Sunfish (*Mola mola;* Molidae) has also been suggested in this context. This species usually stays in water warmer than 10° C, so an increase in the global temperature can extend its range to higher latitudes (Sims et al. 2009).

The Sunfish is the largest bony fish (Pope et al. 2010). It grows on average to a length of 1.8 m and weight of 1 000 kilograms, but individuals up to 3.1 m from head to tail and 4.26 m from the dorsal to anal fin weighing up to 2 235 kg have been observed. This observation indicates that the Sunfish is also the heaviest known bony fish in the world (Carwardine 1995).

The species lives in tropical and temperate waters around the world, and recent tracking studies suggest that its broad-scale movements may be highly directional, with some evidence of magnetoreceptive capabilities (Cartamil & Lowe 2004).

Sunfish feed on a diet that consists mainly of jellyfish, similar to the Leatherback turtle. This prey performs daily vertical migrations, spending daytime deeper in the water column and migrating shallower at night (Hays 2003). Sunfish (as well as leatherbacks) follow these prey movements (Sims et al. 2009, Houghton et al. 2008).

Basking shark

The Basking shark (*Cetorhinus maximus*) is the second largest fish in the world (i.e., including both teleost and cartilaginous fishes) and the largest one in European waters (Berrow & Heardman 1994). Large Basking shark individuals reach on average 10 m in length with weight around 6 tonnes (Berrow & Johnston 2009). This shark is a passive filter feeder consuming mainly zooplankton (especially calanoid copepods and other crustaceans), but also small fish. In winter, when no prey is available near the surface, Basking sharks move to depths of down to 900 metres to feed on deepwater plankton (Gore et al. 2008, Berrow & Johnston 2009). Basking sharks are ovoviviparous, and reach sexual maturity around 6 to 10 years. Because of very low reproductive rate and long gestation periods, Basking sharks are vulnerable to over-exploitation (Berrow & Johnston 2009).

These slow-moving animals live in temperate continental shelf areas of all oceans but they are capable of migrating across oceans or between hemispheres (Gore et al. 2008).

Sightings of this species are regular in waters with surface temperatures over 11.5°C; in colder waters only few individuals have been observed (Berrow & Heardman 1994).

Basking sharks abundance is increasing in Irish waters (Berrow & Whooleys 2008). Only around 10 sightings per year had been recorded before 2003, numbers of sightings increased year by year to 122 sightings in 2007 and the number of observations is still increasing to date (Berrow & Whooleys 2008; more details are given in Chapter II). This increase may be partly due to better recording of sightings but also it probably reflects real increase of Basking shark driven firstly indirectly by climate change (Berrow & Heardman 1994) and secondly by shark fishery closure and their protection in area (Berrow & Johnston 2009; for detail understanding see Chapter II).

Cetaceans

Irish waters are one of the most important regions for cetacean observations in Europe. There is a high diversity (24 species which is around a quarter of the world's total number of species) as well as abundance of cetaceans in this area, and all Irish cetaceans have been protected since 1991 (Berrow report a, O´Brien et al. 2009). Some of the species that have been recorded in my study, including the Harbour porpoise (*Phocoena phocoena)*, Common dolphin (*Delphinus delphis)*, Bottlenose dolphin (*Tursiops truncatus)*, Rissos dolphin (*Grampus griseus)*, White-sided dolphin (*Lagenorhynchus acutus)* and White-beaked dolphin (*L. albirostris*), are also breeding in Ireland (Berrow report a, O´Brien et al. 2009, Wall et al. 2006). Breeding of the Minke whale (*Balaenoptera acutorostrata*), the smallest and most abundant of Irish baleen whales (Tetley et al. 2008), is also suspected.

Harbour porpoise (*Phocoena phocoena*), a relatively small coastal species known in Irish as *muc mara* ("sea pig"), and the Common dolphin are the most abundant cetacean species in Ireland. The latter has been reported as a species which increased in abundance in the Bay of Biscay (North Atlantic – Western Europe) between 1974 and 2000 due to climate change (Hemery et al. 2008).

The Bottlenose dolphin, which is frequently encountered inshore near the coast in estuaries and bays worldwide, is also very common (Berrow report b, O´Brien et al. 2009). Contrary to the Harbour porpoise and the Bottlenose dolphin, the Rissos dolphin has worldwide distribution in tropical and temperate waters in both hemispheres but is not common in the North Atlantic and may be only occasionally sighted (Evans 1990).

Megafauna around Cape Clear

Cape Clear (Oileán Cléire, 51°26'N, 9°30'W), where my study was conducted, is a small island with the surface area 7.5 km^2, situated in the south-west of Ireland (Figure I-1). The island is important place for migratory birds, and provides good opportunities for birdwatching. For this reason, Cape Clear Bird Observatory was established in 1959, and regular land-based sea watching is conducted on the island since this time (Sharrock 1973).

The area of Cape Clear is also, mainly due to prey availibility, one the best localities on the coast of British Isles to watch not only cetaceans (Figure I-3) but also predominantly pelagic megafauna species such as Leatherbacks, Sunfish and Basking sharks. These marine megafauna species have been also recorded during seabird surveys on the Cape Clear (Sharrock 1973).

As previously noted, sea surface isotherms move to the north due to climate change. For example, the summer position of the 15° C isotherm, which had been located further south of Ireland, has moved northwards by 330 km between 1985 and 2000 and now intersects the northernmost part of the Ireland (McMahon & Hays 2006; Figure I-1). This is probably the reason why numbers of accidental observations of Leatherback turtles have become increasingly prevalent in Irish waters (Houghton et al. 2006a). Historical data gathered during seabird surveys in the Cape Clear shows that the island is an extremely important location for leatherback sightings. Only La Rochelle in the north-west France has similar or greater number of Leatherback sightings in Europe (Fig. I-1; Duron 1978; Duguy et al. 1980). However, information on leatherback biology in southern Irish waters, which may become future important feeding ground for the species in the near future, remains scarce.

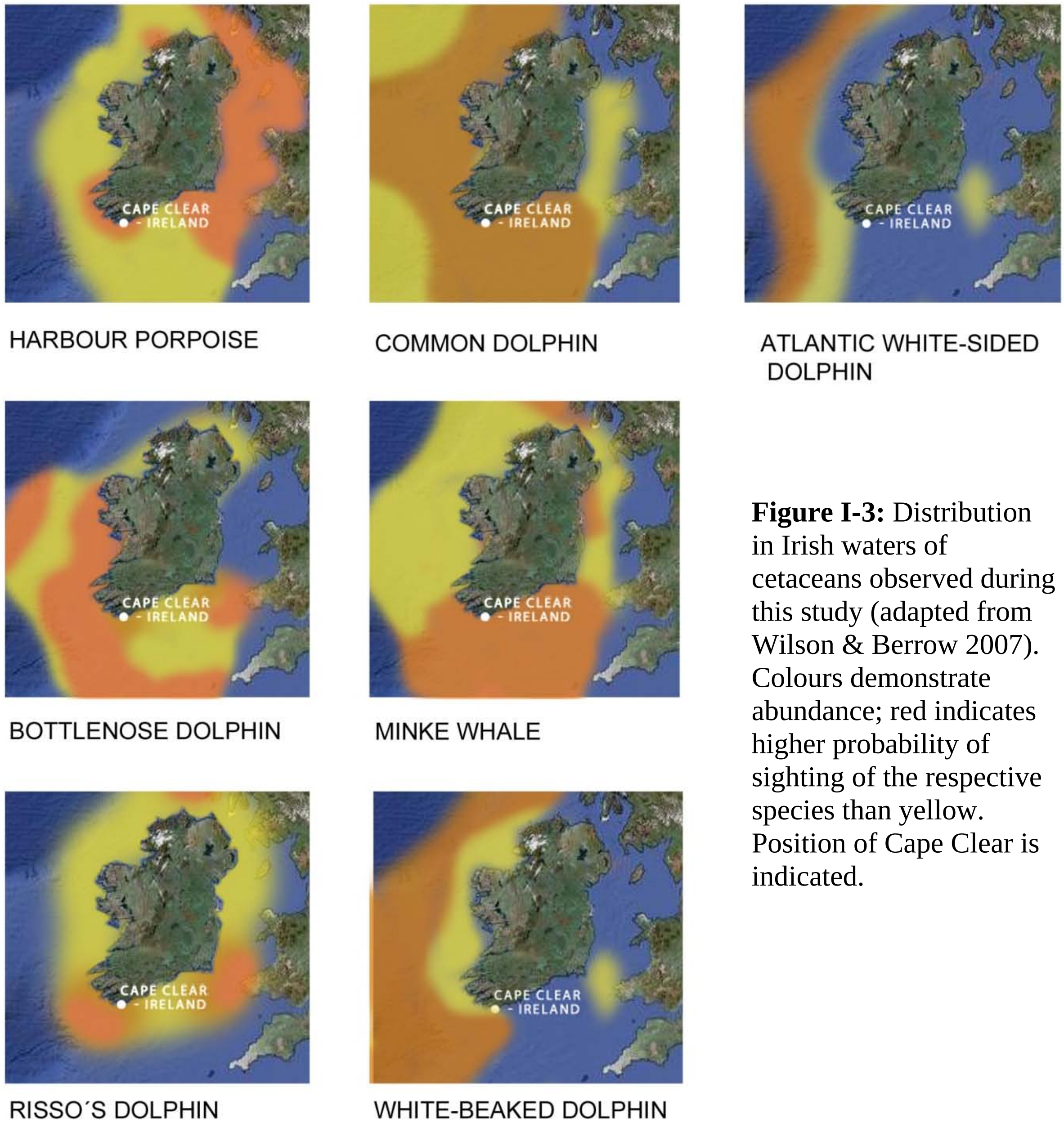


Figure I-3: Distribution in Irish waters of cetaceans observed during this study (adapted from Wilson & Berrow 2007). Colours demonstrate abundance; red indicates higher probability of sighting of the respective species than yellow. Position of Cape Clear is indicated.

Advantages of turtle observation at Cape Clear

As previously stated, most leatherback sightings data at the Cape Clear were collected non-systematically during seabird observations (Sharrock 1973). The island's location and excellent vantage point (Figure I-4) makes it a suitable base for observation of turtles and thus offers great potential to study some aspects of their biology. Despite that, there has been no dedicated study of Leatherback turtles (or any other megafauna) from Cape Clear.

Figure I-4: Myself on the top of Blananarragaun, Cape Clear.

Coastal observations of leatherbacks could provide some insights on how these animals respond to potential anthropogenic hazards. Fixed fisheries have been identified as one of the major causes of leatherback mortalities (James et al 2005b, Doyle 2007); however, it is unclear how and when turtles get entangled in fishing nets. Simple observations on how turtles behave near pot ropes and buoy ropes and how they respond to an approaching boat would be extremely useful; as such information has not been collected yet.

From a more strategic and long-term conservation goal, it is important not only to know what these turtles do in coastal waters and what their abundance trends are, but also their migratory response to sea temperature changes. With this knowledge, we would improve our understanding of the distribution patterns of this endangered species, which is critical for identifying where implementation of conservation efforts would be most effective.

The satellite tracking method can be used to reach this goal. The attachment of satellite tracking devices could provide important information on turtle ecology and behaviour (Hays 2008). However, it is necessary to capture a leatherback before such a tag can be attached. Doyle et al. (2008) tracked by a satellite two leatherbacks caught in fishing gear off the coast of Dingle (south west Ireland) during 2006 and 2007. That study was only possible with the collaboration of the local salmon fishermen who occasionally caught leatherbacks in their salmon drift nets. However, with a ban on salmon drift net fisheries now in place, the possibility of tagging more leatherbacks from Ireland this way is doubtful. Considering the number of leatherback sightings from Cape Clear, it may be possible to actively catch leatherbacks using a boat and hoop net, as James et al. (2005a) did in Nova Scotia and Cape Breton in Canada. However, before such efforts are put in place, much more information on the behaviour of leatherbacks around Cape Clear, such as the mean time spent on the surface, main direction of travel, and locality of most sightings, is required.

Methods for observing large marine vertebrates

In contrast to large terrestrial animals, large marine ones are, because of rapid locomotion covering long distances each day and seasonal migrations of thousands of kilometres, difficult to study. Marine mammals and turtles go to the surface to reach the air, so they spend here relatively little of their time. Similarly, Sunfish and Basking shark occasionally approach the surface. Under such circumstances, these taxa can be observed, approached, counted or even followed by tracking technologies such as radio and satellite telemetry. The last-mentioned option – tracking individual animals – brings a wealth of information about ecology and behaviour of studied species (e.g. Hays et al. 2004, Doyle et al. 2008, Read & Westgate 1997, Mate et al. 1997, Gore et al. 2008). However, it is costly and it often requires initial handling of the animals and has associated ethical issues (Wilson & McMahon 2006).

For cetaceans and other animals which produce sounds regularly, indirect recording using acoustics have been used to gather information on abundance and behaviour. Passive acoustic surveys offer many potential advantages over visual methods. For example, acoustics can detect submerged animals, extend search distances, and allow for night-time surveys. However, acoustic surveying can be only used under conditions which prevent damage of hydrophone equipment, so these approaches are limited to low wind speeds, higher depths (usually over 100 m), and areas with low intensity of fishing or shipping activity (Gannier et al. 2002).

With the advent of such tracking technologies and indirect methods, it is often easy to neglect the long established traditional methods of recording behaviour, abundance and population data of aquatic animals. Nevertheless, aerial sighting or line-transect surveys using boats (Gordon 2001), and identification of marine mammals from land-based observations (Bejder & Dawson 2001) are still widely used.

Line-transect surveys are suitable for estimating the abundance of large marine vertebrates such as turtles and cetaceans, as they provide representative coverage of the studied area (Evans & Hammond 2004). They can be carried out using aircrafts or boats. Aircrafts, because of their speed, can cover large areas in a short period, and for this reason might be favoured in regions with short periods of suitable weather. Unfortunately, smaller sized species are hard to detect except in good conditions by this survey method (Hammond et al. 2002). Boats, travelling more slowly, allow more time for an animal to surface, and therefore boat surveys typically count a much larger proportion of the population (Dawson et al. 2008). However, there are also drawbacks associated with this method, for example, the possibility that animals might respond to the survey ships (Berrow et al. 1996, Hammond et al. 2002).

Observation from fixed stations (Denardo et al. 2001; details in introduction of Chapter I) offers some potential advantages over many of the above methods. For example this method is cheap and data from it are easy to standardize. The disadvantage is that observation area is always limited, nevertheless observations from land allow for identification and estimation of numbers of species present in the coastal area, and for various behavioural observations, such as feeding and social activities, or travelling speed and direction. These are very important information, especially for species for which scarce data are available in the study area.

Main goals of my research

This thesis summarises results from my stay on Cape Clear Island during the summer 2008. The main goal was to conduct systematic land-based observations of local ocean megafauna from a fixed coastal point. Additionally, I digitized data on accidental observations of Leatherback turtles, Sunfish and Basking sharks, which have been recorded at the Cape Clear Island since 1971. As the results included in this thesis come from my own observations carried out in summer 2008, as well as from historical data, the thesis is divided into two parts.

The first chapter is written as a potentially self-standing manuscript, therefore in several places it partly overlaps with the general introduction. Additional details, which I find important for a thesis but should not include in a manuscript, are provided in the boxes accompanying the main text, or in the footnotes.

During my observations, I collected detailed information about local marine megafauna species diversity and seasonal variation in numbers. We also tested the hypothesis that the sea surface temperature can explain changes in abundances and diversity of megafauna during a given study period. The original aim was also to add observation-based data of Leatherback turtle biology in the area, especially foraging behaviour and behaviour of this species near anthropogenic hazards. Unfortunately, during the whole study I did not observe this species, probably due to particular weather conditions of summer 2008.

The second chapter of the thesis concerns a preliminary analysis of historical data on megafauna observations at Cape Clear since April 1971 compared to present data, to evaluate possible influence of climate change on megafauna migrations. We tested the hypothesis that the sea surface temperature, the North Atlantic Oscillation, or presence at other nesting or foraging localities, may explain a significant proportion of changes in abundances of Leatherback turtles in the study area.

CHAPTER I

VARIATION IN NUMBERS OF OBSERVATIONS AND SPECIES COMPOSITION OF OCEAN MEGAFAUNA OF CAPE CLEAR ISLAND (SOUTH-WEST IRELAND) IN THE SUMMER 2008 SEASON

Hana Svobodová, Adam Petrusek, Thomas K. Doyle

INTRODUCTION

In contrast to terrestrial environments, marine habitats are less accessible to direct observations by humans, and studying large marine animals, such as marine mammals and turtles, possesses specific problems to data collection. Members of these animal groups swim rapidly, may range over long distances on a daily basis, and often have seasonal migrations of thousands of kilometres. They are especially difficult to follow because they disappear during dives and do not leave long-lasting traces of their activities, such as tracks, scats, or dens (Mann 1999), with the exception of turtles leaving traces on their nesting beaches (Dutton et al. 2005, Chan & Liew 1996, Bouchard & Bjorndal 2000).

Although air-breathing marine vertebrates (marine mammals and turtles) spend a substantial part of their time underwater, they have to surface regularly to get air. Other marine megafauna, such as Sunfish and Basking shark, also occasionally occur at the surface. Sunfish basking is probably a method of "thermal recharging" after deep dives and the Basking shark often feeds on plankton concentrations near the surface (Sims et al. 2009, Berrow & Heardman 1994). Under such circumstances, these megafauna species can be directly observed.

Observation from fixed stations (Denardo et al. 2001) is cost-effective and non-intrusive method. The data collected are easy to standardize, surveys are generally cheaper to undertake than boat- or aicraft-based studies, and so can be made at greater frequencies, and there are no additional complications of movement of the observer that can affect sight ability. A major disadvantage is that the area of coverage is limited; generally to marine areas immediately adjacent to land (although fixed stations such as oil and gas platforms may be available in offshore areas). Regular land-based watching for defined periods of time has frequently been used to identify coastal areas important for particular species and to determine variation in numbers both seasonally and over the longer term (Berrow & Taylor 2005, Perryman et al. 2002). When using fixed stations to monitor status changes, however, it is important to keep in mind that one is monitoring the occurrence of animals in a particular restricted area and not the population at large. Despite these limitations, land-based studies also provide sufficiently robust data for statistical analyses (Taylor et al. 2007).

Irish waters count among the most important localities for observing cetaceans in Europe. In particular, Cape Clear Island (South-west Ireland; 51°26’ N, 9°30’ W) is, mainly due to prey availability, one of the best places in the region to watch cetaceans. Strong currents offshore promote mixing coastal and oceanic water. These nutrient upwellings result in high productivity of phyto- and zooplankton, and high densities of fish may also be found there (Berrow 2001). Moreover, the island is positioned close to whale migration routes and lies near the edge of the continental shelf, so oceanic cetacean species, Sunfish, Basking sharks and Leatherback turtles may also come within sight (Sharrock 1973).

As a result of its geographical position and coastal cliffs, the island is often the first land encountered by migratory birds. The island commonly receives birds from Europe and America as well as vagrants, many of which have rarely or never been recorded in Ireland (Sharrock 1973). Accidental observations of megafauna (Sunfish, Basking sharks, Leatherback turtles and cetaceans) have been also recorded during seabird surveys in Cape Clear waters but this data were collected only accidentally and non-systematically (Sharrock 1973).

Cape Clear has the most leatherback sightings in Ireland and the UK, which makes it an extremely important location for leatherback turtle observations. There is only one location in the whole Europe where similar or greater numbers of this species are sighted: La Rochelle at the Atlantic coast of France (Duron 1978; Duguy et al. 1980). Due to the climate change and shift in isotherm positions, both of these localities are now in the northernmost part of distribution of this species (McMahon & Hays 2006). It is likely that even more leatherbacks (as well as other thermophilic marine fauna) will be observed in these areas in the future.

All above-mentioned facts were the reasons for a field study conducted in summer 2008 at Cape Clear, during which we were interested in systematic observations of ocean megafauna. Summer, especially July and August, is when most thermophilic megafauna are sighted in Irish waters, both in numbers and diversity because sea surface temperature are highest during this time of the year (Evans 1990, Berrow & Heardman 1994, Houghton et al. 2006b, McMahon & Hays 2006). The aim of the study was to obtain information about species diversity and temporal variation in observed numbers of individuals and species, as well as factors which may influence such data collection.

METHODS

Cape Clear Island (Oileán Cléire; 51°26'N, 9°30'W; Fig. 3) is the most southerly inhabited location in Ireland, with only an uninhabited Fastnet Rock located further south. The island is 5 km long and at its broadest, just over 1.5 km wide. Sea watches, i.e., land-based sea observations, were conducted from Blananarragaun Point (altitude 50 m; 51°25'22" N, 9°30'47" W; Fig. 3; Fig. I-4), which is regularly used by birdwatchers and provides good conditions for screening for megafauna. The first author of the study observed the sea for a total of 51 days between June 30 and August 26, 2008 (Fig. 1-1).

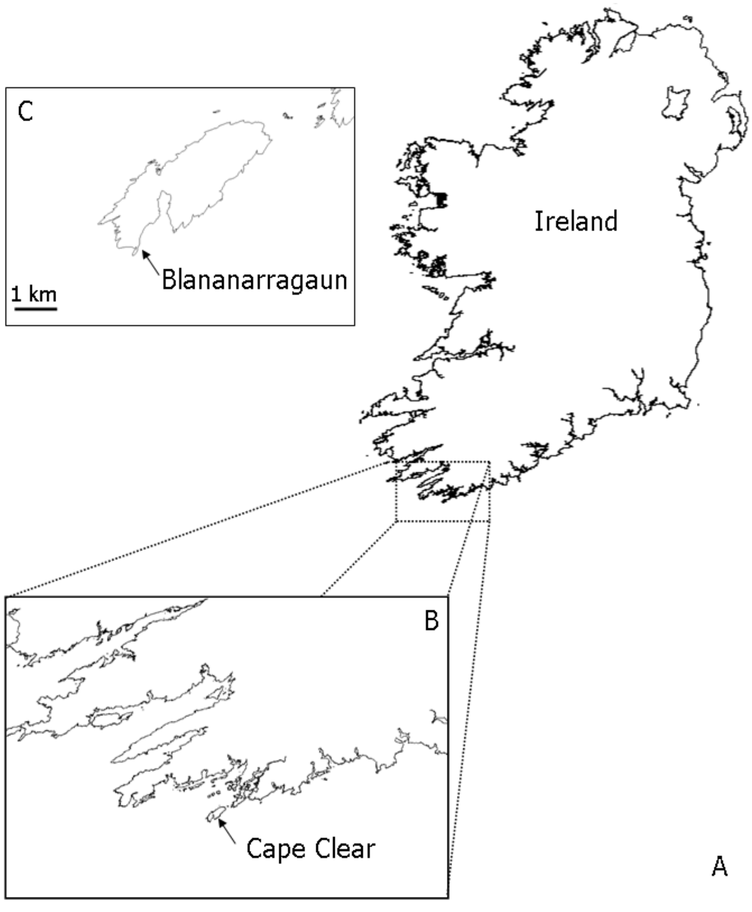


Figure 1-1: Study area: a) Ireland, b) South west coast of Ireland illustrating Cape Clear's southerly position, c) Cape Clear Island, with Blananarragaun Point (observation point during my visit) indicated.

No observation took place on seven days; three times (July 4, August 9 and 23) because of bad weather conditions (fog, heavy rain), on four days (July 23, 25, 26 and 28) for other reasons. The weather also did not allow observations between August 27 and September 1, when the study was terminated. On all other dates, between one and eight hours per day (on average 4.4 hours) were spent on the observation point, mostly between 10:00 and 16:00 GMT.

Observations were conducted when sea conditions were suitable (Beaufort Sea State less than 3), however, higher sea states were sometimes recorded when conditions deteriorated during the observation day. Sea watches consisted of continuous 10 minute scans of the immediate seascape (up to ca. 3 km from the shore) using a combination of naked eye scans and binoculars (8 x 40). For some observations, a spotting scope (30 x magnifications) was necessary. A 5-minute break followed each scan to minimise observer fatigue as continuous use of binocular or telescope can causes eye-strain and result in loss of efficiency (Sharrock 1973). Observations were finished when the weather extremely deteriorated, or early in the evening (between 18:00 and 19:30). All presented data, except for a single Sunfish observation from July 26, originated from sea watches by a single observer (first author). This Sunfish was recorded by members of The Irish Whale and Dolphin Group (IWDG) during their Whales and dolphin identification course from the same location as the first author regularly conducted the observations, and although presented in Fig. 1-2, it was not included in the subsequent data analyses.

Weather variables (cloud cover, glare, sea state, and visibility) were recorded every hour during the sea watches. Glare was recorded using a system of octares (Houghton et al. 2006a). For this, the seascape was visually divided into 8 sections. The number of sections obscured by glare was subsequently noted. Cloud cover (in percentage of obscured sky) was estimated similarly: by dividing the sky field into 8 sections, and subsequent estimate of proportion covered by clouds. Sea state was recorded in the Beaufort scale[1] (Evans & Hammond 2004). We also recognised five categories of visibility, based on how well the Fastnet Rock, located approximately 6 km southwest of the Cape Clear, and its surrounding sea surface could be observed (see box 1 for more details).

Sea surface temperature data was obtained for each observation hour for Databuoy M5 (51.69°N and 06.70°W), located 50 km offshore in the Celtic sea, 198 km eastwards from the

[1] Details of Beaufort scale categories can be found in http://www.bbc.co.uk/weather/features/understanding/beaufort_scale.shtml.

observation point, from the website of the Marine Institute (Galway, Ireland; http://www.marine.ie/home/publicationsdata/data/buoys). This temperature data was used to calculate a mean day and week sea surface temperature.

Box 1: Details of visibility categories determination

Visibility category	description of visible area of the sea
1. Excellent	Fastnet Rock and the sea area behind it clearly visible
2. Very good	Fastnet Rock clearly visible but the sea area behind it not so well
3. Good	Fastnet Rock clearly visible but not sea behind it
4. Poor	Fastnet Rock not visible
5. Extremely poor	Less than half of the area before the Fastnet Rock visible

Figures show examples of observed visibility conditions (left - excellent visibility – zoom Fastnet Rock photo was taken from the observation point; right - good visibility – oval indicates the Fastnet Rock).

The following parameters were recorded whenever one or more megafauna specimens were sighted: time of sighting, number of individuals, their behaviour, and additional noteworthy observations such as the presence of birds and animal size (estimated from comparison with nearby seabirds; Houghton et al. 2006b). Sightings were identified to species level where possible. The following characteristics were used during animal identification (see Wilson & Berrow 2007 and box 2): estimated body length, shape of dorsal fin and its position on the back, body colour and pattern, head-shape, surfacing sequence and presence/absence of tail and blow. Certain dolphins, which could not be reliably identified to species, were pooled into a category of “black and white” dolphins. In all likelihood, these were in most cases Common dolphin *Delphinus delphis*. However, the presence of the Atlantic white-sided dolphin *Lagenorhynchus acutus* or the White-beaked dolphin *L. albirostris* could not be ruled out (for more details, see discussion).

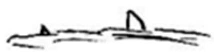
Behaviour was divided into two main categories: a) swimming (travelling steadily in one direction with regular surfacing intervals), b) feeding (individuals moving in a variety of directions relative to each other; repeated dives and surface rushes). Feeding animals were often associated with diving birds.

Data analysis

We tried to estimate the potential influence of the most important weather characteristics on the abundance and diversity of observed megafauna species. Because the data originate from serial observations, numbers of different species observed per day as well as their abundances were at first investigated for the partial temporal autocorrelation using the acf function in the R software (R Development Core Team 2010). As the autocorrelation was insignificant, we used four separate generalized linear models with Poisson distribution (GLM-p) to estimate the relationship between recorded weather variables (sea state, visibility, cloud cover, glare) and observed species richness (i.e., the number of species observed per day; model 1), abundance of all megafauna species pooled (model 2), and separately abundance of two most common species, the Common dolphin (model 3) and the Harbour porpoise (model 4).

Furthermore, we tested the significance of temporal trends and influence of surface sea water temperatury in additional four models (GLM-p), using the same dependent variables as above, but with the day of observation and with temperature as independent variables. To compensate for the observation effort, logarithms of observation hours for each day were added to all models as an offset parameter. All the analyses were performed in the R software package.

Box 2: Species observed during the study and characteristics used for their identification:

Species	Maximum length	specific identification marks	surfacing animal body pattern
Harbour porpoise - *Phocoena phocoena* family Phocoenidae	1.8 m	Small size and robust shape, low triangular fin, rounded head, no distinct beak, nondescript colouring, slow forward rolling move, usually alone or small groups.	
Common dolphin - *Delphinus delphis* family Delphinidae	2.7 m	Tall dorsal fin, dark cape with a "V" under fin, hourglass pattern on sides, tan or yellowish patch on both sides, prominent beak, highly active.	
White-beaked dolphin - *Lagenorhynchus albirostris* family Delphinidae	3.5 m	Prominent dorsal fin, short thick beak, white, grey and black body, pale patch on tail stock, white stripe on each side, fast swimmer.	 
Bottlenose dolphin - *Tursiops truncatus* family Delphinidae	3.8 m	Subdued grey colouring, distinct beak, much larger than common dolphin, jumps completely out of the water, highly active.	 
Rissos dolphin - *Grampus griseus* family Delphinidae	3.8 m	Body extensively scarred, robust body, indistinct beak, large rounded head, very prominent fin, older animals may be white, active at surface.	
Minke whale - *Balaenoptera acutorostrata* family Balaenopteridae	10 m	The smallest whale in the area with no visible tail or blow, blowhole and fins often visible together, white bands on flippers. Normally alone but 2-3 at times.	
Basking Shark - *Cetorhinus maximus*	10 m	Dorsal and tail fin visible under the water; often swimming at the surface with mouth wide open.	

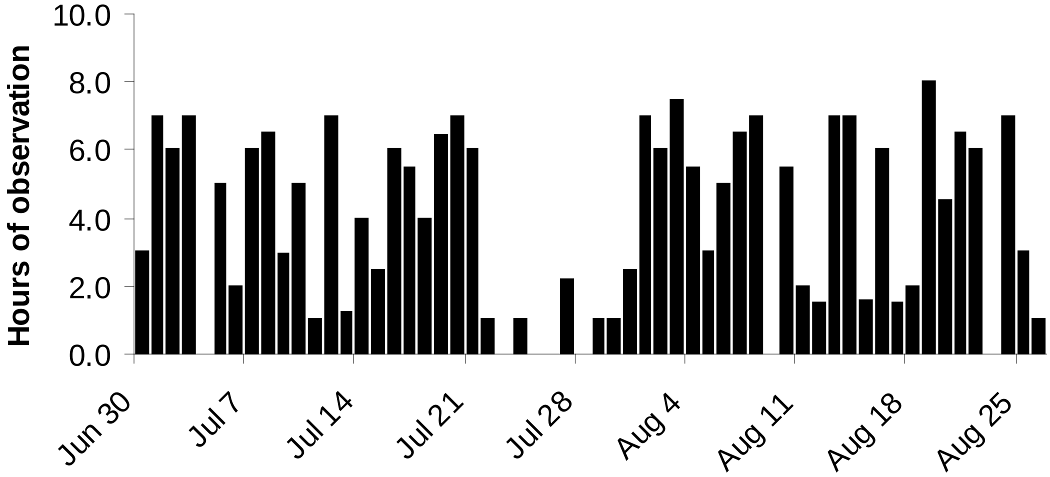
RESULTS

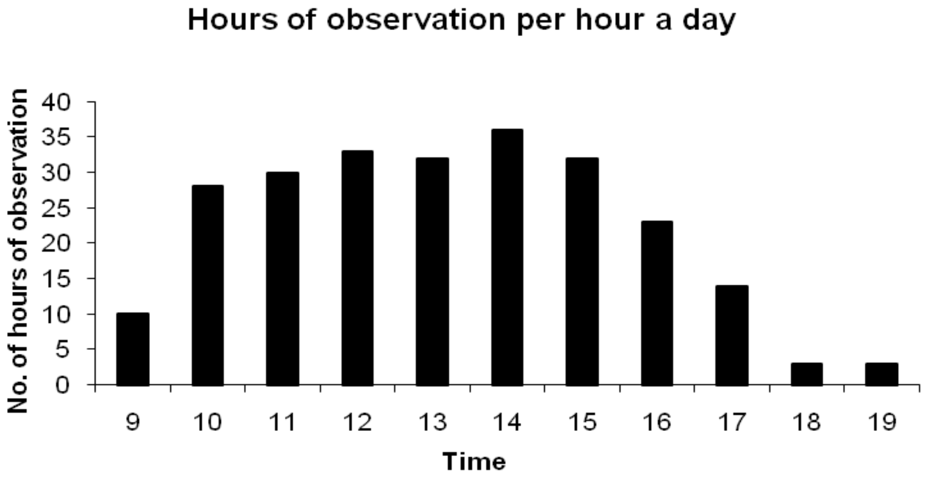
Sea observations

In total, data are available from 233 hours of observation, with 221 hours (92 %) of Beaufort sea-state 3 or lower (see box 3).

Box 3: More details of effort distribution

Hours of observations per day in study period (June 30 and August 26, 2008) are shown in the top chart. Distribution of observation hours during days is visible in lower chart.





The prevailing conditions during sea observations were good visibility (during 80 % of observation hours, the Fastnet Rock was clearly visible but not sea behind it), cloudy sky (at least 50 % of sky obscured by cloud during 53 % of observation hours), little or no glare (no octare of sea surface obscured by glare during 54 % of observation hours), and little wave action (Beaufort scale 2 or less during 68 % of observation hours).

Megafauna observations

At least seven megafauna taxa were identified (Table 2, Fig. 1-2) during the study period: six of them to species level, one taxon ("black and white" dolphin) identified to family (i.e., Delphinidae, but most likely these were common dolphins, see Discussion).

Species	**No. of observa-tions**	**No. of individuals (best estimate)**	**Group size**	**Behaviour; [Swimming direction]**	**Association with seabirds (%)**
Harbour porpoise *Phocoena phocoena*	83	151	1 – 8 (1)	61/39 [26/5]	0
"black and white" dolphin *Delphinus delphis* or *Lagenorhynchus* sp.	21	88	1 – 11 (3)	52/48 [10/0]	19
Bottlenose dolphin *Tursiops truncatus*	3	43	8 – 23 (12)	100/0 [2/0]	0
Rissos dolphin *Grampus griseus*	1	4	4 (4)	100/0 [1/0]	0
Minke whale *Balaenoptera acutorostrata*	8	8	1	88/12 [4/3]	75
Basking Shark *Cetorhinus maximus*	1	1	1	100/0 [1/0]	0
Sunfish *Mola mola*	6	6	1	100/0 [5/1]	0

Table 1-1: Summary of megafauna sightings during the study period (51 observation days, 233 hours). For group size, the range and median (in parentheses) are provided. Percentages of observations for each species are provided for associations of the megafauna with seabirds and for two distinguished behaviour categories (travelling/feeding), during travelling swimming direction (west/east) was noted so numbers of moving to each direction are shown.

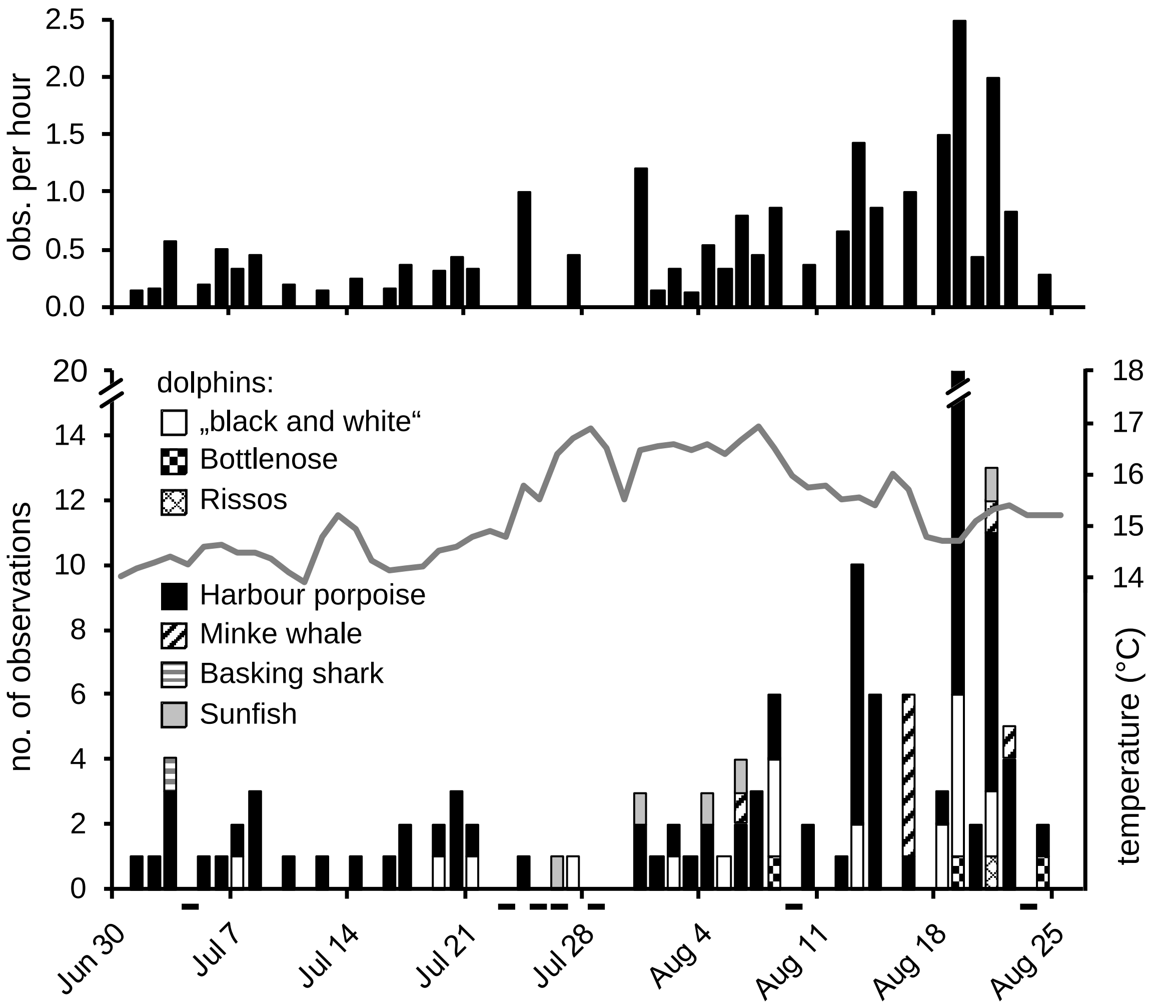


Figure 1-2: Distribution of recorded megafauna species, and the hourly frequency of megafauna observation, during the study period. Number of sightings of all megafauna species per hour of observation are shown in the top chart, numbers of sightings of all individual megafauna species in each day in the lower chart. Species are marked by patterns. The grey line indicates the sea surface temperature at databuoy M5. Short horizontal lines under the x axis show dates when no land-based sea observations were conducted.

In total, there were 123 cases of megafauna observations (Fig. 1-2), totalling approximately 301 individuals. Most of the species observed were cetaceans (at least five taxa, 116 sightings). The Harbour porpoise (*Phocoena phocoena)* was the most regularly sighted animal (observed 83 times; Table 2, Fig. 1-2, box 7). “Black and white” dolphins were second most frequently observed cetaceans with 21 observations. These two taxa occurred during the whole observation period in July and August; the rest of observed cetacean species were seen in August only (Fig. 1-2). Eight individual sightings of Minke whales (*Balaenoptera acutorostrata*) were recorded, five of them on a single day, August 16 (see box 5). However, it is not clear whether four of these five observations represented different individuals or whether a single individual was foraging in the area and repeatedly passed by the observation point (swimming direction in different observations varied). The fifth Minke whale was approximately one third bigger than others seen during the day. In all cases on this date, the whales were associated with seabirds (for more details see box 8), such association was also occasionally observed with “black and white” dolphins (Tab. 1-1). Three groups of Bottlenose dolphins (*Tursiops truncatus*) were seen during the study. The least commonly observed species was Risso’s dolphin (*Grampus griseus*) with only single observation.

Apart from cetaceans, a single Basking shark (*Cetorhinus maximus*; July 3) and six Sunfish (*Mola mola*) were observed. All Sunfish were small, with body length approximately 1 m. Most were seen actively swimming with dorsal fin flapping from side to side as they moved through the water; one animal was swimming without fin flapping. No ‘basking’ behaviour (when the animal is laying horizontal on the sea surface) was observed, although it is a common position of the species when observed on the surface, e.g., from boats (for more details, see box 5). The swimming direction of Sunfish was nearly in all cases to the west; only one Sunfish moved in the opposite direction. We did not record any Leatherback turtle during the study.

Box 4: Details of Minke whale focal observations (August 16)**:**

Table below provides detailed information about time, duration of observation and direction of swimming of Minke whales.

case no.	date	time of first observation	time of second observation	time of third observation	time of fourth observation	total duration of observation (mins)	direction of swimming
1	6.8.	13:56	13:58	14:04	n/a	8	W
2	16.8.	12:28	12:34	12:47	12:54	26	W
3	16.8.	13:37	13:39	13:42	n/a	5	E
4	16.8.	14:52	14:56	n/a	n/a	4	W
5	16.8.	17:02	17:06	n/a	n/a	4	E
6	16.8.	17:33	n/a	n/a	n/a	1	
7	21.8.	13:37	13:44	13:54	n/a	17	W
8	22.8.	10:51	10:57	n/a	n/a	6	E

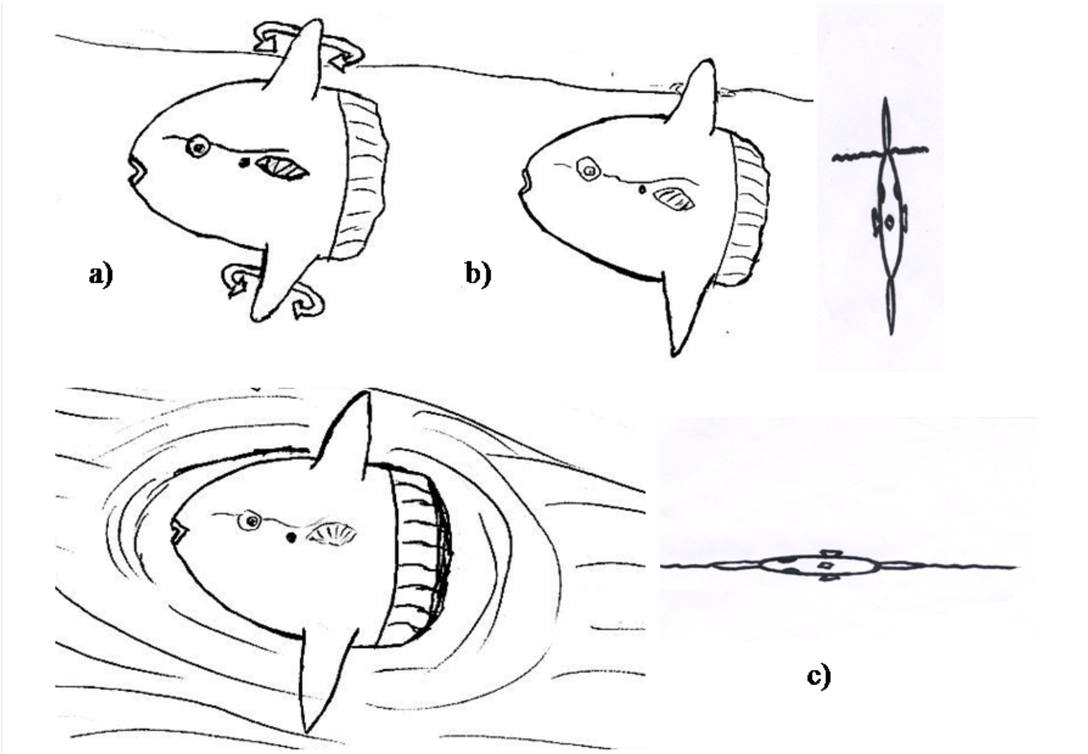
A typical Minke whale breathing sequence consists of a deep dive of typically 3- 5 minutes, but may last up to 20 minutes before which there are 3 – 8 shallow dives followed with 5-8 blows at intervals less than a minute (Wilson & Berrow 2007). This is supported by my observations from August 16 when Minke whale average breathing sequence was nearly 6 minutes.

None of the recorded weather characteristics (sea state, visibility, cloud cover, glare) was significantly correlated with the observed species diversity (GLM-p, $p > 0.26$), abundance of all observed species (GLM-p, $p > 0.31$), or with the abundance of any of two most common species (GLM-p, $p > 0.11$).

Significant increase in abundance of megafauna species was observed during the study period; it is shown by a strong positive correlation between the date (expressed as number of days since the beginning of the study) and the number of observations, both for all species merged together (GLM-p, $F_{1,47}=24.4$, $p << 0.001$) and for both two most common species separately, Common dolphin (GLM-p, $F_{1,47}=5.8$, $p = 0.02$) and Harbour porpoise (GLM-p, $F_{1,47}=17.4$, $p =0.001$). Positive correlation with the date was significant also for the species diversity (GLM-p, $F_{1,47}=5.4$, $p =0.025$). The temperature was significantly, but very slightly negatively correlated with number of Harbour porpoise observations (GLM-p, $F_{1,46}=5.2$, $P=0.027$) but not with the remaining tested veriables.

Box 5: Details of Sunfish focal observation

When a Sunfish was sighted, more detailed focal sampling was conducted until the animal was no longer in sight. Three types of behaviour, shown in drawings below, were expected based on Doyle et al. (report): A) swimming with fin flapping (vertical orientation), B) swimming without fin flapping (vertical orientation), and C) basking (animal horizontal on surface). Observed behaviour type, time, duration and transitions between behaviour categories were noted.



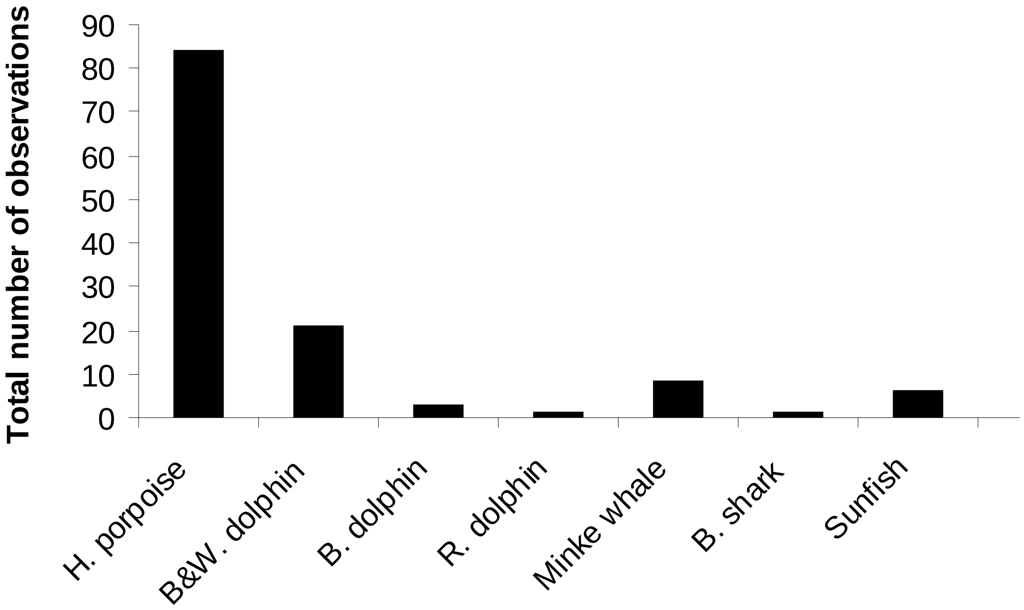
In total, I observed five individuals during my study, with a mean observation of 9.6 minutes per fish, 48 minutes in total (see table below). Only one Sunfish was seen when sea was calm (sea state = 0), the majority of sightings (four out of six) were recorded when the Beaufort scale was 2.

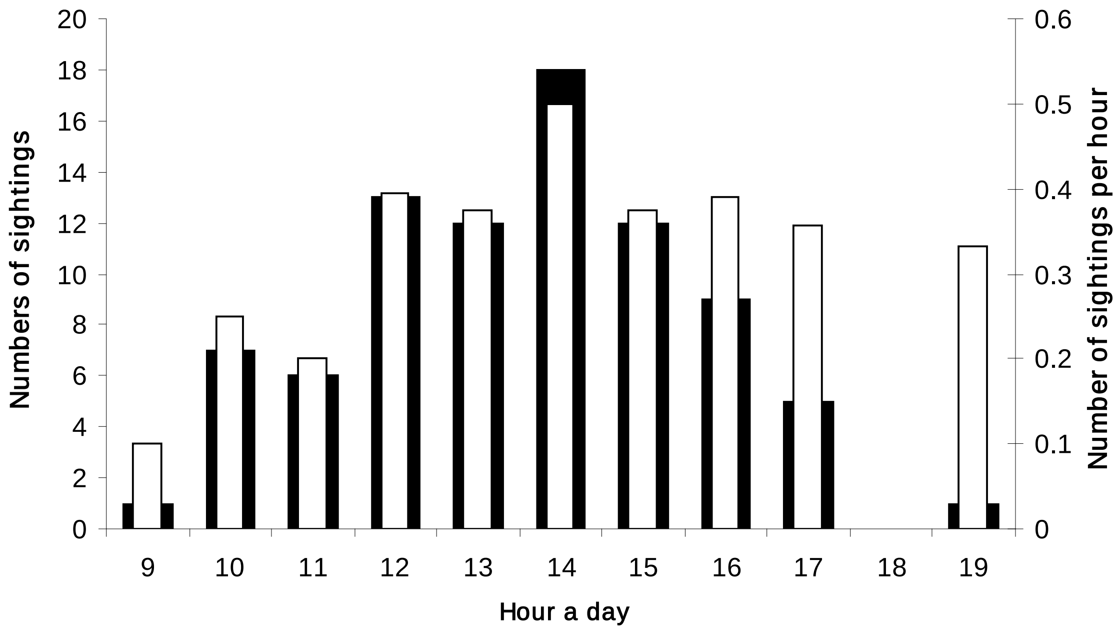
Unlike other studies (Houghton et al. 2006b, Doyle et al. report), no 'basking' behaviour of Sunfish was observed. This is probably because of a short observation period (mean Sunfish observation was also only 9.6 minutes per fish with the longest observation of 20 minutes) as well as a stationary observation position in the Blananarragaun Point. Basking is usually observed from boats.

case no.	date	time of first observation	total duration of observation (mins)	direction of swimming
1	26.7.	11:20	n/a	W
2	31.7.	15:41	20	W
3	4.8.	14:14	12	E
4	6.8.	15:38	2	W
5	19.8.	13:21	3	W
6	21.8.	12:08	11	W

Box 6: Details of Harbour porpoise observations

The most common animal observed during the study was the Harbour porpoise (upper chart). Due to this, I looked in more details to distribution of its sightings (lower chart) during the day (black) and this observation corrected for effort, i.e., the number of observation hours per day (white).





DISCUSSION

The absence of any Leatherback recording during our study can be most likely explained by unusually cool weather – the temperatures were below long-term average during the whole summer. It was the coolest summer since 2002 in many places of Ireland, particularly in its south-western part where Cape Clear is located, and the August mean of daily maximum air temperature was below normal almost everywhere in the country (in its westen part, it was lowest in 12-16 years; Lennon 2008). The Leatherback spends minimum (2 %) of the time in areas where the sea surface temperatures are below 15° C (McMahon & Hays 2006), and there were only a few days when temperatures increased above this limit in Cape Clear in the summer of 2008. Furthermore, these days were often separated by cooler periods, so the whole period was not convenient period for the species. Alternatively, turtles might have preferred reproduction at nesting habitats instead of migrating to foraging grounds in 2008, which would also reduce the likelihood of their observation. Inconvenient conditions for turtles in the north-eastern part of Atlantic Ocean in the summer of 2008 were confirmed by records from La Rochelle, where on average 49 Leatherback sightings per year had been recorded between 1988 and 2007 (France; Figure I-1). Only three Leatherbacks were observed in this best place for Leatherback turtle sightings in European water during 2008 and only one from them during the summer months (Dell´amico & Moriniere 2010).

One hundred twenty three sightings of seven megafauna taxa identified during the study is of course only a fraction of animals present in the area. To be counted, the animals must have been near the coast, on the surface and present during observation hours. Negative bias could arise because the sea-watcher was alone, which may lead to missing even animals well-presented on the sea surface (Dawson et al. 2008, Sharrock 1973). One person is not able to cover at the same time the whole visible sea surface, especially as screening the nearshore areas requires observation by naked eye, more distant areas binoculars, and the most distant a telescope. Additionally, even the active period of observation is not spent fully by screening the sea surface but also by other activities such as taking notes.

Weather conditions could also influence the results of observations. More animals should be detectable if visibility is excellent or good because an observer can cover a bigger area. The probability of animal detection should be lower with greater number of seascape octares obscured by glare and also in sea-states greater than Beaufort 3 (Hammond et al. 2002). However, we did not detect any significant effect of these variables on number of magafauna observations or number of observed species in our study.

Megafauna observations

Harbour porpoise was the most often observed species, consistently with previous studies made in the Celtic sea (Sharrock 1973, Berrow 2001, Rogan & Berrow 1996, Evans 1990). The Harbour porpoise was observed travelling alone or in group of up to three individuals, which seems to be characteristic for this species (Rogan & Berrow 1996).

Twenty one sightings of "Black and white" dolphins were recorded. These were probably Common dolphins (*Delphinus delphis*), the most abundant dolphin species in the west coast of Ireland (Wall et al. 2006, Berrow 2001). However, in some cases dolphins of such phenotype could have been the Atlantic white-sided dolphin (*Lagenorhynchus acutus)* or the White-beaked dolphin (*L. albirostris*), which are frequent offshore but rarely observed in inshore waters (Sharrock 1973, Wall et al. 2006). The former species would be less likely of the two, as it is less abundant in coastal waters (Evans 1990, Wall et al. 2006) and prefers surface water temperatures between 9 and 13° C (Skov et al. 1995). These values were exceeded in the studied area in summer 2008; the sea surface temperature daily mean measured at Databuoy M5 ranged from 13.9 to 16.9° C (Fig. 1-2).

Minke whales, Bottlenose dolphins and Risso's dolphins were seen only in August during our study. It could be related to sea water temperature, which was significantly higher in August than in July. Despite that, we did not detect a significant relationship between the species diversity and temperature. The Minke whale, the smallest and most abundant of baleen whales in the UK waters (Tetley et al. 2008, Berrow 2001), was the only whale seen in our study. Minke whales are directly affected by temperatures. In a 4-year study from Scotland (Tetley 2004), Minke whales were seen in great frequencies during September 2002 and July 2003, the months of highest sea surface temperatures. These historical observations suggest that the appearance of Minke whales may be linked to increased temperatures. Some others important factors that can determine the species distribution are abundance and distribution of their prey, which can be also related to temperature (Perry 2007). Although Minke whales and Bottlenose dolphins are opportunistic species adapting their diet according to local prey availability (Robinson & Tetley 2007, Tetley et al. 2008, Evans 1990), overall food supply may influence their distributions.

Bottlenose dolphins in the waters of British Isles occur mostly in groups (ranging from 2 to more than 40), only rarely as solitary individuals (Evans 1990, Culloch & Robinson 2008). The above-mentioned studies reported that the number of individuals tends to increase in late summer, when tens of individuals can be seen. In our studied period, only three groups of Bottlenose dolphins were observed, the largest of them, 23 individuals, was the first one seen; therefore we did not observe such trend. Risso's dolphins were observed only once in our study, this agrees with the fact that the species is rare in the area (Evans 1990).

Six out of eight Minke whale observations were associated with birds, as well as four out of 21 observations of "black and white" dolphins. This phenomenon is reported in a number of studies (e.g., Anderwald & Evans 2007, Robinson & Tetley 2007, Tetley 2004; see box 7 for more details)). In particular, Minke whale associations with birds are very common (Hodges 1993 observed association with birds in 27 %, Robinson & Tetley 2007 in 76 % and Gill et al. 2000 in 34 % of all Minke whales observations). For some bird species, association with cetaceans is a characteristic, and apparently beneficial, foraging method (Pitman & Ballance 1992). Whales exploit concentrations of small fish such as herring, sprat and sand eels, by driving and concentrating them close to the surface. This makes the fish prey available to surface-feeding and shallow-diving birds (Hebshi et al. 2008, Gill et al. 2000), which were observed feeding (diving) close to cetaceans several times during our study.

Six Sunfish were observed only from the end of July to August, also probably due to higher sea surface temperatures in this period. The species is almost certainly more abundant in the local waters than the frequency of observations suggests. Unlike cetaceans, which regularly surface for breathing, vertical movements of Sunfish are less predictable. Sunfish follow their vertically migrating prey, which they are in shallower depths of the water column at night and deeper in the day, and spend only 20 – 30 % of their time in the top 5 m of the water column (Houghton et al. 2006b). During that time, Sunfish are moving, re-warming after diving, or attracting birds and fish to remove parasites from their skin (Sims et al. 2009). This temporal pattern in the Sunfish depth distribution of the water column reduces chance to observe them on the surface in comparison with more regularly surfacing cetaceans. Recorded Sunfish individuals were relatively small (no more than 1 m), similar to the observations of Houghton et al. (2006b) in the Irish and Celtic Seas. Observed animals moved in most cases (5 out of 6) to the west. This seems to be the typical swimming direction of megafauna in Cape Clear waters, as it was already noted in historical records (Sharrock 1973). In our study, the Basking shark, Rissos dolphins and most of the observed Harbour porpoises, "black and white" dolphins, Bottlenose dolphins and Minke whales that were observed while travelling, swam in this direction. Possibly, this prevalence of westward swimming of megafauna observed from Cape Clear is related to direction of ocean current in the area (Fernand et al. 2006, Hill et al. 2008).

Observation of one individual Basking shark with a length around 4-6 m at the beginning of July corresponds with normal temporal and size distribution of sightings of this species in Cape Clear (and Ireland in general). Most Basking sharks are generally seen between April and November, with two seasonal peaks in June and September (Berrow & Heardman 1994) and decrease in July and August. As in our case, Basking sharks are mostly observed during sunny days with excellent visibility and nearly calm sea surface. In most cases only a single individual is observed, although group size can range up to twenty animals (Berrow & Heardman 1994).

Our Cape Clear study was the first systematic land-based observation of marine megafauna in the area of south-west of Ireland that covered an extended period of the summer season. Despite relatively cold weather and absence of Leatherback turtles, we recorded high species diversity as well as abundance of megafauna species. This confirms that Cape Clear waters are very important area for cetaceans as well as other large marine species, making it potentially a great resource for local ecotourism industry. Only future more regular monitoring may provide more information about the status of Leatherback turtles in the area.

Box 7: Review about megafauna association with birds

Six of the eight Minke whales observed during the study period were associated with birds. Also four out of twenty one “black and white” dolphin observations in our study were connected with this behaviour. Birds are not associated only with cetaceans. This phenomenon is geographically widespread and known for many taxa (Anderwald & Evans 2007, Robinson & Tetley 2007, Tetley 2004, Hodges 1993). Reports about association with pinnipeds, schooling fishes, marine turtles and floating non-living objects also exist (Pitman & Ballance 1992).

Turtles as well as cetaceans and schooling fish also prepare feeding opportunities for birds by acting as passive fish aggregators (small fishes are often attracted to floating objects on the open ocean). For some bird’s species, following cetaceans and diving for fish near them, is a characteristic foraging method (Hebshi et al. 2008, Gill et al. 2000).

However, it is possible to observe also opposite behaviour. Whales may detect birds feeding on big shoal of small fish, which were previously aggregated close to surface by foraging mackerels (Robinson & Tetley 2007).This method, feeding of prey previously concentrated by some other animal(s), is profitable for whales (very often Minke), as it allows to spend less energy to get the prey. This bird-associated feeding is recorded in most cases during the productive summer months (Robinson & Tetley 2007).

The cetaceans most commonly observed in association with bird flocks at British east coast, were Harbour porpoise, White-beaked dolphins, and Minke whales (Camphuysen & Webb 1999). Birds are observed diving below the surface near cetaceans on many occasions. For example, Parkinson's Petrel, kittiwakes, gulls, gannets, auks and shearwaters associated mainly with large, slow-swimming species of dolphins. Mentioned birds during this occasion feed by diving under the surface where dolphins feed (Pitman & Ballance 1992, Robinson and Tetley 2007). They must benefit from this association when they follow whale movements (Gill et al. 2000). Nevertheless, small fish, typical prey of both cetaceans and seabirds, usually are not visible at the surface during observations (Pitman & Ballance 1992, Camphuysen & Webb 1999). I also would not notice small fish at the surface during the study.

Birds may associate with cetaceans also for additional reasons than only a shared prey. Some seabird species, including Sooty Shearwater, Northern Fulmar, and Great Skua, also feed on excrements of Minke whales which they accompany (Camphuysen & Webb 1999).

CHAPTER II

TRENDS IN OBSERVATIONS OF SELECTED MEGAFAUNA SPECIES AT CAPE CLEAR SINCE 1971

Processing of historical data: Introduction

The second important part of my stay in Ireland was the digitisation of historical records on observations of Leatherback turtles, Sunfish and Basking Sharks at the Cape Clear. Despite the fact that the Bird Observatory on the island is used mainly for birdwatching, birdwatchers have been recording also the occasional observations of these three taxa for more than 30 years. These records were hand-written in observatory notebooks (Figure 2-1) and no one has evaluated them so far. Data can be useful for proxy analysis of trends in the abundance of megafauna in Irish waters.

Digitisation of the detail historical records about Leatherback, Sunfish and Basking Shark sightings at the Cape Clear were made from hand-written notebooks. All records about marine megafauna observations since 1971 until 2008 (37 years) included detailed data about weather conditions, sea state, and especially observation effort (minutes of sea watching and numbers of observers for each day of observation). Only preliminary analyses of this dataset are included in this thesis; the data may nevertheless be subjected to further studies.

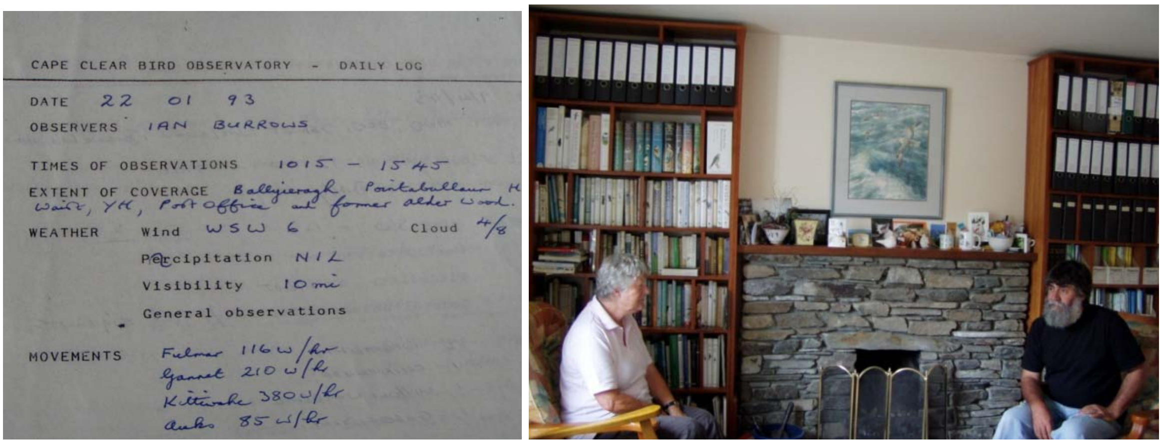


Figure 2-1: Historical records of megafauna observations at the Cape Clear Bird Observatory. Left – example of a record in a hand-written observatory notebook; right - array of notebooks in the Bird Observatory library (top shelves).

For the attempt to explain temporal trends in megafauna observations at Cape Clear, I used data on sea surface temperatures and on the North Atlantic Oscillation (NAO) index Figure 2-2). NAO is the climatic phenomenon consisting of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic Low and the Azores High. The North Atlantic Oscillation controls the strength and direction of westerly winds and storm tracks across the North Atlantic, and influences dynamic of organisms in aquatic and terrestrial ecosystem through changes in temperature (Ottersen et al. 2001, Blencker & Hillebrand 2002). For example, changes in plankton abundance and in length of the growing season during the period of the positive NAO index were observed (Weyhenmeyer et al. 1999, Straile & Adrian 2000, Reid et al. 1998, Fromentin & Plangue 1996).

METHODS

Long-term climatic data

NAO data for the period 1971–2008 were obtained from the Climate Prediction Center (http://www.cpc.noaa.gov/products/precip/CWlink/pna/nao_index.html). The sea surface temperature data was obtained from the HadISST 1.1 dataset for the same period. This dataset contains global 1 degree grids of monthly mean sea surface temperature data since 1870, combining in-situ and AVHRR satellite (since 1982) observations (Rayner et al. 2003). The values from six one-degree cells over the area 50 to 52°N; 8 to 11°W were extracted from the dataset and averaged for each month in the period 1970 to 2008; furthermore, yearly averages were calculated. For testing the hypothesis that the North Atlantic Oscillation can explain changes in abundances of Leatherback turtles, Sunfish and Basking sharks, I used only records from months since April to October, because these animals are observed only in this period in Ireland.

Numbers of Leatherbacks, Sunfish and Basking sharks sightings per year were at first investigated for partial temporal autocorrelation using the acf function in the R software (R Development Core Team 2010). Because the autocorrelation was not significant, three separate generalized linear models with Quasipoisson distribution (due to overdispersion) were used for testing the relationship between numbers of all three above-mentioned species of marine megafauna sightings in south-west Ireland, and North Atlantic Oscillation and sea surface temperature. North Atlantic Oscillation and sea surface temperature were response

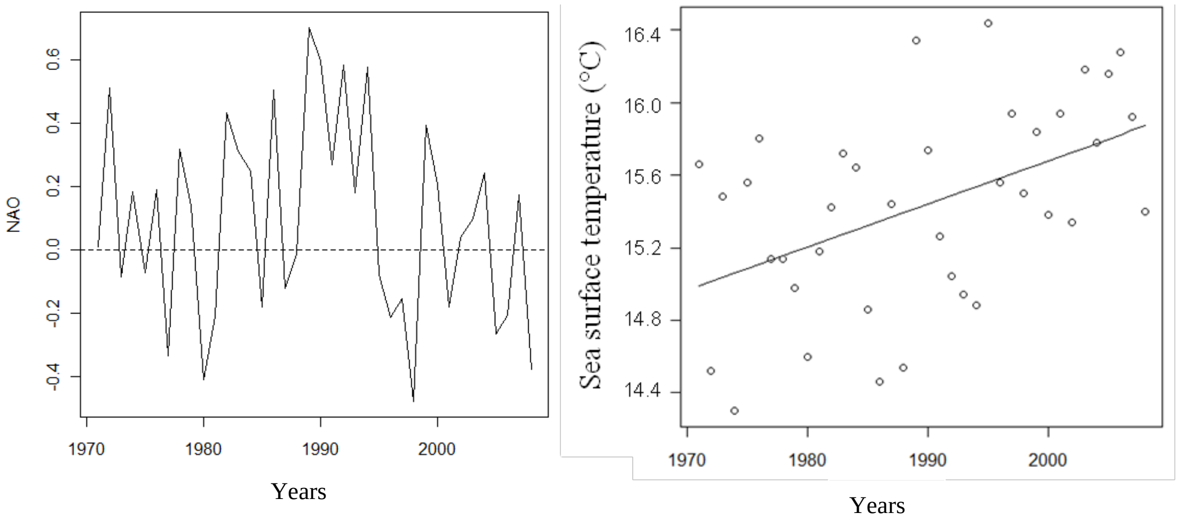


Figure 2-2: Temporal trends in the NAO index (left) and Sea surface temperature (right) between 1971 and 2008. Sea surface temperature is expressed as the mean of average monthly temperatures since June to October in each year.

variables. As the studied megafauna species tend to stay in Irish waters in the months with higher temperature, the sea surface temperature was represented in the models by the sum of average monthly temperatures from June to October for each particular year.

Log–transformed sums of observation hours for the whole period since June to October for each year were added to all models as a predictor parameter to compensate for the variation in observation effort.

When analysing the Leatherback turtle and Sunfish observations, we did not use all sightings data in the models; we excluded a year in which most observations of the particular species were recorded (1993 for the Leatherback turtle, and 2002 for Sunfish). The reasons for exclusion of these years were too abnormal residuals in the analysis. Most likely, it is due to repeated observations of the same individuals of Leatherback turtle or Sunfish staying at the locality for prolonged periods; in that case, the observers would have recorded the same individuals multiple times. A linear model was used to test if the number of Sunfish observations increase with time. All analyses were conducted in R (R Development Core Team 2010).

Leatherback turtle sightings at other localities

For potential explanation of trends in historical Leatherback observations at Cape Clear, I tried to collect as many data as possible about the species sightings at other locations in the Atlantic Ocean (Table 2-1). The original aim was to test the hypotheses that the presence of Leatherback turtles at other nesting or foraging localities may explain a significant proportion of changes in abundances of Leatherback turtles in the study area, or that more turtles in nesting habitats correlate with less turtles in foraging habitats. Unfortunately, the data I managed to collect were from different sources, different time periods and recorded by different methodology, so it was not possible to include them in any statistical analysis I could perform.

Locality	**Years**	**Character of data**	**Source of data**
foraging areas:			
Canada	1998 –2006	reported sightings	James et al. (2006), James et al. (2007)
France	1998–2006	number of sightings	James et al. (2007)
nesting colonies:			
French Guiana	1971–2002	number of nesting turtle females	Caut et al. 2006
French Guiana and Suriname	1977–2005	number of turtle nests	Fossette et al. 2008
Florida	1986–2003	number of turtle nests	Antworth et al. 2006
Caribbean	1982–2001	number of nesting turtle females	Dutton et al. 2005
Costa Rica	1995–2006	number of turtle nests	Troeg et al. 2007

Table 2-1: Sources of data and details (locality, years for which data were available) which were collected in the attempt to explain trends in Cape Clear turtle sightings.

RESULTS

Sea observations

In total, data were available from 3510 days (8157 hours) of land-based sea observation (Figure 2-3, Table 2-2).

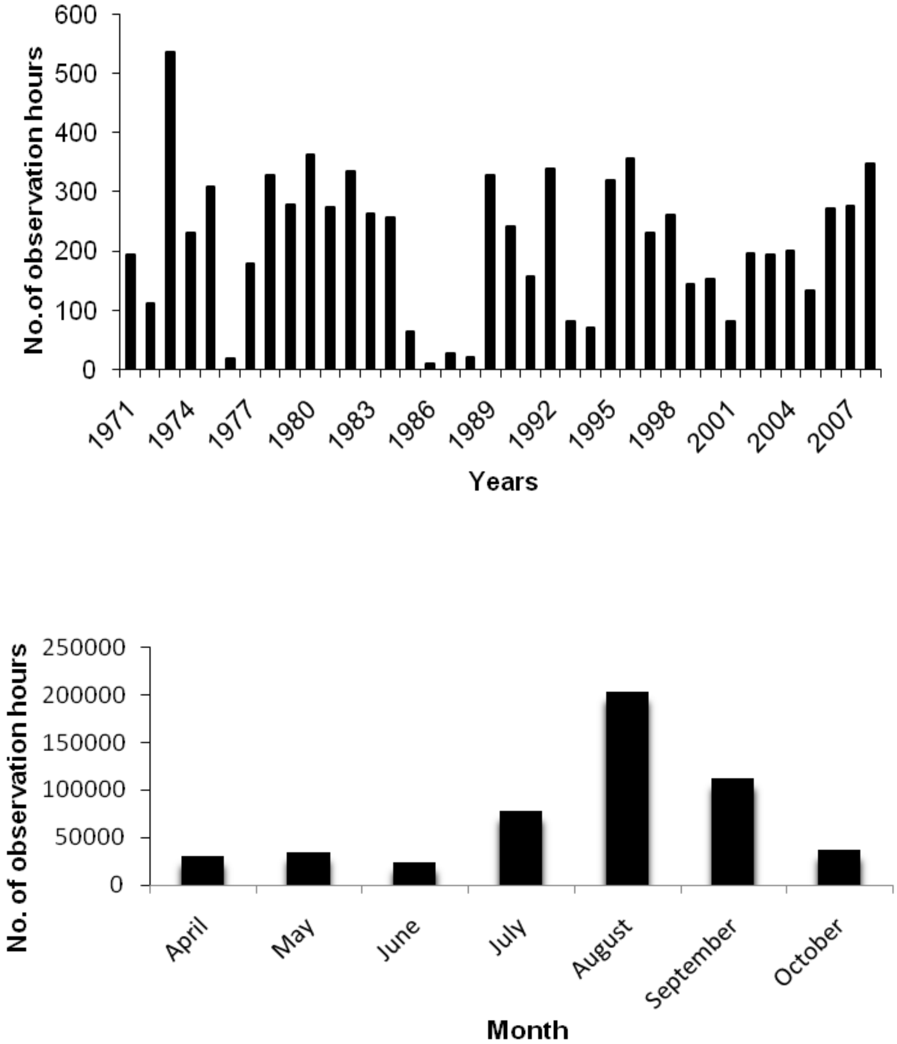


Figure 2-3: Observation effort distribution in the period from April 1971 to October 2008 as extracted from Cape Clear Observatory notebooks (hours of observations per year are given in the top chart, hours of observations per month in the lower chart).

No. of observers	1	2	3 - 5	6 - 10	11 - 15	16 - 20	21 - 40
No. of observation days	364	480	1180	676	166	47	14

Table 2-2: Observation effort distribution in the period from April 1971 to October 2008**:** numbers of days when a given number of observers were present at the observation point (not necessarily all of them together)

Megafauna observations

In total, 1001 cases of megafauna observations (446x Sunfish, 329x Basking sharks, and 226x Leatherback turtles) were recorded during the investigated 37 years.

Leatherback turtle sightings

Since April 1971 to October 2008, 266 turtles were recorded (Figures 2-4, 2-5). Most of them (98.5%) were seen between the years 1989 and 2008. In most years, the numbers of sightings were low (2 to 6 individuals per year).

There were two peaks in the number of turtle observations – the first in the period between 1989 and 1996, when around 30 turtles were observed every year (82% of all observations), with the maximum of 99 turtles observed in 1993 (37% of all observations). The second peak was in 2000, when 19 turtles were observed in a single year. However, the records since then have declining tendency and the mean number of observed turtles since 2003 to 2008 was just 1.8 per year (Figure 2-5). Leatherbacks were recorded since June to October, when the temperature is suitable and Leatherback gelatinous prey, mainly jellyfish, is plentiful. Most Leatherbacks (232, i.e. 89.5%) were seen in August – the peak is also clear after correction for the uneven observation effort (Figure 2-4). There was no single record of a Leatherback during the late autumn and winter.

Sunfish sightings

Records of Sunfish come from the months since April to October (Figure 2-4). There are no records of Sunfish during the remaining months in the year. Similarly to Leatherbacks, most Sunfish were seen in August. However, after correction for effort, the peak is not as sharp.

223 Sunfish were recorded between April 1971 and October 2008 (Figure 2-5). There are years with higher and lower abundance but the records have increasing tendency overall (LM, $p = 0.0003$; Figure 2-5).

Basking Shark sightings

There were no records of Basking Shark observations before 1976 from Cape Clear, and it is not clear whether this is due to the absence of the species or of the records on the Bird Observatory. However, 329 sightings were recorded between 1977 and 2008 (Figure 2-5) and there are three visible peaks – the first in 1977, the second in the period between 1994 and 1997, and the third in 2007. Overall, most Basking sharks were also observed in August; however, this is due to high observation effort in this month. When corrected for the number of observation hours, it seems that there is much higher likelihood to see Basking Shark in June (Figure 2-4).

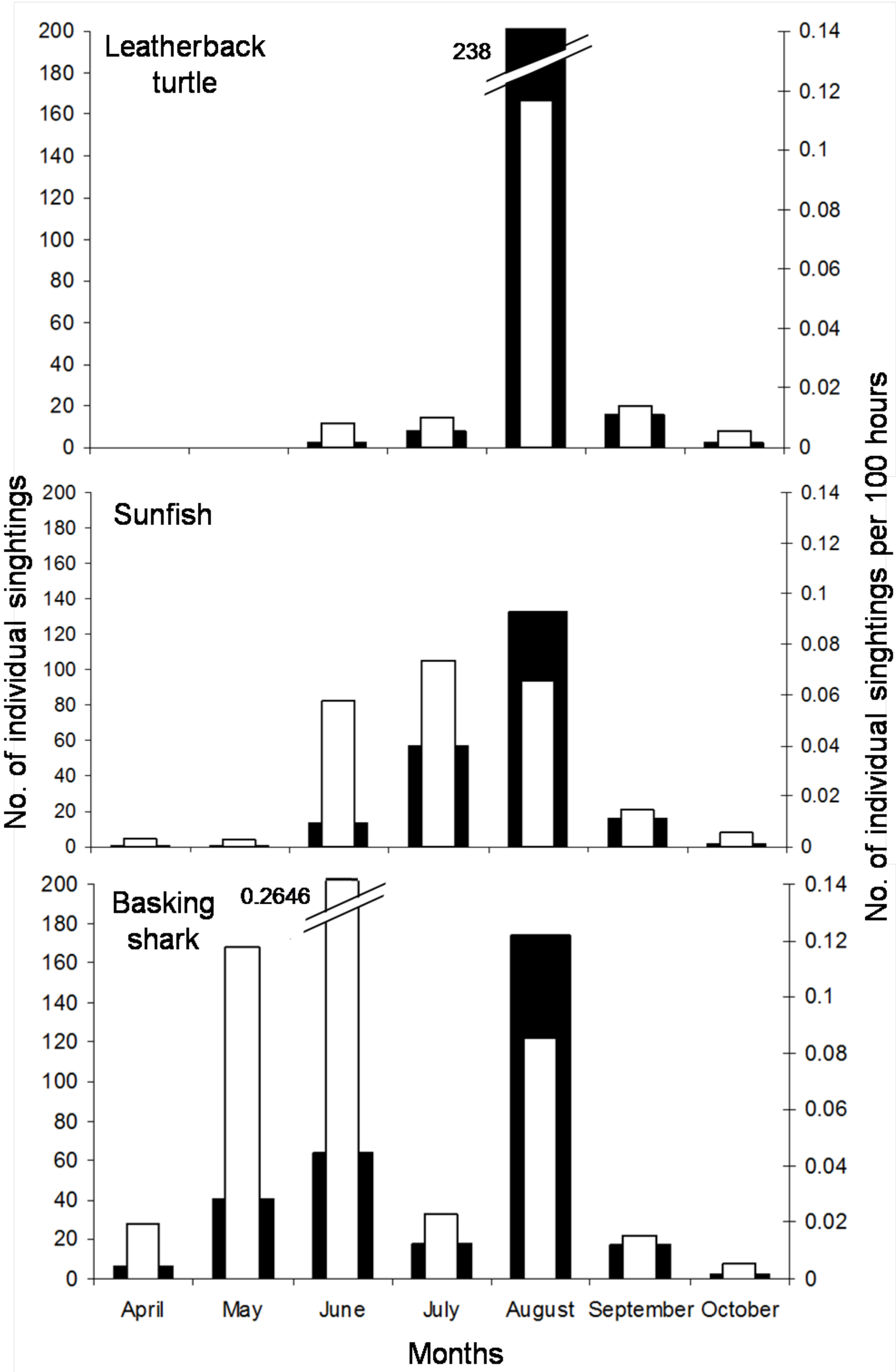


Figure 2-4: Distribution of Leatherback, Sunfish and Basking shark sightings among months (black) and these observations corrected for effort, i.e., the number of sightings per 100 observation hours (white) within the evaluated period (1971 to 2008).

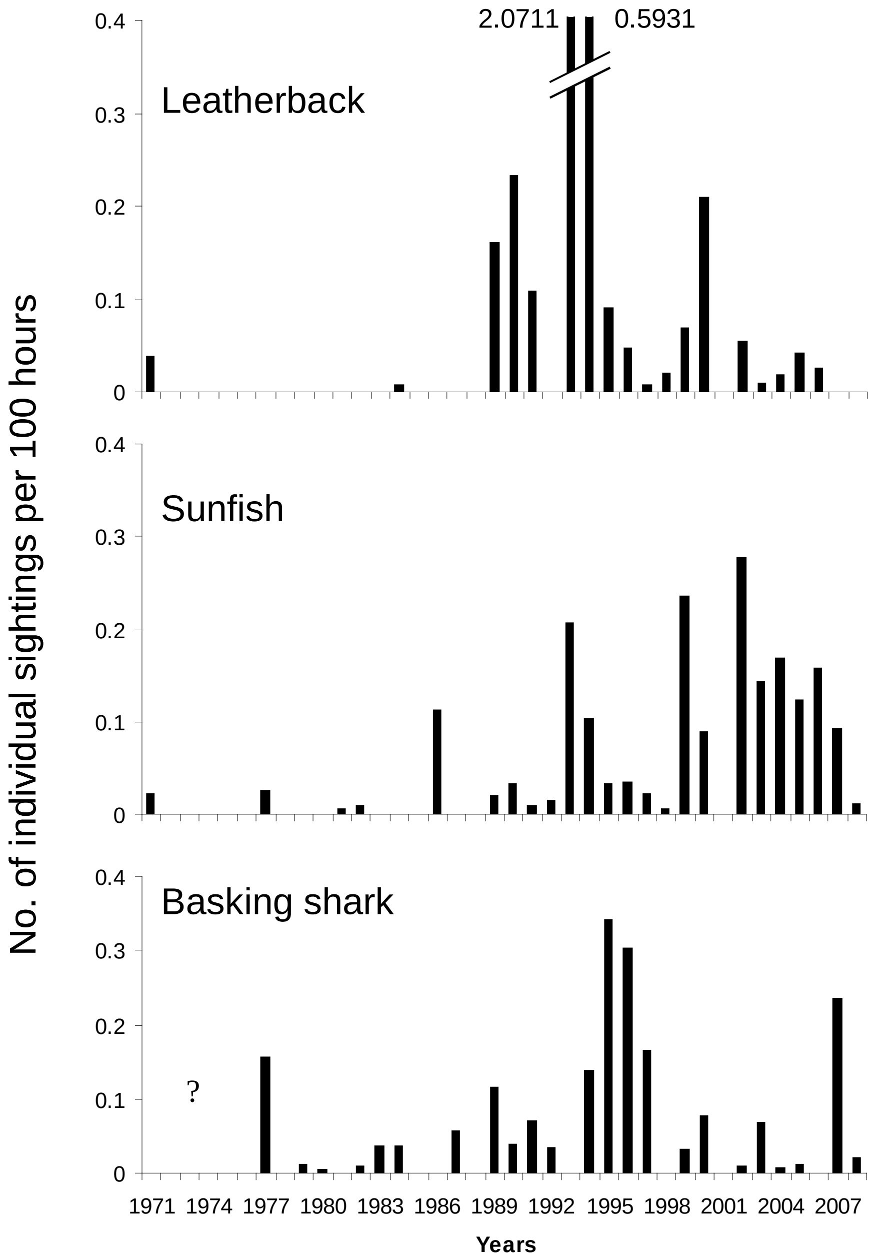


Figure 2-5: Temporal trends in the number of recorded Leatherbacks, Sunfish and Basking shark at Cape Clear, corrected per unit effort (expressed as number of sightings per 100 observation hours).

a) Leatherback turtle

Factor	Df	Deviance	Effect	F value	p-value
Log (effort)	1	7.839		0.8479	0.3640
Sea surface temperature	1	38.452	+	4.1594	0.0497 *
NAO	1	113.267	+	12.2524	0.0014 **
Sea surface temperature:NAO	1	6.435		0.6961	0.4103

b) Sunfish

Factor	Df	Deviance	Effect	F value	p-value
Log (effort)	1	8.744		1.2513	0.2716
Sea surface temperature	1	90.402	+	12.9377	0.0011 **
NAO	1	1.189		0.1702	0.6827
Sea surface temperature:NAO	1	11.738		1.6799	0.2042

c) Basking shark

Factor	Df	Deviance	Effect	F value	p-value
Log (effort)	1	174.922	+	9.7640	0.0042 **
Sea surface temperature	1	107.610	+	6.0067	0.0210 *
NAO	1	16.633		0.9285	0.3438
Sea surface temperature:NAO	1	1.318		0.0736	0.7883

d) Summary

	Log (effort)	Sea surface temperature	NAO
Leatherback turtle		*	*
Sunfish		*	
Basking shark	*	*	

Table 2-3: Results of GLM used to determine the effects of NAO, Sea surface temperature and observation effort to the number of historical Cape Clear observations of a) Leatherback turtles, b) Sunfish and c) Basking sharks. Table d summarises the three tables above. Significant relationships are indicated by asterisks.

Both NAO and sea surface temperature had a significant effect on the numbers of Leatherback turtle observations (Table 2-3, Figure 2-6), but the impact of sea surface temperature was not as high as the impact of NAO. When the influence of NAO and sea surface temperature is filtered out, there are cycles in numbers o Leatherback Sea turtle observations – positive one every 2 and 4 years and negative one every 7 years.

Numbers of Sunfish observations were positively impacted by sea surface temperature (Table 2-3, Figure 2-6). After filtering out the effect of this variable, the numbers still show increasing tendency during the analysed period (LM, $p = 0.0002694$; Figure 2-5). Significant relationship was observed also between numbers of Basking shark observations and sea surface temperature (Table 2-3, Figure 2-6) but much bigger impact to number of sightings of these animals had observation effort.

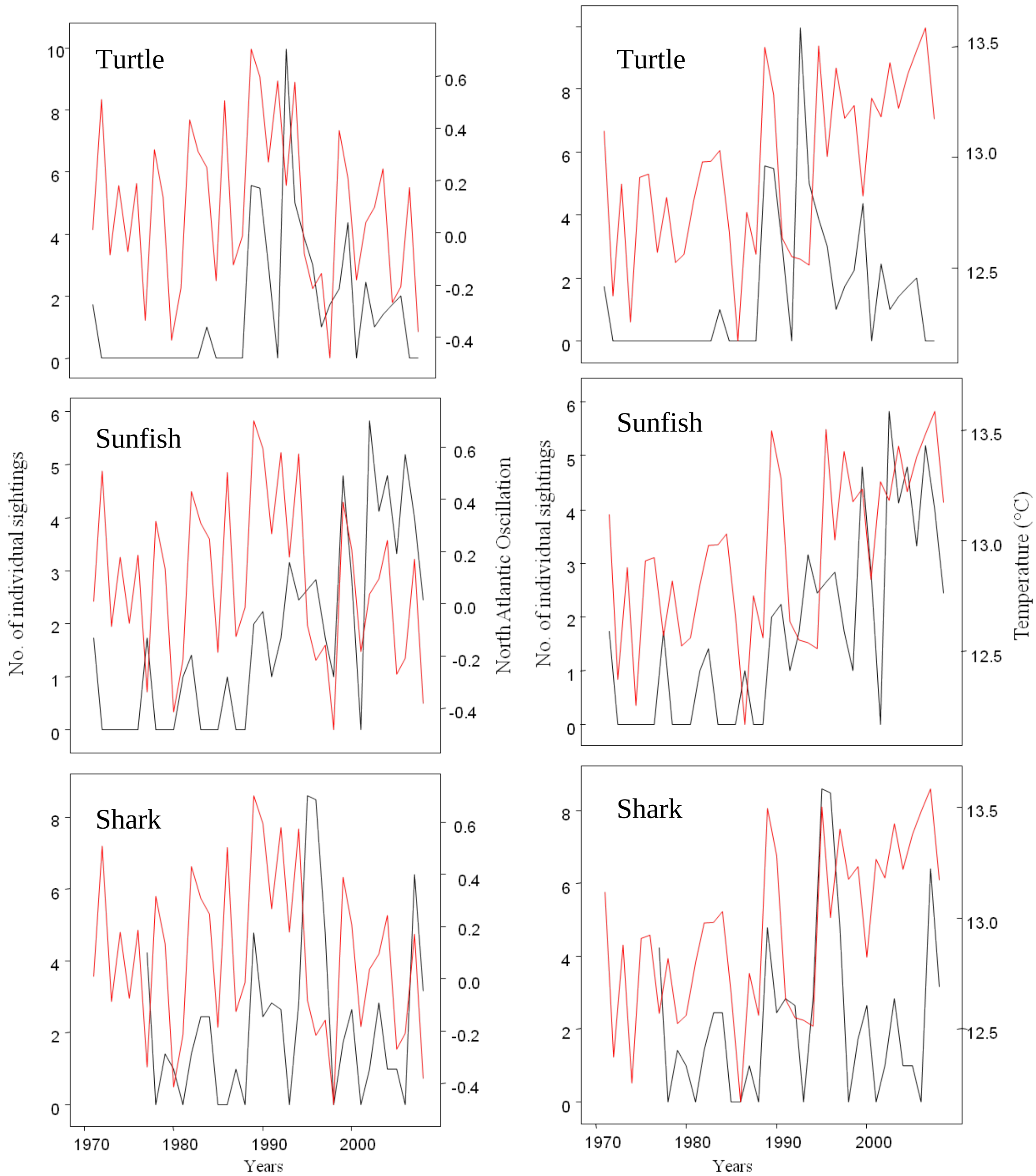


Figure 2-6: Relationships between numbers of Cape Clear observations of Leatherback turtles, Sunfish, Basking shark and North Atlantic Oscillation (left column) and sea surface temperatures (right column) are shown.

Figures 2-7 and 2-8 summarise the presence of Leatherback turtles at other localities in the Atlantic Ocean. As I mentioned in the Methods section, due to missing data and their incompatible character I was not able to test statistically the hypothesis that turtle's presence at other localities may explain changes in abundances of this species in Ireland, or that more turtles in nesting habitat correlate with less turtles in the foraging one.

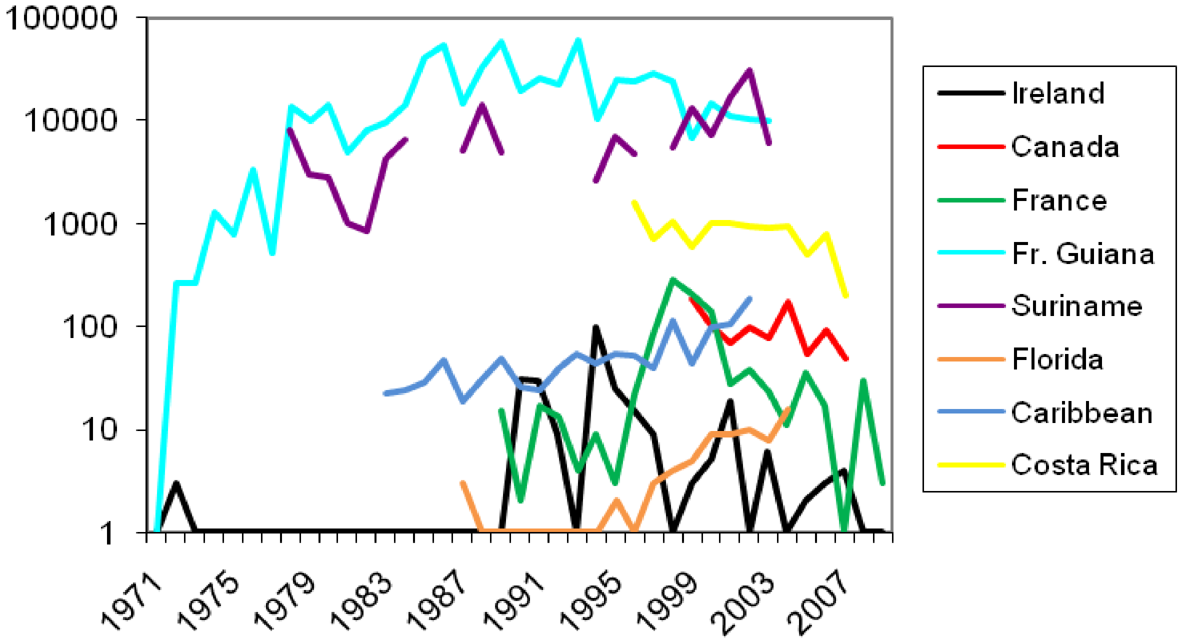


Figure 2-7: Distribution of Leatherback sightings at recorded localities in the Atlantic Ocean.

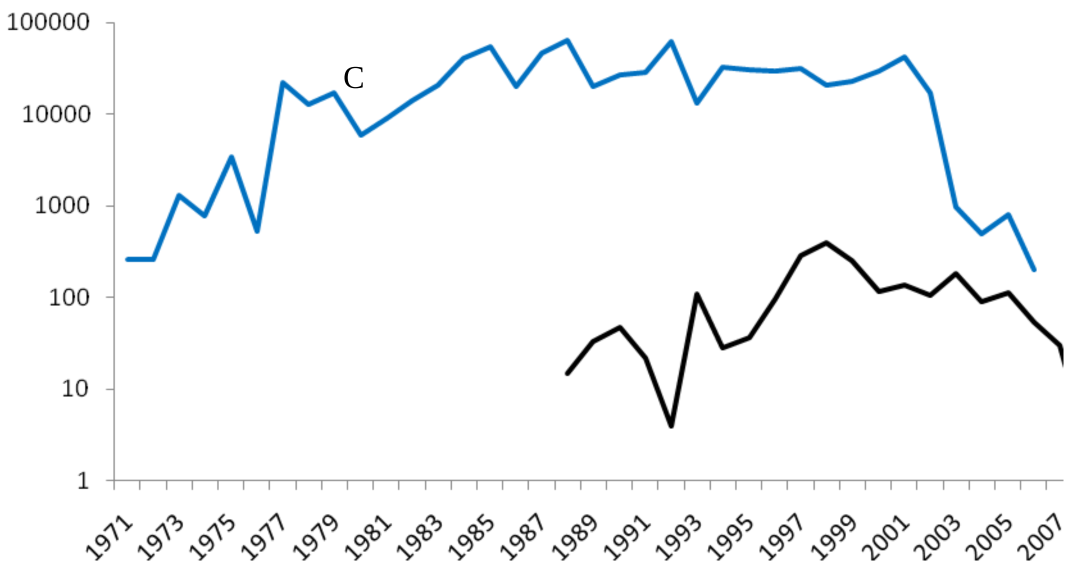


Figure 2-8: Distribution of Leatherback sightings in nesting (blue) and foraging (black) habitats. Number of sightings from all nesting (French Guiana, Suriname, Florida, Caribbean and Costa Rica) and foraging regions (Ireland, France, Canada) were summed up.

DISCUSSION

Observations of Leatherback turtles, Sunfish and Basking sharks were recorded during 37 years in the Cape Clear Island. In most cases (in 3146 from 3510 observation days) more than one person was present during the day at the observation point. Although it is not clear that this always represents a parallel presence (and attention) of more observers at the same time, we presume that mostly this was the case, and that the presence of more persons at least partly reduced the likelihood that animals well-presented on the sea surface in the vicinity were missed. Although some general information on the local weather was recorded during the years, it was not detailed enough; therefore I did not use such data for analysis. Although the weather variation is undoubtedly important, and likely impacted the number of records of the target species, we did not detect any significant relationship between them and the numbers of megafauna observations during the 2008 season.

Megafauna observation

Leatherback turtle

There was a big variability in numbers of Leatherbacks turtle observations during the years. There can be a few explanations for this:

Firstly, the temperature: Leatherback sea turtles are exothermic animals which spend only 2% of their time in waters with sea surface temperature colder than 15°C (McMahon & Hays 2006; details in general introduction and also in discussion of Chapter I). This Leatherbacks behaviour is also supported by 1455 sightings of Leatherback turtle in foraging grounds of the NE Atlantic during the period 1954 – 2003. The medium sea surface temperature for turtle observation was 18.6°C from the area of nine countries (Witt et al. 2007). The significant relationship between turtle numbers and sea surface temperature in our study corresponded to James et al. (2007). Sea surface temperature does not impact only Leatherbacks but it positively correlates also with the abundance of their prey (Lynam et al. 2011). Relationship between Leatherbacks sightings and the North Atlantic Oscillation was also significant in our data. The distribution of turtles in foraging grounds also depends on momentary prey abundance and distribution (Doyle et al. 2006, James et al. 2006a, James et al. 2006b, Sherrill-Mix et al. 2007). Occurrence of Leatherbacks, similarly as another jellyfish predator, the Sunfish, is positively correlated with abundance of jellyfish (Houghton et al. 2006b), which abundance depends on climatic conditions. Therefore, the sea surface temperature and NAO most likely impact Leatherback turtle both directly and indirectly through their jellyfish prey (Lynam et al. 2004).

Secondly, re-nesting intervals: turtles choose from a few places in Atlantic and their choice affects the number of turtle sightings in individual localities. Turtles migrate between the nesting beaches and food-rich foraging areas in higher latitudes. Main nesting colonies in the Atlantic are in French Guiana, Suriname, Dominican Republic, Costa Rica, Trinidad, Columbia, Guyana, Virgin Islands, Florida, Puerto Rico, Brazil and in Gabon (Spotila et al. 1996). In these tropical areas, turtles breed and create nests for their eggs. 40 % of worldwide Leatherback nesting population reproduce in a single country, French Guiana (Spotila et al. 1996, Maros et al. 2003), and 90 % of these nest on the single beach of Awa:la-Ya:lima:po (Caut et al. 2006).

Turtles nest at this place mainly between March and August, including a peak in June (Caut et al. 2008). As mentioned above, the majority of Irish sightings are also from summer months. This would not be possible if the turtles nested every year. However, due to many threats and long distances involved with reproduction migration, Leatherbacks usually have 2 to 3-year remigration intervals (Rivalan et al. 2005). This fact contributes to variability in numbers of nesting females among years. The positive cycles every 2 and 4 years in the residuals of Leatherback sea turtle observation numbers in Ireland after filtering out the impact of the NAO and sea surface temperature might be related to remigration intervals. I did not observe any turtle in summer 2008 in Ireland. When I asked a French Guiana turtle specialist, I learned that more Leatherbacks than usual nested in that country in 2008 (Girondot, pers.comm.). Therefore, less Leatherback turtles were likely to be observed in the Atlantic foraging areas at higher latitudes. This also corresponds to results from the French foraging area (La Rochelle), where only 3 turtle individuals were seen during the whole year 2008 (see Discussion of the Chapter I for more details).

Thirdly, choice of foraging grounds: even if weather is suitable, and there is no strong nesting year, turtles can choose other areas for foraging. Leatherback turtles visit several foraging areas in the North Atlantic, including Nova Scotia (eastern Canada), the north-eastern United States, Ireland, France, United Kingdom, Norway, coasts of Iberian peninsula or more southern West Africa (Caut et al. 2008, James & Herman 2001). Therefore, the reason for lower number of turtles in Europe may be that that more of them are at the coast of USA and Canada. The turtles’ choice depends on a few different factors, primarily distance. Nova Scotia (Canada - 44° N, 60° W) is approximately 4400 km from Awala Yalimapo (French Guiana - 5.7° N, 53.9° W) but Cape Clear (Ireland - 51°26’N, 9°30’W) is around

6500 km away from this main nesting site and 2100 km further than Nova Scotia. Turtles cover maximum 32.5 km in one day; this means around 126 days to Nova Scotia and 220 days of travel from French Guiana to Ireland (Doyle et al. 2008). Turtles leave nesting ground after they finish their reproduction and move to more productive areas to forage (Hughes et al. 1998, James et al. 2005b, Sherrill-Mix et al. 2007). As noted above, the peak of nesting season at the beach of Awa:la-Ya:lima:po in French Guiana was in June (Caut et al. 2008) so turtles could arrive to Nova Scotia no sooner than in August and to Ireland in mid-November.

However, the weather in the Irish and adjacent seas in this period of the year would not allow turtles to stay there. It suggests that for female Leatherbacks, it is nearly impossible to go to Ireland at the same year when they nest but the journey to Nova Scotia is feasible. In years between breeding remigration, turtles are usually in pelagic waters closer to foraging areas (James et al. 2005b) and they can start their way to foraging habitats sooner so it is possible for them visit Ireland and other parts of Europe.

Aerial Leatherback observations record on average 6.85 Leatherbacks per 1000 km in continental shelf waters around Nova Scotia but only 0.25 Leatherbacks per 1000 km in Irish waters (Doyle et al. 2008). But why are there at least some Leatherbacks recorded in Ireland if it seems so disadvantageous to travel there? Possibly, this can be explained by ocean currents. As already mentioned, Leatherbacks migrations routes are strongly influenced by ocean currents (Lushi et al. 2003) and their distribution in the Atlantic Ocean. Especially the trace of Gulf Stream and North Atlantic current can help turtles to surpass the great distance from French Guiana and other nesting grounds to foraging localities (Figure 2-9).

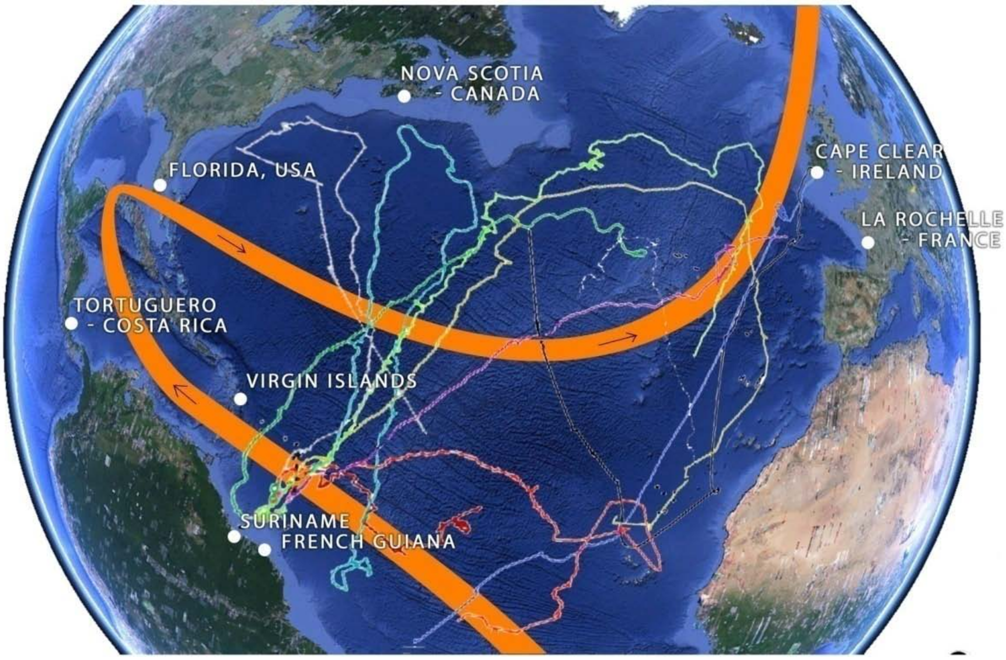


Figure 2-9: Map of North Atlantic Ocean. Orange line shows the position of warm shallow ocean currents including the Equatorial Current, Florida Current, Gulf Stream and North Atlantic Current. Ireland, France and Canada foraging grounds are indicated in the map, together with main Atlantic nesting beaches in French Guiana, Surinam, Virgin Islands, Costa Rica and Florida. This figure also shows the movements of 12 Leatherback turtles tracked between 2002 and 2006 (two from Ireland and ten from Grenada) based on Houghton et al. (2008).

Sunfish

In total, 223 Sunfish were recorded at Cape Clear during the studied 37 years. The analyses reveal a significant relationship between the number of reported individuals and sea surface temperature, similarly as in other studies (Sims et al. 2009).

Sunfish were recorded only during the period between April and October in our records, in agreement with Sims et al. (2009). This team tagged Sunfish from Portugal and Ireland. Fish tagged in February travelled westwards and northwards, while the fish tagged in August travelled southwards. These observations correspond to the general behavioural trend of Sunfish moving north at the end of the winter and south at the end of the summer (Sims et al. 2009); movements probably linked to the restricted thermal tolerances of Sunfish. Winter sea surface temperature west of Ireland is typically between 8 and 10°C, probably too low for this species. However, it is possible that with increasing global temperature this trend will change and Sunfish will spend more time in the northerly regions.

Numbers of Sunfish observations increase during the time period, and the trend is significant even after filtering out the influence of sea surface temperature. This tendency may reflect increased interest in the species and its better recording, strongly non-linear increase of abundance or local presence of the species in response to climatic factors, but also other factors that improve conditions for Sunfish in general, or in Irish waters in particular.

Basking shark

There is an increasing trend of Basking shark reports in the whole Ireland.

On average, there were only 10 recorded sightings per year of this planktivore before 2003, sightings increased to around 40 per year between 2004 and 2006, and further to 122 sightings in 2007. 129 encounters with sharks were recorded since the beginning of the year season until June 2008; this is a 20 % increase in comparison with the same time period in 2007 (Berrow & Whooleys 2008). In total, there were 174 sightings during the whole year 2008 season, and the number of observations has been increasing afterwards as well. According to summary of the IWDG database, locally reported sightings from fishermen, boatmen etc., and also Marine Conservation Society & the Sharktrust, 243 sightings were reported during 2009 and 276 in the 2010 season (data provided by Lucy Hunt, one of Basking shark specialist in Ireland). Most likely, these changes are driven indirectly by climate change through influencing abundance of Basking shark's zooplankton prey (Berrow & Heardman 1994).

Another factor that may play a role in increase of Basking shark population in Ireland is the fishery closure since 1975, and their protection. In UK territorial waters Basking sharks are protected under Schedule 5 of the Wildlife and Countryside Act (1981) and they were added to Appendix II of CITES in 2002 (Berrow & Johnston 2009). Basking sharks are also listed as vulnerable on the IUCN's Red List and endangered in the North-east Atlantic (IUCN Red List, 2004). Target fishing of the species is now illegal in European waters and internationally by EU registered vessels (EC No41/2007 of the 21/12/2006). Although there is no special national legislation to protect the species in Irish waters, the shark is sufficiently protected by EU legislative (Berrow & Johnston 2009). However, sharks are still caught accidentally in other fisheries such as trawlers or gill nets (Southall et al. 2006).

Increase of Basking shark sightings in Irish waters may at least partly result from better recording of the sightings. However, I detected also a significant relationship between numbers of Basking shark sightings in Cape Clear waters and sea surface temperature. Most likely, climatic variation impacts this species not only directly but also indirectly by changes of its prey abundance (Fromentin & Plangue 1996, Sims & Reid 2002).

Conclusion

Records from 37 years of Leatherback turtle, Sunfish and Basking Shark observations recorded at the Cape Clear Bird Observatory brought interesting, though preliminary, results on the variation in observation of these megafauna species, and possible impact of climatic factors on their sightings. Although these records were noted occasionally and non-systematically, and they may not be considered a direct proof of climate change impact on megafauna distribution in Irish waters, the significant relationships between climate variables and numbers of observations of the target taxa are intriguing. They are in agreement with other studies that suggest that marine megafauna, and Sunfish and Leatherbacks in particular, may be used as indicators of climate change. The results suggest that coastal waters of Southern Ireland represent a potentially important area for further studies on the relationship between climate, local conditions, and large marine species.

SUMMARY

- The first systematic land-based observation of marine megafauna was conducted in summer 2008 from the island Cape Clear; south-west of Ireland.
- It covered 51 days between June 30 and August 26, 2008 (233 observation hours).
- 123 observations of marine megafauna were recorded: approximately 301 individuals of at least seven megafauna taxa: Harbour porpoise, „black and white” dolphins (Common dolphin or *Lagenorhynchus* sp.), Bottlenose dolphin, Rissos dolphin, Minke whale, Basking Shark, and Sunfish.
- Leatherback turtle was not recorded during the study, probably due to unusually cold summer weather.
- Recorded weather characteristics (sea state, visibility, cloud cover, glare) did not impact significantly the observed species diversity or numbers of megafauna observations.
- A significantly increasing trend in numbers of observations as well as diversity of observed megafauna species was recorded during the summer 2008 season.
- Historical records on observations of Leatherback turtles, Sunfish and Basking Sharks at the Cape Clear from time period since 1971 until 2008 (37 years, 3510 days, 8157 hours) were digitised.
- During this period, 1001 encounters with megafauna (446 observations of Sunfish, 329 observations of Basking sharks and 226 observations of Leatherback turtles) were recorded.
- Significant relationships were observed between the numbers of observations of these megafauna species and the sea surface temperature.
- A strongly significant impact of the North Atlantic Oscillation index (NAO) on the number of Leatherback turtle sightings was also detected.

High species diversity as well as abundance of megafauna species was recorded during the summer study as well as great number of observations was done during 37 years of recording Leatherback turtles, Sunfish and Basking shark. This confirms that waters around Cape Clear Island are important locality for marine megafauna. We hope this large dataset will be used for detailed analysis, and future observations will be conducted from Cape Clear Island more systematically. Additional data can improve our knowledge on the status of Leatherbacks, Sunfish and Basking shark in this region, and their relationship to climate change.

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