Scottish Natural Heritage

Commissioned Report 339

Basking Shark Hotspots on the West Coast of Scotland: Key sites, threats and implications for conservation of the species

COMMISSIONED REPORT

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Key sites, threats and implications for conservation of the species

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COMMISSIONED REPORT

Summary

Basking Shark Hotspots on the West Coast of Scotland: Key sites, threats and implications for conservation of the species

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BACKGROUND

The Wildlife Trusts' Basking Shark Project conducted effort-corrected line transect surveys for the basking shark (*Cetorhinus maximus*) along the west coast of Scotland between 2002-2006. A total of 11,179km of linear transects consisting of 956 hours duration were covered, and a total of 593 sharks were recorded whilst on transect.

The project aimed to establish whether key sites (hotspots) existed for the species within the overall region, where significant numbers of sharks could be seen at the surface on a regular basis. This information could then be used to develop practical means of protecting surface swimming sharks at such sites, such as educational maps of the hotspot sites for distribution to leisure and commercial boat users, and to inform future developments within the marine environment e.g. fisheries and renewable energy developments.

MAIN FINDINGS

- The project established two hotspot sites conclusively:
  The islands of Hyskeir and Canna situated in the Sea of the Hebrides, and
  The island of Coll in the Inner Hebrides.
- High numbers of sharks involved in courtship were recorded at the Hyskeir and Canna hotspot site, and it was also where most breaching activity was recorded (five individuals). On two occasions more than 50 sharks were recorded (15/08/2004, 52 sharks and 26/07/2006, 83 sharks).
- The Coll hotspot site was predominantly concentrated around Gunna Sound, but in fact sharks were recorded all around Coll during the surveys. The highest levels of courtship were recorded here (28 occasions, in groups of up to four) but breaching was recorded on slightly fewer occasions (four individuals). The survey recorded its best ever daily tally of sightings around Coll, (08/08/2005, 94 sharks).
- The high number of effort corrected sightings of sharks at these sites, plus the high levels of courtship and breaching recorded here, suggest they form important habitats for sharks seeking mating partners, which would confirm their importance as sites of significant conservation value.
- No significant threats (e.g. from fisheries bycatch, marine ecotourism or marine tourism) were identified at either of the hotspots identified within this study. However, this does not preclude these threats becoming a problem, nor suggest that other potential threats may not become significant in the future (e.g. climate change, offshore renewable energy devices, gill nets). Although the basking shark is not currently under any significant

known threat, the authors regard this work as timely in anticipating what actions can and should be taken to safeguard the species in the waters off western Scotland for the longer term. Mitigation actions should always be explored fully where any potential impact upon this protected species may occur, and suggestions are made within this report for further areas of research that could contribute to a better understanding of potential threats, and develop ways to minimise them.

- Further work to investigate areas not covered in this survey is necessary.

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1. INTRODUCTION

The basking shark (*Cetorhinus maximus*) is the second largest fish in the world, potentially reaching up to 11m in length, and a weight of up to 7 Tonnes. The shark is a K-selected species, typified by slow growth, large size, late sexual maturity (at 16-20 years), and produces irregular litters of up to six living pups of around 1.5m in length after a long gestation period (1-3 years) (Compagno 1984). Hunters have targeted the shark throughout numerous generations, however initial conservation measures are now being implemented. Much is yet to be understood of the population size, distribution, behaviour and characteristics of the animal.

In an attempt to address part of this vacuum of information, The Wildlife Trusts' (TWTs) Basking Shark Project conducted surveys along the western seaboard of the UK between 1999 and 2007 to establish whether key sites – 'hotspots' – existed where the basking shark could consistently be sighted at the surface of the sea. This included surveying the waters of the Clyde Sea (2002-2004) and the Sea of the Hebrides (2002-2006) in Scotland. The project used standard line transect methodologies to conduct the first long term, long distance, effort corrected survey for the shark in UK waters.

The highly successful Marine Conservation Society (MCS) national public sightings project has for many years offered an invaluable insight into the distribution and surface abundance of the shark around the UK, and indeed has published comprehensive reports on the subject, including a commissioned report for Scottish Natural Heritage (Nicholson et al. 2000) covering the west coast of Scotland. However, public sightings schemes do have some well recognised limitations, such as the variable quality of submitted data, multiple sightings where several people report the same shark, or lack of quantifiable effort related to weather or seasonal variations that may affect the number of observers in an area, all of which have the potential to affect the integrity of the data set.

Through being boat based, our study was able to cover large and remote sea areas in a standardized manner, thus enabling a far more accurate picture to be obtained. Being effort-corrected, the study was also able to eliminate many of the potential bias factors inherent in a public sightings scheme, and thus present a more complete picture, and identify hotspot sites that might otherwise have been overlooked due to their distance from areas of human habitation or leisure activity. The survey data generated through this project has been regularly submitted to the MCS database, to ensure the information gathered was combined into the UK national recording system.

Therefore, the results presented in this report are the first to be obtained and published from an effort-corrected study of the basking shark in the waters of western Scotland, and therefore present conclusive findings concerning key sites.

1.1. Aims

The aim of this study was to identify key sites (hotspots) where basking sharks could consistently be observed at the surface and ascertain the reasons why they are hotspots. The study also sought to examine what threats to the species might exist at such sites, and determine what further conservation measures or mitigation might be appropriate.

1.2. Conservation status

In the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Fowler 2007), the species is listed as Vulnerable (A1a,d, + 2d) globally, However, it is listed as Endangered (EN A1 ad) in the north-east Atlantic largely reflecting the perception that numbers in this area have been significantly diminished by two centuries of over-exploitation. Between 1952 and 2004, 81,639 sharks were killed within the region according to International Council for the Exploration of the Sea (ICES) statistics. Formerly hunted for their large livers, which yielded valuably high oil content, they have been more recently hunted in European waters for their colossal fins, fetching remarkably high prices in the East Asian market. Recently reported fin prices suggest an average price of US$50,000, with one exceptionally large “trophy” fin fetching US$57,000 (Harelde 2006).

Additionally the species received an Appendix II listing under the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES) in 2002, led by the UK Government. This listing ensures that any trade will not be detrimental to the survival of the species in the wild and allows certain conditions to be set for any trading taking place - a significant step that reflected not just the endangered nature of the species, but its critical importance in the canon of our national heritage. UK waters remain one of the most rewarding areas in the world for surface sighting the basking shark.

The basking shark is currently protected within the 12 nautical mile limit of Scotland under the Wildlife and Countryside Act 1981, as amended. In addition, the species has been included as a priority species in the Scottish Marine Wildlife Watching Code (SMWWC) that was introduced in 2006. It also has legal protection in England and Wales under the Wildlife & Countryside Act (1981) and the Countryside and Rights of Way Act (2000). In the Isle of Man and the Channel Islands it has protection under local legislation but not, as yet, in the waters of Northern Ireland although protection for the species is under consideration within the current review of the Wildlife (Northern Ireland) Order 1985. The species is not protected within the Republic of Ireland.

Satellite tracking surveys indicated that basking sharks tagged within UK coastal waters spent considerable amounts of time outside the 12 nautical mile national limits (Sims et al. 2003a, Southall et al. 2006), and were therefore vulnerable to direct threats such as hunting undertaken outside those limits. This led to a successful proposal being submitted in 2005 to the Convention of Migratory Species of Wild Animals (the Bonn Convention) - this Convention aims to conserve migratory species throughout their range. Appendix I lists species threatened with extinction, and Appendix II lists migratory species with unfavourable conservation status, or those that would significantly benefit from international cooperation. As a highly migratory species the basking shark is now fully protected within both Appendix I and II of the Convention.

Evidence of the need for further conservation measures directly related to the potential impacts of targeted fisheries has come from ICES. An ICES report, recommending zero catch of basking sharks in the north-east Atlantic from 2005, resulted in Norway announcing the cessation of their targeted hunting of the shark (2006). The discovery that the basking shark has the lowest level of genetic diversity of any shark (Hoelzel et al. 2006) with an effective genetic population size of only 8200 individuals, means that the shark is very vulnerable to any form of exploitation or impact, and that management and conservation efforts should be made to avoid any further erosion of genetic potential. The basking shark has also been included in the current OSPAR list of threatened and/or declining species and habitats (OSPAR 2008).

However, the recent discovery that a basking shark will, on occasion, make a transatlantic migration (Gore et al. 2008) suggests a more spatially co-ordinated strategy for conservation may be necessary. In the north-east Atlantic, locally focused conservation measures addressing the vulnerability of potential breeding populations are highly important, but unless wider strategic actions are taken on a global scale, the success of such local measures may be diluted.

The basking shark is a priority UK National Biodiversity Action Plan (BAP) species, with a Species Action Plan outlining the necessary actions required to maintain the UK basking shark population at its current level (English Nature 1999). The Wildlife Trusts' Basking Shark Project aims to fulfil many of the actions outlined in the basking shark BAP (http://www.ukbap.org.uk/UKPlans.aspx?ID=203). Delivery of these aspects of the BAP will be all important, as they concentrate on the interface between man and the basking shark, such as identifying areas of critical importance for the species, and evaluating and enhancing the existing Basking Shark Code of Conduct.

1.3. Potential threats to the basking shark

1.3.1. Marine ecotourism

The last two decades have seen the rapid development of marine ecotourism in the UK, especially in Scotland (Hoyt 1995). On the west coast of Scotland, tour operators work from many of the more popular harbours such as Oban and Tobermory, and offer wildlife watching tours that can range from a few hours duration to ten days or more, generating considerable amounts of income. In one study, the value of marine ecotourism was estimated at £7.8m (Warburton et al. 2001), much of it taking place in some of the more remote areas and communities of western Scotland where the benefits in terms of bringing visitors and revenue are much needed. It has been estimated that the number of boats involved in marine ecotourism in Scotland has increased from 80 in 2002, to 165 in 2006 (C. Warburton pers. comm.), with a likely associated increase in revenue generated. The commercial impetus for watching the basking shark was first identified for south-west England (Speedie 2001), and soon developed on the west coast of Scotland. Visitors to this area can choose between several operators running dedicated shark watching trips during the season, whilst other operators advertise the opportunity to see sharks alongside other species such as seals and various cetaceans.

Basking sharks appear relatively unaware of the presence of surface craft. It should be highlighted that most basking sharks killed in the harpoon fishery were shot at very close range, showing little or no indication of any evasive action (Maxwell 1952). In addition, scientists conducting satellite tagging exercises with Pop-up Archival Tags (PAT) typically use spear guns to attach the tags, making an approach to the shark from behind and 1m to one side and inserting the tag as the bow of the vessel draws level with the first dorsal fin (Sims et al. 2005a). Generally sharks tagged in this manner are reported to show little reaction, and if they do dive at all, are soon back at the surface feeding.

A study carried out in south-west England (Wilson 2000) identified that engine noise has some limited effect on shark behaviour, as does the angle of approach, but beyond that the effects were inconclusive.

Manoeuvring the project sailing vessel around nearly 1100 sharks during the duration of the overall survey (English Channel – Outer Hebrides), very rarely was there any observed reaction from sharks approaching within 10m of the vessel. Large sharks feeding at the surface seem particularly immune to the approach of vessels, whilst younger sharks (more commonly seen on their own) react more readily. It often appears that groups of large sharks at the surface are in a "trance-like" state, especially when courtship-like behaviour is taking place - we have found that slow-speed boat handling, when undertaken in a careful and responsible manner, has no visible effect on shark behaviour. However, that does not mean that no risk exists, simply that whilst distracted by feeding or courtship, the risk changes to one of collision rather than simple disturbance. A vessel travelling at 6 knots (a low average cruising speed) will cover a distance of 10m in 3 seconds, at which range even a relatively aware animal would have no chance to evade a collision, nor a helmsman to avoid it. Therefore reductions in speed in areas of high likelihood of surface sighted sharks may prove to be the soundest policy at hotspot sites.

1.3.2. Marine tourism

The development of marine tourism of all kinds (sailing, motor boating, diving etc.) has been rapid throughout the whole of the UK. Scotland has been spearheading use of its marine waters by the general public, especially in the more developed areas such as the Firth of Clyde.

Development in this sector brings with it an associated expansion of infrastructure to support it. The British Marine Federation (BMF) produces regular reports on the status and value of the marine industry in the UK, and the most recent report (BMF 2007) indicated the direct value (boats, moorings etc) to Scotland was £98.9m, which represented 3.4% of the national total of £2.952 billion. The report also established that total employment in the marine tourism trade in Scotland was 1,816 individuals. In statistics concerning participation in marine tourism activities (BMF 2006) it was estimated that there were 28,228 active sailing cruisers and 21,673 motor boaters in Scotland's waters. Although these figures may currently make up a small fraction of the UK whole, there is little spare capacity (if any) in the more mature areas further south. As more boat-owners look further afield for marina berths and moorings, an increased influx will likely be observed in areas with a lower density of leisure boat users, including Scotland. For example, currently some 30% of marina berths in the Firth of Clyde are held by owners with English postcodes, so this is already a factor.

In recent years there has been considerable development of mooring and marina capacity along the coast of the Republic of Ireland and Northern Ireland (Scottish Enterprise 2006) that may also result in an increase in visiting craft to the west coast of Scotland. This may also drive a more rapid expansion of marinas and mooring facilities in Scotland in the short to medium term.

Such development is most likely to occur in the Firth of Clyde, due to its proximity to the major conurbations of the Central Belt, and better access to motorway, rail and air links. A recent report "Sailing in the Clyde estuary – the potential for future development" (Scottish Enterprise 2006) identified that there were 2,787 marina berths in the area at that time, with a total of 2,060 swinging moorings. A key recommendation of the report was that the Clyde area should seek to double the number of available marina berths over the next ten years to 5,574 to cope with increased demand. This will, if it takes place, potentially double the pressure on wildlife such as the basking shark within the Clyde Sea unless practical steps are taken to mitigate against the worst effects.

One of the attractions of leisure boating in Scotland is its wildlife, as was recognised in the above report - 40% of respondents stated that wildlife was a key reason for visiting the area (Scottish Enterprise 2006). Basking sharks have long been an important part of the Clyde Sea fauna, sharing the area with boating routes between the popular marinas at Largs and Kip in the Firth of Clyde and the most popular leisure port in the area, Tarbert in Lower Loch Fyne (where 61% of overnight stays were by visiting yachts (Scottish Enterprise 2006)), and also the route to the Firth of Lorne via the Crinan Canal. Leisure craft usage of this area will undoubtedly increase if the proposed ten-year plan (Scottish Enterprise 2006) goes ahead. Expansion is indeed already occurring, as the new Marina facility at Portavadie (240 berths) has opened since the report was published, and further expansion of the facilities in the form of an additional 80 berths at Tarbert are under way.

As has been identified in the southwest of England (Speedie & Johnson 2008) ship-strike is becoming an increasing threat, with reports of collisions being reported in the yachting press (Dunn 2002, Yachting World 2008). Anecdotal reports from sailors and other sea users to team members during the Firth of Clyde surveys suggested that this is not unique to Cornwall, and indeed, in 2003 the survey vessel had very close encounters with two sub-surface sharks in the Firth of Clyde, neither of which broke the surface.

The risk of collision with a basking shark does not just pose a threat to the animal. In the case of a recent collision in the course of a major ocean race (the Artemis Transat) in 2008, the lead boat had to be abandoned in the mid Atlantic after a collision with a basking shark (the collision was also fatal for the shark) (Yachting World 2008). A similar collision for a smaller boat could easily capsize or sink the craft, as was the case that led to the only report of fatalities involving a basking shark, (Fairfax 1998). During this incident in 1937, a small boat was capsized off Carradale with the loss of three lives by what was believed to be a breaching basking shark – so conservationists and leisure sailors have a common interest to try and avoid this eventuality.

1.3.3. Fisheries bycatch

Historically in Scotland, there appears to have been an element of bycatch in ring nets and fixed salmon nets. Gavin Maxwell (1952) referred to the problem in his book in reference to the dislike for sharks felt by ring netters targeting herring (pp 27-31) and salmon netting (p. 183), due to the considerable damage caused to their equipment by sharks, and reported that on occasion fishermen asked the shark hunters to kill specific sharks that were endangering their nets (p.178).

Basking sharks have been regularly recorded as bycatch in a range of different fisheries, from bottom and surface set gill nets off southern Ireland (Berrow 1994), deep water trawls for Hoki and Barracoute in New Zealand (Francis & Duffy 2002) and creel ropes, gill nets and trawls around Britain (Doyle et al. 2005). The MCS keeps a record of stranded sharks and dead sharks sighted at sea as part of their public sightings recording scheme, and between 1987 and 2004 of all such sharks in UK waters 23% were recorded in Scotland, a percentage exceeded only by south-west England (45%) (Doyle et al. 2005). Whilst it is virtually impossible to have a clear understanding of the overall level of shark mortality as bycatch due to low levels of reporting, high levels of basking shark bycatch have been recorded in fisheries such as that in New Zealand, reaching a total of 58 sharks per 1000 trawls (Francis & Duffy 2002). The implications are such that more animals may be impacted than we are currently aware of. It has been suggested that bycatch might have a ‘hidden’ effect on the overall population in the important basking shark habitat waters around the UK, including those off Scotland (Southall et al. 2006).

1.3.4. Additional potential threats

Other existing or future threats to the basking shark may include offshore renewable energy devices, climate change and ocean acidification. Currently their characteristics and implications are less understood, and there is only early speculation as to which mitigation or adaptation measures might be most effective in reducing any potential impact on the basking shark. Further discussion on these additional impact characteristics, significance, and mitigation possibilities are provided in Section 4.

1.4. Distribution

1.4.1. Habitat selection

Basking sharks are filter feeding planktivores and are regularly sighted swimming at the surface during late spring and summer periods within the coastal waters of the western coasts of the UK and Ireland, displaying both feeding and courtship-like behaviour (Sims & Merrett 1997, Sims et al. 2000). The seas in this region are characterised by an extensive continental shelf reaching up to 200 nautical mile (nm) offshore. This extensive shallow sea area, combined with the intense tidal forces that occur within the area cause strong thermal fronts to form, acts as a boundary between the tidally mixed inshore water and stratified offshore water. These fronts, and the distribution of plankton within these water masses, are further disrupted by the complex topography typical of the British and Irish coastline and bathymetric features of the shelf sea floor (Pingree et al. 1975, Simpson & Pingree 1978, Le Fevre 1986).

1.4.2. Fronts and plankton distribution

Frontal areas are consistently regarded as regions of high productivity that act as strong aggregating features for planktonic organisms and for species throughout the trophic levels (Pingree et al. 1975, Le Fevre 1986). Two particular types of fronts typically occur in the waters described here.

- Thermal fronts (oceanic or shallow sea) can occur when different sea water bodies meet and are distinctly characterised by the temperature differential between those different bodies.
  - An example is the Ushant front, which occurs in the approaches to the English Channel. A sea surface temperature (SST) contrast of 4-5 degrees Celsius (°C) has been measured at its defining boundary between the well-mixed, strong tidal conditions near the French coast, and the more stable, stratified water in the weaker tidal regime of the southern Celtic Sea (Simpson & Pingree 1978).
  - Studies of chlorophyll-a distribution across the front show dense phytoplankton blooms persist throughout late spring and early summer on the stratified side of the frontal boundary (Simpson & Pingree 1978). Chlorophyll-a distribution is seemingly explained by lower levels of light penetration on the mixed side of the boundary. However, in the mixed area, levels of inorganic nutrients are relatively high. As a result, the front between these water masses offers a stable region where the combination of high levels of nutrients and a non-limiting light regime create suitable conditions for rapid or sustained phytoplankton growth (Simpson & Pingree 1978).
  - Thermal fronts, where sharks aggregate to feed on the richest patches of zooplankton, may also play an important role in bringing basking sharks together to find mates. High levels of courtship-like behaviour have been observed within frontal areas (Sims et al. 2000), giving them a high priority in terms of conservation.

- Shelf sea and headland fronts generally form in shallow coastal waters where a combination of strong tidal streams, variable bathymetry and coastal topography combine (Simpson and Bowers1981).
  - The thermal differences between these shallower, well-mixed water bodies and the surrounding well stratified offshore water, leads to sharply defined (and thus highly productive) frontal systems (Simpson & Pingree 1978, Alldredge & Hamner 1980).
  - As with thermal fronts, headland fronts aggregate surface debris, buoyant matter and oily, slick surfaces, visual clues to the higher levels of zooplankton below the surface.

It has been conclusively shown that a relationship exists between basking shark abundance and areas with high levels of primary (phytoplankton) and secondary (zooplankton) productivity, centred on shelf sea and headland fronts (Sims & Quayle 1998). Areas around headlands where tidal fronts persist have also been shown to yield the highest levels of surface sightings in the waters of southern Cornwall (Speedie & Johnson 2008). Sims et al (2003b) showed that the sharks may reside in areas of persistent frontal activity throughout the year, and that the species may utilise thermal cues as their primary means of orientating themselves to areas of high secondary productivity over long distances (Cotton et al. 2005).

During a study in the English Channel, basking sharks were shown to surface-feed in areas where their preferred calanoid copepod prey, *Calanus helgolandicus*, was two and a half times as numerous (~ 1,500 organisms per m^3) and 50% longer (~ 2mm) than in areas in which sharks did not feed (Sims & Quayle 1998) – this shows selective foraging for specific aggregations of their preferred zooplankton species. It has been suggested they use a combination of cues in addition to thermal variability to orientate themselves towards such areas at close range. These cues may include electro-reception of copepod muscle activity, as well as olfaction of chemical clues such as dimethyl sulphide, released when zooplankton graze upon phytoplankton (Sims & Quayle 1998). Although we now know the energetic requirement of the basking shark is lower than had previously been suggested (Sims 1999), these sensory abilities are critically important for a planktivorous creature that may have to forage over long distances to find the best exploitable levels of prey species.

1.4.3. Reverse diel migration

Another factor contributing to the high level of sharks observed at the surface within frontal areas may be the discovery that the basking shark employs habitat specific diel vertical migration (DVM) patterns (Sims et al. 2005b). In deep, well-stratified waters, sharks exhibit normal DVM patterns (dusk ascent, dawn descent) by tracking migrating sound scattering layers characterised by their favoured plankton prey *Calanus* and euphausiids. Sharks occupying shallow, inner-shelf waters near thermal fronts conduct reverse DVM (dusk descent-dawn ascent) possibly due to zooplankton predator-prey interactions that result in reverse DVM of *Calanus*. Sharks may also remain at the surface during the day for considerable periods in these circumstances (Sims et al. 2003a, Priede and Miller 2009) . These opposite DVM patterns therefore result in the probability of sighting a basking shark being in the order of sixty-fold higher in frontal areas than in well-stratified zones (Sims et al. 2005, Southall et al 2005). This may have important implications for the conservation of basking sharks at hotspot sites that are also busy areas with high daytime levels of boat traffic, where, as a result, there may be an increased risk of collision with surface (or just sub-surface) swimming sharks.

1.4.4. Spatial range

Basking shark sightings appear to be cyclical, with their long-term spatial and temporal distribution driven by changes in the current gyres in the North Atlantic, driven by the North Atlantic Oscillation (NAO). These NAO driven changes may lead to reductions in the levels of available zooplankton (Fromentin & Planque 1996), and thus surface sighted sharks in areas in which they had previously been abundant, and where their absence had been attributed to other factors. For example, it is believed that excessive hunting captures in the Achill Island (west Ireland) fishery caused a long-term decline in numbers of sharks in the area (Parker & Stott 1965). However, it may also be the case that the long-term decline may have been partly caused by a parallel decline in zooplankton in the local ecosystem (Sims & Reid 2002) during the lifespan of the fishery.

Basking sharks can, and will, migrate over long distances to forage for the most productive food sources, including inter-annual shifts in zooplankton distribution (Sims & Reid 2002, Sims et al. 2000, Gore et al. 2008). Tagging studies conducted with PAT tags in the English Channel (Sims et al. 2003b) have shown that one animal tagged potentially exhibited regional philopatry (returning to birthplace), having covered a linear distance in excess of 500km before returning to the location in which it was originally tagged. Another shark moved from the English Channel along the continental shelf edge to the west of Ireland before moving up to the west of the Hebrides, covering a distance of 1878km in 77 days (Sims et al. 2003b). Therefore such journeys are perfectly within the normal seasonal parameters of a foraging basking shark.

Even more remarkable has been the recent example of a tagged shark that made a transatlantic migration, between the Isle of Man and Newfoundland. Two sharks were tagged off the Isle of Man in this study (Gore et al. 2008), the first of which, an 8m female travelled a horizontal distance of 9589km from the tagging location to a region east of the Newfoundland shelf before the tag released. During that time she made repeated deep dives to a maximum depth of 1264m, and on occasion spent up to 12 hours per day at depths of between 800 and 1000m, behaviour that suggested she might have been foraging for mesopelagic copepods (Gore et al. 2008). This puts the basking shark into the select group of elasmobranchs that make similar long distance transoceanic migrations, such as the white shark (Bonfil et al. 2005, Boustany et al. 2002) and the whale shark (Rowat & Gore 2007).

2. THE BASKING SHARK SURVEY IN WESTERN SCOTLAND

The Wildlife Trusts' Basking Shark Project was originally based in the waters to the south-west of the UK (1999-2006) (Speedie & Johnson 2008). However, it became increasingly apparent that additional value would be derived from expanding the spatial extent of the survey, to include other areas around the UK where the basking shark was repeatedly surface-sighted. Through increased support and summer season extension, the survey vessel made annual visits to the waters west of Scotland from 2002-2006.

2.1. Survey locations

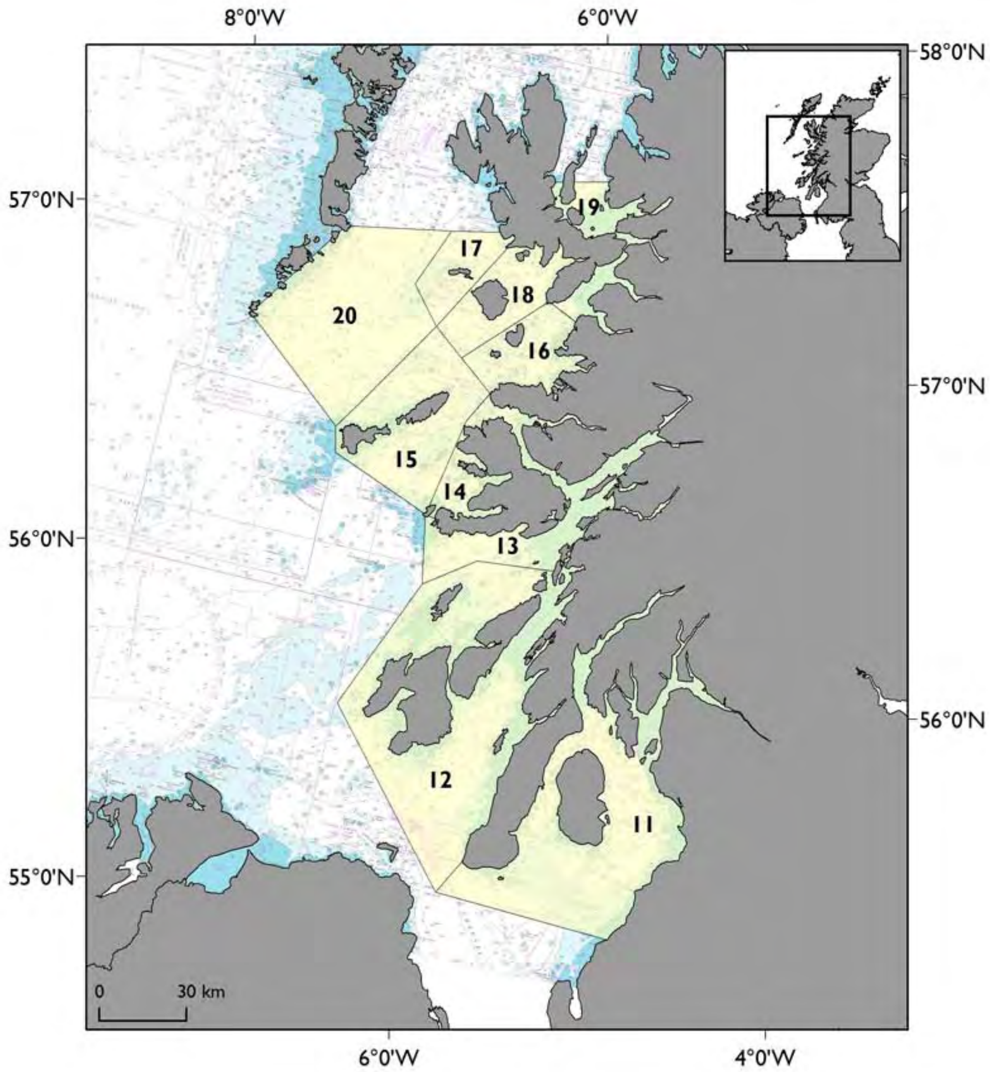
Two large-scale areas in western Scotland were selected for the survey: the Clyde Sea and the Sea of the Hebrides (see Figure 1). These were selected on the basis of their historical importance as areas of extensive commercial exploitation of the basking shark, and where a considerable body of anecdotal evidence suggested that more in-depth surveys (when compared to solely public sightings schemes) might reveal previously unrecorded hotspots for the species (Doyle et al 2005). The logistical setup of the survey and extensive use of volunteer observers determined the overall spatial scale of the areas surveyed. For example, the majority of surveys were of five days duration due to the need to return to the vessels home-port to change crew and replenish supplies. A potential average of 60 nautical miles (nm) per day was considered the maximum achievable range given the type of vessel, her potential average speed of 6 knots and the prevailing weather conditions.

The two main study areas in western Scotland (The Clyde Sea and Sea of the Hebrides) were further divided into smaller areas to associate where repeated survey routes, or transects, occurred. This division was derived through grouping geographically close locations that contained similar coastal/bathymetric features. All areas surveyed were allocated a number on a contiguous basis from the surveys further south in the English Channel and the Irish Sea, with the areas surveyed in Scotland presented in Table 1 and Figure 1.

Table 1: Survey areas

Area	Geographic extent
11	Clyde Sea: Firth of Clyde, Inner Kintyre, Ailsa Craig
12	Sound of Jura, Scarba, Colonsay, Islay
13	Firth of Lorne, Loch Linnhe, Sound of Mull, Oban
14	West of Mull out to Treshnish Islands and Iona
15	Coll and Tiree including Passage of Tiree & Gunna Sound
16	Eigg, Muck, Ardnamurchan Point to Point of Sleat
17	Canna, Hyskeir Lighthouse
18	Rum, west of Point of Sleat, south of Skye and Soay
19	Sound of Sleat, Loch Alsh, Scalpay and Crowlin Islands
20	Outer Hebrides, Sea of Hebrides west of Hyskeir

Figure 1: Map showing areas surveyed in western Scotland



Note: Survey Area 11 is the Clyde Sea, Areas 13-20 are the Sea of the Hebrides.

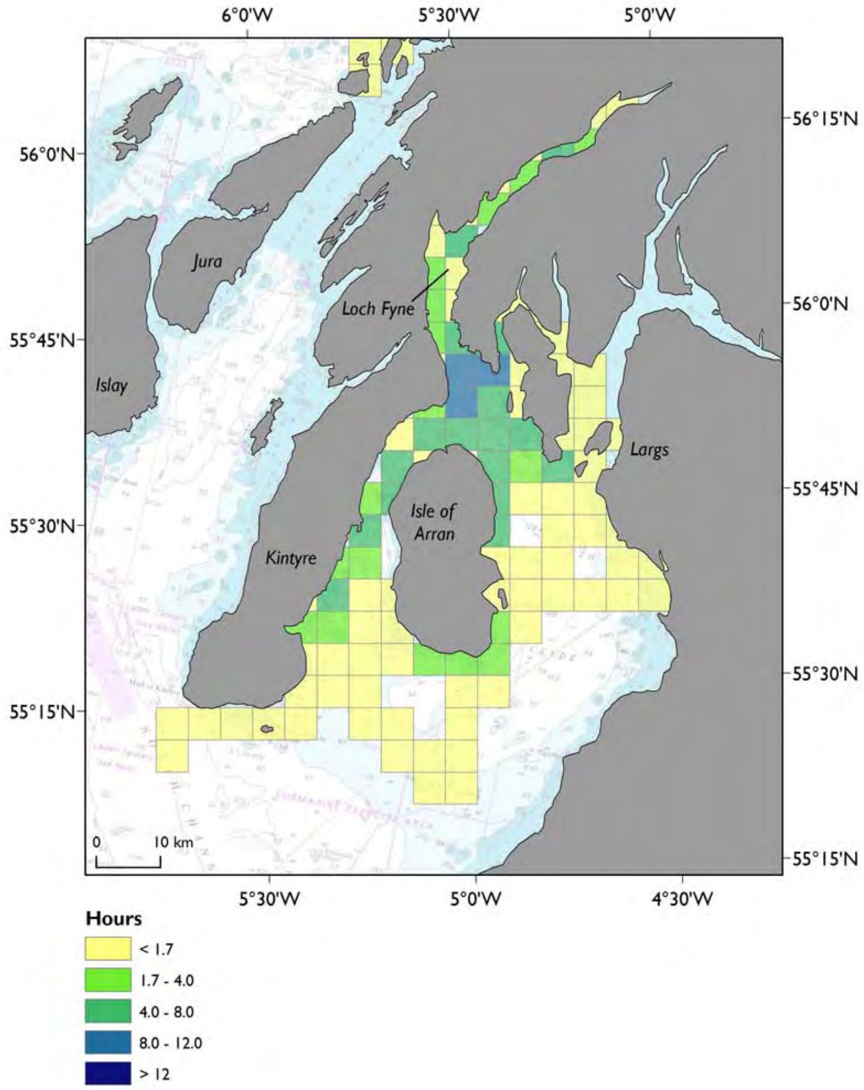
2.1.1. The Clyde Sea survey area

Historic records, some factual, some anecdotal, suggested that the Clyde Sea had supported very considerable levels of sightings throughout the area. Sharks had been sighted in large numbers from the Ayrshire coast to Loch Fyne. The fact that the most successful of the hunters of the twentieth century, Anthony Watkins, built his original factory on the Kintyre peninsula was testament to the considerable abundance of sharks that existed there at that time. The Clyde was the last sea area in Britain that supported a basking shark harpoon fishery (until 1995). The last of the hunters, Howard MacCrindle, was based at Girvan on the Ayrshire coast during much of his time hunting sharks.

An MCS report (Doyle et al. 2005) suggested that the levels of surface sighted sharks in Scottish waters, including the Clyde Sea, had declined during the 1990s, although there was no solid explanation for this decline beyond the recognised cyclical nature of shark sightings (Kunzlik 1988). As the first study to conduct effort corrected work within the area on a systematic basis, it was hoped that this survey would allow a more complete assessment of the current situation within this historically highly important area.

The survey vessel arrived in the area in late July each year and the homeport chosen for the Clyde survey area was Largs in Ayrshire. In spite of its relatively sheltered nature and low tidal stream rates (seldom exceeding 1 knot) by comparison with the North Channel outside the Kintyre peninsula (up to 3 knots in places), the Clyde Sea proved to be a challenging environment to survey. The more exposed outer area south of The Isle of Arran proved particularly difficult due to the short steep seas that build rapidly in even moderate wind strengths. As sufficient time (3 weeks) was allocated to cover the area effectively, this was not an insurmountable problem; however this did mean that the more protected Inner Clyde Sea area was more thoroughly covered as a result. Figure 2 provides an indication of the survey extent within the Clyde Sea, and an indication of the intensity of time spent in each 5x5km grid square within the area. It proved impossible to study Area 12 during the survey owing to adverse weather conditions during the period allocated to transit that Area in all three years of the Clyde Sea survey.

Figure 2: Total hours on linear boat transects in the Clyde Sea survey area 2002-2004, evaluated using a 25km^2 grid (5km x 5km).



2.1.2. The Sea of the Hebrides survey area

Of all of the known regions of basking shark surface sighting abundance along the western seaboard of England and Scotland, areas in the Sea of the Hebrides had consistently stood out as supporting high levels of sightings (Doyle et al. 2005).

There was also a wealth of historical material (Fairfax 1998, Maxwell 1952, Watkins 1958) confirming its long term importance as a primary UK habitat for the species, from as early as the first records of hunting in Canna in the 1760s (Fairfax 1998). Many of the notable shark hunters from the period just prior to, and post World War II, left highly readable accounts of their exploits, (Maxwell 1952, Fitzgerald O'Connor 1953, Watkins 1958 and Geddes 1960). These contained detailed and intriguing information on where they had discovered the most reliable hunting sites to be.

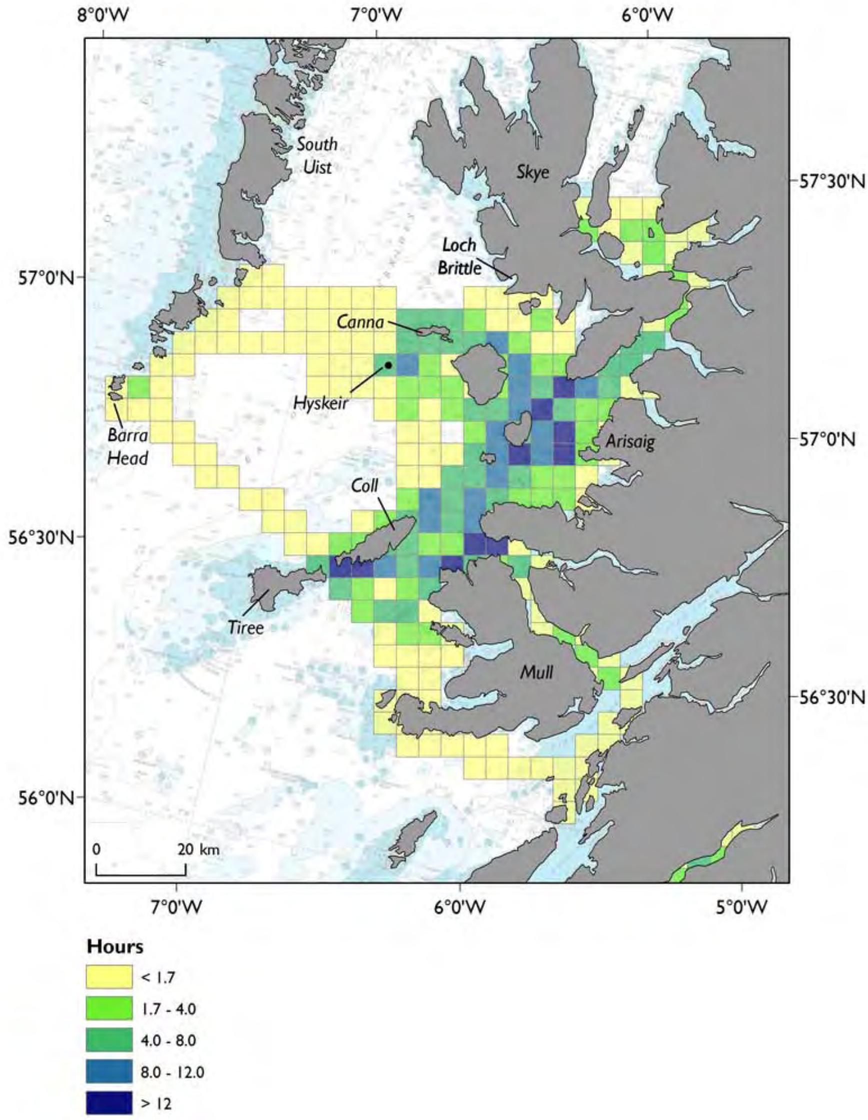
During 2002-2004, the survey vessel arrived in the area in early August (in 2005 in mid July), and continued with the survey until mid-September. For the 2006 season, it was decided to base the survey vessel in the Sea of the Hebrides area for the entire season (early May – mid September).

The survey vessel was normally based at the small village of Arisaig in West Lochaber, which offered road and rail links for volunteers joining the survey, as well as necessary support facilities. Another advantage in operating from Arisaig was its location, with direct access into the survey area, and depending on the wind direction and forecast outlook, the vessel could head into either the northern or southern sector of the survey area immediately on departure.

The limits of the survey were bounded in the south by Staffa and Tiree to Barra Head (Berneray) in the West, and to the North from Loch Brittle (Skye) out to South Uist. Areas around Mull, and the Inner Sound of Skye were also covered. Figure 3 provides an indication of the survey extent within the Sea of the Hebrides, and an indication of the intensity of time spent in each 5x5km grid square within the area.

The Sea of the Hebrides was a testing area to survey, due to the distances involved, the remote and exposed nature of the coastline and islands, the strong tidal streams (up to 3 knots in places) and the fact that once outside the Inner Hebrides, no shelter exists from the Atlantic until the Outer Hebrides are reached.

Figure 3: Total hours on linear boat transects in the Sea of the Hebrides survey area 2002-2006, evaluated using a 25km² grid (5km x 5km)



2.2. Survey methodology

The standard platform throughout the survey was the 11.7m sailing vessel 'Forever Changes'. A sailing vessel provides a stable platform with a reasonable height of eye for observation purposes, is capable of staying at sea in most conditions where a motor vessel might be less comfortable, and can operate far more economically in environmental and financial terms. All sailing vessels are 'quiet' through the water when underway, and thus tend to reduce disturbance of sensitive species such as bottlenose dolphins and basking sharks when in close contact (Goodwin & Cotton 2004, Wilson 2000). Nevertheless, the survey vessel was adapted to include additional sound deadening material in the engine compartment to reduce noise underwater when under power, and was fitted with a Variprop feathering propeller system which offered less drag and turbulence when under sail.

Figure 4: Survey vessel 'Forever Changes' under sail

During the five years of the project in Scotland, the majority of the surveys were of five days duration (Saturday-Thursday). A new volunteer crew met and left the boat from a designated home port each week and lived aboard during the survey period. In order that the potential area covered within each survey be maximised, the survey vessel did not return to her home port each night, but instead sought shelter in ports or remote anchorages near to transect start/end locations. It was recognised early on that the five-day survey period might be a geographically limiting factor in the second survey area, the Sea of the Hebrides, therefore during 2005 & 2006 a ten-day survey was also conducted in that area. This proved successful in allowing a wider spatial extent to be surveyed, and allowed for more flexibility in planning transect routes to optimise weather conditions.

The volunteer crews all received full training in aspects of the line transect survey structure, with particular attention being paid to observation techniques. Observation tasks were rotated on a maximum two-hourly basis, to minimise fatigue, boredom and eyestrain for observers thus reducing variability of observer records. Attention was paid to ensuring that data was accurately recorded, and the research crew of Principal Investigator (PI) and Mate monitored all volunteer activities constantly whilst on survey, especially those areas (observation, accurate data recording) recognised as being of high importance where volunteers are involved (Evans et al. 2001).

2.2.1. Transects

The survey was structured to cover a pre-determined area in a balanced, complete and systematic manner (to the extent possible when using a primarily weather-dependent survey vehicle). Line transects were of variable duration and distance, although wherever possible each transect route was completed at least twice each year – in addition, the same network of transects was maintained in each area from one survey year to the next. Effort was not concentrated, but spread widely across the whole of each survey area. The areas adjacent to the home ports received more coverage due to their necessary weekly visits, but distortion of effort was avoided through all sightings data being effort corrected (see paragraph below on sharks per unit effort).

The survey employed a simple, scientifically sound observation methodology, taking into account perception bias factors (e.g. sea state, height of eye, swell height). Whilst on transect, a standard height of eye for observation was employed (3m), and two observers scanned at all times (one to port, one to starboard) through a 90º sector relative to the ship's bow. A third individual acted as data recorder, and was responsible for capturing a wide variety of relevant positional and environmental data every thirty minutes, using specially designed recording forms (see Form B in Appendix 1). The other volunteers would be rested during periods of inactivity, or would help with steering the vessel.

No survey was started when conditions exceeded sea state 4 (Beaufort scale – small waves growing longer; fairly frequent white horses), or with less than moderate visibility (2-5 miles) to avoid operating in conditions that would have materially diminished the observer's ability to sight sharks. [Note: Whilst conducting a line transect, if sea state increased beyond sea state 4, or visibility fell below moderate, the transect was abandoned.]

It is reasonable to assume that the longer a survey duration the more sharks you are likely to encounter; similarly, the more time spent in a particular area might naturally observe a higher number of sharks. To eliminate the potential for any bias, sightings data are compared against time on observation and survey conditions ('survey effort'), and expressed in scientifically valid terms as a per unit effort value i.e. the number of sharks observed per hour spent in transect, or 'sharks per unit effort' (SPUE h^{-1}). This corrected number allows the SPUE value to be used as a comparable indicator between different regions, seasons and years (see Results in 2.3).

2.2.2. Shark observations

When shark sightings were made, a dedicated sightings form (see Form A in Appendix I) was used to capture all relevant identification data, including size, sex (where possible) and individual markings, as well as selecting (and recording) from a suite of recognised behavioural activity such as feeding, courtship and breaching. Digital image numbers of identification photographs were logged as they were taken, to avoid any potential confusion between different animals. Video footage was gathered whenever conditions allowed, in order to allow further behavioural (and identification) analysis at a later date, and to build up an archive for educational purposes.

Whenever an approach was made towards a shark either the Skipper or Mate took charge of steering the boat (the helmsman). Whilst it is true that basking sharks can be unpredictable in their movements when foraging, sometimes changing their direction very quickly, there is often a perceptible rhythm to their movements, and it was important that whoever was in charge of steering the boat had experience of this behaviour. The Skipper or Mate not acting as helmsman was placed in the bow of the boat (the bowman) and was responsible for communicating the position of the shark, its movements relative to the boat and noting any observable characteristics relevant to the shark's identification.

[Note: Basking sharks are protected under the Wildlife and Countryside Act 1981 (as amended). Intentional or reckless disturbance or harassment of a basking shark is an offence. A licence from Scottish Natural Heritage (under the provision of Section 16 (3) of the Act) was required prior to undertaking this research.]

Whenever possible, the vessel was handled under sail, generally with the mainsail alone deployed. The survey vessel was highly manoeuvrable with this sail configuration, even at very slow speeds, as well as being quiet, thus allowing clear communication between the bowman and helmsman, and was likely to cause less disturbance to the shark. The decision on how close an approach could safely be made was based on the sea state and wind conditions prevailing at the time. In calm conditions a close approach could be made (less than 10m), with distance increasing in line with deteriorating sea conditions. Where appropriate, the engine would be used to manoeuvre the vessel, but would be taken out of gear if a shark approached the vessel (to avoid any potential damage to the shark from a turning propeller).

The helmsman was responsible for steering the vessel parallel to the shark to allow an estimation to be made of the overall length of the individual. When the vessel was in a parallel position, the shark would be measured against fixed points on the vessel, using two volunteers, thus allowing as accurate as possible an estimation of size to be obtained.

When in contact with larger groups of sharks (more than 10 animals), a systematic approach was made to observe and record the individuals within the group along a compass derived axis, e.g. West-East. This avoided confusion when recording individuals, and thus the risk of double counting. Large shoals could not always be viewed as a cohesive whole, sometimes being made up of smaller groups foraging individually within the shoal. Additionally, these smaller groups did not always remain at the surface constantly; sometimes slipping beneath the surface as they foraged for layers of plankton a few metres or more below the surface. Therefore extreme care was taken when handling the vessel amongst groups of animals, using minimum speed whenever possible to avoid the risk of collision with an animal just subsurface.

Only animals that had been approached and identified individually were entered in the log of sharks recorded each day, as opposed to mass counting from a distance. On occasions this meant that some animals were not included in the records, due to the risk of estimation error; however, this means the numbers of sharks recorded can therefore be viewed as being a conservative figure.

Two Canon digital SLR cameras, each with a lens of at least 200mm focal length were used to obtain high quality images of the shark, principally of the first dorsal fin for photo-identification purposes. In order to obtain the best images, the vessel was manoeuvred into a parallel position with the animal that would allow fin images to be as near perpendicular as possible. Preferably the sun was kept behind the vessel to highlight significant mark, scars, injuries and anomalous pigmentation, enabling individual sharks to be identified. All images were downloaded at the end of each day onto backed-up hard drives for later examination and incorporation into the European Basking Shark Photo-identification Project database held at the Shark Trust (www.sharktrust.org).

2.3. Survey results and analysis

During the 2002-2006 survey period spent in Scottish waters, a total of 593 sharks were recorded whilst on transect. A total of 11,179 survey kilometres were covered, with transect time totalling 956 hours, with an overall average SPUE value of 0.61 h^{-1}. No sharks were recorded during 2002, the first year of survey, probably due to unfavourable weather conditions, as strong winds affected much of the most productive areas throughout the survey period. Sharks observed whilst not on transect have been excluded from this analysis so that all data is presented as effort corrected.

2.3.1. Sharks Per Unit Effort

Sharks Per Unit Effort (SPUE) values (as described in Section 2.2.1) were derived by correcting shark sighting records for the effort (hours, or h^{-1}) expended during survey. SPUE values could then be used to compare different areas; Table 2 provides SPUE values to two decimal places for each area surveyed (see Figure 1 for these areas represented graphically). Where a SPUE figure is shown as zero, this represents zero sightings of sharks.

Table 2: Sharks Per Unit Effort (SPUE) values, by area

Area	Sharks observed	Hours on survey	SPUE h^{-1}	Geographic extent
11	11	225.20	0.05	Clyde Sea: Firth of Clyde, Inner Kintyre, Ailsa Craig
12	0	0.88	0.00	Sound of Jura, Scarba, Colonsay, Islay
13	19	82.17	0.23	Firth of Lorne, Loch Linnhe, Sound of Mull, Oban
14	22	41.68	0.53	West of Mull out to Treshnish Islands and Iona
15	251	144.52	1.74	Coll and Tiree incl. Passage of Tiree
16	9	185.22	0.05	Eigg, Muck, Ardnamurchan Point to Point of Sleat
17	268	95.03	2.82	Canna, Hyskeir Lighthouse
18	2	82.12	0.02	Rum, west of Point of Sleat to Soay
19	0	80.77	0.00	Sound of Sleat, Loch Alsh and the Inner Sound
20	11	18.27	0.60	Outer Hebrides, Sea of Hebrides west of Hyskeir

From this data, it is apparent that the likelihood of observing sharks on the surface differs significantly between the various areas in west Scotland.

Areas 15 (Coll) and 17 (Hyskeir and Canna) both have an average SPUE value greater than 1.5 h^{-1}; Area 15 SPUE of 1.74 h^{-1}, and Area 17 SPUE of 2.82 h^{-1}. From this it is reasonable to conclude that for every two hours spent at either of these locations (in weather/sea conditions conducive to survey), you might expect to see between three to five sharks. Area 14 (Mull and Treshnish) with an SPUE of 0.53 h^{-1} also compared favourably with previously established hotspots such as Lands End in Cornwall (Speedie & Johnson 2008) (SPUE 0.48 h^{-1}). By way of comparison, a long-term effort-corrected study in the English Channel (Sims et al, 2005b) proposed an average SPUE value of <0.01 h^{-1} for a well-stratified zone of water, and around 0.6 h^{-1} in a frontal area.

Despite the amount of time spent surveying in Area 11 (Clyde Sea), and the historical records of shark hunting in the area, the 0.05 h^{-1}SPUE value was lower than the overall average value for the west of Scotland of 0.61h^{-1}

All SPUE indices are related only to surveys when weather conditions were within acceptable parameters for survey (i.e. sea state less than 4). Unfortunately, these conditions were relatively infrequently encountered in Area 20 (Outer Hebrides) to allow the survey vessel to travel to the more exposed Outer Hebrides. As a result, this area was only visited in 2005 and 2006, therefore confidence intervals for SPUE data in this area are likely to be wider.

The areas detailed in Table 2 show SPUE values averaged across their entire extent. For the Clyde Sea and the Sea of the Hebrides, these number areas were further broken down into 5x5km (25km^2) grid squares, to better identify where specific hotspot zones may occur. The coloured grid squares in Figure 5 and Figure 6 represent SPUE h^{-1} values at the 5x5km scale, and more clearly delineate areas with a higher likelihood of observing sharks on the surface.

Figure 5: SPUE h^{-1} in the Clyde Sea area, 2002-2004, using a $25km^2$ grid (5km x 5 km)

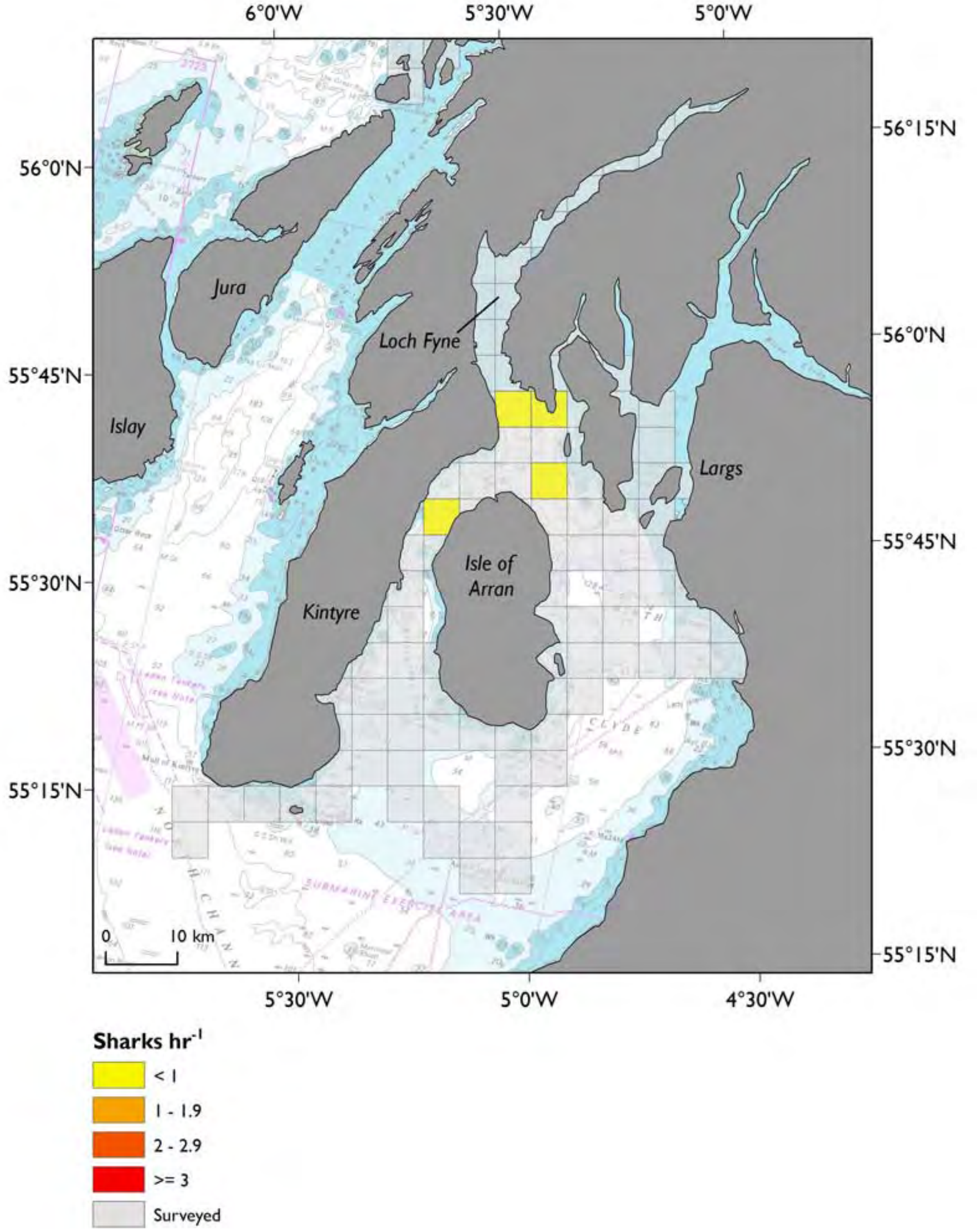
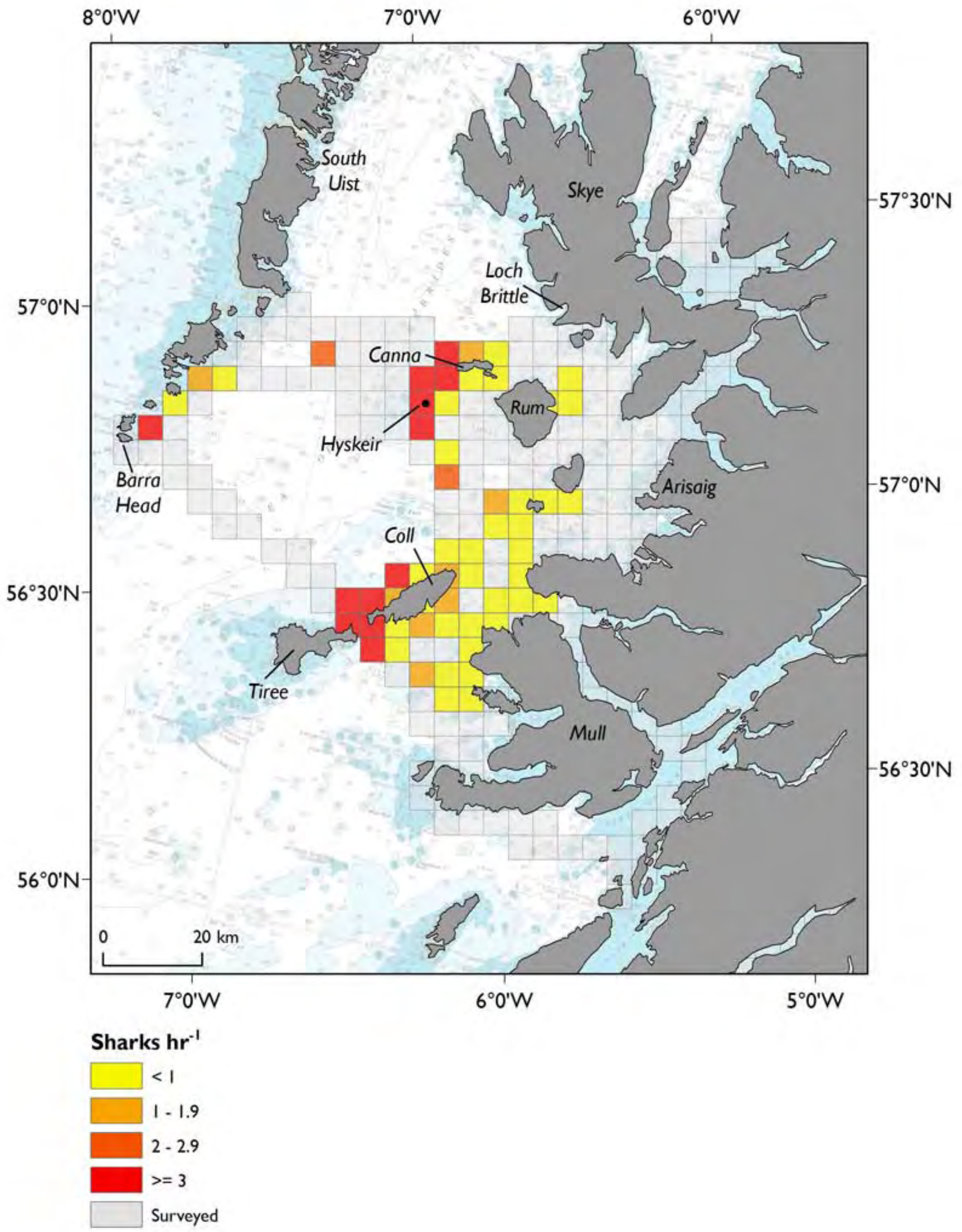


Figure 6: SPUE h^{-1} in the Sea of the Hebrides, 2002-2006, using a $25km^2$ grid (5km x 5km)



The SPUE value for each area differed from one year to the next, however Areas 15 (Coll) and 17 (Hyskeir and Canna) were consistently the two most productive areas for observing sharks, with Area 14 (West Mull and Treshnish) usually the third most productive area; this data is presented in Table 3, with SPUE h^{-1} values greater than 1.00 highlighted.

Table 3: SPUE h^{-1} values for each area surveyed, by year

Area	2002	2003	2004	2005	2006	Average
11	0.00	0.09	0.03			0.05
12		0.00				0.00
13	0.00	0.00	1.96	0.14	0.21	0.23
14	0.00	0.79	1.61	0.62	0.08	0.53
15	0.00	0.68	1.46	4.46	1.41	1.74
16	0.00	0.40	0.06	0.00	0.05	0.05
17	0.00	1.51	4.14	2.96	2.93	2.82
18	0.00	0.00	0.00	0.12	0.03	0.02
19	0.00	0.00	0.00	0.00	0.00	0.00
20				0.91	0.14	0.60
	0.00	0.29	0.65	1.00	0.81	0.62

(Note: blank cells indicate zero hours spent in the area for that period; zero indicates no sharks were observed whilst on transect)

In 2004, Area 13 (Firth of Lorne, Loch Linnhe, Sound of Mull) also proved valuable with a one-off SPUE of 1.96 h^{-1}, primarily due to an increase in sightings clustered around the western end of the Sound of Mull, a tidal area with associated fronts in calm weather during a year when high levels of sharks were sighted across the adjacent survey areas. However this increase was viewed as a one-off event, as it was not observed in the following two years.

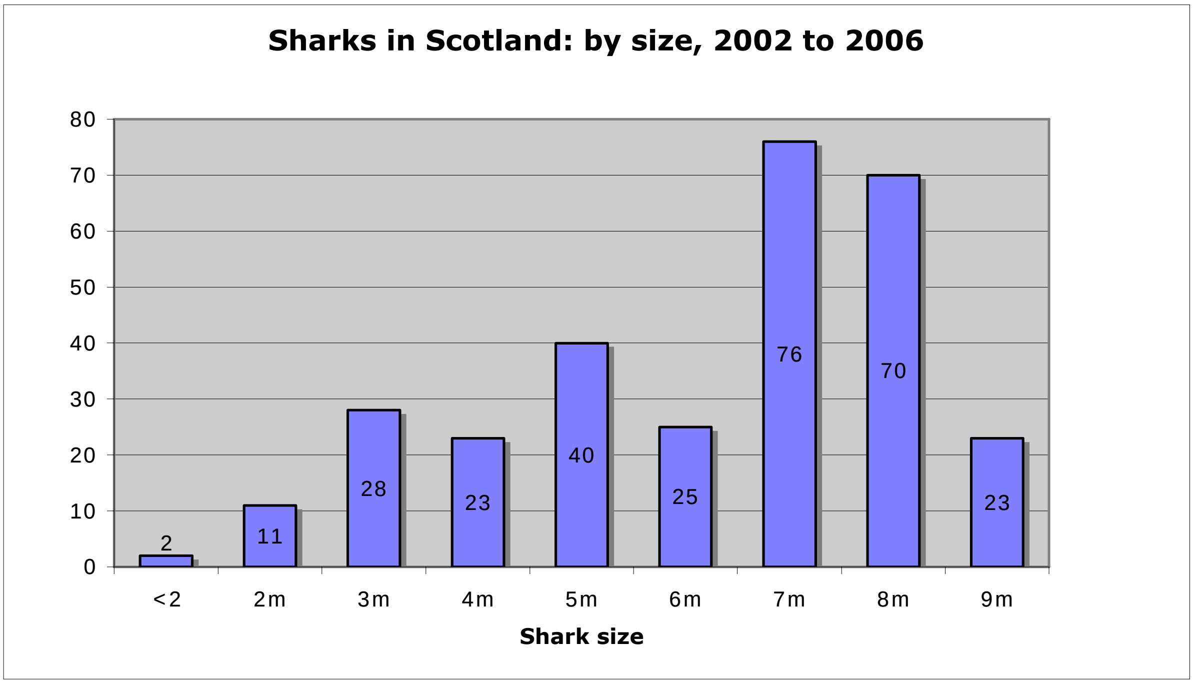
Comparing SPUE values throughout the duration of survey season from one year to the next (see graph in Appendix II) indicates a seasonal peak in August in years 2003-2005, but with significant numbers of sharks still being sighted in September. The SPUE peak in August increased each year. In 2006, a peak was instead observed during July, which might be explained by the survey vessel being present in the Sea of the Hebrides during July as opposed to the Clyde Sea as in previous years. A longer-term data set would be required to conclude this matter categorically.

A comparison of SPUE values for these areas against the suggested average SPUE value of 0.6 h^{-1} for a frontal area (Sims et al. 2005b) highlights the specific importance and reliability of Areas 15 (Coll) and 17 (Hyskeir and Canna) for observing basking sharks on the surface. The apparently very low value of <0.01 h^{-1} suggested to be more representative of well stratified waters (Sims et al, 2005b) does not necessarily mean that sharks were not present, simply that such values relate to habitat representative of well stratified waters, where any animals may be present deeper in the water column. Despite the lower SPUE values observed for some of the areas in this study, they may still be important for sharks.

2.3.1. Shark length

It was not possible to estimate the length of all basking sharks observed whilst on transect. This was either due to the animal being too distant from the boat to determine its length accurately, or where only the tip of the dorsal fin was visible i.e. no nose or caudal fin could be seen to deduce the shark's extremities, and thus estimate size. For those sharks where an accurate size was able to be determined (298 sharks), Figure 7 presents the number of individual sharks seen, split by size.

Figure 7: Shark size profile, split by 1m increments (n=298)



This indicates the total range of shark sizes seen during all years of the project, and shows clearly that the majority of sized sharks (57%) were 7m or larger. Table 4 shows a breakdown of recorded shark size by year, expressed as a percentage (this is shown graphically in Appendix II). The majority of sharks recorded and sized were in the 6 to 7.5m (34%) and 8m or greater (31%) categories. A previous analysis of the Scottish data contained within the Marine Conservation Society (MCS) database (Nicholson et al. 2000), indicated a considerably different size profile, with the majority of their sharks being less than 6m, and only 5% of recorded sightings being of sharks larger than 8m. This may indicate a change in population size profiles over time, or that this survey was able to reach larger shoals of sharks further offshore or away from typical coastline observation points.

Table 4: Sharks observed, in each size category (%of total), by year

Shark Size category	2003	2004	2005	2006	Average
<2m	0	0	0	2%	1%
2-3.5m	5%	15%	11%	17%	13%
4-5.5m	7%	31%	16%	27%	21%
6-7.5m	25%	23%	40%	36%	34%
>8m	64	31%	33%	18%	31%

Watkins (1958) recorded that in their commercial fishery in the Sea of the Hebrides the average sex ratio of females to males caught was 18:1, whilst Kunzlik (1988) quoted a minimum figure of 10:1, whenever large numbers were involved in the latter day fishery in the Clyde Sea. Therefore it is a possibility that the majority of sharks sighted at the surface during our survey might be females, although it was not possible to confirm this in practice owing to the difficulty of identifying the sex of animals in the water from the deck of a boat (except in exceptionally calm conditions).

Basking sharks have been estimated to become sexually mature at a total length of 4-5m for the male and at 8-10m for the female (Compagno 1984). If this were the case, then the majority of sharks recorded on the west of Scotland were mature (86%), and the high proportion of sharks recorded of size greater than 8m (31%) may include a substantial stock of females of breeding age.

2.3.2. Shoal size

Just over half the sharks sighted were observed to be alone, but where sharks were seen swimming in groups, the shoal size was noted. This data is represented in Table 5. Apart from Area 18 where only solitary sharks were noted, all other areas included at least small groups of two to three sharks.

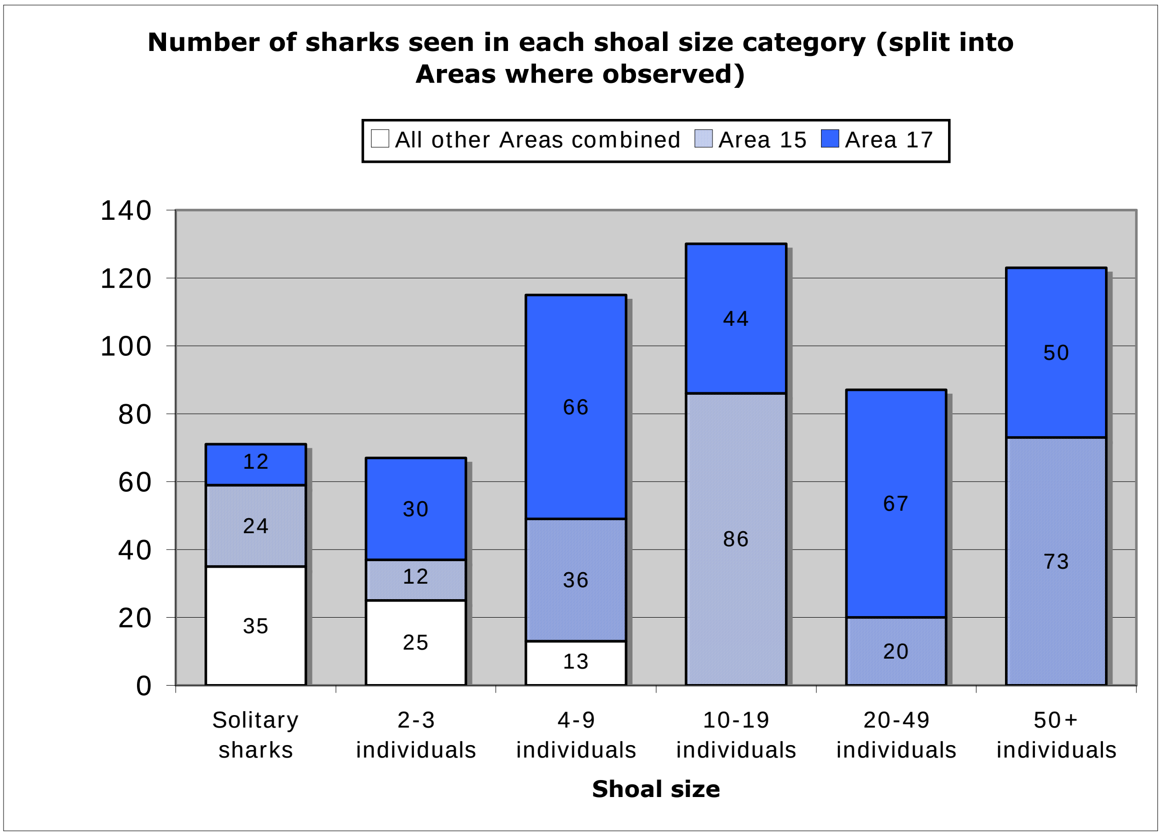
Table 5: Shark sightings by area, with shoal size indicated

Numbers of sightings (%)

Shoal size observations by area	Solitary sharks	2-3 sharks	4-9 sharks	10-19 sharks	20-49 sharks	50+ sharks
11	87.5%		12.5%			
13	58.3%	41.7%				
14	58.3%	33.3%	8.3%			
15	54.5%	11.4%	15.9%	13.6%	2.3%	2.3%
16	71.4%	28.6%				
17	28.6%	28.6%	28.6%	7.1%	4.8%	2.4%
18	100.0%					
20	87.5%		12.5%			
Average	52.6%	20.7%	16.3%	6.7%	2.2%	1.5%

Figure 8 presents the total number of sharks seen on transect (n=593) broken down by shoal size and area in which observed. This clearly indicates that Areas 15 (Coll) and 17 (Hyskeir and Canna) overwhelmingly account for larger shoals encountered.

Figure 8: Sharks observed, by area and shoal size, 2002-2006



During the course of the survey, groups of sharks (of shoal size four or greater) were consistently recorded within Areas 17 (Hyskeir and Canna) and 15 (Coll). On three days exceptionally large numbers of animals were recorded.

- On 15/08/2004: 52 sharks were recorded in Area 17 (Hyskeir and Canna), including a shoal of 50 animals;
- On 26/07/2006: 83 sharks were recorded in the same Area, although this number comprised groups of varied sizes spread out over a larger area;
- On 08/08/2005: 94 sharks were recorded in Area 15 (Coll), including a shoal of 73 animals, together with smaller groups on both sides of the island.

Such remarkable aggregations were therefore comparatively rare during this study. However, as Figure 8 shows, at all other sites solitary animals or pairs were most commonly recorded with very few records of shoals containing greater than four individuals.

There was a clear difference between the shoal size recorded during this study, compared with the previous SNH report (Nicholson et al. 2000). In the earlier study, 70% of all sightings were of individual sharks – the current study by comparison indicated just over 52% of sharks were spotted as solitary sharks. Indeed, the difference is even more pronounced if the data is analysed by area - within Area 17 (Hyskeir and Canna) only 28% of sharks sighted were solitary.

When solitary animal data was combined with small shoal sizes (two to three animals), this accounted for 90% of all sightings in the earlier SNH study, in comparison with just over 72% from this study. And in the earlier study, no sightings of shoals in excess of 10 animals were recorded, whereas over 10% of shoals seen during our survey were in excess of that value (including 1.5% representing two sightings in excess of 50 animals). As was indicated during shark length data analysis, this may again be indicative that our survey was able to reach larger shoals of sharks further offshore or away from typical coastline observation points.

2.3.3. Social behaviour - courtship and breaching

The survey kept a record of behaviour displayed by all sharks observed. Primarily the dominant behaviour observed was feeding, where the animal was observed swimming slowly with its mouth fully open for extended periods, before swallowing and then resuming feeding. This was not only the case with individuals, but also amongst groups, where feeding sharks have been observed to keep a distance from other conspecifics, and actively avoid any that approach too close by swimming away (Sims et al. 2000).

However, on occasion, when several individuals were seen in relatively close proximity, or when in larger groups, social behaviour such as courtship-like activity and breaching were observed. Courtship-like behaviour was observed, including nose-to-tail following), close flank approach where one or more animals swam closely alongside another, close approach involving rostral contact where an animal was observed to touch another, and parallel and echelon swimming where one or more individuals were observed beside or just below another (Harvey-Clark et al. 1999, Sims et al. 2000). In total, 45 individuals were observed undertaking courtship-like behaviour, on 19 separate occasions. Twelve instances of courtship-like behaviour observed in this study involved only two sharks, four instances where three sharks were involved, and three instances where four sharks were involved. Courtship-like behaviour was recorded in all years of the survey except 2002, when no sharks were recorded.

Figure 9: Nose to tail courtship-like behaviour involving three individual sharks, Coll 2005

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Sharks engaged in putative courtship were recorded in two areas: Areas 15 (Coll) and 17 (Hyskeir and Canna). Courtship was recorded in all years that sightings were made (2003-2006) in Area 15 (Coll), and was recorded in 2004 and 2006 at Area 17 (Hyskeir and Canna). In addition, these two Areas had high levels of groups of sharks, and hence support the hypothesis that courtship is only undertaken where groups of sharks congregate in productive frontal areas (Sims et al. 2000b).

Breaching, where a shark made one or more leaps clear of the water (Figure 10) was observed on seven separate occasions, involving ten different individuals. There was one instance of two separate sharks breaching in the same group, and one instance of three sharks breaching in the same group.

Figure 10: Shark breaching, Hyskeir 2006

© Colin Speedie / Shark Foundation.

All five instances where breaching was observed around groups in Area 17 (Hyskeir and Canna) were also occasions when courtship between sharks was recorded. Breaching generally occurred on the outer extremities of a group. In Area 15 (Coll), breaching and courtship were also observed within the same group, but here there were also two instances where the breaching shark was not seen to be associated with any other sharks at the surface. This does not necessarily mean that other sharks were not present, as on both occasions the animal breaching was in a position close to rocks where the survey vessel could not safely be navigated to confirm whether other animals were present. Also, on a number of occasions when animals engaged in courtship-like behaviour have passed close to the survey vessel, it was possible to discern that other animals were present below the surface, seemingly also engaged in the social activity visible at the surface. A breach amongst a group of sharks was also recorded on one occasion in Area 11 (Clyde Sea). In both Areas 15 and 17, where breaching was observed amongst groups of sharks, courtship-like behaviour was also recorded (with only one exception).

It has been suggested that breaching may be linked to courtship-like behaviour (Sims et al. 2000). The white shark (*Carcharodon carcharias*) is believed to use breaching as a means of social communication during the mating season (Pyle et al. 1996), and it may be that breaching performs a similar function in the basking shark, either in the form of a male shark advertising his potency, as with the humpback whale *Megaptera noviangliae* (Whitehead 1985) or warding off potential rivals. However, an animal that breached close to a survey vessel during a study in the English Channel, showed its ventral area to observers, allowing them to identify the animal as a female (Sims et al. 2000) - this might imply that females advertise their receptivity in this manner. It was also observed in the same study that only large animals were involved in breaching, and that multiple breaches only occurred when three sharks interacted. Consistent with these observations, our findings also indicate that breaching was only observed when groups of sharks were present, and all sharks recorded were of mature length.

A number of sharks were sighted at these times with highly visible white abrasions to their body, including the pectoral fins. In a study in the north-west Atlantic, observations of similar body markings were made when observing ‘courting’ basking sharks off Newfoundland (Harvey-Clark et al. 1999), suggesting that these might have been caused by the sharks pectoral biting and abrading their bodies during copulation. A number of sharks were observed during our survey with heavy abrasions to the rostrum and upper mandible areas (Figure 11), suggesting persistent courtship activity where rostral contact is often made.

Figure 11: Shark with heavily abraded rostrum, Hyskeir 2005

3. HOTSPOTS

3.1. Selection of hotspot areas

From the results presented, the selection of hotspots in this report was based on a number of factors:

(1) Sharks Per Unit Effort (SPUE) values consistently recorded (i.e. greater than 1.00 h^{-1}),

(2) High levels of groups recorded, and

(3) Group related social behaviour (courtship, breaching).

The previous SNH report (Nicholson et al. 2000) identified two sites considered to be hotspots from examination of MCS data. These were the Isles of Arran and Mull. Additionally, there were regular sightings recorded from Rum, Eigg, Muck, Skye, Ayr Bay, the Mull of Galloway and the Western Isles. Neither of the hotspot sites identified in this study (Coll, Hyskeir and Canna) were mentioned, probably reflecting a comparative lack of human activity around those sites and thus under-reporting of sightings, a widely recognised factor with public sightings schemes (Speedie 2003, Doyle et al. 2005). As the sightings from this study (including off transect sightings) are now incorporated in the MCS dataset, a more complete picture will emerge over time, once again highlighting the importance of supporting public sightings data with dedicated survey effort at sea covering areas of low human activity.

3.1.1. Hotspot 1 – Area 17, Hyskeir and Canna

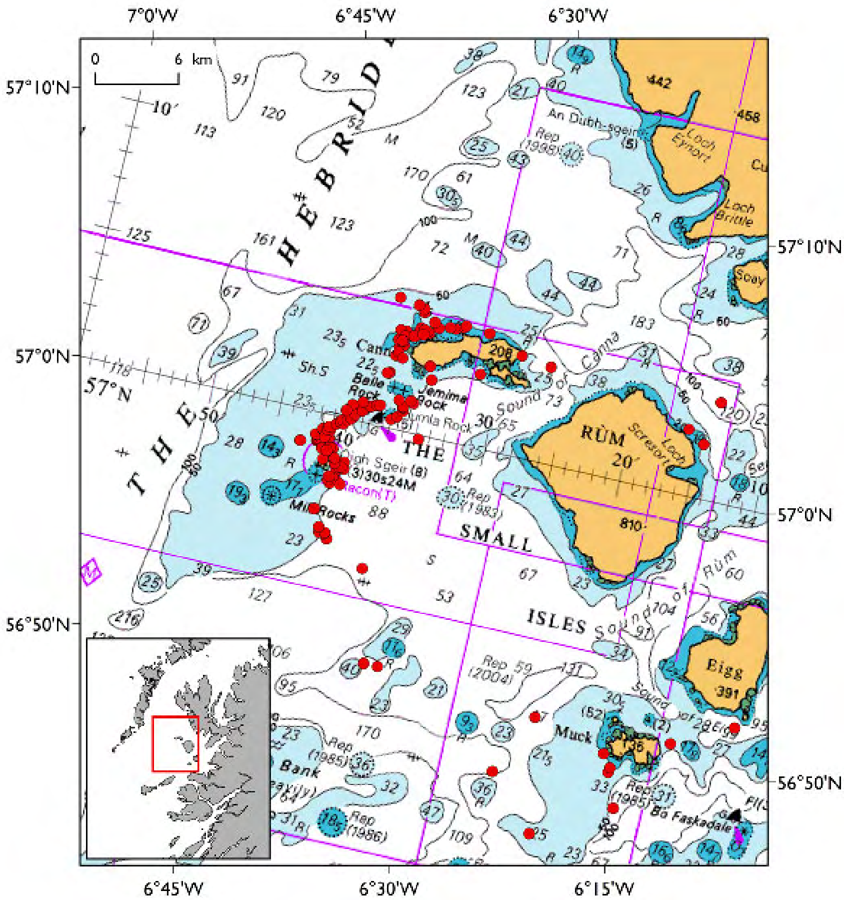
The island of Canna is the most western of the Small Isles, and shares a shallow, uneven plateau to the southwest with the remote islets at Hyskeir, together with a number of rock groups that lie around and between them (see Figure 12). They lie in the strong tidal streams (up to 3 knots in places at spring tides) that run between the Little Minch and the Sea of the Hebrides, and are open to the Atlantic. However, in calm conditions, this is an area in which productive small scale tidal fronts become established.

There is a historical resonance to the site, as the first recorded basking shark fishery in 1765 (Fairfax 1998) was based on Canna, and this was no doubt due to the proximity of the island to productive hunting grounds.

The greatest concentrations of sharks were recorded close to the eastern side of the Hyskeir islet, and then to the North towards the Humla Rock buoy. Around Canna, the greatest concentrations of sightings were recorded along the northwest shore and out beyond Garrisdale Point at the western end of the island.

We established our highest average SPUE value at this site, at 2.82 h^{-1}, consistently recording high values in all years except 2002 (no sightings), with the annual SPUE value for the years 2003-2006 always exceeding 1.50 h^{-1}. The peak value was in 2004, when a value of 4.14 h^{-1} was recorded. On two occasions very high levels of sharks were recorded, including one shoal of 50 sharks. To put this into perspective, it is worth considering that the hotspot site with the highest SPUE value established from an effort corrected study in the English Channel was the Lands End peninsula, with an average value of 0.48 h^{-1} (Speedie & Johnson 2008), demonstrating the highly important nature of the Hyskeir and Canna hotspot site, and indeed the other hotspot site at Coll.

Figure 12: Map of Area 17, Hyskeir and Canna, showing individual shark sightings 2002-2006



A total of 268 sharks were recorded at this site (each shark indicated by a red dot in Figure 12). High levels of social behaviour were recorded, with 16 sharks (5.97%) engaged in courtship. Courtship was recorded at this site in 2004 and 2006. Five sharks (1.87%) were recorded breaching. All animals recorded breaching were part of groups, and were associated with animals involved in courtship at the same time.

Bycatch:

Although no formal record was kept of fisheries activity, few signs were observed of fixed fishing equipment such as buoys marking prawn creels, especially in the more open water by the Hyskeir lighthouse islands. Small amounts of gear were sighted from time to time close inshore, presumably marking crab or lobster pots, but as most sightings were made further offshore these may not be considered to pose a significant threat.

Fishing vessels trawling for the Dublin Bay prawn (*Nephrops norvegicus*) were encountered on occasion in the region around the Hyskeir lighthouse islands, but as very little is known of the possible levels of bycatch associated with such types of bottom trawl, it is difficult to evaluate the level of potential threat to sharks this may pose.

Marine ecotourism:

Due to their remote nature, the small-scale ecotourism vessels that operate short trips within Area 17 seldom visit Canna and Hyskeir. The distances involved, and thus the time it would take to reach the location, coupled with the additional licensing and equipment requirements for vessels operating further from a safe haven mean that this is likely to remain the case.

A number of the larger vessels that operate day charters or extended live aboard cruises regularly visit Canna, a popular destination in its own right. The Hyskeir islets are not on the route between any of the more popular ports, and do not possess a safe anchorage and so are far less visited, except in the calmest of conditions, At no time did we observe any interaction between ecotourism vessels and sharks within Area 17.

In order to mitigate against the potential effects of disturbance on wildlife from marine ecotourism vessels, the WiSe Scheme was developed and launched in 2003 (www.wisescheme.org). Drawing on the experience from this project, cetacean, seal and seabird studies, WiSe created a training template to help define disturbance for eco-tourism operators, presenting techniques on how to avoid it, whilst at the same time explaining what constituted good practice and how to best achieve it. Working in conjunction with Scotland's leading ecotourism organisation Wild Scotland, and with support from Scottish Natural Heritage, WiSe has run three training courses in western Scotland since 2005, with over 120 operators and their staff attending in that time. This has given all of those attendees training in safe and sustainable boat handling techniques around basking sharks. WiSe has now gone a stage further and trained a number of highly experienced individuals to deliver future courses in Scotland, to ensure that the information delivered via WiSe continues to gain as wide an audience as possible, and that all operators are aware of the need to lead by example.

Additionally, the Scottish Marine Wildlife Watching Code (SMWWC) (www.marinecode.org) was produced as a result of legislation within the Nature Conservation (Scotland) Act 2004 and can be used as material consideration in any case brought for prosecution. The Code applies to all individuals watching marine wildlife, whether commercially or not, and is a straightforward and comprehensible guide to safe wildlife viewing in Scottish waters. It is a pragmatic and complimentary piece of legislation that is understandable and practical, and includes advice on handling boats around basking sharks that are of particular significance in regard to hotspot sites:

(1) The requirement to slow down when approaching an identified hotspot site to a speed of 6 knots or less, and to keep a careful look out,

(2) To use only minimum speed when in sight of a shark, as there will likely be others within the vicinity, offering an obvious risk of collision,

(3) To exercise extreme caution around courting groups, approaching no closer than 100m, and

(4) To leave the area slowly and carefully if breaching is taking place.

Marine tourism:

The west coast of Scotland is becoming more popular as a cruising ground for yachtsmen, although by comparison with other parts of Britain it is still little frequented. Canna harbour is one of the more popular anchorages on the west coast, being within easy reach of Skye and the mainland, and as it makes a safe haven to stop overnight on the way to or from the Outer Hebrides.

Although several cruising yachts reported seeing sharks to us, we heard no reports of collisions with sharks. Given the relatively low amounts of traffic around the western end of the island (where we recorded the highest levels of sharks), this may be a true reflection of the current situation on the water.

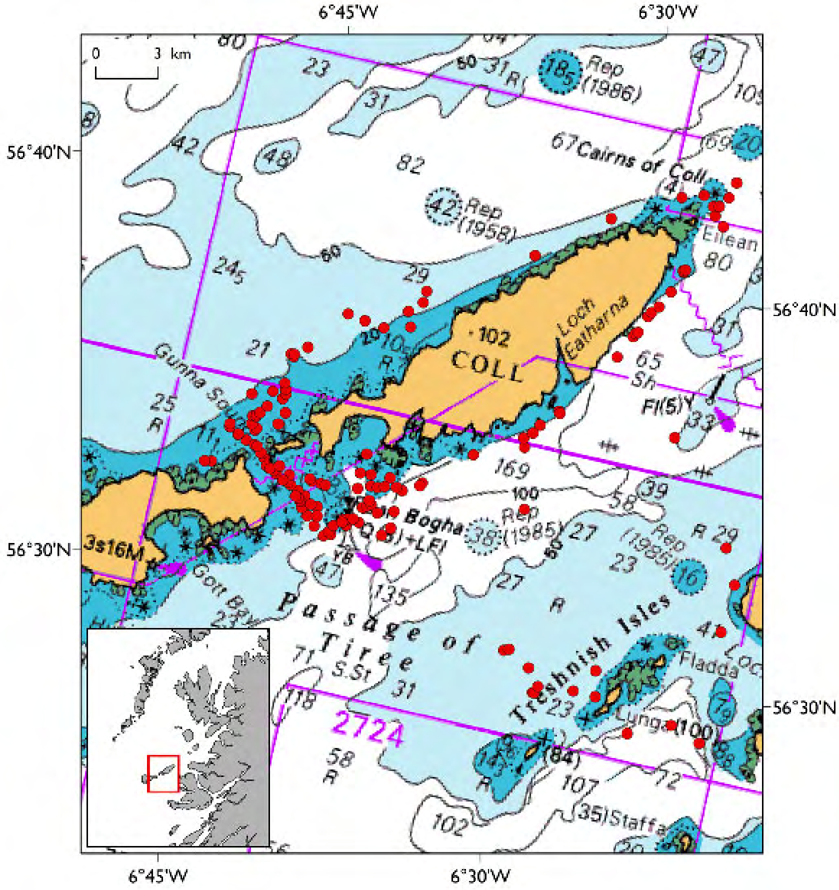
3.1.2. Hotspot 2 – Area 15, Coll

The island of Coll is the northernmost of two low-lying islands in the Inner Hebrides to the West of Mull, the other island being Tiree (see Figure 13). The two islands are separated by a narrow, shallow channel, Gunna Sound, through which strong tidal streams occur (up to 4 knots at spring tides). The west coast of the island is characterised by a shallow (20m) shelf and on the east coast by a rapid drop off to relatively deep water (100m). Off the north of the island lie the Cairns of Coll, a group of islets with an off lying rock reef, where strong tidal streams occur, and tidal shelf sea and headland fronts become established in calm conditions.

Historically, Coll was the base for one of the post war shark hunting operations (O'Connor, 1952), although not the main hunting ground of that operation.

The greatest concentrations of sightings were recorded in the south-eastern bay of the island (Crossapol Bay) and the eastern entrance to Gunna Sound. However, groups of sharks were seen at a number of localities around the island, both on the eastern and western sides.

Figure 13: Map of Area 15, Coll & Gunna Sound, showing individual shark sightings 2002-2006



The average SPUE value for the Coll site was 1.74 h^{-1}, with a peak in 2005 of 4.46 h^{-1}. No sightings were made in 2002.

A total of 251 sharks were sighted at this site. The highest levels of social behaviour were recorded with 28 sharks (11.16%) involved in courtship. Courtship was recorded in all years (2003-2006) that sharks were sighted. Four sharks (1.59%) were recorded breaching, with two individuals breaching alone, and with two breaching in groups.

Bycatch:

Low levels of fishing activity were recorded around Coll. Some potting was observed inshore, and on occasions fishing vessels presumed to be trawling for prawns were seen off the eastern shore.

Marine ecotourism:

Ecotourism vessels regularly visit Coll, principally those working out of Tobermory on the adjacent island of Mull. A wide variety of cetacean species (whales, dolphins and porpoises) are seen near the island, particularly around the Cairns of Coll, and there are dedicated shark watching trips run on occasion in the season when sharks are present. No evidence was seen of any disturbance of sharks by ecotourism vessels. Most of the operators in the area are long established with considerable levels of experience around marine life including sharks, and the majority of crews have attended a WiSe training course.

Marine tourism:

The island is popular with yachtsmen, partly due to it being relatively close (11Nm) from the sheltered waters of the Sound of Mull, thus allowing short voyages out and back to a Hebridean island, without too much exposure to bad weather. The main harbour, Loch Eatharna is on the eastern side of the island, and containing fixed moorings is popular as it is sheltered from the prevailing westerly winds. Small numbers of vessels use Gunna Sound as a short cut from Coll, Tiree and the west coast of Mull out to the Outer Hebrides. However, this tends to be only in calm conditions as Gunna Sound can become rough very quickly with wind against tide, particularly at the western end. In calm conditions, sharks at the surface are more likely to be seen from a boat, thus reducing the risk of collision.

As with the Hyskeir and Canna site, there is a clear need to adhere to a safe speed (e.g. 6 knots or less) in this area, due to the high level of surface sighted sharks (perhaps on a seasonal basis). As part of this study, maps of the two hotspot areas (Appendix III) have been prepared showing the areas in which extra caution should be exercised (see Recommendations). These maps are intended for widespread circulation to all watercraft users likely to visit the area, and as an aid for marine spatial planning.

An attempt to reduce the potential impact of leisure craft usage on sensitive wildlife has been made by the Royal Yachting Association and British Marine Federation's 'The Green Blue' project (www.thegreenblue.org). Their training CD-ROM "Into The Green Blue" demonstrates a wide range of sensible, practical and economical ways to minimise the environmental impact of boating activities. This includes a film section (developed in conjunction with WiSe) on ways to safely handle small craft around a range of wildlife, including the basking shark. In Scotland, copies have been distributed to 149 cruising instructors, 219 Training Centres and 80 Yachtmaster Instructors, with the aim that they will cascade the knowledge contained in the CD-ROM to future generations of trainees (S. Black, pers. communication 2008). The Green Blue has also undertaken a series of educational workshops to promote use of the CD-ROMs are used by the target audience and continue to deliver education via the Yachtmaster syllabus and instructor update conferences and literature.

During the recent Round Britain Power Boat Race, advice was forwarded by this project, The Wildlife Trusts, Statutory Agencies and the MCS on the position of key sites for basking sharks that lay along the race course via The Green Blue, in an effort to avoid injury to the sharks and the race boats and their crews. This has now been taken a stage further by agreement by the RYA to ensure that all future events of this nature have assessed the risk to the environment before commencing the race. If deemed necessary, the event organisers must undertake a full environmental risk assessment, e.g. if approaching or passing through a Special Areas of Conservation (SAC) or known hotspot for a range of species, including the basking shark. When doing a risk assessment, organisers will be encouraged to consult Statutory Government Agencies such as SNH. The RYA will then have the ability to decline to sanction any race whose organisers or participants have not acted in an acceptable manner and/or not assessed the environmental risk appropriately. Using the data on shark sightings obtained via this study, in combination with additional data such as recreational use and fisheries, may help to identify sites where potential conflicts involving sharks and surface craft may exist, and allow mitigation measures to be put in place.

The RYA have also committed to making all training centres aware of hotspots or statutory responsibilities that may exist within their sphere of operation. The creation of A3 hotspot wallcharts as a result of this report will help to inform the users and operators of all types of small craft of the risks involved in navigating through hotspot areas in which basking sharks might be encountered at the surface. These materials will be informative, easy to understand and should prove useful in assisting this process.

The Green Blue recently conducted a questionnaire survey (2008) in both Wales and Scotland concerning attitudes and awareness of environmental matters amongst leisure craft users. Ninety-one% of the respondents had heard of The Green Blue, and 59% of respondents in Scotland stated that they had found out about wildlife in their home waters (compared to 30% in Wales), whilst 63% stated that they were concerned about potential loss of wildlife. By comparison, a study in southwest England (Kelly et al. 2004) examined the extent of wildlife disturbance within that region, and examined people's awareness of existing legislation. The results revealed a low level of reported incidents and a lack of awareness of marine protection legislation. It would appear from the results of The Green Blue survey that the message is more widely understood in Scotland, probably as a result of ongoing education and outreach programmes. Current levels of awareness are good foundations upon which to build. However, considering the potential risks from an increasing level of boat traffic, more of the same remains to be done.

In conjunction with practical guidance such as the SMWWC (see Section 3.1.1), these measures may have the desired effect of reducing the potential impacts of marine tourism and ecotourism to a minimum. In the event of serious misconduct, such as reckless or intentional disturbance, the current legislation has substantial powers, and hefty penalties. Until there is clear evidence of the need for further legislation, education via these current voluntary systems should be given a chance to prove their efficacy, at least in the case of the basking shark.

We observed leisure craft watching sharks from a safe distance on a number of occasions, but heard no reports of collisions with sharks. We did, however, record an animal with what appeared to be a fresh propeller injury in Crossapol Bay, adjacent to Gunna Sound, Coll, which might have been incurred in the locality (Figure 14).

Figure 14: Shark with propeller injury, Coll 2006

3.2. Other areas with high SPUE

A number of other sites were identified within this study where high SPUE values were recorded on occasion. However, those high values were sporadic, and there were no recorded instances of social behaviour, or large shoal sizes, for there to be sufficient justification for these sites to be considered for hotspot status (as was the case with the two hotspot sites identified in Section 3.1).

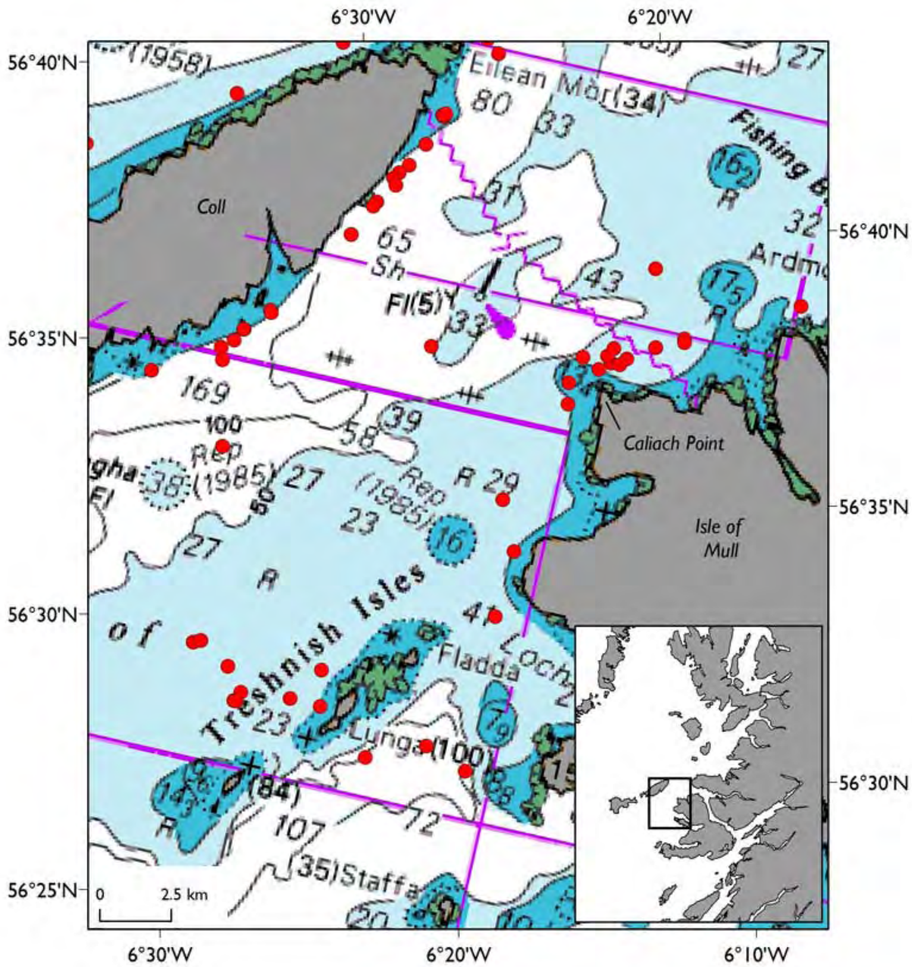
3.2.1. Area 14 – West Mull and the Treshnish Isles

This site runs from Caliach Point on the northwest extremity of the island of Mull down to the Sound of Iona in the south, encompassing a number of islands including Gometra, Staffa, Ulva and the Treshnish Isles – represented in Figure 15. Tidal streams of up to 2 knots at springs run through the site, most particularly around the Treshnish Isles. Most sightings were made around Lunga, the largest of the Treshnish Isles, and the west coast of Mull between Calgary Bay and the tidal headland front at Caliach point.

This site had an average SPUE value of 0.53 h^{-1} with a peak of 1.61 h^{-1} in 2004. A total of 21 sharks were sighted, with only one group of five animals recorded (see Figure 12). No observations of social behaviour were recorded at this site.. The SPUE values recorded at this site, although not as high as the Canna/Hyskeir and Coll hotspot sites, were higher than those identified in the earlier study in the English Channel (Speedie & Johnson, 2008) where the highest SPUE value of 0.48 h^{-1} was recorded at the Land End site. However in Area 14, high SPUE values were not consistent year on year, there were no recorded instances of social behaviour, nor large shoal sizes at this site – these criteria were considered necessary for the site to attain hotspot status (see section 3.1).

Being adjacent to the Coll hotspot, this site may at times support high levels of surface sighted sharks, and should therefore be considered as a site of considerable importance.

Figure 15: Map of part of Area 14, Treshnish and Mull, showing individual shark sightings 2002-2006



Bycatch:

Low levels of inshore potting were observed at this site, as well as low levels of trawling.

Marine ecotourism:

Commercial ecotourism and trip boats are regularly seen at this site, principally visiting the seal and seabird colonies on the Treshnish Isles, and the volcanic island of Staffa. No evidence was seen of any adverse interaction between sharks and ecotourism vessels.

Marine tourism:

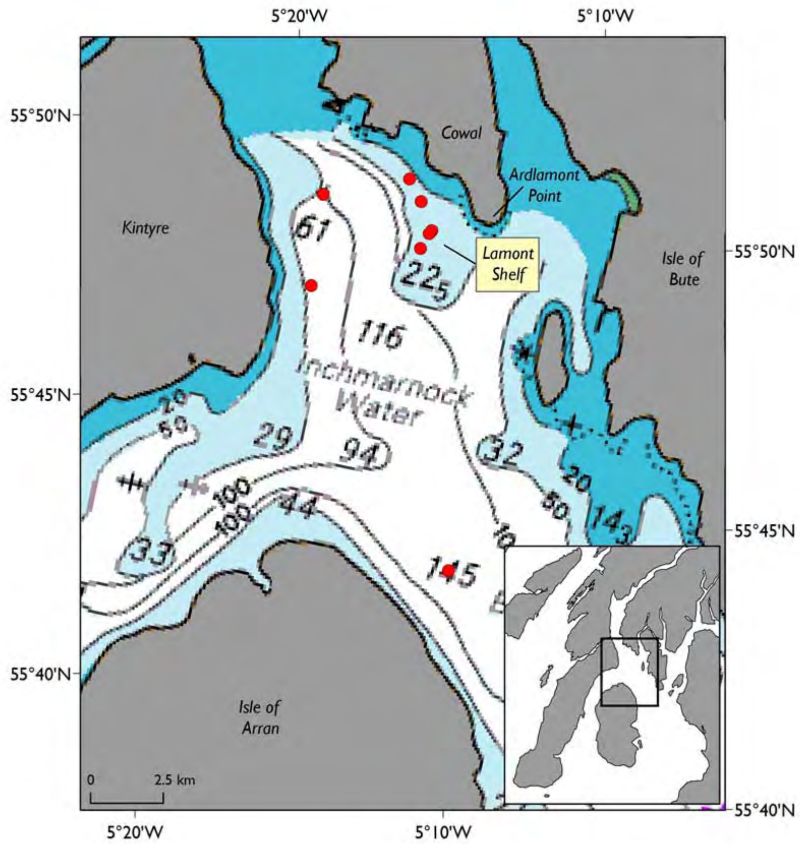
Yachts passing between Ardnamurchan Point and the Sound of Iona visit this site, and there are a number of popular anchorages that are regularly frequented. Site use is relatively low level, and we heard no reports of conflict between small craft and sharks.
One injured shark with a freshly severed upper lobe of its caudal fin was recorded in 2003. It may therefore be sensible to advise small craft transiting the area to keep a careful look out for sharks at (or just below) the surface, and to advise a maximum speed of 6 knots when sharks have been sighted in the area.

3.2.2. Area 11 – The Clyde Sea

The deep, fjord-like Clyde Sea has been recognised as an area in which at times large aggregations of basking sharks were recorded feeding at the surface. However, shark sightings have fluctuated over the decades, with periods of high levels of sightings being rapidly followed by very low levels (Kunzlik, 1988).

A low average SPUE value of 0.05 h^{-1} was observed, with the highest value of 0.10 h^{-1} being achieved in 2003. Only one group of six sharks was recorded, and the only breach sighted in the area occurred on that occasion.

Figure 16: Map of part of Area 11, Lamont Shelf, showing individual shark sightings 2002-2006



Sightings were clustered inshore of the 100m isobath where the bottom shelves steeply upward on the shallow Lamont shelf, between the Skate islands and Ardlamont Point on the Cowal peninsula (where tidal fronts were clearly visible on several occasions) – sightings in this area are illustrated in Figure 16. Only one sighting was made in Kilbrannan Sound, between Arran and the shore of the Kintyre peninsula.

The Clyde Sea area, although not supporting significant numbers of sightings during this survey, has certainly been an important site in the past (Watkins 1958, Kunzlik 1988), and the timing of our surveys may simply not have overlapped with periods of high shark abundance. It must be recognised that even effort-corrected, boat-based surveys are limited in the sense that they can count only surface sighted animals, and require moderate weather conditions to operate effectively. It may be the case, therefore, that due to the generally changeable weather conditions during the Clyde Sea surveys sharks were present, but lower in the water column, and that might to some degree account for the lower than expected SPUE value.

Bycatch:

Trawling activity was higher in the Clyde Sea than at the sites farther north, and occasional fixed markers were recorded that were believed to mark prawn creels. There was no evidence, anecdotal or physical, of bycatch or stranding during the survey.

Marine ecotourism:

There are currently few ecotourism vessels operating within the area. There are Rigid Inflatable Boats (RIB's) offering seasonal trips operating from bases in the Firth of Clyde, Arran and Kintyre, but it is not known whether they sight sharks during their cruises.

Marine tourism:

The Clyde Sea supports a considerably higher level of leisure traffic than the other areas covered in this report, due to the number of marinas and ports within the Clyde, their proximity to major urban centres such as Glasgow and the sheltered nature of the waters. The cluster of sharks sighted along the Lamont Shelf lies along the direct route from the Firth of Clyde to the popular harbour at Tarbert and other yachting centres, and so sharks feeding at the surface may be vulnerable to collision with small craft navigating through those waters. Two anecdotal reports of small craft collision with craft were reported to the research vessel crew during the survey, both along the route outlined above. In light of this information it may be sensible to advise small craft transiting the area to keep a careful look out for sharks at (or just below) the surface, and to recommend a maximum speed of 6 knots when sharks have been sighted in the area.

4. ADDITIONAL POTENTIAL THREATS

In addition to the primary current potential threats examined in Section 1.3, other existing or future threats to the basking shark may include offshore renewable energy devices, climate change and ocean acidification. Currently their characteristics and implications are less understood, and there is only early speculation as to which mitigation or adaptation measures might be most effective in reducing any potential impact on the basking shark.

4.1. Offshore renewable energy devices

The Scottish Government has recently indicated through its Renewables Obligation (Scotland) (ROS) programme its commitment to generating as much as 50% of the nation's electricity demand by 2020 via a suite of renewable energy technologies including offshore wind, wave and tidal power (Scottish Government 2008). Government has announced plans (ROS) to work with the Department for Energy and Climate Change (DECC) to create an appropriate consents regime for offshore wind, wave and tidal power projects. There is currently only one commercial scale proposal that has successfully applied for planning permission, that being the Solway Firth Offshore Wind Farm, with a projected output of between 180 and 200MW (Scottish Government 2008). There are, however, a number of test or prototype wind, wave and tidal turbines that have been approved and installed and there are ongoing application rounds for Crown Estate leases which will determine the extent and pace of future development applications.

It has long been recognised that elasmobranch species may be affected by Offshore Renewable Energy Devices (OREDs) through disturbance during construction and installation and electrical current bleed that might affect navigation and electro-reception (Gill 2005, Gill & Kimber, 2005). In the case of the basking shark there is clear potential for collision with underwater turbine devices, as well as disruption of surface feeding and courtship behaviour due to the aforementioned installation and servicing of offshore sites. The Round 3 Offshore Wind Farm Tender process (Crown Estates press release, 26/09/2008) does not indicate development interest in any of the sites highlighted in this survey as it focuses on zones outside of territorial waters (12nm). Applications for wind development lease sites within Scottish territorial waters were invited by the Crown Estate during 2008, and the 10 successful sites have been awarded exclusivity leases. One of these leases is to the south west of Tiree, an area within 20 km of the Coll hotspot, but out-with the areas surveyed in this project. Development near shark hotspot sites may be inevitable, particularly at the remote and shallow water site of the Hyskeir islet. Far from human habitation and in an exposed and windy site with strong tidal streams, there might be the potential to develop appropriate wind and tidal installations in that area, subject to suitable technologies being identified.

Apart from the already identified threats such as disturbance during construction, or electrical current bleed, there may be additional risks. The potential effects on tidal flows and frontal development at a site like Hyskeir that might affect surface feeding and courting basking sharks are as yet unknown. It might even be argued that, once established, fixed installations such as wind turbines might increase shark sightings at the surface in the vicinity, due to increased water mixing around the fixed structures, as often occurs at nearby isolated rock outcrops such as the Humla rock (within the Canna and Hyskeir hotspot), which regularly seems to have a small attendant group of sharks around it.

Tidal turbines are recognised to pose an obvious risk to sharks feeding around such installations, especially at hotspot sites that support regular aggregations of sharks, not all of which will be at the surface, all of the time. The risk of sharks suffering increased mortality through entering such devices cannot be ruled out. Indeed, the Hayle Wave Hub Environmental Statement (South West England Regional Development Agency, 2006) tacitly admitted this would be the case, concluding that it was not possible to mitigate against operational impacts regarding sharks and cetaceans, and that residual impacts would remain. Development of such devices within hotspot sites could have a major impact on highly important local populations.

In order to understand these risks more thoroughly careful attention should be paid to any impacts occurring at Strangford and at the proposed Wave Hub development off St Ives in Cornwall, both sites in which a potential conflict with basking sharks has been identified, albeit at a far lower level than would exist at either of the key hotspot sites identified within this report. Due to the potential for significant impacts on protected species from the Strangford Lough tidal development, further investigations within an Appropriate Assessment were required to fulfil the requirement for protection under the Habitats Directive (EC, 1992). A comprehensive monitoring programme to identify impacts upon species such as the basking shark is underway, and the authorities have the power to revoke the consent in the event of significant adverse effects occur (Sustainable Development Commission, 2007).

4.2. Climate change

A number of studies have demonstrated that basking sharks migrate into coastal waters to feed on seasonally abundant aggregations of zooplankton (Sims & Merrett, 1997, Sims & Quayle, 1998, Sims et al, 2003a), principally copepods. Sims & Merrett (1997) established that the predominant zooplankton species taken in samples of zooplankton collected near feeding basking sharks in the English Channel off Plymouth were calanoid copepods, principally *Calanus helgolandicus*, although there were other copepod species present such as *Temora longicornis* and *Acartia clausi*.

Sims & Quayle (1998) demonstrated that surface feeding basking sharks actively foraged along thermal fronts seeking the richest and densest patches of large zooplankton, and that foraging behaviour might be regarded as an indicator of plankton abundance, especially in relation to oceanographic and climatic fluctuations (notably the state of the North Atlantic Oscillation) that affect the abundance of *Calanus*.

Research from the Sir Alistair Hardy Foundation for Ocean Science, which operates the Continuous Plankton Recorder survey, has shown a progressive shift in distribution of the cold-temperate *Calanus finmarchicus* and the warm-temperate *C. helgolandicus*, in response to rising sea surface temperature. This mass biogeographical displacement northward of the two plankton species has been estimated to represent a movement in the order of 10º of latitude over the last fifty years (Beaugrand et al. 2002, Edwards & Johns 2005), and this trend appears to have accelerated over the last five years (Edwards et al. 2008). However, the overall trend in copepod abundance is down, by 70% in the North Sea for example (Reid et al. 2003; Edwards & Richardson 2002; and Nash & Geffen 2004, Edwards et al. 2008), despite an increase in the percentage of *C. helgolandicus*. This pattern has also been recognised on the west coast of Scotland, with substantial reductions in *Calanus* being recorded, with levels that are now below the long term mean (ICES, 2007).

If *C. helgolandicus* is replacing *C. finmarchicus* as the dominant calanoid species off western Scotland, this might not pose a major problem for the basking shark, as long as the overall *Calanus* levels do not continue to decline. *C. finmarchicus* has a single seasonal maximum in May, whereas *C. helgolandicus* has two maxima, the first and lesser one in May-June and the second and major one from September-October (Planque & Fromentin 1996), thus potentially offering the basking shark a longer feeding season, which might prove to be advantageous. It seems reasonable to assume that the basking shark, which feeds selectively on *C. helgolandicus* in the English Channel, might equally do so in the waters of Scotland, especially because the two *Calanus* species are so closely related and play a similar role in the ecosystem (Planque & Fromentin 1996).

The basking shark is an efficient forager, as was demonstrated by Cotton et al. (2005) who showed that long term patterns in relative abundance of basking sharks within a region are integrally linked with climate driven changes in SST, and to a lesser extent, *C. helgolandicus* density. The same study also postulated that basking sharks use thermal fronts as “foraging or migration corridors”, and that this may be one means by which they orientate themselves towards the most abundant prey.

A study of the Achill Island shark fishery in the West of Ireland suggested that the decline (and eventual cessation) of that fishery might not solely be due to overfishing of a discrete local population, but might have also been caused by a parallel decline in *Calanus* sp within the area over the same period (Sims & Reid 2002). This study also suggested there had been a considerable increase in the Norwegian basking shark fishery during that period, that might suggest a spatial shift northwards in response to the movement of zooplankton prey. A recent study by Provan et al. (2009) showed that *C. finmarchicus* is able to track changes in habitat availability and maintain stable population sizes, suggesting that the 70% decline in biomass in the North Sea may be viewed as a range shift, as opposed to a straightforward decline in abundance. Anecdotal reports (D Benham – pers.comm) suggest that commercial whale watching vessels in Iceland have observed significant numbers of basking sharks in the last two seasons (2007-2008) for the first time, which may be linked to the multi-decadal shift of *C. finmarchicus* further north, with sharks tracking the increase in available prey further north.

Given the current level of understanding concerning basking shark utilisation of thermal cues as a means of orienting themselves to high levels of available prey (Sims et al. 2003b, Cotton et al. 2005), and its ability to make an ocean basin scale migration (Gore et al. 2008) it may be reasonable to conclude that the basking shark will continue to track changes in availability and distribution of favoured prey efficiently, even over long distances. It seems reasonable to conclude that surface sightings of sharks in hotspot areas, such as those identified in this study, will be sustained as long as the thermal regime is acceptable and sufficient quantities of zooplankton prey persist.

4.3. Ocean acidification

The chemistry of the marine environment is changing - absorption of carbon dioxide (CO_2) into the marine environment has lowered the average pH of the oceans by about 0.1 units from pre-industrial (1750) levels (IPCC 2007). The Royal Society warns that the pH of our oceans is reducing in a manner that is unprecedented, foreseeing a drop of a further 0.5 units by 2100 – this is a level lower than has been experienced for hundreds of thousands of years, lowering at a rate one hundred times faster than at any time within that period (Royal Society 2005). They predict that even current levels of acidification are irreversible within our lifetime.

This may have severe consequences for the marine environment, not least for carbonate shelled-organisms unable to survive without the carbonate saturation state they require. Examples include coccolithophore plankton, molluscs, echinoderms and cold-water corals – pH is a fundamental variable for marine biogeochemical processes. In addition, the sub-lethal effects on copepods (in particular egg production rate and early development) are a concern (Kurihara et al, 2004b, as quoted in Royal Society, 2005) especially regarding the implications on feedstock for the basking shark.

However, as ocean acidification is only a recently observed phenomenon, there are few outcomes we can predict accurately. As the scale of anticipated disruption to normal ecosystem functioning has not been experienced previously, how successfully the basking shark will be able to acclimatise to the resulting changes in food distribution and composition has yet to be determined. As OSPAR states “Clearly, unravelling the combined impacts of declining pH on nutrient concentration and speciation, on nutrient uptake by natural phytoplankton assemblages, their primary production or their nutritional value to the organisms that feed on them will be a challenge.” (OSPAR 2006). The only clear mitigation action appears to be reducing the amount of CO_2 emissions released into the atmosphere, even acknowledging there will be a time lag before a natural (i.e. non-anthropogenic influenced) equilibrium will return.

5. RECOMMENDATIONS AND FURTHER RESEARCH

The findings of this study show that Scotland hosts significantly important areas for basking sharks, of potentially global significance given the status of the species.

Whilst recent legislative measures and conservation initiatives have significantly contributed to a more favourable climate for the basking shark to slowly recover in numbers, there is huge merit in continuing to study this iconic species to better understand its status and ecology in western Scotland in the future. As our understanding increases on the potential for impact from both existing and future threats, information gained through targeted research should contribute towards safeguarding sharks in Scottish waters.

Scotland has a unique opportunity and responsibility to ensure that the measures taken so far achieve their desired effect. If further measures prove necessary to achieve real conservation benefits for the species at the hotspot sites established so far (and at others that may be established as a result of future studies) then these should be based on sound scientific fact.

Sites such as the Clyde Sea that have previously hosted high levels of surface sightings (Kunzlik 1988) may in the future be deemed hotspot sites as numbers once again increase. Other sites that have demonstrated high (but not consistent) SPUE values (Outer Hebrides, West Mull and Treshnish) may yet prove to deserve hotspot status after further survey effort. If that were to be the case, then the arguments put forward for practical conservation measures at the hotspot sites identified should be considered valid for any additional sites.

5.1. Recommendations

(1) Public awareness and educational measures should be expanded, in conjunction with suitable partners. Levels of reported incidents involving disturbance or harassment currently appear to be very low, so any future educational developments should be designed to underpin this situation. This should include further promotion of the Scottish Marine Wildlife Watching Code, widespread dissemination of the findings of this report at all levels of influence and interest, and the production and distribution of wallcharts and leaflets portraying the hotspot information to the marine leisure craft community. In addition:

   a. Concentrated local public awareness events such as evening presentations should be considered in the vicinity of the key hotspot sites, giving local people a greater understanding of the reasons for shark selection of such sites, and hopefully increasing local interest and enjoyment of the presence of the species in their home waters.

   b. Provision of species based information on hotspots should be delivered to the leisure boating community, either via pilot books, electronic charts or through targeted local awareness initiatives. This would be of particular importance where the sites are small scale, the density of sharks sighted at the surface is high, and boat traffic levels are above average.

(2) The widespread adoption of fast craft such as Rigid Inflatable Boats (RIBs) by both marine ecotourism operators and sectors of the leisure boating community (e.g. divers), brings a new level of potential threat to such sites, and all measures to reduce the risk to sharks and boat operators should be evaluated. A combination of voluntary speed restrictions and advice will assist this process.

   a. For areas identified as hotspots (see Section 3.1), where very high levels of sharks at (or just below) the surface are more likely to be encountered, voluntary speed limits should be implemented, perhaps on a seasonal basis (May-October), A suggested safe speed would be 6 knots or less. An illustration of how voluntary speed limits could be portrayed is provided in hotspot maps within Appendix III. Also see the separate wallcharts and leaflets produced in conjunction with this report.

   b. For areas of high SPUE (see Section 3.2) awareness campaigns should stipulate increased caution be used in these areas, encouraging the careful lookout for sharks, safe boat speeds e.g. 6 knots or below, and adherence to the recommendations for safe observation of basking sharks described within the SMWWC.

(3) Further training of ecotourism operators, who are most likely to regularly encounter basking sharks in the course of their day-to-day activities, should be given.

   a. Locally based WiSe instructors (www.wisescheme.org) will have hands on experience of safe boat handling around sharks, but will also have first hand knowledge of the hotspots identified in this report, and can pass on useful site specific knowledge. They will also have a vested interest in ensuring that safe boat handling is employed at all times around sharks, to support and sustain their enterprises, and the species that they depend upon.

   b. Additional training for ecotourism operators should also be considered via ‘Master classes’ that offer training in data recording and handling, and archival photography that could assist with photo-identification initiatives. Much additional useful data could be gathered in this manner that would provide a real benefit for scientific projects seeking to further investigate the reasons for hotspot importance, or for monitoring the species at such sites.

(4) Support for public sightings initiatives, such as the successful long-term Marine Conservation Society public sightings scheme should be provided. This project is highly effective in raising public awareness, and provides valuable data on monitoring the general distribution and abundance of basking sharks in a UK and regional context, as well as monitoring levels of stranded sharks.

(5) Site-specific measures such as spatial management and/or Marine Protected Areas should be considered, with the basking shark and other species in mind. e.g. use of marine spatial planning in areas known to feature surface feeding basking sharks, would better identify the capacity of these habitats to sustain a variety of multiple uses, including conservation of protected species. For example, engaging with local authorities in raising awareness of critical areas for sharks will help address any potential conflicts with marine developments such as the installation of renewable energy devices.

5.2. Further research

(1) The effort-based surveys outlined in this report were limited in their ability to examine a number of other potential key sites on the west coast due to time, distance and weather constraints. There were a number of sites (in addition to those identified here) that were considered highly important historically by the shark hunters – the sounds between many of the outer islands, Scalpay, and the north and west coasts of Skye – that were beyond our physical ability to cover. These are undoubtedly more difficult sites to survey, but we believe they would certainly repay the effort required to survey them adequately. Boat based surveys would be ideal, allowing as they do closer range contact (and thus photo-identification of individuals), accurate counting and measurement of individuals. However, aerial surveys using light aircraft and trained observers might also be considered, allowing some of the difficulties associated with such remote and exposed sites to be circumvented. The addition of extra effort-corrected surveys to explore remote sites with little human habitation or visitation is

clearly vital in terms of completing the picture outlined by the MCS public sightings scheme. This is particularly in the light of the findings of this report, highlighting hotspot sites that do not feature equally prominently in the MCS public sightings scheme.

(2) It would be important to include effective plankton sampling (species and abundance) in any future survey structure, so that any future changes in shark distribution and abundance might be better understood in the context of shifting baselines. A system to properly store and analyse plankton samples taken would need to be developed to ensure that accurate results were obtained from sampling efforts.

(3) Submission of good quality shark photographs should continue to the photo-identification study, the European Basking Shark Photo-identification Project, which has been ongoing since 1999 and based at the Shark Trust (www.sharktrust.org) in Plymouth. This would allow continued evaluation of levels of anthropological threats through images of injured sharks, quantifying anthropogenic impacts such as ship strike involving leisure and commercial craft, and the likely localities involved.

(4) Collection and analysis of data on current levels of bycatch would be valuable. Identification and evaluation of the fishery and gear types most likely to be involved could then provide indications of the level of threat anticipated from different fisheries zones.

(5) Collection and analysis of research data into the likely effects from shark interaction with tidal or wave renewable energy devices, as this would assist in the research and development of effective mitigation techniques or equipment.

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7. APPENDICES

7.1. Appendix I: Sightings and Recording forms

Form A : Basking Shark Sighting Form

Transect number:	Sighting number in season:	Sighting number in day:	Date:	
Start time:		Finish time:		
Ships heading:	Relative bearing:	Distance:		
Latitude:		Longitude:		
Markings:	Size:	Sex:	Tags:	Scars:
Behaviour:				
Mating behaviour associations:				
Breaching:				
Other species associations:				

EOS 1d photos:	EOS 10d photos:	
XL1 film footage:	Time start:	Time finish:

Wind:	Sea state:	Swell height:
Weather:	Cloud cover:	Visibility:
Water depth:	Water temp:	Turbidity:
Other notes:		

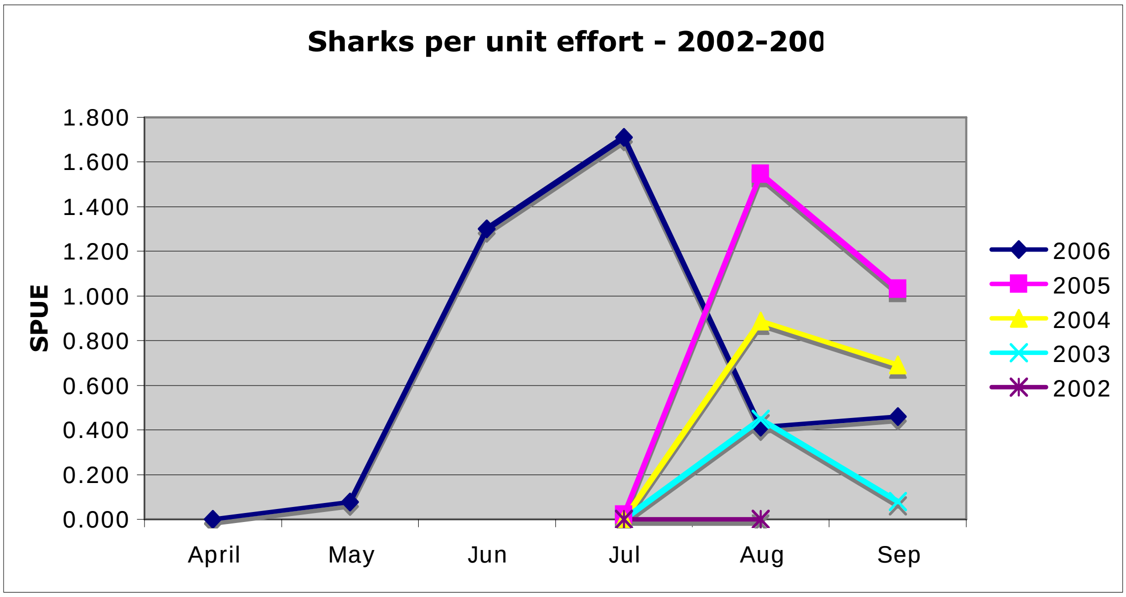
Form B : Cruise Log / Transect Form

CRUISE ROUTE: ………………………………………………………………………………. DAY/MONTH/YEAR:……………………
VESSEL: ………………………………. OBSERVATION HEIGHT: …………………….. VESSEL SPEED: ……….
OBSERVER NAME: …………………. CONTACT ADDRESS: ………………………….. TRANSECT NUMBER: …………………

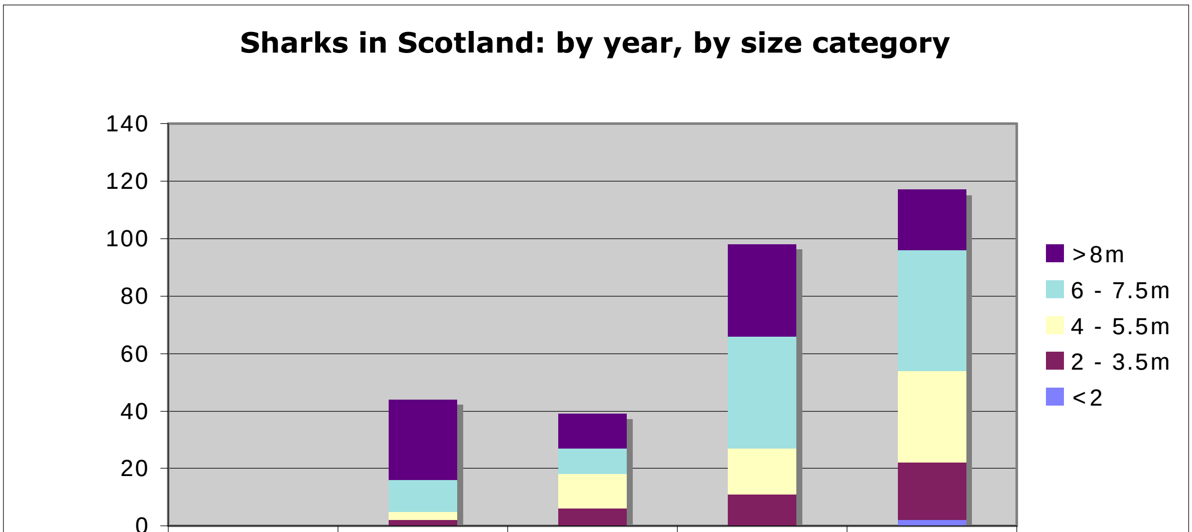
Time (BST)	Location (lat & long)	Vessel bearing e.g. 270°	Wind dir & speed e.g. NE, Force3	Sea depth & temperature e.g. 25m, 17°C	Tide direction & speed e.g. 020°, 3knts	Sea state (Beaufort scale 1-9)	Swell height e.g. <0.5m	Weather & cloud cover e.g. fair, 5/8	Visibility

7.2. Appendix II: Additional graphs

1- Sharks per unit effort compared between years.



2- Shark size category, by year.



	2002	2003	2004	2005	2006
>8m	0	28	12	32	21
6 - 7.5m	0	11	9	39	42
4 - 5.5m	0	3	12	16	32
2 - 3.5m	0	2	6	11	20
<2	0	0	0	0	2

7.3. Appendix III: Hotspot maps

As highlighted in Recommendation 2, voluntary seasonal speed reductions of 6 knots or less would be applicable within the pink-hatched areas (or caution zones) in the hotspot maps below. In the transparent-hatched areas, increased caution should be implemented, encouraging the careful lookout for sharks, safe boat speeds and adherence to the recommendations for safe observation of basking sharks described within the SMWWC.

Figure 17: An illustration of spatial management displayed on a map of Coll & Tiree

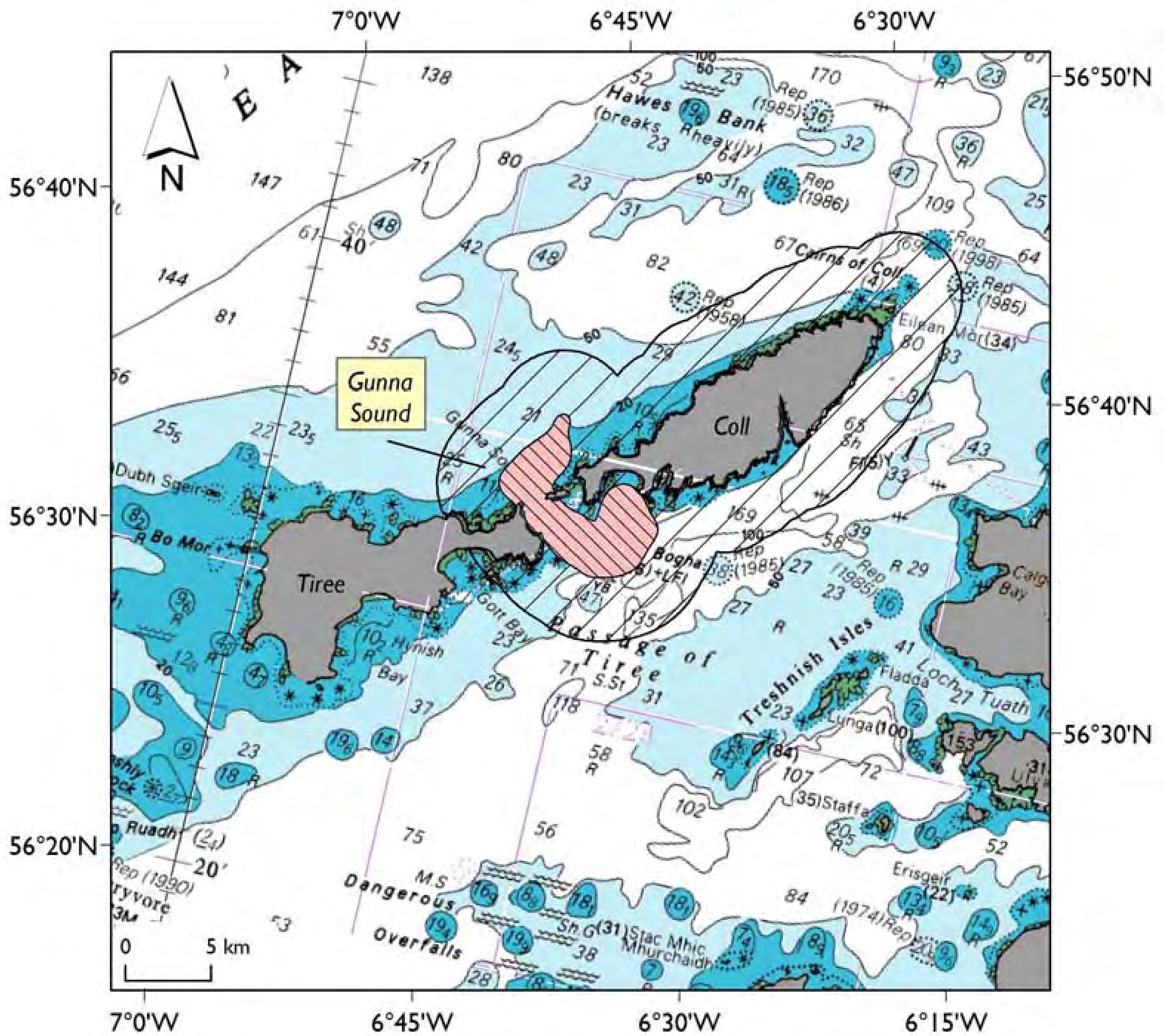
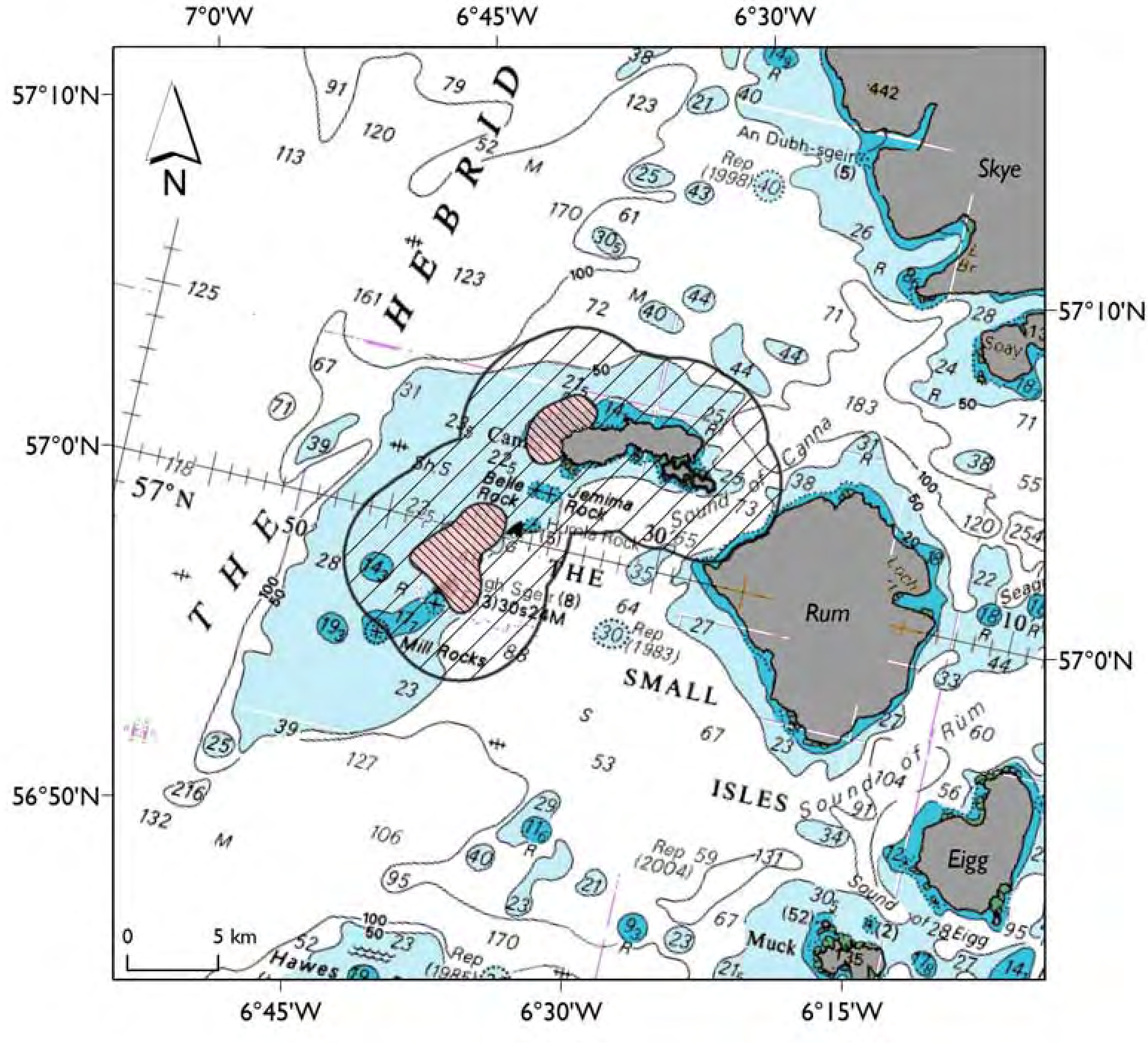


Figure 18: An illustration of spatial management on a map of Canna and the Hyskeir



Scottish Natural Heritage is a government body responsible to the Scottish Government.

Statement of principles:

Scottish Natural Heritage – the government body that looks after all of Scotland's nature and landscapes, across all of Scotland, for everyone. Our 5 strategic priorities are:

- Caring for Scotland's nature and landscapes
- Helping to address climate change
- Delivering health and well being
- Supporting the Scottish economy
- Delivering a high quality public service

Find out more at **www.snh.org.uk**

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