Natural England Research Report NERR018

The Basking Shark (Cetorhinus maximus) in West Cornwall. Key sites, anthropogenic threats and their implications for conservation of the species.

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The Basking Shark (Cetorhinus maximus) in West Cornwall.

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Project details

This report results from research commissioned by Natural England in order to further the understanding and knowledge of the Basking Shark in West Cornwall.

A summary of the findings covered by this report, as well as Natural England's views on this research, can be found within Natural England Research Information Note RIN018 – The Basking Shark (Cetorhinus maximus) in West Cornwall. Key sites, anthropogenic threats and their implications for conservation of the species.

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The backbone of any project of this nature are the individuals who take part, and whilst they are far too numerous to acknowledge individually, every one of the volunteers who took part in the surveys played their role in the production of this report.

*There are 47 local Wildlife Trusts across the whole of the UK, the Isle of Man and Alderney. We are working for an environment rich in wildlife for everyone. With 765,000 members, we are the largest

UK voluntary organisation dedicated to conserving the full range of the UK's habitats and species, whether they be in the countryside, in cities or at sea. 135,000 of our members belong to our junior branch, Wildlife Watch. We manage 2,200 nature reserves covering more than 84,000 hectares; we stand up for wildlife; we inspire people about the natural world and we foster sustainable living.

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1 Introduction

1.1 The Wildlife Trusts' Basking Shark Project conducted six years of effort corrected line transect surveys in the waters of South Devon and Cornwall between 1999 and 2004 to establish key sites for the basking shark (*Cetorhinus maximus*).

1.2 In the first three-year phase (1999-2001) the survey covered the entire south-west coast between the Isles of Scilly in the West, to Torbay in the East, in an effort to discover sites showing high levels of surface sightings – "key sites". Two such sites were identified as a result of these surveys, both in West Cornwall, namely the Lizard peninsula and the Lands End peninsula.

1.3 The second three-year phase (2002-2004) was driven by the results achieved during the first survey, and focused on the two sites identified in a more intensively structured manner, as well as continuing to monitor the region as a whole.

1.4 This study set out to examine whether the key sites established were consistently important, not just during a cyclical period of high levels of surface sightings, but also during a low period in the cycle when fewer sharks were sighted. The cyclical nature of surface sightings driven by climatic and oceanographic factors has long been recognised, and the long-term nature of this study offered an opportunity to gain an insight into this area through reliable and replicable scientific study.

1.5 Emphasis was also placed on establishing the incidence of behavioural activity such as courtship and breaching, consistent with reproductive activity. A careful record was also kept of shark size, with a view to establishing the presence (and spatial and temporal distribution) of sharks <2m in size. This would represent young of the year, and might therefore suggest that parturition takes place within the region seasonally or cyclically.

1.6 Finally, the study has sought to identify potential threats of an anthropogenic nature to the basking shark within the key sites, such as by-catch, ship strike (surface collision with craft) and disturbance. Whilst it was beyond the scope of the project to quantify the implications of each of the individual threats identified, nonetheless it is possible to suggest ways in which these factors might be quantified, evaluated and mitigated against in simple, practical ways.

1.7 This report will set out the results achieved by the study over the six-year period, and will examine the factors influencing shark selection of these key sites, the long-term conservation implications of that site selection, and recommend practical initiatives to safeguard the sharks within those key sites, where necessary.

2 The Surveys

Methodology

2.1 The 11.7m sailing vessel "Forever Changes" was used as the standard platform throughout the survey period. A sailing vessel was chosen as it provided a stable platform for observation, with good sea-keeping qualities, capable of economically operating over long distances at low environmental cost or impact. As the vessel had to cover such a large area, the crew lived aboard for the duration of each survey, mooring or anchoring in safe harbours or bays overnight along the chosen survey route. In this way, a substantial distance could be effectively covered each week.

2.2 When under sail, such vessels are relatively "quiet" through the water, causing minimal disturbance to marine life, even at close quarters. In addition, the survey vessel had extra sound deadening material fitted in the engine compartment to reduce external noise under power, and had been fitted with a feathering Variprop propeller to minimise drag and noise under sail.

2.3 The survey employed a simple, scientifically sound methodology, taking into account perception bias factors (e.g. sea state, height of eye, swell height). A wide variety of environmental data was recorded on a half hourly basis including:

- Time of day.
- Latitude and longitude via the vessels' GPS navigation system (an MLR FX 412 12 channel GPS receiver), interfaced with a Dell Inspiron 8600 notebook PC running Sea Pro Plus navigational software.
- Sea depth and Sea Surface Temperature (SST) data, via an Interphase TwinScope forward scanning sonar, with built-in temperature sensor accurate to 0.1ºC.
- Wind direction and speed (Beaufort scale).
- Sea state (Beaufort scale).
- Weather and cloud cover.
- Visibility.

2.4 The crews consisted of volunteers from all walks of life, all of whom received full training in all aspects of the line transect survey structure, with particular attention being paid to observation techniques. This is of vital importance in reducing variability of observer effort, which can form a potential weakness with this type of survey. For the same reason, tasks were rotated on a maximum two-hourly basis, to minimise fatigue, boredom and eye-strain for observers. Attention was also paid to ensuring that data was accurately recorded, and the regular crew of Principal Investigator (PI) and Mate monitored all activities constantly whilst on survey, especially those areas (observation, accurate data recording) recognised as being of high importance where volunteers are involved (Evans, Foster-Smith & Welch 2001).

2.5 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 ships bow. A third individual would record all relevant positional and environmental data on a half-hourly basis, using specially designed recording forms (Appendix 1).

2.6 All line transect surveys were corrected for sea state, operating up to a maximum Beaufort scale value of sea state 4 (small waves growing longer; fairly frequent white horses), as it was recognised that perception bias for sharks in excess of sea state 4 would move beyond acceptable parameters. Similarly, visibility would affect perception, with anything less than moderate visibility (2-5 miles) affecting the ability of observers to sight sharks. No survey was therefore started when conditions exceeded sea state 4, or with less than moderate visibility. If, during transect, sea state increased beyond sea state 4, or visibility fell below moderate, the transect was abandoned. Sightings data recorded during the survey period could then be correlated with survey effort and prevailing conditions, and expressed in terms of a per unit effort value, such as sharks sighted/ hours of observation.

2.7 When shark sightings were made, a dedicated sightings form (Appendix 2) was used to capture all relevant 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 or courtship-like behaviour. Records of identification photographs were simultaneously logged as they were taken, to avoid confusion between individual 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.

2.8 The standard methodology employed for these basking shark surveys is identical to that employed for cetacean surveys (amongst others), and corresponds to the highest category (7) identified in terms of effort intensity, i.e. “dedicated watching for cetaceans by experienced observers using line transect methodology” (Evans, Anderwald & Baines 2003). As a result, data gathered on cetacean observations whilst on survey has allowed the project to provide valuable additional information on the status, distribution and relative abundance of cetaceans encountered throughout the survey period, including a study of the harbour porpoise (*Phocoena phocoena*) along the west coast of the UK (Goodwin and Speedie 2008).

The first survey - 1999-2001

2.9 The first three-year survey was conceived as a baseline study of spatial and temporal distribution of surface sighted basking shark in the western English Channel.

2.10 A minimum of four line transect surveys of six days duration were carried out each year, with one survey each May, June, July and August to give as broad a temporal scale as possible. Spatially, the study area extended from the Isles of Scilly (49 52.40N 06 27.00W) in the West to Torbay (50 23.70N 03 28.40W) in the East, and between these points line transects were established, using either prominent headlands as starting/finishing points, or offshore buoys and lighthouses such as the Eddystone light off Plymouth. The lattice of transects was established to include inshore and offshore elements without favouring any potentially rewarding areas, and to ensure adequate and unbiased coverage of the local waters. It was the aim of the project to complete each line transect at least twice per season.

2.11 During the three years (1999 – 2001) of the first survey duration, a total of 92 line transects were covered in this manner, amounting to a total of 209 hours of observation, over a distance travelled of 2088km.

Results

2.12 A total of 141 sharks were sighted on transect, giving a sightings per unit effort (SPUE) ratio (sharks/hours observed) of 0.68h-1. This data is represented in Table 1.

Table 1 Basking shark sighting 1999-2001

Year	Hours observed	No. of sharks	SPUE
1999	46	102	2.22h-1
2000	71	11	0.15h-1
2001	89	28	0.32h-1
Total	206	141	0.68h-1

2.13 The year 1999 proved to be a particularly productive year for surface sightings of basking sharks in the waters of the south-west. To study this data more closely, a breakdown of sightings by months is provided in Table 2, and by area in Table 3.

Table 2 Temporal distribution of shark sightings 1999-2001

Year	May	June	July	August
1999	0	1	24	77
2000	0	0	11	0
2001	0	26	1	1
Total (%)	0 (0%)	27 (19%)	36 (26%)	78 (55%)

Table 3 Spatial distribution shark sightings 1999-2001

Year	Dodman Pt to St Anthonys light	St Anthonys light to Lizard	Lizard to Runnelstone	West of Runnelstone
1999	0	0	72	30
2000	0	0	11	0
2001	0	1	27	0
Total	0	1	110 (78%)	30 (21%)

2.14 Surface sightings of basking sharks are usually expected to coincide with and follow the early increase in zooplankton density, normally occurring in May or June (Sims & Merrett 1997). Later in the summer stratification will usually have occurred in most inshore waters of the region, where warmer water forms a surface layer over colder water, with a discontinuity in the form of a thermo cline developing between the two layers. Zooplankton density will then be greater lower in the water column than at the surface, leading to a reduction in surface sightings of sharks from mid July onwards. The exception to this may be in areas of shelf sea and headland fronts where high levels of water mixing may continue throughout the season.

Analysis for 1999-2001

2.15 In order to further understand the distribution of the basking shark population around Cornwall, analysis of the sightings made on transect reveals that, with one single exception, all sightings were made to the west of Lizard Point. The majority of sightings (78%) were made in the area between the Lizard and the Runnelstone buoy (south-western tip of Lands End). The next most prolific area for surface sightings was the area to the west of the Runnelstone buoy (21%). This spatial bias may be explained by the proximity of these localities to productive coastal front areas in which basking sharks are known to forage for the highest densities of their preferred prey (Sims & Quayle 1998). Within these areas, water may remain mixed from the seabed to the surface throughout the summer, inhibiting stratification, due to a combination of strong tides, and a rapidly rising or uneven bathymetry. As a result, greater levels of zooplankton may be expected to migrate to the surface consistently during all months of the summer, sustaining high levels of surface feeding sharks, which may explain the level of sightings recorded in July and August within these areas (Speedie 2002).

2.16 Clearly the sightings data recorded to this stage displayed a marked bias towards these key sites, pointing the way forward for further studies that could confirm the long term validity of such a hypothesis, and to examine what threats of a natural or anthropogenic nature might impact upon the animals within those sites.

The second survey - 2002-2004

2.17 The second survey entailed more than a simple development of the existing structure, and was considerably modified in both spatial and temporal scale.

2.18 It was decided to concentrate more directly on three key areas within the southwest, two of which would encompass the two key sites identified so far – Falmouth Bay to Lizard Point, and the southern sector of the Lands End peninsula. The third site, encompassing Dodman Point to Gribben Head was used as a control site, to allow comparison with the two other sites. Whenever possible, the survey vessel attempted to conduct line transect surveys within these sites, weather permitting. One major limitation that affected the first two sites was their exposed nature, open as they are to swell from the Atlantic. This, when combined with their strong tides and uneven, shallow bathymetry, meant that in stronger winds weather parameters such as sea state might be outside acceptable levels for surveys. Therefore the survey continued to gather the full suite of environmental data every 30mins (as detailed in Methodology), so that sea state could be used for later analysis.

2.19 At the same time, the survey continued to cover the existing range (Isles of Scilly to Torbay); in order to monitor the overall area with a view to observing whether any change in spatial distribution occurred over time.

2.20 The surveys concentrated on the months of May and June, with a minimum number of eight surveys conducted during that period each year. This effectively doubled the level of effort devoted to the overall area, but in a far more concentrated manner, timed to coincide with high levels of surface sightings, and before stratification occurred in local inshore waters (usually in July).

2.21 The same line transect survey pattern was followed in each year, and every effort was made to conduct each line transect survey at least twice during the season, during the same period. In an ideal world this would be the optimal way of conducting such a study, with absolutely equal sampling effort spatially and temporally, however, due to the constraints of having only the one survey vessel, coupled with vagaries of wind and weather, this could not be achieved. However, every effort was made to keep variability to a minimum, and thus whilst we recognise that there may be some confounding influences in the data as a result of such variability, we hope to have significantly reduced their influence on the overall data set.

2.22 At the end of each early summer study in south-west waters, the survey vessel then departed North into the Irish Sea, Northern Irish waters, the Clyde Sea and the Sea of the Hebrides for the remainder of the summer (July to Sept).This enabled the project to establish in northern waters an overall survey structure similar to that developed during the original three-year cycle in the southwest.

Results

2.23 A total of 56 sharks were sighted on transect during the survey periods 2002-2004. Figure 1 presents the shark distribution data by area and Table 4 presents the sharks by area over each year of the survey period.

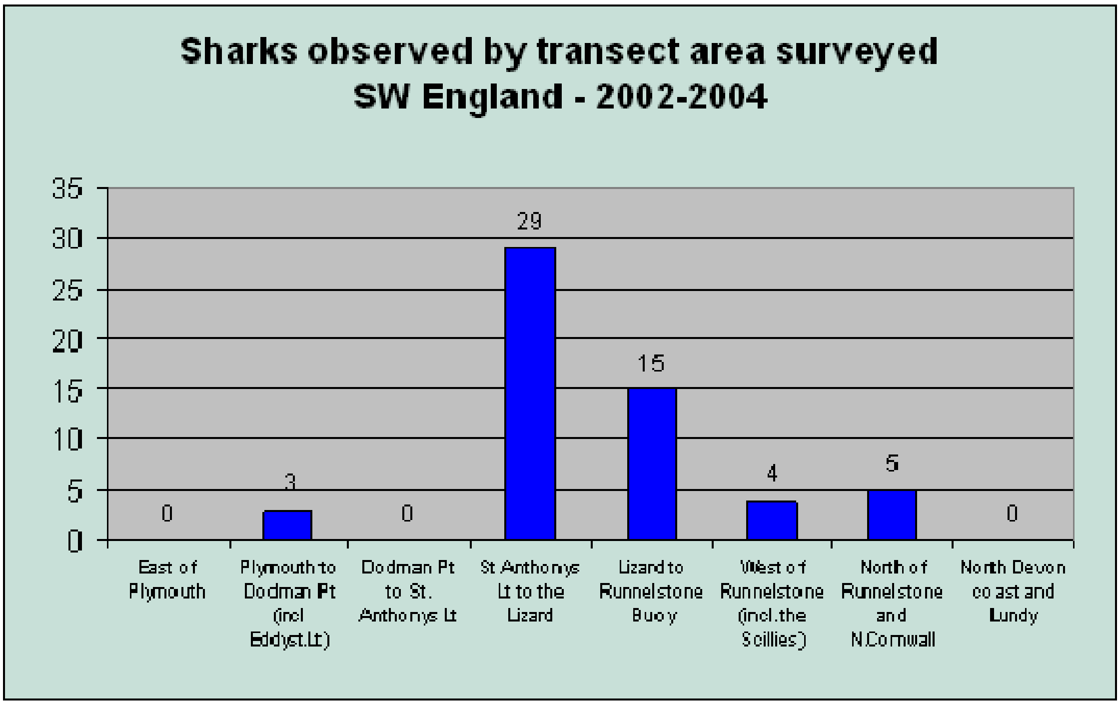


Figure 1 Sharks observed by transect area 2002-2004

Table 4 Number of sharks observed on transect by area by year 2002-2004

Area	2002	2003	2004	Geographical area
1				East of Plymouth
2		3		Plymouth to Dodman Pt (incl. Eddystone Lt.)
3				Dodman Pt to St. Anthonys Lt
4	5	19	5	St Anthonys Lt to the Lizard
5		14	1	Lizard to Runnelstone Buoy
6		4		West of Runnelstone (incl. the Scillies)
7	5			North of Runnelstone and North Cornwall
8				North Devon coast and Lundy

Effort

2.24 An analysis was made of the spatial bias of the study, in terms of the amount of time spent in each of the three south-western study sites, and then correlated with sightings to give a view of the amount of sightings of sharks per unit effort SPUE) by time (hour). This corrects the data for the amount of effort dedicated to observing for sharks, to provide a normalised dataset and eliminate bias. This allows the areas with highest SPUE values to be identified - this is represented in Figure 2 and Table 5.

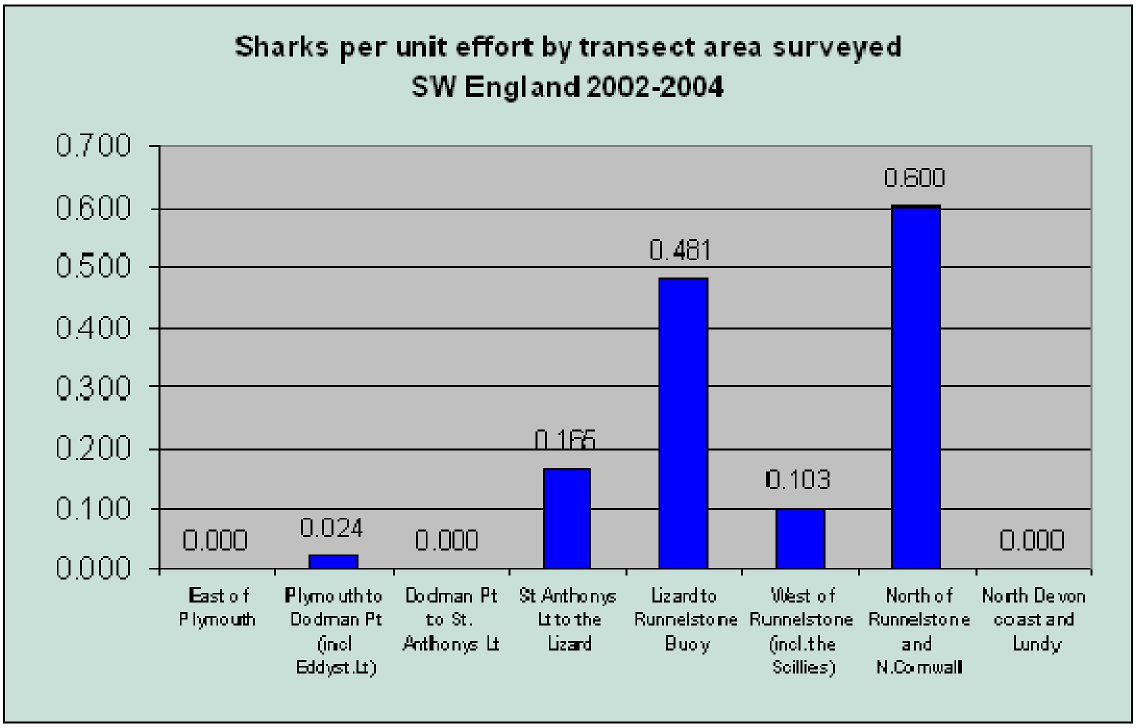


Figure 2 Sharks per unit effort by transect area surveyed 2002-2004

Table 5 Sharks and survey hours by area to calculate SPUE, 2002-2004

Area	Sharks	Hours	SPUE h-1	Geographical area
1	0	32.17	0.000	East of Plymouth
2	3	123.67	0.024	Plymouth to Dodman Pt (incl. Eddystone Lt)
3	0	60.98	0.000	Dodman Pt to St. Anthonys Lt
4	29	175.5	0.165	St Anthonys Lt to the Lizard
5	15	31.2	0.481	Lizard to Runnelstone Buoy
6	4	38.87	0.103	West of Runnelstone (incl. the Scillies)
7	5	8.33	0.600	North of Runnelstone and North Cornwall
8	0	6.65	0.000	North Devon coast and Lundy

2.25 The data represented in Figure 2 and Table 5 show the amount of time spent on transect in each area, and the corresponding number of surface sighted sharks observed whilst surveying in each area.

Analysis of 2002-2004

2.26 Two areas repeatedly proved productive from a surface sighting perspective i.e. Areas 4 & 5. Area 4 was particularly productive in terms of shark sightings largely because a substantial amount of survey time was spent transiting this location as it was en-route to other transect sites. However, once this data is effort corrected, these areas are still highlighted as favoured sites, along with a third location (Area 7), as a result of sightings on one particular day spent surveying the north Cornish coast in 2002, and as such should not skew the longer-term data analysis. Overall, assessing the full three years of survey, the area between the Lizard and the

Runnelstone buoy (Area 5) represents a consistently good area, replicating the results from the first survey period.

Analysis of the period 1999-2004

Behaviour

2.27 The principal behavioural activity observed was feeding, where sharks were observed at the surface swimming with their mouth agape, although other behaviours, including courtship and breaching were observed.

2.28 The basking shark, in common with other elasmobranch species is believed to engage in courtship behaviour prior to copulation. Observed behaviours were common with previously described behaviours, including parallel swimming, possible pectoral biting, nose to tail following, close approach involving rostral contact and echelon swimming (Harvey-Clark and others 1999), amongst other behaviours associated with this type of activity. Similar social behaviour has been recorded and described in frontal areas in southwest England (Sims and others 2000a), involving groups of up to four sharks.

2.29 Courtship behaviour, where sharks were seen parallel swimming and close following, was observed on four occasions whilst the vessel was on transect, with three of those events occurring within Area 4, St Anthony's Light – Lizard Point (total of 6 sharks observed in courtship), with the fourth example being recorded within the Dodman Point site, all in 2003. Additionally, courtship was recorded twice during 2002 off transect within Area 4.

Breaching

2.30 Basking sharks do in fact breach on occasion, sometimes leaping clear of the water entirely, often turning in mid air, inverting and landing on the dorsal surface with a loud, percussive splash. Fifteen occurrences of shark breaching were observed during the period 1999-2004 whilst on transect, although in total there were 33 breaches observed if those seen whilst not undertaking effort-corrected survey are included. The majority of these were seen in 1999 on several days when observations of breaching sharks reached previously unprecedented numbers.

2.31 It was originally suggested that observers of this behaviour were mistaken, and that the animal involved might have been a cetacean or thresher shark, but this opinion was withdrawn after convincing testimony from many onlookers (Maxwell 1952). It has been suggested that the main purpose of breaching is to dislodge ectoparasites such as the parasitic lamprey (*Petromyzon marinus*), but most experts agree that this seems to be far too high an energetic investment to redress what appears to be at worst a minor inconvenience to the shark. The white shark (*Carcharodon carcharias*) is believed to use breaching as a means of social communication during the mating season (Pyle and others 1996), and it may be that breaching performs a similar function in the basking shark. Matthews and Parker (1951) examined detailed records from Scottish waters of the frequency of breaching, which showed that it was most prevalent at a suggested mating time of May and June, results that were supported by Sims and others (2000a) in the western Channel, suggesting that basking sharks undertake courtship during the summer months off south-west England. Another possibility might be that of a male shark advertising his potency, as with the humpback whale (*Megaptera noviangliae*) (Whitehead 1985) or warding off potential rivals. Whilst we have been able to positively identify a male shark breaching off western Scotland during our study, that might lend credence to this hypothesis, equally, Sims and colleagues (2000a) observed a female breach during a study in the English Channel and so postulated the theory that this might imply that females may advertise their receptivity in this manner, so this matter remains unclear. It was also observed in the same study (Sims and others 2000a) that only large animals were involved in breaching, with some animals breaching on multiple occasions. Consistent with these observations, during this study breaching was only observed when groups of sharks were present, and all sharks recorded were of mature size.

2.32 A number of sharks were sighted at these times with highly visible white abrasions to their body, pectoral fins and, most obviously, the rostrum. In a study in the northwest Atlantic by Harvey-Clark and colleagues sightings of such body markings were made when observing “courting” basking sharks off Newfoundland (Harvey-Clark and others 1999), and postulated that these might have been caused by the sharks pectoral biting and abrading their bodies during mating.

2 metre sharks – young of the year

2.33 The only known record of parturition occurred when a Norwegian hunter was towing a female shark back to harbour and the animal gave birth to five live and one stillborn pups of between 1.5 and 2.0m in length (Sund, 1943). This gave rise to a base length at birth of 1.5m being utilised in a subsequent study on likely growth rates for the species (Parker & Scott, 1965). Pauly (1997) proposed an annual growth value (K) of 0.062 for the species, hence sharks of 2m and below might likely have been born early in the season of their first sighting.

2.34 During our surveys, records were kept of sharks up to and including 2m in length, which were likely to be first year animals. Between 1999 and 2004, 10 sharks of 2m or below were observed in Areas 4 & 5 (St. Anthonys Light to Lizard, and Lizard to Runnelstone Buoy). Although these areas correspond to the key sites identified in this report (suggesting that parturition may occur within, or near to such sites), sightings were not of sufficient numbers to accurately determine whether these sites were specifically favoured for parturition.

3 Basking shark status in UK waters

3.1 The basking shark (*Cetorhinus maximus*) is the second largest fish in the world, potentially reaching up to 12m in length, and a weight of 7 Tonnes. It is believed that basking sharks become sexually mature at 16-20 years, and produce irregular litters of up to six pups of around 1.5m length. Formerly hunted for their large livers which yielded a high oil content, they have been more recently hunted in European waters for their colossal fins that fetch remarkably high prices as trophies in the East Asian market.

3.2 A filter feeding planktivore, during late spring and summer periods, basking sharks are regularly sighted swimming at the surface within the coastal waters of the western British Isles and Ireland, displaying both feeding and courtship behaviour (Sims & Merrett 1997, Sims and others 2000a). 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 are known to occur within the area cause strong thermal fronts to form, acting as boundaries 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 and others 1975, Simpson & Pingree 1978, LeFevre 1986).

3.3 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 and others 1975, Le Fevre 1986). Two particular types of fronts typically occur in the waters described here.

3.4 Oceanic fronts, such as the Ushant front that occurs in the approaches to the English Channel may have a Sea Surface Temperature (SST) contrast of 4-5 degrees Celsius as 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). This 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).

3.5 Shelf sea and headland fronts occur generally in shallow coastal waters where a combination of strong tidal streams, rapidly rising and variable bathymetry and coastal topography combine to cause powerful local mixing and therefore a reduction in stratification (Simpson 1981). This can be exacerbated where the surrounding offshore water is well stratified, leading to sharply defined and thus highly productive frontal systems (Simpson & Pingree 1978, Alldredge & Hamner 1980). In a similar manner to oceanic fronts or shallow sea fronts productivity is greater in these regions as nutrient mixing and up welling is enhanced. As with oceanic fronts, headland fronts aggregate surface debris, buoyant matter and oily, slick surfaces, visual clues to the higher levels of zooplankton below the surface.

3.6 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 oceanic fronts (Sims & Quayle 1998). Areas where strong headland fronts persist have also been shown to yield the highest levels of sightings in the waters of South Devon and

Cornwall (Speedie 2001a). Recent research shows that the sharks may reside in areas of persistent frontal activity (Sims and others 2003a) throughout the year, and may utilise thermal cues as their primary means of orientating themselves to areas of high secondary productivity over long distances (Cotton and others 2005). In addition, the recent discovery that sharks possess a remarkable ability to detect the sometimes minute temperature gradients associated with frontal activity (to 0.001ºC) via an extra cellular gel contained within the electro sensory canals (Brown 2003) lends support to this hypothesis.

3.7 Basking sharks surface-feed in areas in which their preferred calanoid copepod prey, *Calanus Helgolandicus* is 2.5 times as numerous (~ 1,500 organisms per m^3) and 50% longer (~ 2mm) than in areas in which sharks do not feed and will selectively forage for specific aggregations of their preferred zooplankton species (Sims & Quayle 1998). It has been suggested that they can orientate themselves effectively towards such areas at close range using a combination of cues in addition to thermal variability. These may include electro-reception of copepod muscle activity, as well as olfaction of gases such as dimethyl sulphide, produced when phytoplankton is grazed upon by zooplankton (Sims & Quayle 1998). These abilities are critically important for a planktivorous creature that may have to forage over long distances to find exploitable levels of prey species, despite the fact it has now been shown that the energetic requirement of the basking shark is lower than had previously been suggested (Sims 1999), and that as an obligate ram filter-feeder, the species has optimized its feeding and cruising speeds consistent with reducing power output and energy intake (Sims 2000).

3.8 These thermal/tidal effects may also have an important role to play in bringing sharks together for the purpose of mating, as high levels of courtship have been observed within frontal areas (Sims and others 2000), giving them a high priority in terms of conservation.

3.9 Owing to the lack of concrete knowledge of its current population numbers, distribution and habitat requirements, any sites recognised as providing a favoured habitat where mating behaviour may take place should be considered in the future as worthy of some form of site protection such as the proposed Highly Protected Marine Reserves. Another factor that could contribute to this further level of protection might be the presence of young of the year sharks (<2m) at recognised sites of surface abundance, as has occurred at a significant number of the sites so far identified. Evidence of regional philopatry over the short term (<5d) to long term (767 – 1023d) has been demonstrated through re-identification of individuals using photo-identification techniques (How, Speedie and Sims 2003), that would support demands that the precautionary approach should be applied for such sites.

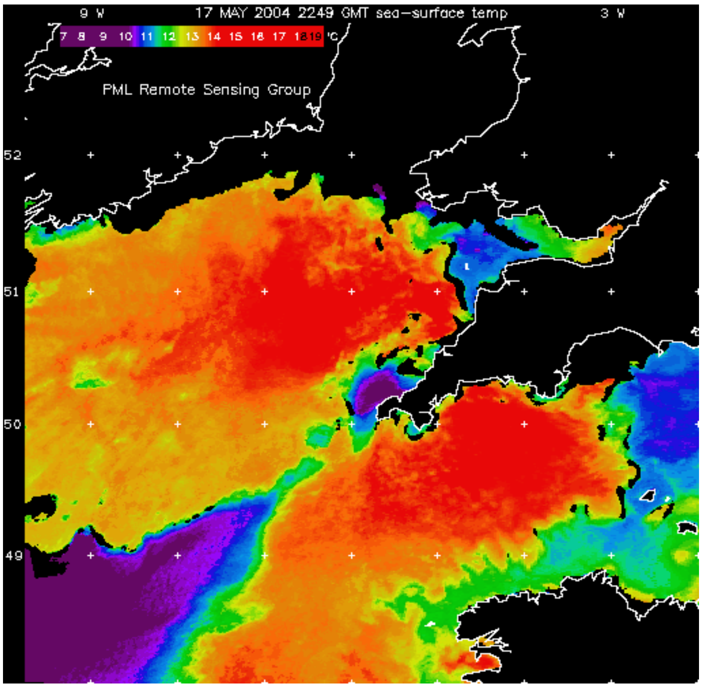
3.10 Other factors such as the tidal cycle may have an effect. It has been shown in other areas that extensive plankton blooms only occur during neap tides when water masses are relatively stable, but do require stronger spring tides to bring nutrients up to the surface, thus initiating plankton blooms (Pingree and others 1975). There is, of course, a time lag involved in this equation associated with the development of primary and secondary production. Periods of stronger winds may also disturb the equation, as even large channel fronts are still susceptible to meteorological factors, and wind stress plays an important role in the mixing of surface layers through disturbance of the surface layer (LeFevre 1986). Shorter spells of moderately increased wind can cause some surface mixing which can act constructively, as primary production becomes enhanced by a fresh nutrient supply. In the case of longer spells of much stronger winds, the resulting mixing will eventually limit activity by removing organisms from the photic zone (LeFevre 1986). This might well explain the lack of sightings in 2002 in the southwest, as strong winds affected much of the most productive areas throughout the survey period. In 2004 the survey vessel was in the area during a long spell of settled, high pressure weather, that would have allowed localised frontal systems to stabilise, accounting for the surface sightings in the second and third weeks of the survey.

3.11 A further factor that might shed light on the high level of sharks sighted within these sites is the relatively recent discovery that the basking shark employs habitat specific diel vertical migration (DVM) patterns (Sims and others 2005). 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*. 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 and others 2005). This may have important implications for the conservation of basking sharks in these often extremely busy areas with high levels of daytime surface traffic.

3.12 The survey vessel has a built in temperature sensor in the hull, enabling sea surface temperature (SST) readings to be accessed via the mechanism of the sonar unit at all times. During the surveys SST is recorded (along with all other environmental data) at 30 minute intervals, and provides a simple means of observing large (or small) temperature discontinuities associated with fronts. At the same time, a careful visual lookout is kept looking for the tell tale signs of fronts such as seabird activity, lines of surface debris and long, calm slicks on the water. This also enables areas of high levels of water mixing associated with strong tides, uneven bottom topography and downstream of headlands and islands to be watched for, with their associated lower SST relative to more stable areas of stratified water. Areas identified in this manner include the two key sites thus far identified – the Lizard and Lands End.

3.13 The use of Advanced Very High Resolution Radiometer (AVHRR) satellite images offers a means of assessing SST, the location of different water masses and therefore the location of front boundaries. Figure 3 shows well defined frontal activity close to the Lizard and Lands End peninsulas, during a period of surface sighted shark activity. False colour images of AVHRR recorded SST processed by the Remote Sensing Data Analysis Service at Plymouth Marine Laboratory (PML RSDAS) allow broad scale identification of mixed, stratified and frontal water within a study region, and have a spatial resolution of 1 km and a sensitivity of +/- 0.1K (Ashley 2003). Composite front maps (Miller 2001) processed by PML RSG offer a method to observe the temporal and spatial development, movement and breakdown of fronts with greater accuracy. Using this more accurate mechanism, when fine-tuned, may allow a means of predicting the likely presence of surface feeding basking sharks relative to frontal systems via remote sensing means (Ashley 2003).



Courtesy Plymouth Marine Laboratories Remote Sensing Data Analysis Service

Figure 3 AVHRR image of the western approaches during w/c 24/05/2004

3.14 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). For example, it has long been 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. During the survey period, a dramatic short-term shift in shark spatial distribution has been observed by this survey from the English Channel (after a period in that region of high abundance between 1997 & 2001), towards more northerly Latitudes (Figure 4). 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).

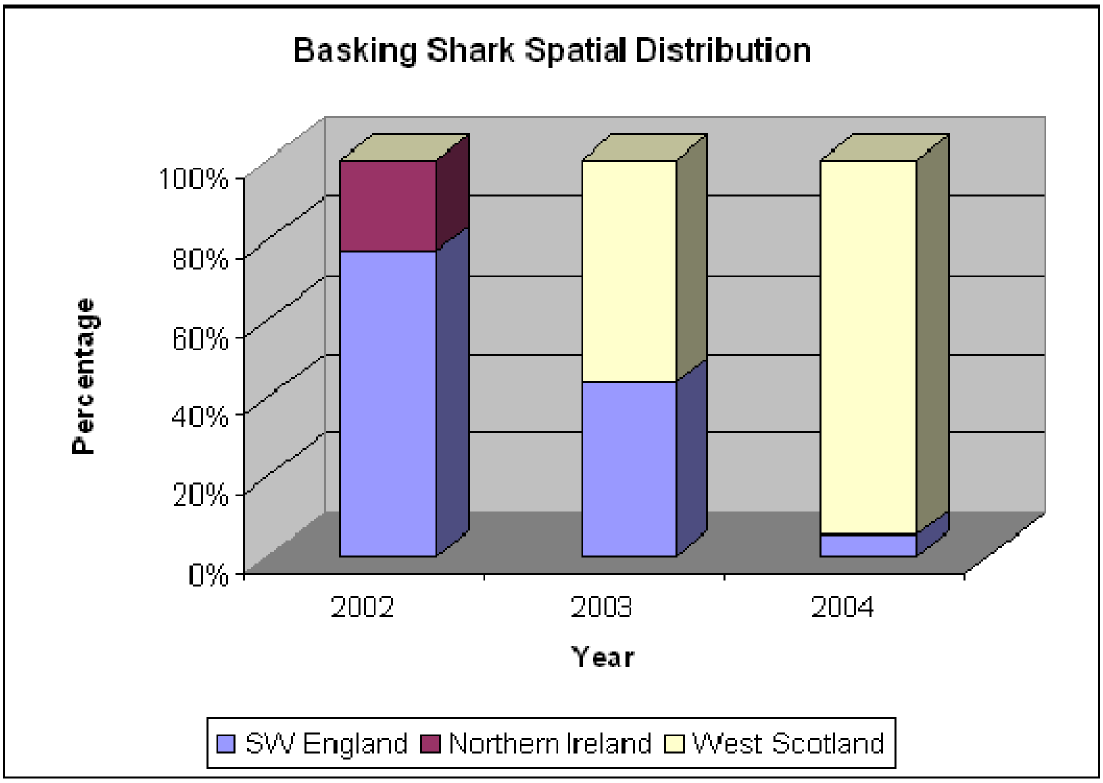


Figure 4 Basking shark spatial distribution 2002-2004

3.15 Recent tagging studies conducted with Pop-up Archival Tags (PAT) in the English Channel (Sims and others 2003b) have shown that one animal tagged exhibited potential philopatry, having covered a distance of over 500kms 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 1878 km in 77 days (Sims and others 2003b), so such journeys are perfectly within the normal seasonal parameters of a foraging basking shark.

The Conserving Endangered Basking Sharks Project (CEBS)

3.16 The line transect data gathered during the Wildlife Trusts Basking Shark Survey is clearly highly valuable, comprising the first long-distance effort corrected data for the waters around the western seaboard of England, Wales, Northern Ireland and western Scotland. However, by sharing this data with other researchers, we are able to multiply its value several times over, and work towards the eventual goal of population estimate for UK waters.

3.17 This is the case with the Wildlife Trusts' Basking Shark Project, where data (for all regions) was pooled with other Organisations within the CEBS project (URL: www.mba.ac.uk), led by Dr David Sims, NERC Research Fellow at the Marine Biological Association (MBA), Plymouth. Each of the contributing Organisations provided data or expertise from their particular field. The MBA team provide effort corrected line transect data, satellite tracking data and surface behavioural studies, the Marine Conservation Society provided data from their long running public sightings scheme, whilst the Hebridean Whale and Dolphin Trust and the International Fund for Animal Welfare provided more localised line transect data and photo-identification images. The Shark Trust provided photo-identification expertise, including data entry and management of the European Basking Shark Photo-identification project (URL: www.baskingsharks.co.uk).

3.18 The combination of these various strands of information offered a vital opportunity to work towards a number of goals in terms of establishing the distribution and abundance of the species. The inclusion of availability bias factors such as surface swimming duration and dive activity (Sims and others 2003a) was seen to be of critical importance, such that when combined with data from effort-corrected line transect work might permit a statistical model to be created enabling an overall population estimate to be postulated. Similarly, the use of mark-recapture data from photo-identification might also permit an alternative model with the same potential goal.

3.19 However, the recent discovery of reverse DVM patterns of plankton and its effect on the basking shark (Sims and others 2005) has had profound implications for the use of sightings data both in defining population distribution and abundance trends (Southall and others 2005). The indication is that it will be necessary to incorporate further bias-reduction according to habitat type (frontal areas to well-stratified zones) into analyses of survey data when attempting to estimate population abundance (Southall and others 2005).

Photo-identification

3.20 Photo-identification has the ability to compliment such high-tech approaches as satellite tracking in a low-cost benign way that can involve the public (Speedie, 2000). Photo-identification has already shown that it can be successfully employed to examine such awkward aspects of basking shark biology as growth rates (Sims, Fox & Speedie 2000b), which would otherwise be difficult examine with such a sizeable animal which cannot be kept in captivity. Photo-identification, when used as a mark-recapture model also has potential in the long term to offer an additional (or complimentary) means of developing a population estimate for the species in UK waters of abundance using the Peterson two-sample estimator. In order for this to be achieved, however, a large sample will be needed, and active encouragement is being given to public involvement. A training workshop is currently being developed for marine ecotourism operators accredited within the WiSe Scheme in the use of this simple, low impact methodology, together training in accurate data recording to foster a valuable contribution to science from these operators who may encounter significant numbers of sharks in the course of their cruises.

4 Protection of the basking shark

4.1 The species is listed as “**Endangered**” (EN A1ad) on the IUCN Red List of Threatened Species, largely reflecting the perception that numbers in the northeast Atlantic have been significantly diminished by two centuries of over-exploitation. Additionally the species received an Appendix 2 listing under the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES) in 2002, led by the UK Government, 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 finest areas in the world for surface sighting the basking shark, and it is, in fact, our biggest wild inhabitant.

4.2 The basking shark is currently protected within the 12 nautical mile limit of England and Wales under the Wildlife and Countryside Act (1981), and more recently the Countryside and Rights of Way Act (2000). It also has legal protection in the Isle of Man and the Channel Islands, but not, as yet in the waters of Northern Ireland or the Republic of Ireland. Recent satellite tracking surveys indicate that as the sharks can spend considerable amounts of time outside national limits (Sims and others 2003 a, Southall and others 2006), and may therefore be vulnerable to direct threats such as hunting prosecuted outside those limits, this current level of protection (up to 12 nm.) is wholly inadequate. This led to a successful proposal being submitted in 2005 to the Convention of Migratory Species of Wild Animals (the Bonn Convention) that as a highly migratory species the basking shark should be included on Appendix 1 and 2 of the convention. This convention aims to conserve migratory species throughout their range and lists migratory species that would significantly benefit from international co-operation (Doyle and others 2005).

4.3 Evidence of the need for further conservation measures directly related to the potential impacts of targeted fisheries comes from the latest International Council for the Exploration of the Seas (ICES) report recommending zero catch of basking sharks in the northeast Atlantic from 2005. The basking shark has also been included in the 2004 Initial OSPAR list of threatened and/or declining species and habitats (OSPAR 2004).

4.4 The basking shark is a priority Biodiversity Action Plan 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 Project aims to fulfil many of the actions outlined in the UK National Bio-Diversity Action Plan (BAP) for the basking shark, namely 5.4.1, 5.5.2 and 5.5.3, and link directly to 5.7.1. 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 Code of Conduct (Appendix 3).

Current threats to the basking shark

Bycatch

4.5 Threats to the species of an anthropogenic nature include bycatch, and basking sharks have been known to be caught in a wide diversity of fishing gear, including beam trawls, bottom and surface set gill nets, mid water trawls and fixed fishing gear ropes (Doyle and others 2005). The greatest danger appears to be from both surface set and bottom set gill nets in inshore waters, although this still remains poorly quantified. A study in Ireland estimated that between 77 and 120 sharks were caught annually in the Celtic Sea bottom set gill net fishery (Berrow 1994), with a further number of animals caught in surface set nets. Whilst there is a significant difficulty in evaluating levels of bycatch of the species due to the reluctance of fishermen to report bycatch, it would be valuable to have a greater understanding of the scale of the problem. Prior to the protection of the basking shark in 1999, some bycaught animals were sold through fish markets, allowing a very broad understanding of the numbers of fish caught, and the type of fishery involved. Now that there is no incentive to land bycaught sharks, even this limited insight is no longer available. As this obviously causes grave difficulties in evaluating the level of potential risk to the species from fisheries, Southall and others (2006) recommended that it be made a requirement to report incidental bycatch in European fishing zones.

4.6 Seaquest South West, the marine arm of the Devon and Cornwall Wildlife Trusts has a voluntary scheme for attending strandings, and has compiled a list of reports of stranded animals around the shores of Devon and Cornwall. Records from the same period as this study show a steadily increasing pattern of strandings being recorded, despite the parallel decline in surface sightings recorded over the same period (Appendix 4). This might imply that there are more sharks in the area (but not at the surface) or that instances of entanglement are increasing owing to sharks swimming lower in the water column, or more sharks are becoming entangled owing to an increase in fisheries effort. As many of these strandings occurred within the two key sites, or adjacent to them, it would be important to evaluate this phenomenon.

Ship strike

4.7 Ship-strike (i.e. collision between vessels and sharks) could become a significant factor, as an increasing number of small craft add to the existing small and large vessel commercial traffic that travel along the south coast of Cornwall. Anecdotal reports from anglers and yachtsmen, together with reports in the yachting press (Dunn, 2002) indicate that accidental collisions are an increasing problem, and pose a threat to both shark and vessel. This project has photographed a number of sharks over the years that display injuries consistent with collision with surface vessels, and recent reports from southwest England and Wales (Doyle and others 2005) and Ireland (Whooley pers.comm.) indicate that such events may be increasing. This might be exacerbated in the study site off the Lizard due to high levels of boat activity using the main route from the busy Port of Falmouth to Lizard Point through the waters off the Manacles and Black Head, with their associated levels of frequent frontal development, and consistent surface sightings of sharks by day identified in this report.

Marine ecotourism

4.8 Marine ecotourism has only recently become established in the region, but Cornwall has rapidly achieved public recognition as a popular venue for marine tours to view wildlife, not least the basking shark. Offering as it does a valuable opportunity to engage and educate the public about the marine world and its inhabitants, to add value to the visitor experience, and to develop new income streams for coastal communities, ecotourism seems to offer much. However, for ecotourism of this nature to have a long term future, it must put the welfare of the wildlife first, or the resource on which it depends may suffer, and sustainability will therefore remain an impossible goal.

4.9 In line with similar developments in other parts of the UK, the widespread adoption of Rigid Inflatable Boats (RIB's) as cost-effective marine ecotourism platforms within the south-west is ongoing. A wide range of other craft from ferries to classic charter yachts are also advertising wildlife watching opportunities within the region, and these will, of course, preferentially bias such voyages towards the most productive watching areas such as the key sites discussed in this report. To counteract any potential problems that this type of activity may create, the Project has created the WiSe Scheme (URL: www.wisescheme.org), the first UK based Training and Accreditation scheme directed at marine ecotourism, and it is hoped that any potential operators in west country waters would see the sense of availing themselves of the hard-won knowledge that WiSe can offer, so that any disturbance of wildlife may be minimised.

4.10 WiSe was originally piloted in the south west of England (Cornwall, Devon and Dorset), and has branched out into Wales, Scotland and Northern Ireland, Jersey and the Isle of Man. So far, nearly seven hundred and fifty individuals have attended courses, evidence of the demand for this type of activity.

Marine tourism

4.11 There may also be elements of marine tourism activity that may impact upon the animals, as visitors and residents may wish to view them (Speedie 2001a). The proximity of the sites identified in this study to busy tourist towns such as Falmouth and Penzance mean that basking sharks feeding or courting at the surface are under greater pressure from a local public aware of their seasonal presence in these waters. Compared with cetaceans, basking sharks are relatively difficult to disturb, although age may play a part, with juvenile sharks more easily affected (Wilson 2000), possibly due to their being less efficient at finding the densest patches of plankton. Field observations suggest that sharks only react to the approach of a vessel at a maximum distance of 10m, that angle of approach has an effect, that engine noise is a contributory factor to disturbance and that repeated approaches increase disturbance (Wilson 2000). This lack of reaction may mean that sharks simply have no time to react to the approach of surface vessels travelling at even modest speed, thus increasing their vulnerability to collision. For example, a vessel travelling at 6 Knots would cover the maximum reaction distance of 10m in 3 seconds, far too fast for a shark to crash dive, and far too short a distance for any vessel to take adequate avoiding action or stop.

4.12 There is also the question of unintentional harassment and disturbance. It should be noted that in most other areas of the UK there are increasing reports of this type of (potentially illegal) disturbance, and it should be envisaged that this might become a more widespread problem with more and more people taking to the water. Most disturbance or harassment is not deliberate, which does not mean that it may be dismissed as harmless - in the worst cases it most certainly may cause harm. Time and energy spent in public awareness raising, to highlight the presence of the basking sharks in West Country waters may be expected to perform a valuable educational role, protecting both the shark and the general public from disturbance or even injury.

4.13 A recent study in the southwest of England (Kelly, Glegg & Speedie 2004) concluded that levels of disturbance and harassment to marine mammals and sharks in coastal waters of the South West peninsula do not appear to be changing or increasing to any significant degree. However, this was tempered by the likelihood that any such incidents may be unreported owing to a lack of clarity at all levels of the current legislation appertaining to such species, and a lack of co-ordination and consensus amongst agencies and practitioners working within the field. Greater public awareness of the existence of legally protected status of the basking should therefore be a priority, accompanied by a widely publicised chain of command for reporting any such incidents, combined with a viable means of enforcing the law (Speedie 2001b). A further educational element, targeting the boat owning public has been developed by the WiSe Scheme and the Royal Yachting Association’s Green Blue environmental initiative as part of an educational CD-ROM circulated to all registered RYA Instructors, and all Yacht clubs and watersports societies. In addition, WiSe has developed a stand alone 12 minute DVD (The WiSe Way To Watch Wildlife) which covers a wide range of marine life, including the basking shark, advising on ways for owners of pleasure craft to minimise disturbance, harassment and collisions, and fostering a spirit of passive watching of these creatures. 15000 copies of this DVD have been made available for circulation around the UK, with special emphasis on sensitive areas. To this end 1000 copies have been made available for Cornwall, and 1000 copies for Devon, a reflection of their importance for the basking shark, as well as other valued species.

Climate change

4.14 The final threat to the basking shark in all UK waters may be the most difficult to quantify, and also the most difficult to counteract - climate change.

4.15 It has been established that the predominant zooplankton in samples of plankton collected near feeding basking sharks in the Channel off Plymouth were calanoid copepods, principally *Calanus helgolandicus* (Sims & Merrett 1997), and it has also been shown that the sharks exhibit selective foraging behaviour for their favoured prey associated with tidal fronts (Sims & Quayle 1998). Indeed the latter study postulated that the basking shark might be considered as a useful detector of the distribution, density and characteristics of the two *Calanus* species in fronts, especially in relation to oceanographic and climatic (notably the state of the North Atlantic Oscillation) fluctuations that affect the abundance of *Calanus*.

4.16 Recent research suggests that although sharks forage selectively for zooplankton at small spatial scales, other factors may influence movements and distribution of sharks over large spatial scales, such as short and longer term fluctuations in Sea Surface Temperature (SST) and the NAO Index (Cotton and others 2005).

4.17 The North Atlantic Oscillation (NAO) is a large-scale decadal atmospheric phenomenon, relating to the difference in intensity between the low pressure centred around Iceland and the high pressure centred around the Azores to the south in winter and early spring. The variation in intensity will dictate the strength and location of the westerly winds that predominate in the North Atlantic. A positive NAO Index (NAOI) indicates stronger westerly winds further north, bringing warmer and wetter than average weather. A negative NAOI means weaker westerly winds that are displaced further south (WWF-UK, 2005).

4.18 A positive NAO Index with a one-year time delay has a favourable relationship with the abundance of the warm temperate copepod *Calanus helgolandicus*, whilst at the same time diminishing abundance of the cold-water temperate *Calanus finmarchicus*, both in the North Sea (SAHFOS Annual report 2004) and the Celtic Sea (Nash & Geffen, 2004), with *C finmarchicus* moving further North, and *C helgolandicus* becoming the more abundant species. This displacement northward (over the last forty years) has been estimated to represent a movement in the order of 10º of latitude (Beaugrand and others 2002, Edwards and Johns 2005). However, in both areas the overall trend in copepod abundance is down (Reid and others 2003; Edwards & Richardson 2002; and Nash & Geffen 2004).

4.19 In addition, there is growing concern over the potential for mismatch in timing and decoupling of phenological relationships, that might in turn have effects at an ecosystem-level (Beaugrand and others 2003; Edwards & Richardson 2004). This may already be underway in terms of changes in seasonality and growth of phytoplankton (WWF-UK, 2005), with the normal spring and late summer blooms becoming less well defined and the late summer bloom moving to earlier in the summer by four to six weeks (Beaugrand and others 2003; Edwards and Richardson 2004). Both factors might in the longer term affect basking shark populations and their overall distribution.

4.20 Cotton and colleagues (2005) demonstrated for the first time 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 the means by which they orientate themselves towards the most abundant prey.

4.21 A study of the Achill Island fishery in the West of Ireland suggested that the decline (and eventual cessation) of that fishery might not solely be due to over fishing of a discrete local population, but might have also been caused by a parallel decline in *Calanus* within the area over the same period (Sims & Reid 2002) it has also been suggested in the same study that there was a considerable increase in the Norwegian fishery during that period that might suggest a spatial shift northwards in response to the movement of zooplankton prey.

4.22 Given the breadth and depth of new knowledge concerning the sharks’ utilisation of thermal cues as a means of orienting itself to high levels of available prey (e.g. Sims and others 2003b, Cotton and others 2005), and the need for behavioural modification in fish species in response to climate change (Wood & McDonald 1997), these factors would suggest that the basking shark might be a loser in the current period of rising temperatures, at least within localised boundaries.

4.23 The results obtained within our larger study (English Channel - Outer Hebrides 2002-2004) displayed a rapid, progressive and substantial spatial shift northward (Figure 4), at least in terms of surface sighted sharks. It is well known that local variations related to the sharpness of fronts, their persistence and strength play a key role in determining the level of surface sighted sharks (Sims, 1997, Sims and others 2005), so this may not be of major importance when viewed in isolation. In the longer term, however, if frontal development is weakened, due, for example, to the increased levels of stratification that have been suggested will accompany climate change (WWF-UK, 2005), then this might have more substantive implications for shark distribution. The question therefore might be whether shifts such as that observed during the larger study might become more than a short-term natural variation, or part of a longer term more substantive trend driven by climate change. Certainly the overall reduction of available preferred zooplankton assemblages around the UK does not bode well for any planktivorous species, and, in fact, the overall marine food web with which they are so inextricably linked.

4.24 However, as our study shows, the two sites identified currently remain uniquely important regionally for the species, both when surface sighted shark numbers within the larger region are high (1999-2001), or when the peak has passed and a more substantial spatial shift in distribution of surface sighted sharks has taken place (2002-2004). Given the high levels of courtship behaviour and other activity believed to be related to sexual activity such as breaching observed during this study, as well as young of the year sharks, we believe that these sites still represent small-scale localised sites of significant importance for the future viability of the species, at least within the context of the western Channel.

4.25 Although many adverse effects have been suggested with regard to likely impacts of climate change in the future, and have been discussed here, one of the major factors that cause these sites to be so important is unlikely to be affected, i.e. tidal flows. Shelf Sea Currents may not be largely affected, so there should be little significant impact on the strength or patterns of tidal currents (WWF - UK, 2005).

5 Conclusions and recommendations

5.1 The basking shark occupies a unique position within our national marine fauna, our waters being important from the point of view of surface sighted sharks - few other countries can boast of sustaining the level of sightings recorded in Britain each year.

5.2 As a result, the shark has benefited from an increasing level of protection within the UK, and the UK Government has lead the world in seeking further protection on a regional and global scale through a listing under Appendix 2 of CITES, and Appendix 1 and 2 of the Convention for Migratory Species.

5.3 The conservation measures established so far have largely been driven by the relative scarcity of the basking shark, recognising the depleted status of the population in the Northeast Atlantic after sustained hunting pressure during the last century, 81,639 recorded sharks being killed in the region between 1952 and 2004 according to ICES statistics. These measures also recognised the biological factors that would mitigate against rapid recovery in the regional basking shark population - due to its depleted numbers, late maturity (c. 20 years) and low fecundity (c. 5-6 pups every 3 years).

5.4 However, no attempt has been made so far to establish site specific protection measures for the species. The results achieved in this study suggest that this should now be considered, at least in areas where breeding population regularly frequent, and identifiable threats of an anthropogenic nature could cause an impact on these vital and vulnerable groups.

5.5 This study has identified 2 sites in the western English Channel, Lands End and the Lizard peninsula - over six years of study that consistently show high levels of surface sightings during both high and low periods of abundance. Both sites are also areas in which above average levels of human activity, both commercial and leisure based take place, and where reproductive type behaviour has consistently been recorded. As such we believe the following protective type measures be considered within these key sites:

1) Educational measures targeted at Masters of commercial and leisure craft navigating through these areas, informing them that surface aggregations of basking sharks may be encountered by day at, or just below, the surface within these areas on a seasonal basis. This might take the form of information supplied via HM Hydrographic Office such as Notices to Mariners, electronic or paper charts, pilot books, nautical almanacs or harbour guides. Coupled to a campaign targeted at the leisure craft user via training schemes such as those operated by WiSe or the Royal Yachting Association, such measures might greatly reduce the levels of surface collision, safeguarding both vulnerable sharks and small craft and their occupants.
2) A joint evaluation with local inshore fishermen to establish annual levels of shark bycatch within the sites, and to see whether there are particular localities or types of gear that are implicated. Agreement might then be sought on voluntary avoidance of setting such gear within those localities on a seasonal basis, or when high levels of sharks are recognised to be present, to reduce incidental bycatch. This might follow the model of the St Ives Bay Gillnet Fishery initiative, where a temporary closure (21 days) of the fishery is enacted when the deaths of birds exceeds a predetermined level over any consecutive five day period. A benefit for fishermen would be that a reduction in the amount of lost or damaged nets caused by basking sharks could be avoided.
3) Further emphasis on the reduction of potential impacts of commercial marine ecotourism activities, such as speed reduction in the most critical areas on a seasonal basis. This might

most effectively be carried out via the existing mechanism of the WiSe Training and Accreditation Scheme.

4) Promotion of the Shark Trust Basking Shark Code of Conduct (URL: www.sharktrust.org), and the Marine Conservation Society (URL: www.mcsuk.org) public sightings recording scheme and the Cornwall Wildlife Trusts Seaquest project to encourage monitoring of the local population (URL: www.cornwallwildlifetrust.org.uk), and greater public awareness off the presence of sharks within these important sites.
5) Consideration should be given to the potential application of site-based protection measures for the key sites. The Wildlife Trusts are pressing for the forthcoming Marine Bill to introduce two new types of Marine Protected Area: Nationally Important Marine Sites and Highly Protected Marine Reserves, both of which may be useful tools for basking shark conservation, especially within sites that sites that record high levels of surface sightings.

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Appendix 1 Wildlife Trust Basking Shark Survey - Cruise Log

CRUISE ROUTE: …………………………………………………………………………. DAY/MONTH/YEAR: ……………………

VESSEL: ………………………………. OBSERVATION HEIGHT: ……………………… VESSEL SPEED: ……….

OBSERVER NAME: …………………. CONTACT ADDRESS: …………………………. TRANSECT NUMBER: …………………

Table A Wildlife Trust Basking Shark Survey - Cruise Log

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

Appendix 2 Basking Shark Sighting Form

Table B 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:				

Appendix 3 WiSe BASKING SHARK CODE OF CONDUCT

Basking sharks are large plankton-eating sharks. They can grow up to 11m (35ft) long and weigh over 5 tonnes. They are typically seen feeding near the surface individually or in groups in the UK from May to August. When feeding their mouths are agape and an average size basking shark will travel at about 5 kph (2-3 mph) - too fast for a snorkeller to keep up with them. They are however capable of much greater speeds and can even breach (jump clean out of the water) - a phenomenon both people and vessels should avoid!

Vessels

NEVER CHASE BASKING SHARKS, NEVER DRIVE ANY CRAFT DIRECTLY TOWARDS THEM, OR ALLOW SEVERAL VESSELS TO SURROUND THEM AS SUCH ACTIONS WILL PROBABLY FRIGHTEN THEM AND MAKE THEM DIVE.

BASKING SHARKS CAN BE SENSITIVE TO ENGINE NOISE - THE LESS THE BETTER. WHILST OBSERVING BASKING SHARKS DO NOT APPROACH WITHIN LESS THAN 100M OF THE ANIMAL(S). IF YOU FIND YOURSELF CLOSE TO BASKING SHARKS, THE KEY RULE IS TO REMAIN CALM AND QUIET, UNTIL THEY ARE CLEAR OF YOUR VESSEL. BASKING SHARKS AT THE SURFACE OFTEN FEED IN RANDOM OR CIRCULAR PATTERNS, AND SO THEIR MOVEMENTS CAN BE DIFFICULT TO PREDICT. TAKE TIME TO OBSERVE THE DIRECTION(S) OF MOVEMENT OF THE BASKING SHARKS AND THEN QUIETLY POSITION THE VESSEL ALONGSIDE THEIR ANTICIPATED COURSE FOR A SAFE AND ENJOYABLE VIEW.

BOATS SHOULD BE OPERATED UNDER SAIL OR AT THE LOWEST POSSIBLE ENGINE SPEED WHEN WITHIN 100M OF BASKING SHARKS TO MINIMISE DISTURBANCE. REMEMBER: FOR EVERY SHARK VISIBLE ON THE SURFACE THERE ARE LIKELY TO BE MANY MORE THAT ARE SUBMERGED. NO VESSEL SHOULD TRAVEL AT SPEEDS ABOVE 6 KNOTS WITHIN 100M OF BASKING SHARKS AND ALL NOISE SHOULD BE KEPT TO A MINIMUM.

BOATS TRAVELING IN AREAS THAT BASKING SHARKS ARE KNOWN TO FREQUENT SHOULD REDUCE THE POSSIBILITY OF A 'BOAT STRIKE' AND THE EXTENT OF ANY POTENTIAL DAMAGE TO SHARK AND BOAT/PEOPLE BY SLOWING DOWN AND KEEPING A GOOD LOOKOUT. VESSELS OPERATING IN AREAS WHERE BASKING SHARKS CAN BE SEEN ON THE SURFACE SHOULD REDUCE SPEED TO A MAXIMUM OF 6 KNOTS. JET-SKIS ARE INCOMPATIBLE WITH BASKING SHARKS AND SHOULD STAY AT LEAST 500M AWAY.

AVOID PAIRS OR LARGE NUMBERS OF SHARKS FOLLOWING EACH OTHER CLOSELY. THIS MAY BE COURTING BEHAVIOUR AND THEY SHOULD NOT BE DISTURBED. SIMILARLY, BOATS SHOULD ALWAYS REMAIN ON THE PERIPHERY OF ANY GROUPING AND NOT MOVE IN BETWEEN ANIMALS.

PLEASE NOTE THAT UNDER UK LAW, IT IS AN OFFENCE TO KILL, INJURE OR TAKE ANY BASKING SHARK; OR TO INTENTIONALLY OR RECKLESSLY DISTURB ANY BASKING SHARK. UNDER THE NEW CRoW ACT, ANY PERSON COMMITTING SUCH AN OFFENCE COULD FACE UP TO 6 MONTHS IN PRISON.

Snorkellers/Divers

IT IS NOT ADVISABLE TO SWIM WITH BASKING SHARKS, BOTH FOR YOUR SAFETY AND THE SAFETY OF THE SHARKS. IF YOU DO DECIDE TO ENTER THE WATER, PLEASE TAKE NOTE OF THE FOLLOWING PRECAUTIONS:

- **DO NOT TOUCH BASKING SHARKS.**
- **DO NOT SWIM TOWARDS THEM IF THEY ARE NEAR YOU.**
- **DO NOT ENTER OR STAY IN THE WATER IF THE VISIBILITY <4M.**
- **NO MORE THAN 4 PEOPLE IN THE WATER WITHIN 100M OF A BASKING SHARK AT ANY TIME.**
- **GROUPS MUST STAY TOGETHER AND SHOULD IDEALLY REMAIN ON THE SURFACE.**

Basking sharks are huge, powerful, but shy wild animals. Do not try to touch them or swim towards them when they are near you - this is likely to scare them away, or may lash out with their tail. If you stay calm, still, and observe, there is a good chance they will come to you and also come back again! Basking sharks may occasionally trail behind them the likes of fishing line, net or rope. These can potentially ensnare the unwary and the result in such cases is almost certain to be death by drowning.

The plankton blooms basking sharks feed on seriously reduce water clarity. As such divers are particularly vulnerable to being surprised by meeting an animal in a thick plankton bloom and emergency action to avoid a collision might be required by all parties. Such a situation would not only constitute disturbing basking sharks (harassment) but is also potentially very dangerous to people.

The recommended method of observing basking sharks is to check the shark's direction of travel and get the group of not more than four snorkellers in the water 100 metres in front of the animal. As the shark approaches the group should stay close together and calmly fin to remain in front but slightly to one side of the line of travel and start to gently swim in the direction of travel. This will allow maximum opportunities for observation. The shark will swim faster than you so you will soon lose contact, so when this happens and the shark goes past, move away from the tail.

Many people may want to repeat the experience. If this is to be done care and circumspection must be used to avoid frightening or harassing the shark/s. At all times the boat should remain 100m from the sharks and we recommend no more than one ‘repeat observation’ per shark (whether the same group or another). Please note that calmly snorkelling on the surface is considered the optimum basking shark observation method with regards limiting any potential disturbance to basking sharks and minimising risks to people.

Never forget that mature basking sharks are shy, powerful and very large wild animals!

Appendix 4 List of stranded basking sharks in Cornwall

Table C List of stranded basking sharks in Cornwall

Date	Length	Position	Sex	Coast	Gear
14/5/99	4.5m	Duporth Beach	M	DOD	Net
15/5/99	8m	Polkirt Cove	M	DOD	Net
28/7/99		Boat Bay, Harlyn		NC	PR
30/3/00	3m	Boobys Bay		NC	
18/6/00	7.6m	SE of Penberth SW 3620		LE	PR
3/10/00		Black Rock SS2629			
30/5/01	4m	Black Head		LIZ	
14/4/02	9m	Pentreath SW 694127		LIZ	
03/6/02	3m	Booby's Bay		NC	
15/7/02		Portreath		NC	PR
10/6/03		Falmouth docks		LIZ	
13/7/03		Falmouth - same as above?		LIZ	
31/8/03		Porthcothan		NC	
25/5/04		Coverack		LIZ	PR
27/5/04	4.8m	Carne Beach	F	LIZ	
28/5/04		St Just in Roseland	F	LIZ	
09/6/04		Cape Cornwall		LE	
15/6/04	6.1m	Perranporth		NC	
21/4/05		10m S of Lizard		LIZ	PR
16/7/05		Perranporth	F	NC	
03/8/05	5.8m	Porthtowan		NC	
11/8/05		Boscastle		NC	

Appendix 5 Extracted GIS map for whole region 2002-2004

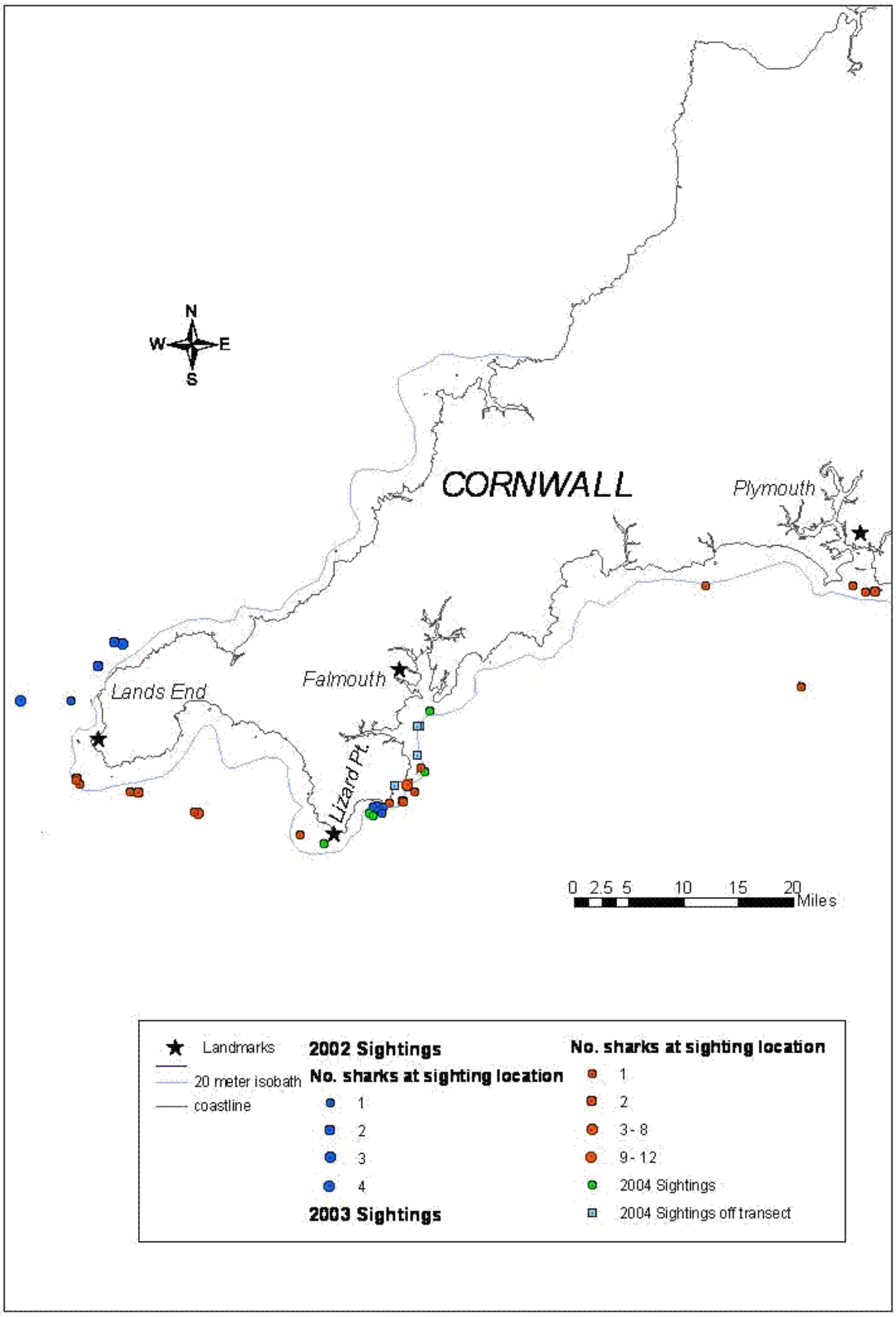

Figure A Extracted GIS map for whole region 2002-2004

Appendix 6 Legend for Lizard and Lands End GIS maps (Appendices 7 & 8)

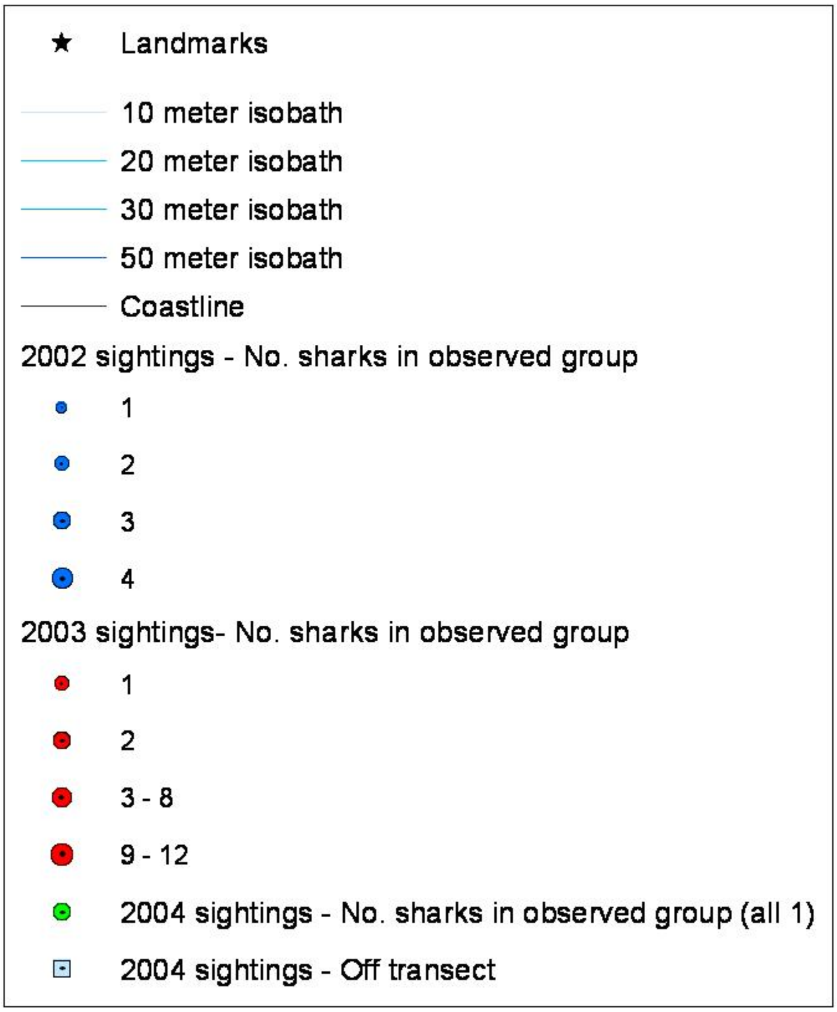

Figure B Legend for Lizard and Lands End GIS maps (Appendices 7 & 8)

Appendix 7 Lizard close-up extracted GIS map

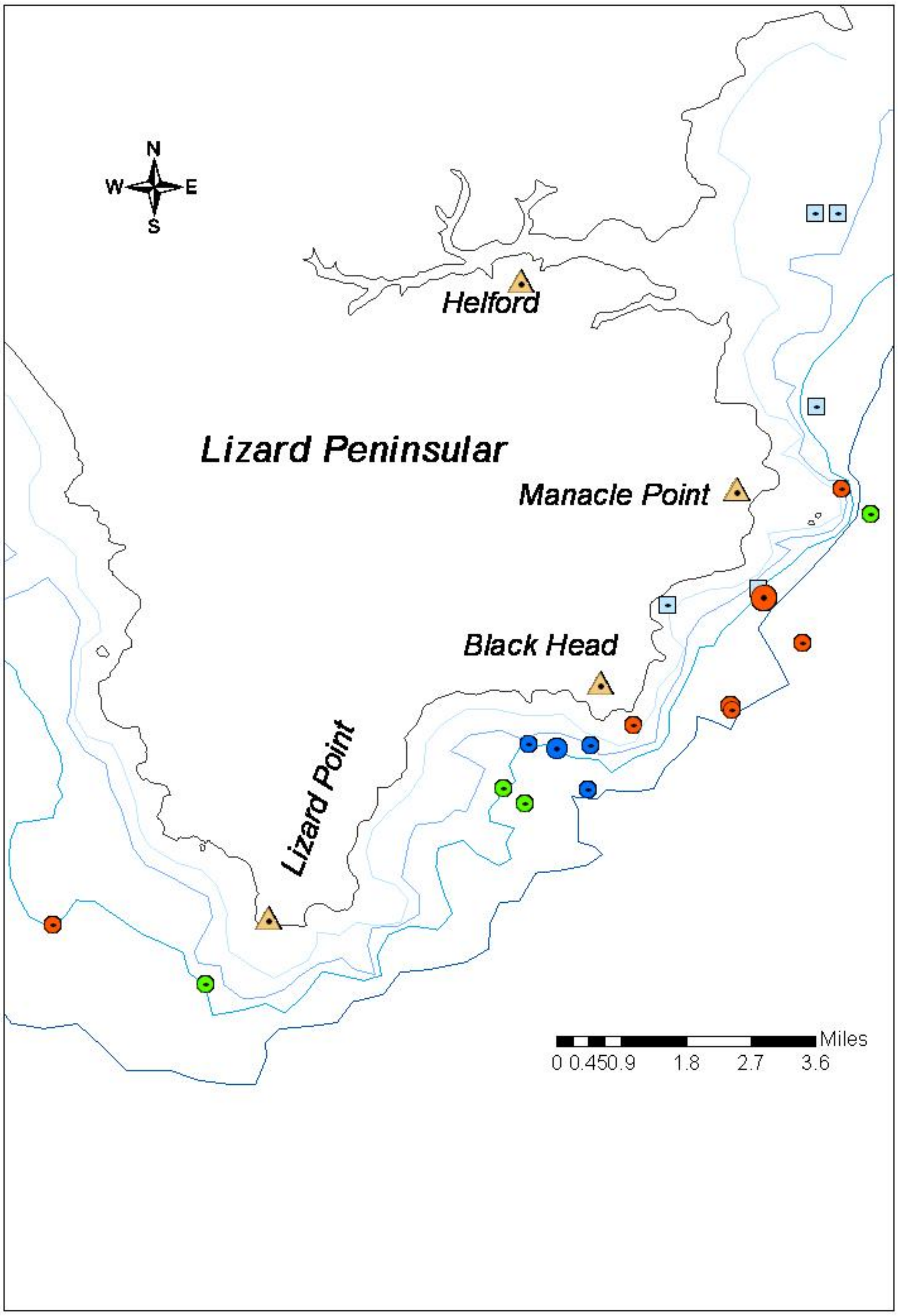

Figure C Lizard close-up extracted GIS map

Appendix 8 Lands End close-up extracted GIS map

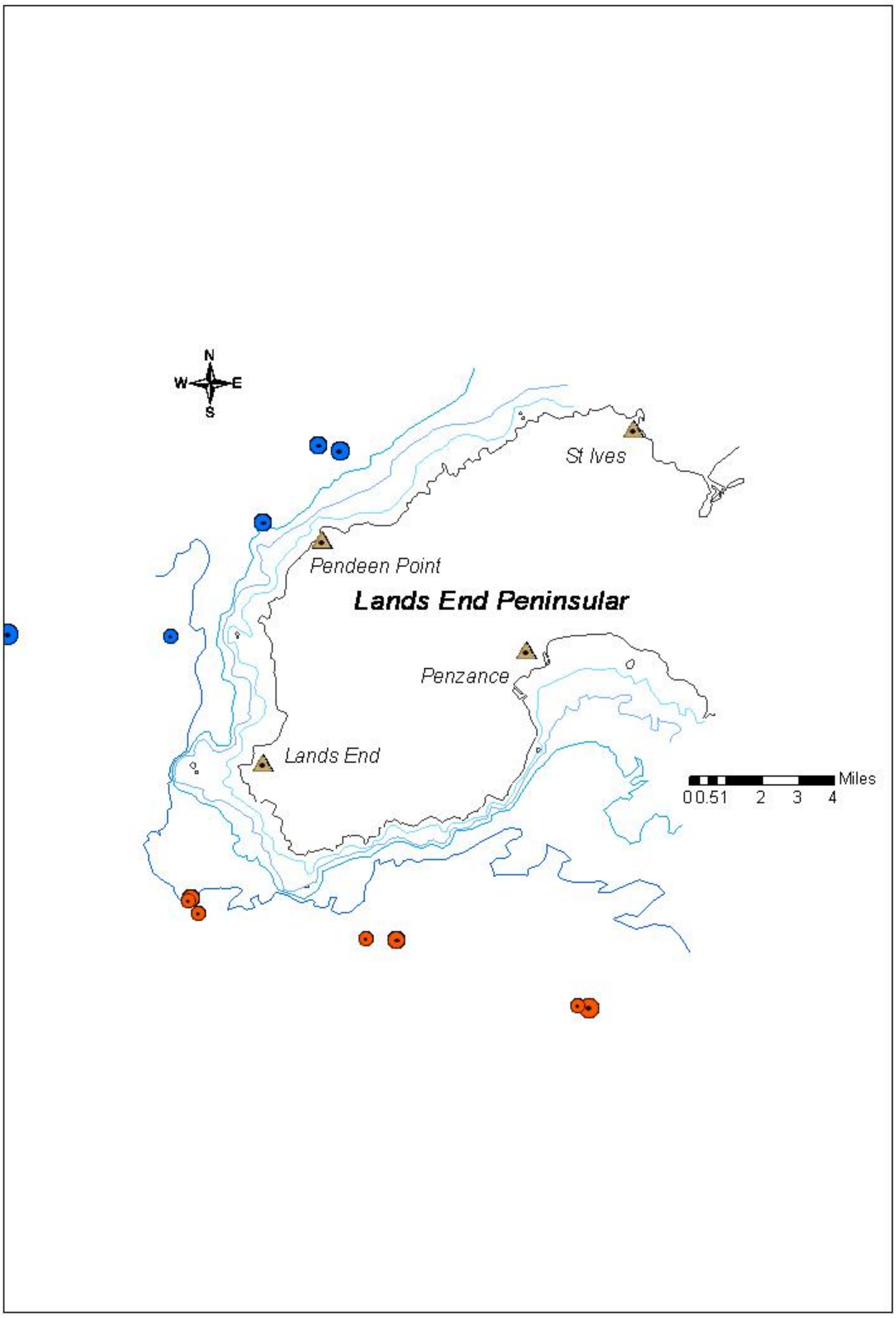

Figure D Lands End close-up extracted GIS map

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