ARGYLL ARRAY WINDFARM

BASKING SHARK DRAFT CHAPTER FOR ENVIRONMENTAL STATEMENT

CORMAC BOOTH, STEPHANIE KING AND CLAIRE LACEY

07 January 2013

Report Code: SMRUL-WSP-2013-001

This report includes contributions from APEM Ltd: Victoria Alle, Heather Webb, Dr Christopher Cesar and Mark Jowett

This report is to be cited as: Booth, C.G., King, S.L. & Lacey, C. (2013). "Argyll Array Wind farm Basking Draft Chapter for Environmental Statement". SMRU Ltd report number SMRUL-WSP-2013-001. January 2013 (unpublished).

Approved by: Cormac Booth, Project Manager

CONTENTS

1 Introduction ... 6

2 Ecology & Conservation status ... 7

2.1 Geographic distribution ... 7

2.2 Conservation status ... 7

2.3 Feeding, foraging and diet ... 8

2.4 Reproduction ... 9

2.5 Legislation ... 10

3 Site specific review of existing data/information ... 10

3.1 Visual surveys of basking sharks – a cautionery note ... 10

3.2 Location and usage of sites in Scotland by basking sharks (Nicholson et al. 2000) ... 11

3.2.1 Overview ... 11

3.3 Scottish National Heritage West Scotland basking shark survey (Speedie et al. 2009) ... 12

3.3.1 Introduction and methodology ... 12

3.3.1 Results ... 13

3.4 Marine Conservation Society: Basking shark watch reports ... 15

3.4.1 Introduction ... 15

3.4.2 Results ... 15

3.5 Community Sightings Programme (Hebridean Whale and Dolphin Trust 2011) ... 16

3.5.1 Introduction ... 16

3.5.2 Basking shark sightings ... 17

3.6 Current research ... 18

3.6.1 Scottish Natural Heritage and University of Exeter tagging study ... 18

3.6.2 University of Aberdeen Genetics work (Reviewed in Drewery 2012) ... 18

3.6.3 Plymouth Marine Laboratory & Marine Biological Association (reviewed in Drewery 2012) 18

4 Review of Argyll Array Survey Data ... 18

4.1 Introduction 18
4.2 Survey methodology 20
4.3 Data analysis 21
4.3.1 Investigating basking shark key environmental factors 21
4.3.1.1 *Statistical analysis* 21
4.3.1.2 *Sources of covariate data* 22
4.3.1.3 *Investigating collinearity* 23
4.3.1.4 *Model Selection* 24
4.3.2 Argyll Array basking shark abundance estimation 24
4.3.2.1 *Distance at detection* 24
4.3.2.2 *Detection function* 25
4.4 Visual survey Results 26
4.4.1 Basking shark encounter rates 26
4.4.2 Basking shark size and group size 29
4.4.3 Basking shark key environmental factors 29
Spatial distribution of basking sharks 31
4.4.4 Argyll Array basking shark abundance estimation 31
4.4.5 Review and identification of potential limitations of the Argyll Array survey data 32
4.4.5.1 *Temporal coverage* 32
5 Impact assessment 33
5.1 Assessment methodology 33
5.1.1 Impact scores 34
5.1.1.1 *Legislative sensitivity index* 34
5.1.1.2 *Population Status Sensitivity Index* 36
5.1.1.3 *Severity of effect* 37
5.1.1.4 *proportion of population affected* 38
5.1.1.5 *Assessing Impact scores* 39

5.1.2 Certainty ... 40
5.1.3 *Example: Basking shark- Collision – Increased vessel presence* ... 40
5.2 Impact scores for Argyll Array wind farm ... 42
5.2.1 Construction phase ... 43
5.2.1.1 *increased vessel activity – Collision Risk & Disturbance* ... 43
Assessment of Significance ... 44
Mitigation ... 44
5.2.1.2 *Non-toxic contamination – Increase in suspended sediment* ... 44
Assessment of Significance ... 45
5.2.1.3 *Increased anthropogenic noise & vibration: Overview* ... 45
Increased anthropogenic noise & vibration: Piling ... 46
Increased anthropogenic noise & vibration: Vessel noise ... 46
Assessment of Significance ... 46
Mitigation ... 47
5.2.1.4 *Entanglement: Interaction with infrastructure (inter-array & export cabling)* ... 47
Assessment of Significance ... 47
5.2.2 Operation phase ... 48
5.2.2.1 *Presence of turbines* ... 48
Assessment of Significance ... 48
5.2.2.2 *Increased vessel activity* ... 49
Assessment of Significance ... 49
Mitigation ... 49
5.2.2.3 *Increased anthropogenic noise & vibration* ... 49
5.2.2.4 *Electromagentic Field (EMF) emissions* ... 49
Assessment of Significance ... 50
5.2.2.5 *Toxic contamination* ... 51
Assessment of Significance ... 51

Mitigation 52
5.2.3 Decommissioning phase 52
6 References 53

1 INTRODUCTION

ScottishPower Renewable Energy Limited is proposing to develop the Argyll Array offshore wind farm, located 5 km off the south west coast of Tiree in the Scottish Inner Hebrides. The original development site covered an area of 361 km^2, occupying waters ranging between 0 and 45 metres depth, though more recently this has been scaled down by ~40% (Figure 1). Argyll Array is considered to be of strategic national importance to the UK and will contribute both to renewable energy targets and the emergence of a novel industry considered to be of considerable economic potential (ScottishPower Renewables 2010).

The potential environmental effects of the Argyll Array development will be identified as part of the Environmental Impact Assessment (EIA), and the developer will seek to avoid, reduce or offset any adverse effects through mitigation measures. The EIA process runs in conjunction with the design of the project such that once potential impacts are identified, the design of the project will be adjusted and mitigation measures proposed accordingly.

An integral part of any EIA is an appreciation of the baseline status of the ecology within the area, including designated species and/or habitats. This document presents a review of current knowledge regarding the basking shark *Cetorhinus maximus* in the vicinity of Argyll Array; including an overview of the species biology, ecology and conservation status, as well as a more detailed review of several pieces of recent and current research. Additionally, the findings of the boat-based surveys commissioned for Argyll Array in relation to basking shark sightings patterns. Using the review and the analyses herein, a detailed impact assessment for basking sharks around the Argyll Array wind farm development is presented.

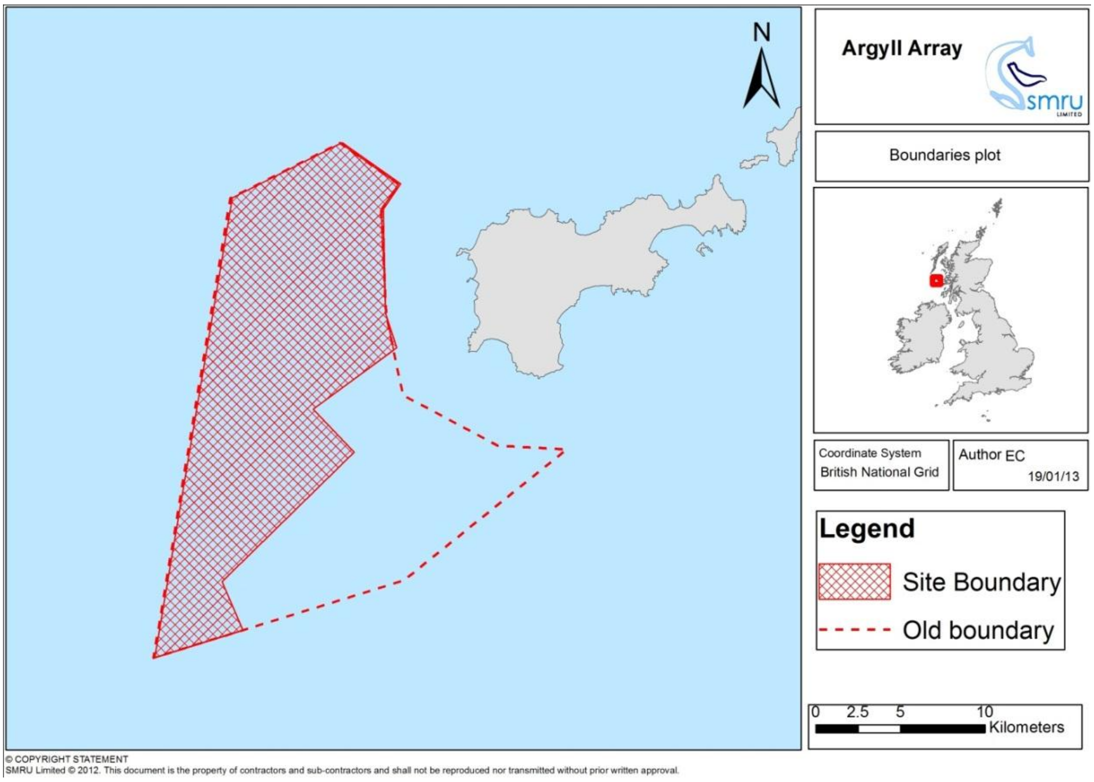

Figure 1 - Site boundaries for the Argyll Array.

2 ECOLOGY & CONSERVATION STATUS

The basking shark (*Cetorhinus maximus)* is the world's second largest fish and one three species of shark known to filter seawater for food. It has a unique feeding strategy which dominates all aspects of its ecology and life history (Sims 2008). Many aspects of basking shark life history and biology are currently poorly understood and this review aims to summarise the current available knowledge on the species globally and with specific reference to the Argyll Array site.

2.1 GEOGRAPHIC DISTRIBUTION

The basking shark is a cold water, pelagic species with circumpolar distribution (Compagno 2001; Gore et al. 2008). In North Atlantic waters, the species is recorded from the Gulf of Maine, Iceland and Russia in the north and as far south as Senegal and Florida (Compagno 2001).

Sightings of most individuals are made in shallow, coastal waters, but sightings from offshore cetacean surveys, pelagic driftnet records and more recent telemetry studies suggest that basking sharks also utilise deeper, offshore waters, and it is likely that this is could be a function of observer effort (eg: Compagno 2001; Southall et al. 2005; Gore et al. 2008).

UK waters contain several "hotspots" for basking sharks – areas where sharks can be seen regularly at the surface - predominantly on the west coast, notably the Hebridean Sea, Clyde Sea, Irish Sea and close inshore around the coasts of Devon and Cornwall (Southall et al. 2005; Witt et al. 2012). More specific discussion of those relevant to this review is included in section 3.

Whilst individual sharks may remain in one place for many days, telemetry data has shown that sharks are also capable of long-range movements, moving rapidly between regions over periods of a few weeks (Sims et al. 2003), movements which were shown to be driven principally by foraging to locate areas with the most abundant zooplankton (Sims et al. 2006). One individual was even found to conduct a transatlantic journey, travelling 9,589km between the UK and Canada (Gore et al. 2008). Sharks tracked around the UK mixed feely, suggesting no evidence of population differentiation at a local spatial scale, although there is some evidence for a degree of regional philopatry, with individuals returning to a region after long distance movements elsewhere (Sims et al. 2003, 2005).

2.2 CONSERVATION STATUS

Basking sharks have undergone widespread historic exploitation in the northeast Atlantic and are of conservation concern (Witt et al. 2012)

The population abundance and density of basking sharks in any sea area of the world is not precisely known (Sims 2008). Aerial surveys flown in New England between 1978 and 1982 (Kenney et al.

1985) and the Californian coast between 1962 and 1985 (Squire 1990) did produce abundance estimates for these regions. However, notwithstanding the low levels of precision in these estimates and potential issues regarding the applicability of the methodology to this species, these data are now in excess of 25 years old so unlikely to reflect the current state of the basking shark population.

The IUCN Red list lists the basking shark is listed Vulnerable worldwide, with the Northeast Atlantic population listed as Endangered. These assessments are based primarily on past records of rapidly declining local populations of basking sharks as a result of short-term fisheries exploitation and very slow population recovery rates.

Records of basking shark exploitation by organised fisheries dates back to the 18th century and continued in some areas until as late as the 1980's. In the North east Atlantic, fisheries were undertaken in Scotland, Ireland and Norway (Kunzlik 19988; cited in Sims 2008). Landing records indicate the removal of over 105,730 sharks within the 51 year period to 1997 (Sims 2008). The absence of basking shark abundance estimates makes it difficult to quantify what proportion of the available population this may have represented.

Recently it has been reported that basking sharks have the lowest level of genetic diversity of any shark with an effective genetic population size of only 8200 individuals (Hoelzel et al. 2006). The effective genetic population size is the average size of a population in terms of the number of individuals that can contribute genes equally to the next generation and is always either equal to or less than the absolute population size. Coupled with its low recovery rate it is therefore very vulnerable to any form of exploitation or impact.

2.3 FEEDING, FORAGING AND DIET

The foraging strategy employed by the basking shark is unique amongst elasmobranchs and dominates the key aspects of the life history of the species (Sims 2008). Although two other shark species, the megamouth shark (*Mehachasma pelagios*) and the whale shark (*Rhincodon typus*) are also planktivorous, their foraging strategy relies on gulp feeding or suction feeding to capture swarms of zooplankton (Clark & Nelson 1997; (Diamond 1985- cited in Sims 2008). By contrast, the basking shark is an obligate ram filter feeder; the flow of water across gill rakers within the mouth is controlled by swimming speed (Sims 2000) The exact mechanism of prey capture is, however, unknown (Sims 2008).

There is evidence that basking sharks show fine scale surface foraging, choosing the most energetically profitable plankton patches in which to forage, and they have been shown to respond to gradients in zooplankton density. Peaks in plankton density are associated with peaks in basking shark abundance (Sims & Quayle 1998).

The most prevalent zooplankton species found in areas with surface feeding basking sharks is the copepod *Calanus helgolandicus*, although other species are also foraged. In some studies this has been shown to comprise 70% of the total plankton density found in the vicinity of surface feeding sharks (Sims & Merrett 1997), as well as the stomach contents of a dead individual found in nets in the English Channel (Sims 2008). In UK waters, plankton samples taken in the vicinity of feeding basking sharks were found to have 46% higher plankton density than control samples. Whilst calanoid copepods predominated in all samples, including the control samples, they were 84% more numerous and individuals were 23% longer in the samples taken near feeding sharks (Sims & Merrett 1997). The peak of basking shark sightings occur in the summer when they can be observed feeding almost continuously and in large, loose aggregations (Sims 2008).

Telemetry studies in the Clyde Sea (Sims et al. 2005), have yielded evidence of basking sharks vertically tracking the euphausiid layers through the water column –following them during their upward migration to the surface at dusk, and following the downwards again at dawn. Diel vertical migration has also been demonstrated in the Celtic sea (ref?). Sharks tagged in the English channel as part of the same study were found to exhibit reverse diel vertical migration, yielding evidence that sharks are more likely to be seen at the surface during daylight hours in areas which are characterised by tidal fronts (Sims et al. 2005). Tagged sharks have also been shown to switch behavioural patterns as they traverse between mixed and stratified waters (Shepard et al. 2006).

The exact mechanisms by which basking sharks find areas of high prey density on a large scale are unknown. It has been hypothesised that basking sharks possess knowledge of the best geographical locations to feed, but whilst this may be a contributing factor, the geographic location is not sufficient in isolation to provide reliable information on the location of prey resources which can shift dramatically. Sharks are capable of tracking zooplankton patches across large spatio-temporal scales (Sims et al. 2006). Shifts in basking shark distribution have been documented when the location of centres of zooplankton abundance also shift, both within and between years (Sims & Quayle 1998; Sims & Reid 2002).

2.4 REPRODUCTION

Very few data are available describing the life history parameters of basking sharks, and many features such as gestation period and fecundity remain largely unknown.

Basking sharks are slow growing and slow to reach sexual maturity. Data reviewed in Sims et al. (1997) show basking sharks are estimated to reach 5m in length when 3-4 years old, and reach sexual maturity at approximately 5-9m long (age 8-15 years). It is not known to what maximum length this species can grow, though a range of 10-12 metres has been estimated (Sims 2008).

Despite a long history of exploitation, there is only one documented capture of a pregnant female basking shark (Sund 1943 - Cited in Sims 2008). The female was captured off the Norwegian coast and was observed to give birth to six pups measuring 1.5-2.0 metres prior to capture. The absence of pregnant females from summer sightings and fisheries records in the UK perhaps suggests the do not surface feed perhaps remaining offshore in deep water (Sims 2008). There are no published records relating to the degree of parental care displayed in basking sharks.

Courtship behaviour has been recorded in UK waters during summer months, and is associated with thermal fronts, possibly as a result of individuals aggregating to forage in areas of high zooplankton density prior to the initiation of courtship behaviour (Sims et al. 2000). Courtship behaviours described included noise-to-tail following, close following, close flank approach, parallel and echelon swimming. These behaviours were observed in animals between 5-8m long, thought to be mature, but not in smaller sharks (3-4m long), thought to be immature. Mating is thought to take place at depth as it has not been observed at the surface (Sims et al. 2000).

2.5 LEGISLATION

Although basking sharks are classified as Endangered within the North-east Atlantic by the IUCN, protection of basking sharks in European waters from disturbance is limited to national legislation. The European Habitats Directive does not extend protection to basking sharks, and as such they are not considered to be European Protected Species (EPS) and do not qualify for the designation of Special Areas of Conservations (SACs).

Basking sharks have legal protection within the 12nm limit of UK territorial waters under the Wildlife and Countryside act (1981)(WCA) and Countryside and Rights of Way (CROW) Act (2000).

This protection was enhanced further by the Nature Conservation (Scotland) Act 2004. Under Schedule 6 of this legislation it is an offence to deliberately or recklessly capture, kill, or disturb basking sharks.

The Wildlife and Natural Environment (Scotland) Act 2011 (WANE) has added a new licensing purpose to the WCA at section 16(3) (i)): 'for any other social, economic or environmental purpose' for certain protected species including basking sharks. There is also a UK Biodiversity Action Plan (UKBAP) for basking sharks, with the objective of maintaining the current basking shark population.

Internationally, basking sharks are listed in Appendix II and III in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). These listings require the close monitoring of trade in basking shark products and thorough assessment of basking shark ecology and biology. Additionally, basking sharks are listed under Appendix 1 and 2 of the Bonn Convention on Migratory Species (CMS) and under Annex 1 of the United Nations Convention on the Law of the Sea (UNCLOS).

The basking shark is included on the current OSPAR list of threatened and/or declining species and habitats (OSPAR, 2008).

3 SITE SPECIFIC REVIEW OF EXISTING DATA/INFORMATION

3.1 VISUAL SURVEYS OF BASKING SHARKS – A CAUTIONERY NOTE

The method most frequently utilised for confirming the presence of basking sharks in an area is the recording of visual sightings. This is understandable due to the cost-effective nature of recording visual sightings, and the fact that data collection can be carried out concurrently with data collection surveys for seabirds and marine mammals. However, caution must be applied when these data are used for the calculation of abundance estimates using Distance Sampling Analyses (e. g. Buckland et al. 2001) .

If statistical methods (such as abundance estimation and habitat preference modelling) that rely on visual survey data are to be robust, however, the species of interest must be available to be counted at the surface (or an assessment on how often they are available to be counted be available for inclusion in analyses). This works (with associated analytical adaptations) for marine mammals which are obliged to surface regularly to breathe, however there is no such obligation for the basking shark. The amount of time basking sharks spend at the surface will have a direct effect on the probability of sightings made by visual surveys. Research (Sims et al. 1997) indicates that the time spent at the surface by basking sharks depends largely on the minimum abundance of prey in the surface layer and the time of day.

This observation is supported by further studies (Sims et al. 2005; Southall et al. 2005) utilising telemetry studies which have the advantage of being able to monitoring sharks when they are not present at the surface. Sims et al. (2005) report that the daytime-surfacing frequency of a tracked individual feeding in an inner-shelf area near a front was over 100 times higher than another shark feeding in well-stratified water. This large difference in likelihood for surface swimming between regions was mirrored in survey data collected as part of the same study: 11.5 times more sharks per unit effort were observed in fronts than in stratified water. Therefore the sighting of basking sharks is contingent on conditions being suitable for animals to be present at the surface

Because of the difficulty in estimating the abundance of basking sharks, a sighting rate is often used as a proxy for comparison. This is usually expressed as sightings per unit effort (SPUE). It should be noted that on large scale surveys covering a wide geographical area, SPUE may not reflect real differences in abundance between areas because the probability of sighting a basking shark shifts from about 0·6 in fronts to <0·01 in well-stratified zones (Sims et al. 2005). For example, this difference would result in a significant underestimation of abundance in stratified areas (by a factor of ~60).

The footprint of the Argyll Array is an area in which surface feeding behaviour of basking sharks has been recorded. However it should be noted that the absence of sightings of basking sharks at the surface does not guarantee the absence of sharks from the area.

3.2 LOCATION AND USAGE OF SITES IN SCOTLAND BY BASKING SHARKS (NICHOLSON ET AL. 2000)

3.2.1 OVERVIEW

The Marine Conservation Society (MCS) commissioned a review of basking shark sightings to identify hotspots in Scotland to provide information to Scottish Natural Heritage (SNH) on basking shark status (Nicholson et al. 2000). Basking shark sightings were recorded by the public on pre-printed record cards. The pre-printed record cards were first introduced in 1987, but historical records are also included in the database dating to 1901. This dataset was analysed to incorporate all records collected between 1901 and 1999.

908 records of basking sharks were received pertaining to Scottish waters between 1987 – 1999. Numbers of sightings peaked in August (32% of reports). The majority of sightings were recorded on the west coast of Scotland (ICES Area V1a). This area accounted for 78% of the 1,860 sightings analysed. Hotspots on the west coast of Scotland were identified, particularly in the vicinity of Arran and Mull (Nicholson et al. 2000).

3.3 SCOTTISH NATIONAL HERITAGE WEST SCOTLAND BASKING SHARK SURVEY (SPEEDIE ET AL. 2009)

3.3.1 INTRODUCTION AND METHODOLOGY

Between 2002 and 2006, the Wildlife Trust's Basking Shark Project conducted annual surveys of basking sharks in the waters of the west coast of Scotland (Speedie et al. 2009). Two large scale areas were selected for survey based on knowledge of their historical importance:

- the Clyde Sea off the coast of Kintyre and the Isle of Arran, and
- the Sea of the Hebrides between the north west coast of Mull and Barra Head in the Western Isles

Between 2002 and 2004, boat-based surveys were conducted between early August and mid-September. The 2005 survey began in mid-July. In 2006, surveys were conducted from early May to mid-September.

Boat based visual surveys were conducted, quantifying sharks visually as the survey vessel travelled along a number of pre-determined line transects (Figure 2).

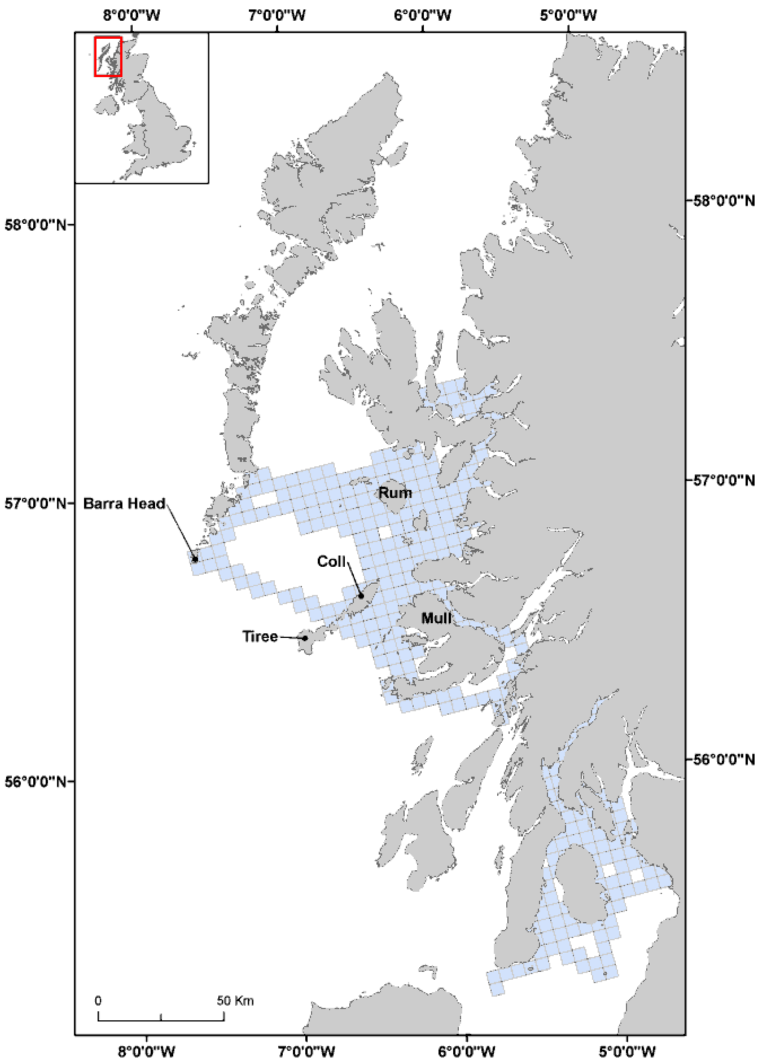

Figure 2: Survey area covered by SNH basking shark surveys 2002-2006.

3.3.1 RESULTS

A total of 582 sharks were recorded during approximately 730 survey hours in the waters around the Hebrides. Standardised sightings rates (Sightings per Unit Effort – SPUE) were calculated to aid comparison of data across different geographical regions. The mean ± standard error SPUE h^{-1} values were 0.75 ± 0.36 h^{-1}. The data showed that there was geographic variation in the number of sightings of basking sharks in different regions of western Scotland. The highest numbers of sightings were recorded in the vicinity of Canna, south west of the Isle of Skye (SPUE of 2.82 h^{-1}) and in the vicinity of Coll and Tiree (SPUE of 1.74 h^{-1}). These compare to average SPUE values of <0.01 h^{-1} for a well-stratified water body and ~0.6 h^{-1} for a frontal area of water conducted during a long-term study in the English Channel (Sims *et al*., 2005).

Figure 3 shows the SPUE values obtained between 2002 and 2006 within the Sea of Hebrides. It is apparent that some of the consistently highest SPUE recordings were taken in Gunna Sound between Coll and Tiree, approximately 20km from the Argyll Array proposed wind farm development.

Estimates of shark size show that the majority of individuals were of length 6 metres or over (65% of sharks) (Speedie *et al.*, 2009). This suggests that the majority of sharks recorded were mature (86%).

The majority of basking sharks encountered within the Sea of the Hebrides were solitary (65.5%). Where more than one shark was recorded during the surveys, shoal size was noted. During the surveys, groups of sharks within shoals of four or more individuals were consistently recorded in the vicinity of Tiree-Coll (Speedie *et al*., 2009).

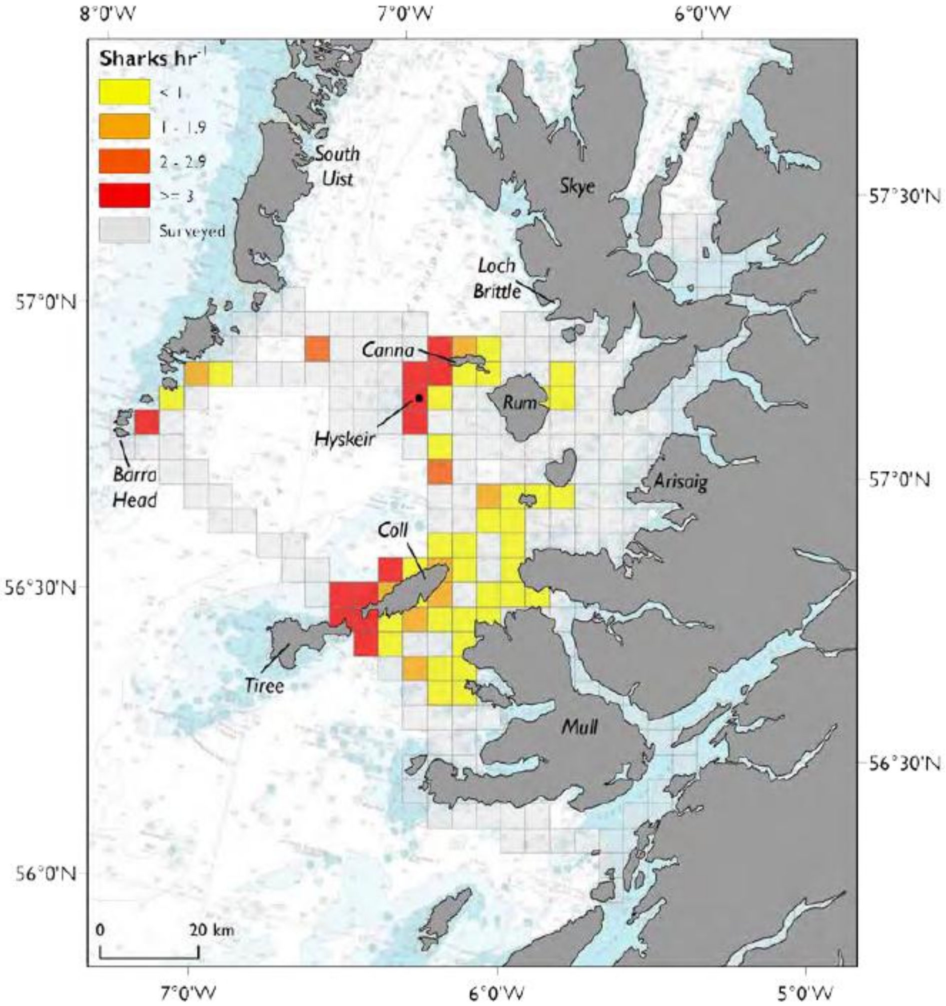

Figure 3: SPUE-1 in the Hebridean Sea, 2002-2006, using a 5km x 5km grid. ©British Crown and Seazone Solutions Limited. All rights reserved. Products Licence No. 032006.006. This product has been derived in part from material obtained from UK Hydrographic Office (www.ukho.gov.uk) "NOT TO BE USED FOR NAVIGATION".

The most frequently observed behaviour was feeding; individual sharks seen swimming slowly with mouth fully open for extended periods before swallowing and resuming feeding.

On occasion social behaviour was observed. This included parallel and echelon swimming, rostral contact and nose-to-tail following. This behaviour has been recorded previously and has been attributed to courtship activity (Wilson, 2004). Sharks engaged in courtship-like activity were recorded during all surveys in the Tiree-Coll area, the closest area to the proposed Argyll Array development.

3.4 MARINE CONSERVATION SOCIETY: BASKING SHARK WATCH REPORTS

3.4.1 INTRODUCTION

The Marine Conservation Society (MCS) launched the Basking Shark Watch project in 1987 as part of its campaign to protect this species in UK waters. To provide general indications of the geographic distribution of this species, details of shark sightings made by independent organisations and the general public are collated. This has allowed the identification of basking shark surface activity hotspots around the UK and has provided an indication of annual and seasonal variations in basking shark distribution, size and behaviour over a twenty year period (Bloomfield & Solandt 2006)(Bloomfield & Solandt, 2008).

3.4.2 RESULTS

Data are available in published reports covering the timespan from project initiation in 1987, up to and including 2009 (Bloomfield & Solandt 2008; Solandt & Ricks 2009).

This multi-year data set consistently shows the highest density of basking shark sightings in three main locations:

- South-west English coast and Scilly Isles
- North-west coast of Scotland
- South-west coast of the Isle of Man

Within north-west Scotland, basking sharks were predominantly and consistently recorded in the surface waters around the Inner Hebrides (Figure 4).

In addition, in line with Speedie *et al*. (2009), basking shark sightings were greatest over the summer months, peaking in August. It is possible, however, that during summer months, more people were making recreational use of surface waters and so any basking sharks present in surface waters were more likely to be sighted and reported.

As this database is not effort-corrected (the sightings may be of the same shark recorded by a number of different observers at the same time), it is however, not a true reflection of relative sighting densities from these regions. Most of the observations come from coastal walkers, and clearly identify areas where sharks are most likely to be seen near to the coast, rather than out at sea. The database therefore serves as a useful guide of shark activity in surface waters that abut the coast, rather than any true reflection of shark hotspots at the coast (within 1nm) relative to offshore (>1nm) sites.

As reported by Speedie *et al.*, (2009), most shark sightings throughout the UK were of individual fish (59% of reports). On occasion, groups of basking sharks were reported in the surface waters of south west Scotland, comprised of 50-99 and 100+ individuals. Bloomfield & Solandt (2008) did not however, identify the number of shoal sightings per UK region.

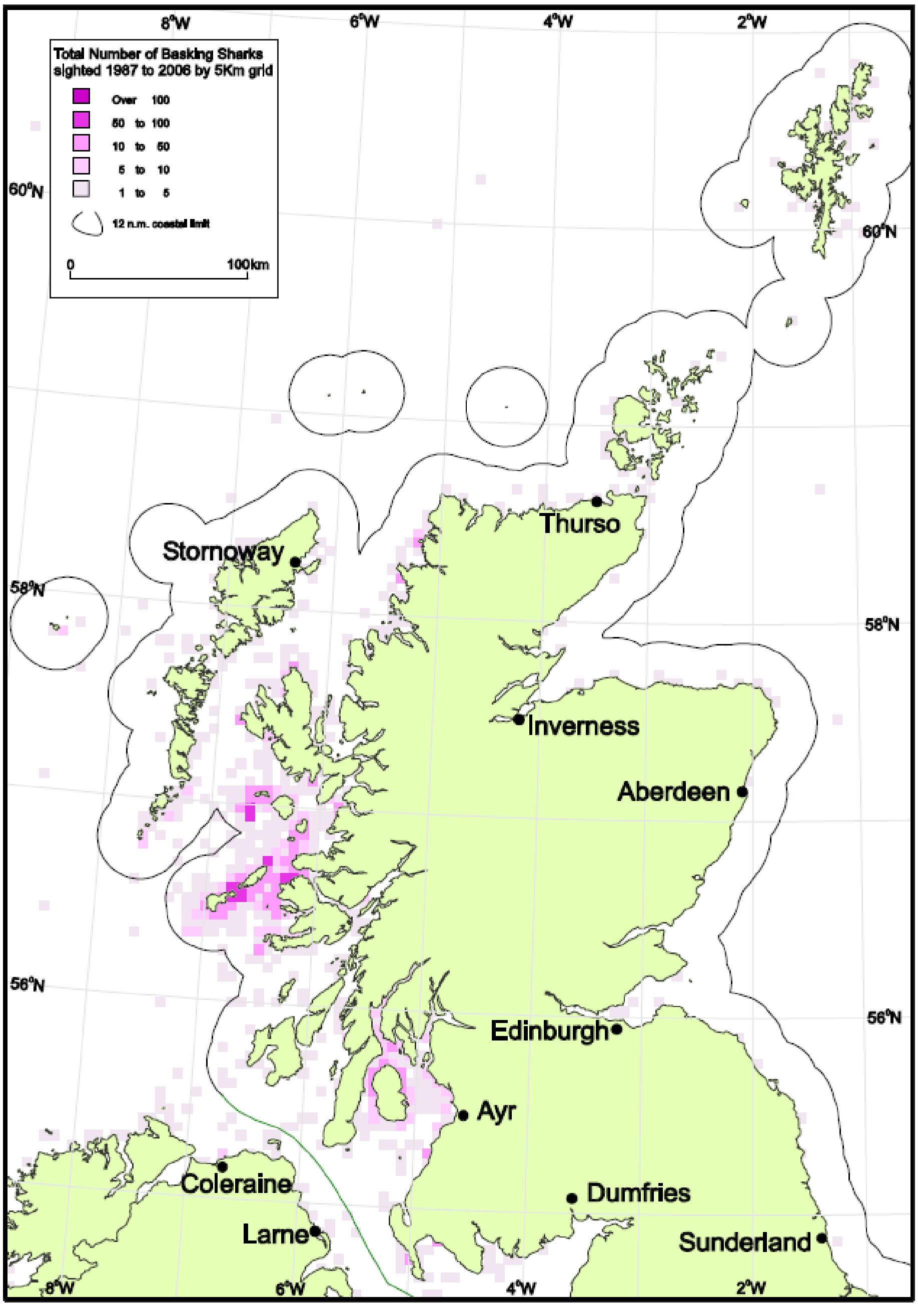

Figure 4 - Total number of basking shark sightings recorded in Scottish waters, 1987-2006, using a 5km2 grid. From Bloomfield & Solandt (2008).

3.5 COMMUNITY SIGHTINGS PROGRAMME (HEBRIDEAN WHALE AND DOLPHIN TRUST 2011)

3.5.1 INTRODUCTION

The Hebridean Whale and Dolphin Trust's (HWDT) Community Sightings Programme gathers sighting reports of basking sharks, whales, dolphins, porpoises from local residents, wildlife operators and visitors within the Hebrides region. The information is collated as monthly sighting data and provides information on the seasonal and spatial distribution of species in the Hebrides area. Sighting data since 2004 are available on the HWDT website. These data are derived largely from opportunistic sightings made by the general public, rather than from purpose-designed surveys and, as with the MCS data (Bloomfield & Solandt 2008; Solandt & Ricks, 2009), no effort-correction is applied to the data to control for the likelihood of increased recreational activity during summer months. Furthermore, the data are restricted to sightings of sharks at the water surface and those located in the vicinity of observers (e.g. close to shore or close to vessels) and one individual may have been reported multiple times by different observers. The data do however provide an indication of the relative density of sharks in the area.

3.5.2 BASKING SHARK SIGHTINGS

Since 2005, a total of 2,137 basking sharks have been reported in the Hebrides region. Of the 2,137 sharks sighted, 10.5% (224 sharks) were recorded from the vicinity of the Tiree coast. Many sightings however provided no location or only a vague indication of the locality (e.g. one sighting of four sharks was recorded as “Oban_Coll_Tiree”). As the geographic distribution of basking sharks cannot be inferred from these descriptions, this section will cover all of the HWDT basking shark sightings in the Hebrides. Basking shark sightings peaked in July and August (Figure 5). This is in agreement with the findings of Speedie *et al*. (2009) and Bloomfield & Solandt (2008) who found higher shark abundances over the summer months.

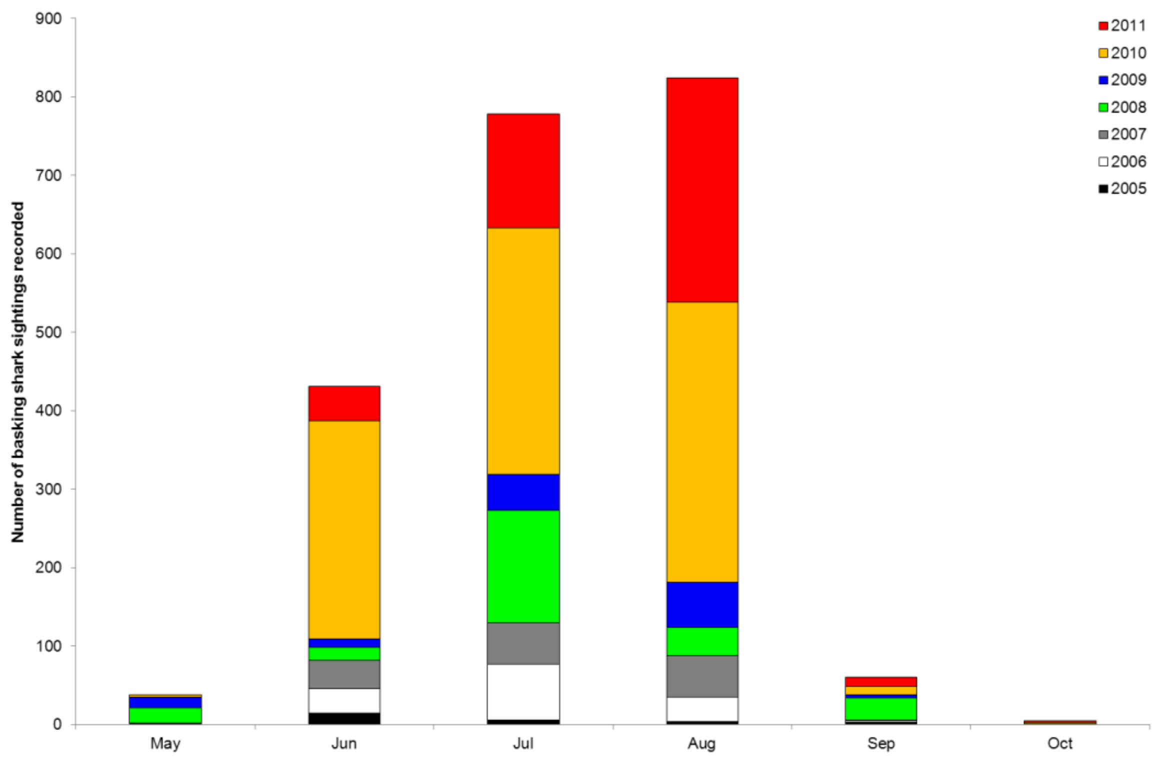

Figure 5 - Monthly basking shark sightings reported to the Hebridean Whale and Dolphin Trust between 2005 and 2011

3.6 CURRENT RESEARCH

3.6.1 SCOTTISH NATURAL HERITAGE AND UNIVERSITY OF EXETER TAGGING STUDY

SNH is currently undertaking a tagging study in conjunction with the University of Exeter. To date 20 basking sharks have been tagged. The study is still on-going but it is hoped that data collected will shed additional light on the distribution and habitat use of basking sharks known to utilise Scottish waters. More information can be found at http://www.snh.gov.uk/about-scotlands-nature/species/fish/sea-fish/shark-tagging-project

3.6.2 UNIVERSITY OF ABERDEEN GENETICS WORK (REVIEWED IN DREWERY 2012)

A genetics study focussing on basking shark population connectivity within the Northeast Atlantic is currently being undertaken by PhD student Lilian Lieber. This project will also focus on the response of basking sharks to oceanic pollution, as well as changes in sea surface temperature and associated shifts in primary productivity. This work is expected to be completed by the end of 2014.

3.6.3 PLYMOUTH MARINE LABORATORY & MARINE BIOLOGICAL ASSOCIATION (REVIEWED IN DREWERY 2012)

Studies at PML and MBA are being undertaken to investigate the use of Ocean fronts as an indicator of marine animals: expediting site selection and survey for offshore renewables. These studies are still on-going.

4 REVIEW OF ARGYLL ARRAY SURVEY DATA

4.1 INTRODUCTION

SMRU Ltd were asked to analyse and comment on the science underpinning the basking sharks sightings data collected during the boat-based surveys undertaken by RPS between 2009 and 2012, within the proposed Argyll Array wind farm site. These data were collected (and SMRU Ltd analysis methods chosen) to provide a site-characterisation of the temporal and spatial patterns of site use by basking sharks. RPS carried out 33 transects spaced 2km apart within an area incorporating the Argyll Array site and a 2km buffer (Figure 6). Surveys were completed monthly, with the exception of November 2009, January 2010, August and September of 2010, May of 2011 and all but July and August 2012 (Table 1).

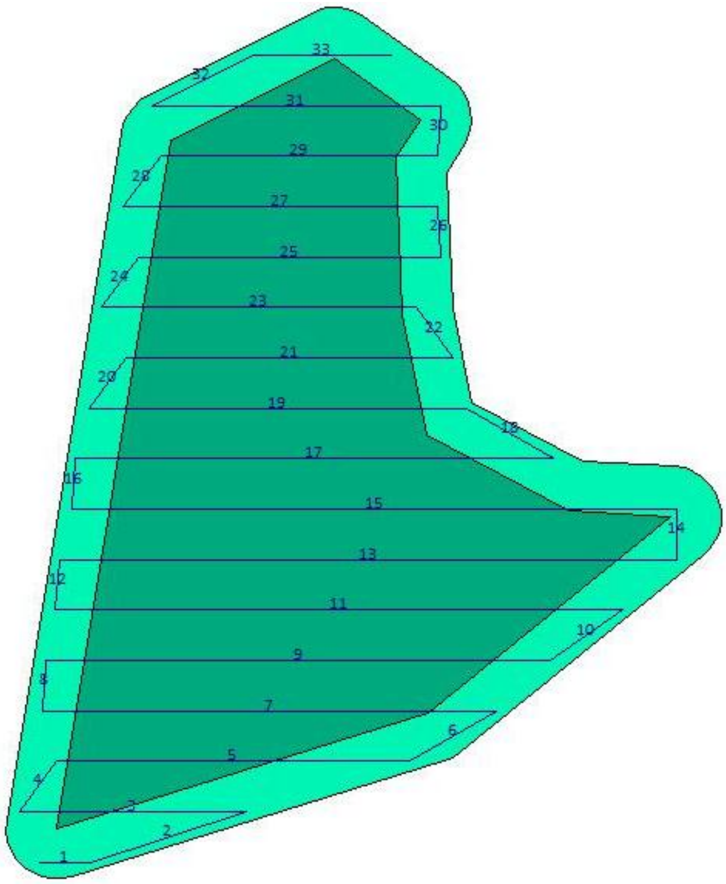

Figure 6 - RPS survey transect lines within the Argyll Array site and including 2km buffer

Table 1 - Boat surveys undertaken by RPS at the Argyll Array Wind farm site between 2009 and 2011. Between 2009-2011 missing 'survey numbers' indicate surveys that never occurred.

Survey Number	Survey dates
1	September 17th – 18th 2009
2	October 14th - 16th 2009
4	December 14th – 16th 2009
6	February 1st - 2nd 2010
7	March 26th – 27th 2010
8	April 21st – 22nd 2010
9	May 22nd – 23rd 2010
10	June 23rd – 24th 2010
11	July 27th – 29th 2010
14	October 13th – 14th 2010
15	November 22nd – 24th 2010
16	December 20th – 22nd 2010
17	January 24th, 27th, 28th 2011
18	March 4th – 5th 2011
19	March 27th – 28th 2011
20	April 25th – 26th 2011
22	June 12th-14th 2011
23	June 24th-25th 2011
24	July 15th-16th 2011
25	August 6th-7th 2011
26	July 10th – 11th 2012
27	August 4th & 5th 2012

4.2 SURVEY METHODOLOGY

Visual surveys were carried out by teams of 1-3 observers positioned on the front deck (eye height: 5 m). A dedicated marine mammal observer was not always present during surveys. When basking sharks were sighted, the species was identified (if possible) and the time of first sighting and number of animals was estimated. For surveys 1-20, sightings were recorded in distance bands. From survey 22 onwards, the estimated range to the animal(s), the bearing to the animal(s) relative to the boat (determined from angle boards on deck), the heading of the animal(s) relative to the boat were also periodically recorded. Group size and behaviour of the animal(s) were also recorded.

Recent draft guidelines from SNH recommend that marine mammal (and basking shark) surveys are carried out in sea states up to 4, however it is stressed that the lower the sea state the better – as sighting rates are known to decline as conditions worsen. The SNH commissioned surveys of basking sharks on the west coast of Scotland (Speedie *et al*, 2009), took place in conditions up to sea state 4. Sea state information for the Argyll Array data was provided by RPS. Sea states ranged from 0 – 6 across all surveys with the greatest sea states observed in September and December 2009 (1-6 and

4-6), and February, March and July 2010 (3-6 on all occasions). It is unlikely that these conditions were appropriate for the accurate detection of basking sharks, and so seastate was included as a candidate covariate in the statistical analysis to account for this issue. Data were included in the analysis providing they were collected in sea state 0-4.

Some survey data were collected during transit to and from the study site. These data were excluded and only 'on-effort' data were considered in analyses. It frequently took multiple days to complete the survey lines across the Argyll Array site (and the 2km buffer). On most occasions surveys were undertaken over a two day period, however there were instances of three day surveys on seven occasions and on two occasions survey days were not consecutive (i.e. surveys in January were undertaken on the 24th, 27th and 28th January 2011, surveys in June 2011 was undertaken on the 12th, 14th, 24th and 25th June 2011). It should also be noted that during periods of high shark presence, there was the potential for double-counting of individuals. How this was dealt with during surveys was not captured in data provided to SMRU Ltd and is therefore possible that the high numbers of sightings on other occasions may partly be an artefact of resighting the same sharks more than once.

4.3 DATA ANALYSIS

The approach SMRU Ltd has taken here is to conduct two separate analyses: 1. To assess the temporal and spatial pattens in basking shark distribution (to provide the basis of the site characterisation) and 2. Generate a site-specific abundance estimate (with 95% confidence intervals) to be fed into the Impact Assessment framework. Here we describe the analytical methods used to complete these analyses. The impact assessment methodology is described in section 5.

4.3.1 INVESTIGATING BASKING SHARK KEY ENVIRONMENTAL FACTORS

4.3.1.1 *STATISTICAL ANALYSIS*

To determine the temporal and spatial patterns of basking shark distribution on the Argyll Array site (and the environmental drivers and survey factors affecting sighting rates) the following analysis was undertaken.

Data collected when the survey team were 'off-effort' were excluded from the analysis and all remaining visual survey effort tracklines were divided into 0.5 km segments for analysis. This segment length was selected as a suitable resolution given the available oceanographic covariates data.

Counts of basking shark sightings, offset by the survey effort conducted per segment was modelled with respect to a range of covariates (Table 2) using a poisson Generalised Additive Model (GAM) in a Generalised Estimating Equations (GEE) model construct. Sighting rates were not corrected for availability as the focus here was the understand relationships with covariates/environment conditions rather than estimating absolute abundance (which was done in section 4.3.2).

GAMs have been extensively used in investigating marine vertebrate habitat preferences and distribution patterns (Bailey and Thompson 2009; Embling 2010; Marubini et al. 2009; Macleod, et al. 2004). However, one of the assumptions of GAM methods is that the model errors are independent. This is unlikely to be the case with a line-transect survey dataset as observations were collected close together in time and space. The resultant autocorrelation should be accounted for in the modelling approach, in order for realistic and robust conclusions to be drawn from the dataset.

A method of accounting for the autocorrelation in datasets is using GEEs along with GAMS or GLMS. GEEs are an extension of Generalised Linear Models (GLMs), facilitating regression analyses longitudinal data and non-normally distributed variables (Liang & Zeger 1986; Hardin & Hilbe, 2002). GEEs are used to account for temporal and spatial autocorrelation within a dataset; data are grouped into 'panels', within which model errors are allowed to be correlated and between which data are assumed to be independent. A suitable 'panel' size was chosen using autocorrelation function plots and a simple *working* independence correlation model structure was also selected. This approach delivers identical coefficients to those of a standard GAM-based model, however the standard errors will differ significantly under the GEE structure which can strongly influence final model selection results, avoiding the incorrect inclusion of covariates. GEEs have also been used in other circumstances to estimate marine vertebrate habitat preferences from autocorrelated data (Booth, 2010; Panigada et al. 2008; Pirotta, et al. 2011).

Hence, here a GAM built within a GEE model construct (henceforth described as a GEE-GAM) was used to robustly investigate basking shark habitat preferences across the study site.

4.3.1.2 *SOURCES OF COVARIATE DATA*

A range of survey covariates was included in models to account for patterns in the data (Table 1). Because visual surveys of marine vertebrates tend to be impacted by sea state (Palka 1996; Speedie, et al. 2009), survey effort was limited to data collected in Beaufort sea state ≤ 4 for the visual data models. The total number of sightings in each 0.5 km survey segment (the response variable) was calculated. Vessel speed, sea state and the number of observers were also included as candidate covariates. Additional data for model covariates were obtained from a range of external sources (Table 2).

As it is well-known that basking shark presence in closely linked the distribution and abundance of its prey, data on the either the predicted or total abundance and distribution of *Calanus* spp. copepods would be best –suited to use a covariate to investigate basking shark sighting rates. However such data were not available at a suitable scale or resolution for inclusion in this analysis. In the absence of such data, a commonly used approach is the use of oceanographic and hydrographic 'proxies' to try to explain the patterns that generated the sightings data. Here, a range of proxy data were used to investigate basking shark use around the Argyll Array wind farm site.

Seasonal variations in basking shark habitat use have been well-documented Sims, et al. 2005). Consequently, in this report 'Month' and Julian Day was included as candidate covariates to determine if basking sharks exhibited seasonal usage patterns in the region.

To investigate whether static oceanographic features like the seabed topography represented preferred habitat for basking sharks the depth of water and the angle of the seabed slope were included as candidate covariates. In addition, the state of the tide was included as a potential covariate for the models (Bloomfield & Solandt, 2008). Tidal prediction data were sourced from Gott Bay using POLTIPS 3. Time of day was also chosen as a candidate covariate to determine where sighting rates changed throughout the day. Sunrise and sunset data were sourced from: http://aa.usno.navy.mil/data/docs/RS_OneYear.php for Gott Bay.

Table 2 - Candidate covariates used in modelling basking shark sighting data.

Candidate Covariate	Description
Month	The month in which surveys were conducted
Julian Day	The day of the Julian calendar in which the survey was conducted
Vessel speed	The speed of the survey vessel during survey effort
Sea state	The sea conditions during survey (0 – 4)
No. of Observers	The number of observers monitoring for basking sharks
Time of day	Position in the day (corrected for day length – i.e. relative to sunrise) (0 = sunrise, 0.5 = middle of day, 1 = sunset)
Time From Low Water	Position in the daily tidal cycle (0/1 = low water, 0.5 = high water)
Seabed depth	Depth of seabed (from Olex depth sounding records)
Seabed slope	Angle of seabed (derived from Olex sounding records)

Month, and the number of observers active were treated as factor variables and all other terms were treated as smooth terms with 4 degrees of freedom – with cubic *B*-splines with a single knot placed at the mean of each covariate term. Year was not used a candidate covariate as there were inconsistent sampling across covering the other covariates collected in each year of the study. As in the highlighted studies employing the GEE-GAM method, QICu was used to govern stepwise model selection. The model was fitted using the *geeglm* function in the *geepack* package in R (Halekoh et al. 2006) the *splines* and *yags* packages were used to fit the models and in model assessment.

4.3.1.3 *INVESTIGATING COLLINEARITY*

Collinearity between covariates, if unaccounted for, in models can cause inflated or underestimated standard errors and *p*-values and lead to poor model selection. To avoid this, collinearity between predictor variables was investigated prior to modelling using 'variance inflation factors' (VIF) (Cox and Snell 1989; Fox and Monette 1992) using the *vif* function in R (Table 3). Large VIF values indicate collinearity and a threshold of VIF = 5 was used here. VIFs > 5 resulted in the retention of the covariate with the best fit to the data (determined in model selection), and the other covariates being removed.

Table 3 - Investigation of covariates that show collinearity and the resultant action to remove collinearity.

Candidate Covariate	Collinearity Issues?	Retained?
Month	with Julian Day	No (**Julian Day** retained)
Julian Day	with **Month**	Yes
Vessel speed	N	--
Sea state	N	--
No. of Observers	N	--
Time of day	N	--
Time From Low Water	N	--
Seabed depth	N	--
Seabed slope	N	--

4.3.1.4 *MODEL SELECTION*

A single main model was constructed using all the data collected from the study site combined. Candidate covariates were offered in the model selection phase to construct the final models. Covariates were selected for models using a manual stepwise selection using QIC. Specifically, a global (all terms) model was constructed and QIC was used to govern model selection of all possible variations of that model. Following this, GEE-based *p*-values were used to determine the statistical significance of each covariate and terms with large *p*-values were removed from the model.

4.3.2 ARGYLL ARRAY BASKING SHARK ABUNDANCE ESTIMATION

4.3.2.1 *DISTANCE AT DETECTION*

For surveys 1-20, sightings were recorded in distance bands. From survey 22 onwards, the estimated range to the animal(s), the bearing to the animal(s) relative to the boat (determined from angle boards on deck), the heading of the animal(s) relative to the boat were also periodically recorded. Information on distance at detection was collected for most of the observed basking sharks. However, the distance of some individuals was estimated to be within a band according to the following categories:

A 0-50m (midpoint 25 m)
B 50-100m (midpoint 75 m)
C 100-200m (midpoint 150 m)
D 200-300m (midpoint 250 m)
E >300m

For the remaining individuals absolute distances were estimated (using range and bearing to the animal). The overall average distance that basking sharks were detected was 172.7 m from the vessel. Please note this is calculated based on the consideration of the mid-point of the above distance bands in the cases where this method of estimating distance was used. The distance from the survey vessel at which basking sharks were recorded has implications for the estimation of shark abundances in the area (see below).

4.3.2.2 *DETECTION FUNCTION*

A number of factors could potentially have resulted in a misleading estimation of shark abundance during vessel based surveys (Thomas et al 2010). The distance of individuals from a survey transect line for example, has been shown to significantly affect the detectability of organisms, with reduced detectability of individuals with increasing distance from the transect line.

Other factors, such as the experience of observers and sea state conditions are known to significantly affect estimations of population abundance (e.g. Ronconi & Burger 2009). It is possible that the higher number of sightings in August 2011 is linked to the predominance of lower sea states (0-4) that are more conducive to the detection of basking sharks.

These surveyor and environmental impacts on estimation are in addition to the potentially high proportion of sharks that may have been present during the surveys, but were not at the water surface and as such were not detected. It is likely therefore that the 766 basking sharks observed within the Argyll Array development site is an underestimation of the true abundance of sharks present at the time of survey. Population assessments based on distance-based sampling can incorporate a detectability function to control for this (Buckland et al. 2001).

The RPS basking shark survey data were analysed using Distance (version 6) software (Thomas et al. 2009). This software provides density estimates in the surveyed area that account for observer error. Corrected density estimates can then be used to calculate population size gained over an entire survey area. Distance models the probability of detection as a function of the observed distances from the transect line. The software also allows additional environmental observations such as sea state to be included in the detection function model as a covariate, in addition to observed distance (Thomas et al. 2009; Marques et al. 2007).

As discussed above, count data were split between those recorded as absolute distances and those recorded as being within distance bands. To maximise the statistical power of the model outputs, all distance data were pooled into the bands and distance bands labelled using the midpoint of each.

As sea state could impact upon the probability of detection, Beaufort sea state data recorded by the surveyors at the time of the observations were incorporated into the model as a covariate. As with the distance data, sea state data were pooled to maximise the statistical power of the model. Sea state data were pooled by those ranging between 0 and 4 and those greater than 4. These values were based on SNH (2011) recommendation on the ideal conditions for marine mammal and basking shark survey.

Distance estimates are typically truncated at 300m, with any observations recorded at distances in excess of 300m considered to be outside of the transect strip (Camphuysen et al. 2004). As such, shark observation data recorded at in excess of 300m from the survey vessel (i.e. those in distance band E) were not incorporated into the model. This follows the methods described as part of the Phase II Joint Cetacean Protocol analyses (Paxton et al. 2011). Shark densities were fitted to a hazard rate distribution function with Hermite polynomial adjustment. SMRU Ltd did not have sight of the detection functions, model selection or goodness of fit analyses conducted by APEM Ltd.

4.4 VISUAL SURVEY RESULTS

4.4.1 BASKING SHARK ENCOUNTER RATES

Table 4 and Figure 7 present the data as sightings of basking sharks detection rates (i.e. basking sharks per km of survey effort). A total of 1846 sharks were recorded during the ~5,968 km of survey hours. Detection rates were low between October and March, peaking typically in July and August (though there is some inter-annual variability in peak detection rates). The highest detection rates were 1.46 and 3.41 animals/km, encountered in August 2011 and 2012 respectively.

Table 4 – Detection rates of basking sharks for the surveys conducted by RPS.

Survey	Year	Month	Total Sightings	Animals/km	Effort (km)
1	2009	September	25	0.09	270.0
2		October	0	0	273.3
4		December	0	0	273.1
6	2010	February	0	0	185.9
7		March	0	0	272.9
8		April	9	0.03	274.0
9		May	9	0.03	268.2
10		June	72	0.17	431.4
11		July	111	0.41	273.2
14		October	0	0	277.4
15		November	0	0	280.5
16		December	0	0	279.7
17	2011	January	0	0	278.7
18		March	0	0	273.1
19		March	3	0.01	280.8
20		April	24	0.09	278.0
22		June	6	0.02	270.0
23		June	2	<0.01	279.2
24		July	99	0.86	115.3
25		August	407	1.46	278.2
26	2012	July	129	0.47	275.7
27		August	950	3.41	279.0

In terms of spatial patterns, the raw data indicate the highest detection rates are in the east of the study region outside of the revised survey boundary. The environmental and survey (e.g. sea state, vessel speed) factors affecting the collection of the data are explored in greater detail in section 4.4.3.

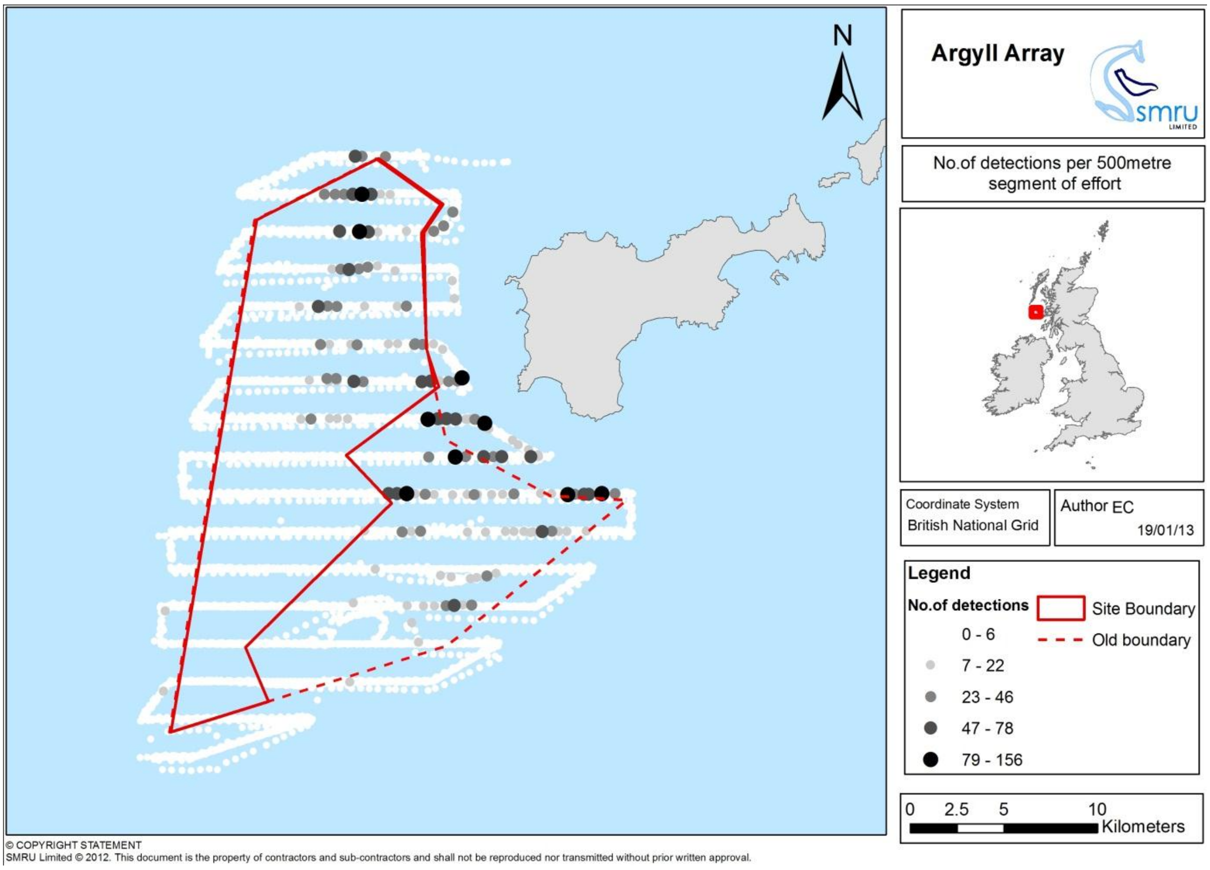

Figure 7 - Effort and sightings of basking sharks across surveys conducted between 2009 and 2012. White dots show survey effort segments (0.5 km) with no basking sharks sighted. Greyscale and variable-sized dots indicate basking shark sightings. The Argyll Array current site boundary (solid red line) and original site boundary (dotted red line) are shown.

The results from the RPS surveys can be compared to the wider study commissioned by Scottish Natural Heritage (SNH) looking at the sighting rates and distribution of basking sharks on the west coast of Scotland (Speedie *et al*., 2009) (see Section 3.3). As far as we are aware no correction factors were applied to the SNH survey data and therefore its form is directly comparable with the sighting rates from RPS surveys presented here.

Figure 8 & Figure 9 presents the sighting rates from the Argyll Array RPS surveys and the Speedie *et al*. (2009) data together. The RPS data have been presented in sightings per hour to make them comparable with the Speedie, et al. (2009) data. The results indicate that according to the criteria used by Speedie *et al*. (2009), in addition to the high encounter rate regions observed during the SNH study west of the Isle of Canna and in the waters between Coll and Tiree, the Argyll Array area is also a potential high-use region for basking shark activity in terms of number of sightings (i.e. SPUE > $1\ h^{-1}$).

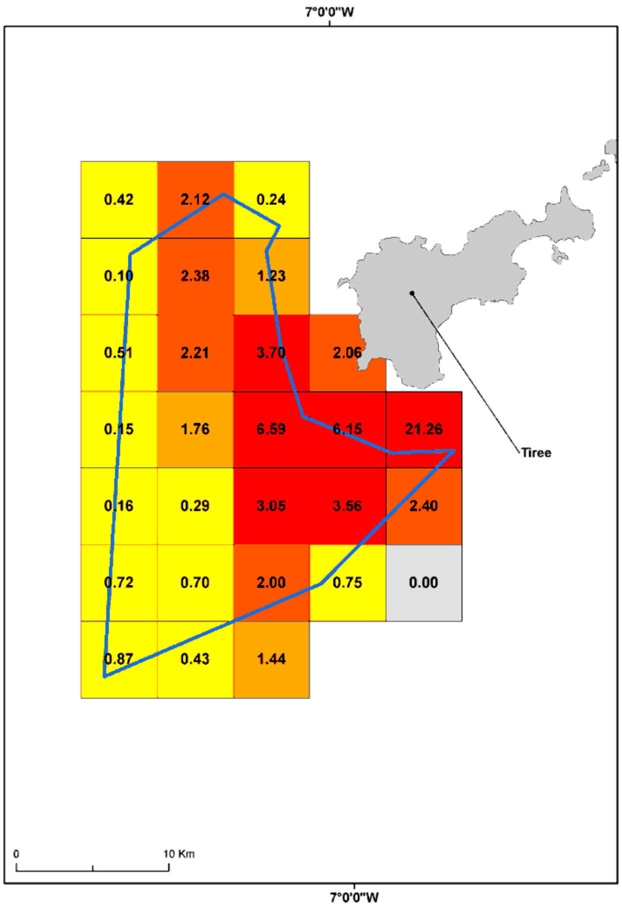

Figure 8 - Basking sharks SPUE h-1 (total sightings divided by total effort) within the Argyll Array site by grid cell

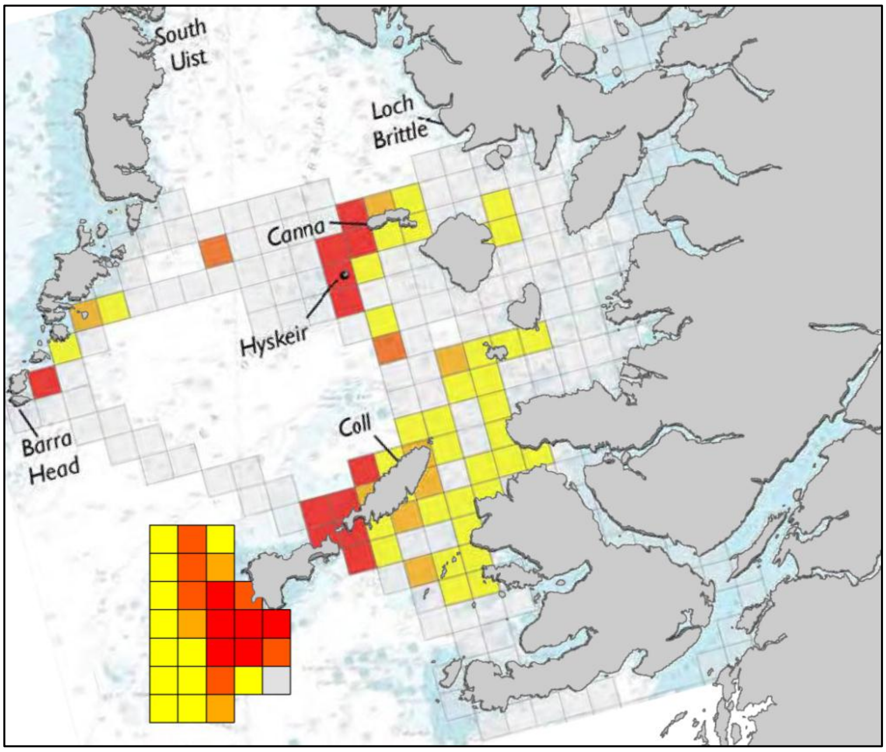

Figure 9 - Survey coverage of Argyll Array (2009-2011) and SNH (2002-2006) data (Speedie et al., 2009)

4.4.2 BASKING SHARK SIZE AND GROUP SIZE

Estimates of shark size were not made for each individual during these surveys. The data available consist of field notes only made for 56 individuals sighted during the 2011 surveys. Of these, the majority of individuals (80%) were recorded as being of between 3 and 4 metres which would indicate the presence of younger individuals. As shark size was not recorded consistently across the survey or in a systematic manner the confidence in these data is limited.

The majority of sharks recorded were solitary (35%). Where more than one shark was recorded shoal size ranged from 2 to 141 although the shoal of 141 was somewhat of an outlier with the majority of shoals consisting of less than 20 individuals (41%). No definition was found as to the geographic extent over which multiple sharks can be considered to be part of a single shoal. It was noted in Speedie *et al*. (2009), however, that "large shoals could not always be viewed as a cohesive whole, sometimes being made up of smaller groups foraging individually within the shoal". Therefore, large numbers of individuals gathered in an area may not necessarily be actively shoaling, but rather gathering together to exploit a resource such as food. Loose aggregations of basking sharks have also been reported in Pentland Firth and Orkney waters (Evans *et al.* 2010).

The only data available on shark behaviour consists of field notes made during the 2011 surveys. Seven individuals were noted as 'breaching' and three 'leaping'. This behaviour is considered as an aspect of social behaviour that may be linked to courtship or reproduction (Wildlife Trust, 2008). As shark behaviour was not however consistently or methodically recorded it is unlikely that these individuals were the only ones displaying this behaviour.

4.4.3 BASKING SHARK KEY ENVIRONMENTAL FACTORS

To investigate the spatial and temporal patterns driving basking shark distribution around the Argyll Array site, a model was constructed to investigate the relationship between predictor variables (as described above in section 4.3.1) and the basking shark sighting rates are shown below (Figure 10). Only predictor variables that had a significant influence on porpoise activity and that were retained in the model are shown.

Time of year (Julian day) had the strongest effect on basking shark presence. Sighting rates were highest during summer months, peaking between April and October. Sightings rates were extremely low, or no sightings were made during winter surveys, even during surveys in good sighting conditions. Sea state was an important factor, as sighting rates of sharks decreased as conditions worsened. Sighting rates also varied significantly across the day, with sighting rates moderate early in the morning, declining as the morning progressed before increasing through the late-morning and peaking around sunset. Position in the tidal cycle (Time From Low Water) was also retained in the final model and basking shark sighting rates were highest during the ebbing tide and lowest during the flooding tide.

Topographic variables, seabed depth and seabed slope angle also explain basking shark presence in the region. Sighting rates were highest in shallow regions with moderate seabed slopes. In regions where water depth was greater and/or where the seabed flattened out, fewer sightings were made.

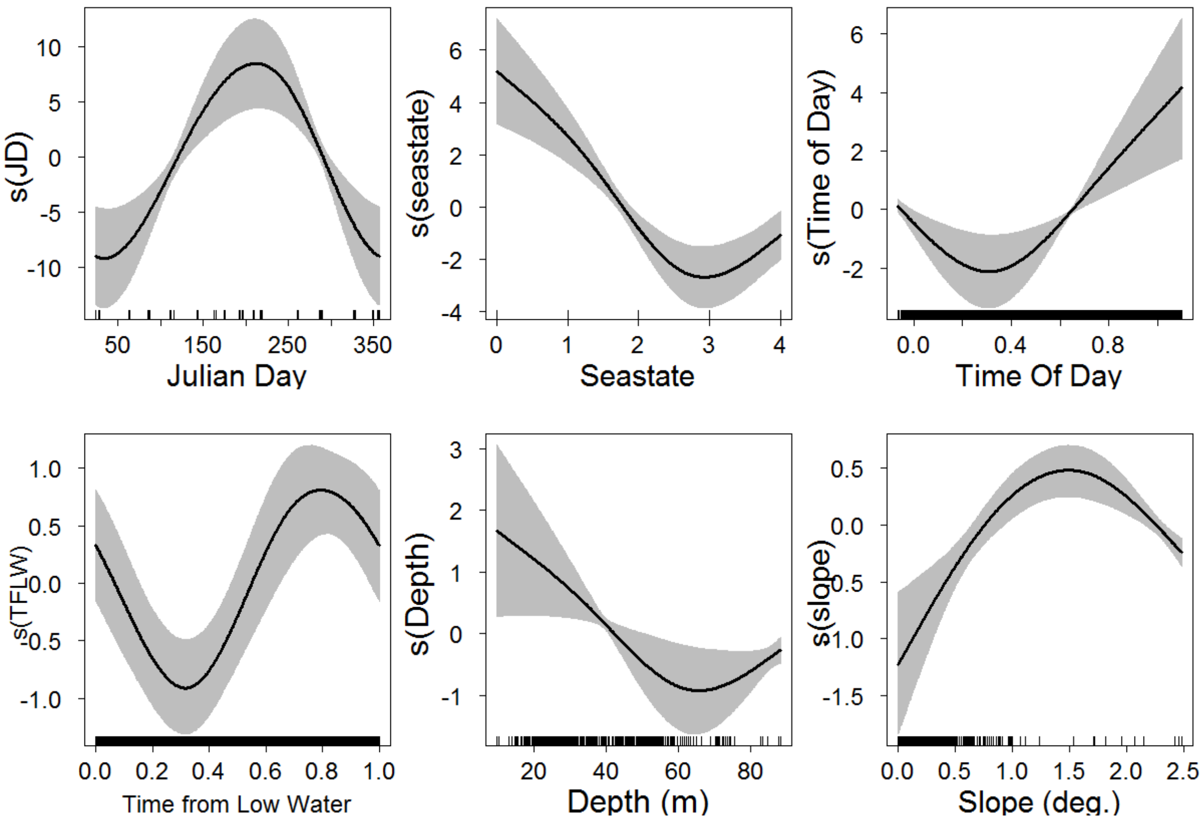

Figure 10 - Fitted relationships for the model with 95% confidence intervals based on GEE-GAM standard errors. The black line shows the relationship between basking shark sighting rates and the explanatory covariate. Grey shading areas indicate the 95% confidence intervals for these covariates. Y axes show the partial residuals for each model covariate generated by regressing the response on the other covariates. A larger y-axis indicates a more important covariate. A rug plot with actual data is also shown at the base of each plot. JD – Julian day, TFLW – Time From Low Water.

Time of year (i.e. Julian day) was the most important factor affecting (i.e. the largest drop in QICu) of basking shark encounter rates (Table 5), followed by the sea state conditions the surveys were conducted in. The time of day and the state of tide that the survey effort was conducted in were also important. Depth and slope were the most important static covariates.

Table 5 – The relative importance of each model covariate in explaining the observed basking shark patterns. 1 indicates the covariate was the most important and 6 indicates the lowest importance.

Covariate	decrease in QICu	Rank
Julian Day	-73,038	1
Sea state	-11568	2
Time of day	-8546	3
TFLW	-7805	4
Depth	-3385	5
Slope	-2347	6

SPATIAL DISTRIBUTION OF BASKING SHARKS

Using the model constructed, the relative spatial patterns of basking shark encounter rates were predicted to estimate the distribution of animals across the study site (Figure 11). As described above, the most important features explaining basking shark presence in the region were temporally varying covariates (e.g. time of year, time of day, position in the tidal cycle). However, spatial covariates depth and slope were also important. This robust analysis indicates that when many of the environmental and survey covariates are taken into consideration, the regions with the highest basking shark presence are outside of the revised site boundary for the Argyll Array.

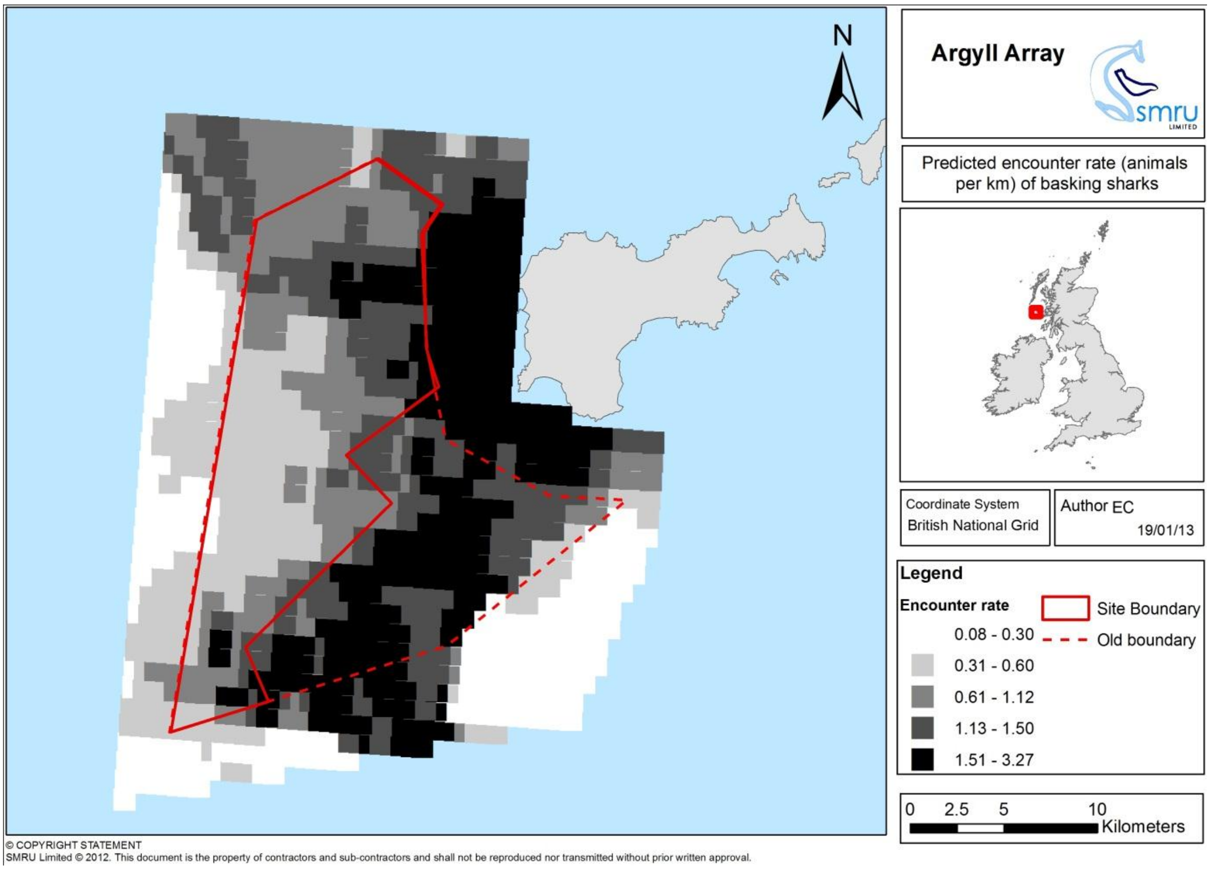

Figure 11 - Spatial distribution pattern of basking shark encounters. 1 x 1 km grid cells wirth the predicted basking shark encounter rates for each cell based on the model outputs. The Argyll Array current site boundary (solid red line) and original site boundary (dotted red line) are shown.

4.4.4 ARGYLL ARRAY BASKING SHARK ABUNDANCE ESTIMATION

The survey data were used to generate an abundance estimate to be used in the Impact Assessment (section 5). Due to inconsistent sampling rates across the surveys, the data were pooled and a single abundance estimate was generated (Table 6). It was estimated that over the course of the surveys on the Argyll Array site, a total of 1,645 basking sharks were present in the survey area between September 2009 and August 2012.

The model outputs include an indication of precision. Precision, based on the coefficient of variation (CV) indicates the ratio of the mean to the standard error. The target level of precision is typically ≤16% and corresponds to a level of precision at which a doubling or halving of the population is detectable (Bohlin 1990). Here the CV for this abundance estimate was predicted to be 13.6%

Table 6 - Basking shark abundances modelled as a function of perpendicular distance from the survey vessel and sea state during survey. CV = coefficient of variation, LCI = lower 95% confidence interval, UCI = upper 95% confidence interval.

Survey	Estimate for Argyll Array footprint	CV%	LCI	UCI
Global Estimate	1645	13.57	1255	2155

4.4.5 REVIEW AND IDENTIFICATION OF POTENTIAL LIMITATIONS OF THE ARGYLL ARRAY SURVEY DATA

It should be noted that there is currently very little available detailed guidance regarding how marine mammal and basking sharks surveys should be conducted from survey vessels for offshore wind farms. Draft guidance although currently under consultation is however available for marine renewable deployments in Scotland (Macleod et al., 2011). This guidance however relates to wave a tidal power generation not wind; although in the absence of any guidance relating specifically to wind it is considered to be of greatest relevance at this time. Guidance is also available in relation to the surveying of birds which RPS appears to have followed in the development of the basking shark survey design.

The use of data to estimate abundance was complicated by many of the source data being unavailable to allow an assessment of model goodness of fit statistics. Most of the limitations of the data (e.g. issues of sea state) were addressed in investigating the temporal and spatial patterns of basking shark distribution.

4.4.5.1 *TEMPORAL COVERAGE*

The two key aspects of site characterisation in terms of temporal scale are to ensure that the data collected accurately identify the importance and use of the site by basking sharks through an understanding of inter-annual variation and seasonal fluctuations. The draft guidance for marine deployment (Macleod *et al*., 2011) recommends monthly surveys for basking sharks. The coverage provided by the RPS data which was recorded over the majority of months over the course of the three survey years is considered sufficient for the purpose of tracking the seasonal use of the site by basking sharks. Macleod *et al.* (2011) also provide guidance on the inter-annual survey coverage with a recommendation of an initial year of baseline data collection followed by the possibility of a further year of data collection for key areas of importance. In terms of identifying the presence of basking sharks within the site and the seasonal fluctuations in numbers it is therefore considered the site characterisation data collected to date is sufficient for the Argyll Array EIA.

5 IMPACT ASSESSMENT

GLOSSARY

Extent - area of which impact is predicted to occur

Duration - time period over which impact is predicted to occur

Severity – the predicted nature of behavioural changes or injury to individual marine mammals and basking sharks as a result of each stressor

Frequency – Frequency of the stressor/activity leading to a potential impact

Timing – The period of the year during which the activity would need to occur to result in the impact. It has been assumed for the impact assessment that construction activities will not occur during winter months.

Reversibility – Whether or not the predicted impact is predicted to be reversed.

Sensitivity of Receptor:

(i) Sensitivity (Legislation) – defined by legislation protecting it/ accounts for vulnerability/ receptor value or importance
(ii) Sensitivity (Population status sensitivity index) - abundance and population trajectory in region of proposed development

5.1 ASSESSMENT METHODOLOGY

The general approach we have taken to assessing the impacts of the proposed Argyll Array wind farm on environmental receptors is, as far as possible, a quantitative one. This involves identifying likely significant stressors based on the sensitivity of the receptor and the magnitude of an effect; where applicable and where data are available investigations of spatial distribution patterns of both the species in question and these stressors will be carried out and if appropriate and suitable data exists to inform these, predictions of the numbers of individuals impacted upon will be given and an assessment made of the population consequences of this level of impact. However, it is clear that for many stressors, a paucity of data limits conclusions to a somewhat qualitative assessment of the potential impacts; nevertheless, we aim to construct a repeatable assessment framework to allow the comparison of a range of different scenarios. This methodology is a significant step forward from the simple, qualitative matrices that are currently used in impact assessments. As an increasing amount of scrutiny is placed on assessments this framework provides repeatability and transparency which is an important advantage as the scale of the developments increase.

The following sections outline how this framework will be used to assess the impact of the construction of the Argyll Array wind farm on receptor species. Our aim is to outline our generic approach for the assessments that will be made for different scenarios.

5.1.1 IMPACT SCORES

The initial assessment of impacts in this methodology is based on the use of indices which describe two fundamental parameters: the sensitivity of the receptor and the magnitude of the effect. However, as described below, we view the sensitivity of the receptor as two separate indices;

(i) The sensitivity of the receptor as defined by the legislation protecting it;

(ii) The sensitivity as predicted by the abundance and population trajectory of the population in the region of proposed development

And the magnitude of the effect as two separate indices;

(i) The severity of the impact;

(ii) The proportion of the population affected

The four different indices are combined to provide an overall impact score which is scaled from zero to one. Currently the indices are weighted so the sensitivity of the receptor accounts for 40% of the impact score, and the magnitude of the effect accounts for the remaining 60%. Finally, a qualitative assessment of certainty is provided alongside the impact scores indicating the degree of confidence that may be placed in the predictions made.

5.1.1.1 *LEGISLATIVE SENSITIVITY INDEX*

As basking sharks are a long-lived, slow reproducing species, they have life history strategies which are similar to those of some marine mammal species. As such, we have assessed them here according to the criteria we would use to assess the legislative sensitivity of marine mammals. The most important wildlife legislation affecting the offshore wind industry is the European Habitats Directive as well as other national and international legislation. Whilst basking sharks are not covered by this legislation, all cetaceans are European Protected Species (EPS) and are listed in Annex IV of the Directive. Under Article 12, member states are required to take the requisite measures to establish a system of strict protection for species in their natural range prohibiting (a) all forms of deliberate capture or killing of specimens of these species in the wild, (b) deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration and (c) deterioration or destruction of breeding sites or resting places. For Annex II species, which include the harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus),* grey seal (*Halichoerus grypus)* and harbour seal (*Phoca vitulina*), Member States are required to designate Special Areas of Conservation (SACs) in order for their habitats to be maintained or, where appropriate, restored at a favourable conservation status in their natural range.

All cetaceans and basking sharks (*Cetorhinus maximus*) are afforded legal protection under the Wildlife and Conservation Act, 1981 and this protection was further enhanced by the Nature Conservation Act (Scotland) 2004. Under Schedule 6 of this Act the intentional killing, capture or disturbance of cetaceans or basking sharks is prohibited out to 12nm around the coast of Great Britain. Species listed under national or international legislation are also of particular importance. For example, the Biodiversity Action Plan (BAP) identifies and protects threatened species and habitats including the bottlenose dolphin, harbour porpoise, harbour seals, minke whales and basking sharks.

In the context of this assessment, the legislative sensitivity of each receptor species was the sum of the values given for each parameter listed in Table 7, using Equation 1. These include whether the species are listed in Annex IV of the Habitats Directive, whether they are listed in Annex II and have an SAC designated for them (whether there is likely connectivity between the wind farm site and an SAC (i) unlikely (ii) potential (iii) proven) and the quality feature listing of the SAC, whether they are listed under Schedule 6 of the Nature Conservation Act 2004 and whether they are a UK Biodiversity Action Plan (BAP) priority species along with what selection criteria they qualify for.

Table 7: Legislative parameters and values used to estimate an overall legislative sensitivity score for each of the environmental receptors considered.

Parameter	Level	Value
Annex IV: European Protected Species (EPS)	No	0
	Yes	1
Annex II: SAC connectivity	No SAC	0
	Unlikely connectivity	2
	Potential connectivity	3
	Proven connectivity	4
SAC quality feature	A	4
	B	3
	C	2
	D	0
Schedule 6: Nature Conservation (Scotland) Act 2004	No	0
	Yes	1
UK BAP Priority Species	No	0
	Yes	1
UK BAP selection criteria (additive)	Other important factors	1
	Marked decline in UK	1
	International responsibility & moderate decline in UK	1
	International threat	1

Equation 1.

$$L_S = \frac{I_{eps} + I_{con} + I_{qua} + I_{sch} + I_{pri} + I_{cri}}{6 \times L_{Smax}}$$

Where:

L_S = the Legislative sensitivity index;

I_{eps} = European Protected Species value;

I_{con} = SAC connectivity value;

I_{qua} = SAC quality feature value;

I_{sch} = Schedule 6 value;

I_{pri} = BAP priority species value;

I_{cri} = BAP selection criteria value (additive), and;

L_{Smax} = max possible legislative sensitivity value;

* the legislative parameters have been adapted from SMRU Ltd's marine mammal impact assessment methodology to include legislation that applies to a wider range of receptor species

5.1.1.2 *POPULATION STATUS SENSITIVITY INDEX*

The abundance and trajectory of a population of animals is a key component to consider when predicting its sensitivity to anthropogenic perturbations. Central to the management of natural populations and a crucial mechanism for predicting the effects of human activity upon species abundance is the identification of biologically meaningful management units (MUs). This is necessary so that management and monitoring programs can be efficiently targeted toward distinct or independent populations. For species identification and classification, genetic principles and methods are relatively well developed; however, within species, the identification of genetically distinct local populations can be challenging. Biologists and managers must be able to identify and define appropriate populations and geographic boundaries between populations in order to effectively predict impacts or to effectively design monitoring strategies.

For the purposes of assessing the impacts of wind farms on marine mammal and basking shark populations around the UK, to date there has been a general lack of guidance from Statutory Bodies on the appropriate management units to consider during impact prediction. However, this process is currently underway for marine mammal species and results should be forthcoming over the next few months. For cetaceans, it is likely that these will be based to a large extent on the outputs of the ASCOBANS/HELCOM workshop on the population structure of cetaceans in the northeast Atlantic (Evans and Teilman, 2009). However, guidance on management units for basking sharks is lacking, which is largely a result of the lack of information. Studies of mitochondrial DNA of basking sharks have yielded a global effective population estimate of just 8600 animals (Hoelzel et al. 2006) which although acknowledged as a rough approximation, is surprisingly low for a species with global distribution. No abundance estimates exist for the UK or the North Atlantic. For the purpose of this assessment we can use a precautionary approach and can take the abundance estimate derived from section 4.4.4 (N = 1645; CI: 1255-2155) and use this as our minimum population size for our relevant management unit. Due to the transitory nature of this species and our limited understanding on their site-fidelity this is likely to be the most cautionary approach.

In terms of assessing the trajectory of the management unit, a score between 1 and 4 is given for each species management unit; where higher scores are given if the trajectory is unknown or decreasing (Table 8). It is understood that trajectory information will be generally lacking for most species considered here. An overall abundance sensitivity score is computed using Equation 2.

Table 8: Abundance parameters and values used to estimate an overall population status sensitivity score for each of the environmental receptors considered.

Parameter	Level	Value
Management unit trajectory	Increasing	1
	Stable	2
	Unknown	3
	Decreasing	4

Equation 2.

$$A_S = \frac{N_{mv}/N_{mu} + I_{tr}}{4 \times A_{S_{max}}}$$

Where:

A_S = the population status sensitivity value;

N_{mv} = the estimated minimum viable population for mammals *: 3876 (Traill et al., 2007);

N_{mu} = abundance estimate for the relevant management unit;

I_{tr} = management unit trajectory value (Table 7), and;

A_{Smax} = max possible population status sensitivity value;

* due to the basking shark's slow growth rates, extended gestation and reduced fecundity we feel it is more appropriate to use the estimated minimum viable population for mammals rather than fish.

5.1.1.3 *SEVERITY OF EFFECT*

The term 'Severity of effect' is used to describe the predicted nature of behavioural changes or injury to individual marine mammals and basking sharks as a result of each stressor. Qualitatively, these incorporate the 'Extent', 'Duration', 'Timing', 'Reversibility' and 'Frequency' of the effect and reflect a continuum of the potential consequences of a response by a receptor to a stressor. This ranges from ‘no response’ at the low end to ‘death or injury leading to significant reduction in survival or fecundity of an individual’ at the upper end (Table 9).

Table 9: Definitions of the severity of an effect occurring

Score	Level	Definition of Severity
0	None	No behavioural responses by or injury to individual animals.
1	Negligible	Short term (minutes) behavioural responses by individuals with no avoidance of area or impact on foraging efficiency. No injury to individuals.
2	Minor	Short term (days) behavioural responses by individuals that may lead to avoidance of area (tens-hundreds of metres) around stressor, leading to short term changes in foraging efficiency. Temporary injury to individuals leading to short term changes in foraging efficiency.
3	Moderate	Medium term (months) behavioural responses by individuals that leads to avoidance of area (kilometres) around stressor leading to medium term changes in foraging efficiency and possible reduction in fecundity. Permanent injury to individuals leading to medium term changes in foraging efficiency and possible reduction in fecundity.
4	Major	Long term (years) behavioural responses by individuals that leads to avoidance of area (kilometres) around stressor leading to mortality or long term reductions in fecundity. Permanent injury to individuals leading to mortality or long term reductions in fecundity.

5.1.1.4 *PROPORTION OF POPULATION AFFECTED*

It is clear that when considering the effect of each stressor on the environmental receptors, the severity of the effect needs to be considered in context of the number of individuals predicted to be affected. The term ‘Proportion of Population affected’ (PoPA) is therefore used to describe the number of individuals predicted to be affected as a proportion of the population. For each stressor, an assessment is made of the potential number of individuals that are likely to be affected, this assessment is quantitative wherever possible and a score is applied based on defined thresholds for the population concerned (see Table 10). Where a quantitative assessment is not possible, either because data are lacking on the abundance of a population or on the exact nature or mechanism of an impact on a receptor, this assessment will be necessarily qualitative and is therefore based on the available information and expert judgement. The methodology for all quantitative assessments is described and all assumptions and uncertainties made explicit; for all qualitative assessments, the rationale is fully explained and justified in the text.

Table 10: Definitions of the proportion of the population affected

Score	Level	Proportion of Population
1	Very Low	< 5% of the population affected
2	Low	5 – 10% of the population affected
3	Medium	10 – 20% of the population affected
4	High	> 20 % of the population affected

5.1.1.5 *ASSESSING IMPACT SCORES*

The sensitivity indices (legislative and population status) and the magnitude indices (severity and proportion of population) are then combined using Equation 3 to produce an impact score which is scaled between 0 and 1. Each impact score is then assigned a level of significance based on the thresholds described in Table 11.

Equation 3.

$$Impact\ score = \frac{S \text{ x } P}{26.7} + \frac{A_S + L_S}{5}$$

Where:

S = predicted severity score of the effect;
P = predicted proportion of population affected;
} Magnitude of Effect

A_S = the population status sensitivity index;
L_S = the Legislative sensitivity index;
} Sensitivity of Receptor

The denominators add the appropriate weighting to both sides of the equation (60% and 40% respectively).

Table 11: Impact score thresholds used to define the level of significance of each effect described in the assessment process.

Impact score	Impact
0-0.1	Not significant
0.1-0.5	Minor significance
0.5-0.9	Moderate significance
0.9-1.0	Major significance

Once Major and Moderate significant stressors are identified a further investigation of the short, medium and long term population consequences of those impacts will be carried out.

5.1.2 CERTAINTY

The prediction of impacts with associated impact scores (levels of significance) have been derived objectively and are quantifiable. Given the uncertainty, however, associated with predicting 'cause and effect' we have qualitatively associated a degree of confidence in the predicted impacts. This is confidence is based on the quality of data available on the relationship between the potential impact (stressor) and the environmental receptor (e.g. basking shark).

Table 11: Criteria used for assessing certainty in the impact predictions made during this assessment

Term	Definition
Certain	High certainty associated with the prediction of impact. The relationship between the stressor and receptor is well documented with evidence from empirical data.
Probable	Fairly certain of the predicted impact. There is some documented evidence to support the prediction coupled with current best knowledge.
Uncertain	Certainty associated with prediction of impact is low. The interaction between the stressor and receptor is poorly understood and is informed by current best knowledge.

5.1.3 *<u>EXAMPLE</u>: BASKING SHARK- COLLISION – INCREASED VESSEL PRESENCE*

Here we provide a worked example of the methodology: the predicted impact of 'collision' on Basking sharks as a result of 'increased vessel presence' during construction:

Legislative sensitivity score

- EPS: No (0)
- SAC connectivity: No SAC (0)
- SAC quality feature: NA (0)
- Schedule 6: YES (1)
- UK BAP Priority Species: YES (1)
- UK BAP Selection criteria: Marked decline in UK, International responsibility and moderate decline in UK, International threat (3)
    - ➢ Total legislative score: 0.33

Population Status Sensitivity Index:

- ➢ Management unit abundance: 1645
- ➢ Management unit trajectory: Unknown (3)

- Total population status score: 0.033

Severity: 4

Justification: The collision of basking sharks with vessel traffic would result in permanent injury to individuals leading to mortality or long term reductions in fecundity (through a reduced ability to feed or reduced mating opportunities).

Proportion of Population Affected: 3

Justification: There is currently no quantitative model available for assessing the frequency of vessel collisions with basking sharks. Given that basking sharks exhibit a relative lack of awareness of vessel traffic and appear to be susceptible to ship strikes a medium score for the proportion of the population affected is assumed

Certainty: Probable

TOTAL IMPACT SCORE: 0.53 (Moderate Significance)

5.2 IMPACT SCORES FOR ARGYLL ARRAY WIND FARM

Table 12 provides a summary of the assessment of the impact scores and predicted impact significant for all impacts identified during the construction and operational phase of the wind farm before any mitigation is applied. The following sections describe these assessments in more detail and where appropriate, potential mitigation is proposed.

Table 12- Impact scores for Argyll Array wind farm for environmental topics with the potential to impact basking sharks; population estimate is 1645 animals (upper and lower impact score confidence intervals are shown; derived from the upper and lower abundance estimates). * - precautionary assessment due to low certainty. These assessments of significance are made without mitigation measures in place. When mitigation could reduce them, this is discussed in the relevant sections below.

			Magnitude of Effect			
Phase	**Environmental Topic**	**Potential Impact**	**Severity of Effect**	**Proportion of Population Affected**	**Impact Score**	**Impact**
Construction:						
1.1	Collision-Vessels	Physical Injury/ Mortality	4	3	**0.53 (± 0.1)**	Moderate Significance
1.1	Physical Disturbance	Displacement from habitat	2	2	**0.23 (± 0.1)**	Minor Significance
1.2	Increase in Suspended	Impairment of foraging ability	--	--	--	Moderate Significance *
1.2	Increase in Suspended	Reduction of potential prey species	3	3	**0.53 (± <0.1)**	Moderate Significance
1.2	Increase in Suspended	Habitat displacement – barrier effects	2	1	**0.16 (± <0.1)**	Minor Significance
1.3	Pile Driving	Non-auditory injury/ Mortality	4	3	**0.53 (± 0.1)**	Moderate Significance
1.3	Pile Driving	Auditory Injury	2	3	**0.31 (± <0.1)**	Minor Significance
1.3	Pile Driving	Displacement from Habitat	2	3	**0.31 (± <0.1)**	Minor Significance
1.3	Vessel Noise	Masking of Vocalisations/ Displacement	2	2	**0.23 (± 0.1)**	Minor Significance
1.4	Entanglement	Physical Injury/ Mortality	4	2	**0.38 (± <0.1)**	Minor Significance
Operational:						
2.1	Collision- Turbines	Physical Injury/ Mortality	4	1	**0.23 (± 0.1)**	Minor Significance
2.1	Barrier Effects	Barrier Effects	2	2	**0.23 (± 0.1)**	Minor Significance
2.1	Habitat Exclusion	Habitat Exclusion	2	2	**0.23 (± 0.1)**	Minor Significance
2.2	Collision-Vessels	Physical Injury/ Mortality	4	3	**0.53 (± 0.1)**	Moderate Significance
2.2	Physical Disturbance	Displacement from habitat	2	2	**0.23 (± 0.1)**	Minor Significance
2.3	Vessel Noise	Masking of Vocalisations	1	2	**0.16 (± 0.1)**	Minor Significance
	Vessel Noise	Disturbance/ Habitat Displacement	2	2	**0.23 (± 0.1)**	Minor Significance
2.4	EMFs	Electromagnetic Emissions	2	1	**0.16 (± 0.1)**	Minor Significance
2.5	Toxic Contamination	Physical Injury/ Mortality	4	1	**0.23 (± 0.1)**	Minor Significance
		Reduction of Prey Species	2	1	**0.16 (± 0.1)**	Minor Significance

5.2.1 CONSTRUCTION PHASE

5.2.1.1 *INCREASED VESSEL ACTIVITY – COLLISION RISK & DISTURBANCE*

DIRECT IMPACTS – COLLISION WITH VESSELS

One potential source of mortality from increased vessel activity for marine vertebrate species, including basking sharks, is physical trauma from collision with a boat or ship. These injuries include blunt trauma to the body or injuries consistent with propeller strikes. The occurrence of vessel strikes is likely dependent on the type of vessels involved and the speed of the vessel when the strike occurs (Laist et al. 2001).

Anecdotal evidence suggests that basking sharks appear relatively unaware of the presence of vessels, which could make them highly susceptible to ship strike, particularly when this is considered in conjunction with the large amount of time they can spend at the surface. Descriptions exist of sharks entering a "trance-like" state, especially when engaged in behaviour which is thought to be associated with courtship (Speedie et al. 2009), which is conducted at the surface.

There is currently a lack of information regarding the frequency of occurrence of boat collisions as a source of basking shark mortality, although the rates and effects of vessel strikes of the northern right whale (*Eubalaena glacialis*), have been studied more extensively. It is possible to consider this as a reasonable proxy species as it also spends large amounts of time at the surface, exhibits negligible avoidance behaviour and feeds on similar prey items. Studies on this species demonstrate that the approximate likelihood of lethal injury is less than 20% at 8 knots or less, 50% at 11.8 or knots or faster, whilst at speeds in excess of 15 knots, the probability of lethal injury is approximately 1 (Vanderlaan & Taggart 2007). Anecdotal evidence for non-lethal injury resulting from propeller cuts for basking sharks is discussed in Speedie & Johnson (2008) and Speedie et al. (2009). Whilst the numbers and overall severity of non-lethal injury is hard to quantify, it should be considered.

Over the construction period for the Argyll Array wind farm it is anticipated that there will be an increase in vessel movements between the designated construction port and the development site. In order to assess the magnitude of the effect, the number of vessel movements during the construction period (4-5 years) needs to be assessed and these numbers compared to baseline levels (number of vessels that currently use the development area). In addition, information is required on the type of vessels that will use the development area and the proposed transit routes. This output will be provided by the Shipping and Navigation Chapter in the ES.

INDIRECT IMPACTS - DISTURBANCE

The basking sharks relative lack of awareness of vessel traffic and susceptibility to ship strikes conversely means that they are not likely to be susceptible to disturbance from the presence of increased vessel traffic (Speedie et al. 2009). Large sharks exhibiting surface feeding behaviour appear to be particularly immune to the approach of vessels, although smaller sharks may react more readily (Speedie et al. 2009). A study carried out in south-west England (Wilson 2000; as cited in Speedie et al. 2009) identified that engine noise has some limited effect on shark behaviour, as does the angle of approach, but beyond that the effects were inconclusive. Telemetry studies of basking sharks typically approach the sharks from behind to attach the tags as the bow of the vessel draws level with the first dorsal fin. Generally sharks tagged in this manner are reported to show little reaction, and if they do dive at all, are soon seen feeding at the surface (Sims 2005; as cited in Speedie et al. 2009).

ASSESSMENT OF SIGNIFICANCE

A full assessment of significance requires the output from the Shipping and Navigation chapter on what the relative increase in vessel traffic will be as a result of the Argyll array development.

It is, however, unlikely that disturbance from increased vessel traffic will have a significant impact on basking sharks. Given the limited effect of vessel traffic on shark behaviour, the impact of increased vessel traffic during the construction phase on basking sharks is considered to be of **minor severity** with a **low** proportion of the population predicted to be affected and thus the impact is of **minor significance**.

Collision risk will depend both on the number of vessels in the area and the speed of the vessels. Although codes of conduct may minimise risk (see below); the impact of collision on basking sharks during the construction phase is considered to be of **major severity** with a **medium** proportion of the population thought to be affected and thus is of **moderate significance**.

Certainty for these predictions is **probable**.

MITIGATION

To mitigate and reduce the risk of collision with basking sharks it is suggested that codes of conduct for vessel operators are implemented. Codes of conduct would advise operators to reduce speed to below 8 knots in designated areas and to have basking shark observers on board. Adoption of this mitigation is likely to reduce the significance of the impact to **minor.**

5.2.1.2 *NON-TOXIC CONTAMINATION – INCREASE IN SUSPENDED SEDIMENT*

DIRECT IMPACTS – IMPAIRMENT OF FORAGING ABILITY

Although it is suggested basking sharks use electroreception to find food patches (Sims & Quayle 1998; Kempster & Collin 2011) the mechanisms controlling this are unclear and there are currently no published data that inform the impact of increased sediment suspension on electrosensitive species.

INDIRECT IMPACTS – REDUCTION OF POTENTIAL PREY SPECIES

Although zooplankton are found in areas of high water turbidity there appears to be an effect where changes in zooplankton composition are correlated with changes in turbidity (Hart 1988). An increase in turbidity as a result of suspended sediment results in a decline in the feeding rates of zooplankton (Arruda et al. 1983; Hart 1988), the extent of this decline, however, differs between species of zooplankton (Hart 1988). As all aspects of basking shark ecology are thought to be driven by their unique feeding mechanism (Sims 2008), we would consider any aspect of the development with the potential to impact the distribution or abundance of zooplankton prey species to also have an impact on the presence of basking sharks. **We therefore recommend that the impact of any increase in suspended sediment on zooplankton at the development site be modelled and the potential impact re-assessed in light of such outputs.**

INDIRECT IMPACTS – HABITAT DISPLACEMENT: PERCEPTUAL BARRIER TO MOVEMENT

Basking shark distribution is largely driven by prey distribution and as such basking sharks do not have definitive 'habitat' in the way other species which exploit more static resources do. Given that basking sharks feed on zooplankton, which can be found in relative turbid waters, it is unlikely that the increase in suspended sediment will act as a perceptual barrier to movement. It may indirectly result in displacement if the change in turbidity negatively affects prey species and basking sharks leave the area to find a new foraging patch.

ASSESSMENT OF SIGNIFICANCE

The current understanding of the impact increased sediment suspension on electrosensitive species and the foraging ability of basking sharks is limited, thus cannot be fully assessed in the scope of this ES. The certainty of the assessment made here is **uncertain**. We are currently unable to sufficiently assess the significance of this impact without the outputs from the modelling indicated above.

The direct impact of impairment of foraging ability are very poorly understood. As a precaution, this has been assigned a **moderate significance.**

One potential indirect impact may be on the reduction of potential prey species. The release of high levels of suspended sediment at the development site is unlikely given the hard rock substrate. The impact of increased suspended sediment on prey species and ultimately on basking sharks is thought to be of **moderate severity** with a **high** proportion of the population being thought to be affected and thus is of **moderate significance**.

The indirect impact of increased suspended sediment on habitat displacement is thought to be of **minor severity** with a **medium** proportion of the population being affected and is therefore of **minor significance**.

5.2.1.3 *INCREASED ANTHROPOGENIC NOISE & VIBRATION: OVERVIEW*

There is growing concern and awareness of the effects of anthropogenic sound on marine life. Research has been conducted into the effects of these sounds on some taxa, such as marine mammals, and is starting to be conducted on teleost fishes. There is, however, currently no existing data on whether elasmobranchs could be affected by sound exposure (Casper et al. 2012). The effects of sound exposure documented for other taxa, such as marine mammals, include physical injury, hearing damage, masking, and disturbance (Richardson et al. 1995; Southall et al. 2007).

Elasmobranchs possess only inner ear labyrinths and they are devoid of many of the accessory organs often found in bony fishes, such as a swim bladder. This may limit the ability of at least some species to detect the pressure component of sound, implying that the particle motion aspect is likely to be considered the primary stimulus for perceiving a sound field (Myrberg 2001; Casper & Mann 2006). Audiograms have been calculated for five elasmobranch species (reviewed in Casper & Mann 2009); with most of the sensitivity occurring at low frequencies. The hearing bandwidth for elasmobranchs appears to be from ~20Hz up to 1kHz, although 20Hz was the lowest frequency tested (Casper et al. 2012).

INCREASED ANTHROPOGENIC NOISE & VIBRATION: PILING

It is possible that pile driving activities conducted as part of the construction works for Argyll Array could produce sounds at levels sufficient enough to yield hearing damage in the form of temporary threshold shift (TTS), resulting in a short-term decrease in auditory sensitivity (Casper et al. 2012). At this time, however, it is not known what these levels may be. To date there have been a limited number of studies that have examined the effects of exposure to anthropogenic sound sources in species of elasmobranch (Casper et al. 2012). There is some experimental evidence that assessed the behavioural responses of sharks to sound (reviewed in Casper et al. 2012), in which loud, sudden onset sounds (20-30dB above ambient noise levels) would result in startling sharks from an area, although reportedly sharks would habituate to the stimuli after a few trials.

The more likely source of damage would be barotrauma as a result of the impulsive energy produced when the hammer hits the pile. Recent evidence (Halvorsen et al. 2012) suggests that some of the barotrauma damage found in teleosts when exposed to pile- driving stimuli is focused in the liver, kidneys, and intestines, and while elasmobranchs were not used in that study, they have many similarities in morphology with those speces (e.g.they have the same organs as teleosts). Therefore we consider that this study is indicative of the potential impacts of barotrauma on basking sharks.

INCREASED ANTHROPOGENIC NOISE & VIBRATION: VESSEL NOISE

There will be an increase in vessel traffic during the construction of the Argyll Array wind farm which will result in increased vessel engine noise. Although vessel noise is unlikely to induce temporary hearing damage (TTS) the masking of acoustic signals is possible. Basking sharks are not known to vocalise, or rely on hearing to forage, so it is unlikely that masking will have an impact. It is also unlikely that increased vessel noise will lead to disturbance or habitat displacement given the limited effect vessel traffic appears to have on shark behaviour.

ASSESSMENT OF SIGNIFICANCE

Given the current lack of knowledge on the effects of high-intensity sound exposure on basking sharks it is difficult to assess the likelihood of the impact and therefore a probable likelihood is used in the absence of any empirical data showing otherwise. Given that basking sharks do not vocalise or rely on hearing to forage the effect of TTS is thought to be of **minor severity**, although with limited data on TTS onset in sharks it is predicted that a **medium** proportion of the population will be affected (as a precautionary approach) and thus the impact is of **minor significance**. In addition, the displacement of basking sharks from the area as a result of pile driving, is of **minor severity** but as sharks have been shown to startle and leave the area in response to loud, sudden-onset sounds it is thought to affect a **medium** proportion of the population and is therefore considered to be of **minor significance**.

The consequence of barotrauma, however, is considered to be of **major severity** with a **medium** proportion of the population affected and therefore is of **moderate significance.**

Finally, it is considered that the impact of noise from increased vessel traffic during the construction phase on basking sharks is of **low severity** with a **low** proportion of the population affected and thus is of **minor significance**.

The certainty for these predictions is **probable**.

MITIGATION

To mitigate and reduce the risk of barotrauma from piling it is suggested that basking shark MMO's are placed on board the piling vessel to detect basking sharks when at the surface. However, due to the basking sharks potential for foraging at depth and therefore unavailable to be sighted at the surface (and their presence in the region confirmed). An observation period of 2 hours with no basking shark sightings is recommended prior to the commencement of piling. Adoption of mitigation would reduce the significance of the predicted impact to **minor**.

5.2.1.4 *ENTANGLEMENT: INTERACTION WITH INFRASTRUCTURE (INTER-ARRAY & EXPORT CABLING)*

Whilst there are no published records of basking sharks becoming entangled in cables specifically, they are susceptible to by-catch in fishing gear and as such it is not unreasonable to consider that entanglement may be an impact. Fisheries with reported basking shark by-catch include deep water trawls (Francis & Duffy 2002), creel ropes and gill nets. Incidental take or by-catch, associated with other fisheries, is mainly reported in set nets and trawls and is most common in coastal waters. Berrow (1994) calculated that between 77 and 120 sharks were taken annually in the bottom set gill net fishery in the Celtic Sea (south of Ireland); (data reviewed in Bloomfield & Solandt 2006).

A potential source of entanglement with the installation of wind farms are the inter-array and export cables. Cable installation usually involves the burial of the cables in the seabed and thus the risk of entanglement with basking sharks will be low, assuming the cables are not disturbed and remain buried. The seabed floor at the Argyll array development site, however, hard substrate and therefore the method of attachment for cable laying would need to be considered.

ASSESSMENT OF SIGNIFICANCE

Given the susceptibility of basking sharks to be caught in fishing gear it is important that their risk of entanglement with wind farm cables is properly assessed. We cannot, however, currently make this assessment without further information on how the cables will be buried or fixed to the sea floor.

Under the assumption the cables will be buried in the sea floor or protected by a layer of rock or concrete and given that basking sharks are not benthic feeders and are unlikely to encounter such cabling frequently then the impact of entanglement on basking sharks is considered to be of **major severity but** with a **low** proportion of the population affected and thus is of **minor significance**.

The certainty for these predictions is **probable**.

5.2.2 OPERATION PHASE

5.2.2.1 *PRESENCE OF TURBINES*

The physical presence of the turbines will alter the underwater landscape, could alter the seabed topography and tidal regime within the development site and may result in a number of impacts on basking sharks. The impacts considered here are (i) collision risk with turbine foundations (ii) barrier effects (iii) habitat exclusion.

A level of uncertainty remains as to whether fixed, submerged structures such as turbine foundations pose a significant collision risk. It is suggested that they represent little risk in comparison to cables, chains and other free moving components that may be deployed in the water column (Wilson et al. 2007). Basking sharks are known to negotiate rocky areas and skerries and it is likely they would quickly habituate to the presence of stationary underwater structures. Therefore the presence of turbines is not considered to pose a significant threat.

The introduction of turbine foundations and other subsurface structures into the water column may also have a negative impact on marine vertebrates if the structures displace animals from the area or cause them to avoid travelling through the development site. The magnitude of this avoidance response, to some extent, will depend on the species in question. As discussed in section 5.2.1.2, however, basking sharks do not have a 'habitat' in the same sense as other taxa and instead the location of foraging patches drives the location of basking sharks. Therefore habitat exclusion is not considered a significant impact.

ASSESSMENT OF SIGNIFICANCE

The impact of turbine presence is thought to be negligible given that the risk of collision with static turbine foundations is thought to be low for marine vertebrates (Inger et al. 2009). Given the basking sharks ability to negotiate rocky areas underwater the impact of turbine presence as a collision risk during the operational phase is considered to be of **major severity** but only a very **low** proportion of the population is predicted to be affected and thus the impact is of **minor significance**.

The impact of turbine presence on basking sharks in the form of habitat displacement and barrier effects is considered to be of **minor severity** with a **low** proportion of the population thought to be affected and thus is of **minor significance**.

The certainty for these predictions is **probable**.

5.2.2.2 *INCREASED VESSEL ACTIVITY*

The impacts of increased vessel activity are risk of collision and disturbance; these are discussed in detail in section 5.2.1.1.

ASSESSMENT OF SIGNIFICANCE

The assessment of significance requires the output from the Shipping and Navigation chapter on what the relative increase in vessel traffic will be as a result of the Argyll array development.

It is, however, unlikely that disturbance from increased vessel traffic will have a significant impact on basking sharks. Given the limited effect of vessel traffic on shark behaviour, the impact of increased vessel traffic during the construction phase on basking sharks is considered to be of **minor severity** with a **low** proportion of the population predicted to be affected and thus the impact is of **minor significance**.

Collision risk will depend both on the number of vessels in the area and the speed of the vessels. Although codes of conduct may minimise risk (see below); the impact of collision on basking sharks during the construction phase is considered to be of **major severity** with a **medium** proportion of the population thought to be affected and thus is of **moderate significance**.

Certainty for these predictions is **probable**.

MITIGATION

To mitigate and reduce the risk of collision with basking sharks it is suggested that codes of conduct for vessel operators are implemented. Codes of conduct would advise operators to reduce speed to below 8 knots in designated areas and to have basking shark observers on board. Adoption of mitigation would reduce the significance of the predicted impact to **minor**.

5.2.2.3 *INCREASED ANTHROPOGENIC NOISE & VIBRATION*

The impacts of increased vessel activity are acoustic masking and disturbance; these are discussed in detail in section 5.2.1.3.

It is considered that the impact of noise from increased vessel traffic during the operation phase on basking sharks is of **minor significance**.

Certainty for these predictions is **probable**.

5.2.2.4 *ELECTROMAGENTIC FIELD (EMF) EMISSIONS*

Electromagnetic (EMF) field emissions are generated from the transmission of electricity through cables, such as the AC inter-array and AC export cables proposed for this development. The cables produce electromagnetic fields which have both electric and magnetic components. The direct electric field is mostly blocked with the use of conductive sheathing and therefore the magnetic field and the resultant induced electric field are emitted into the marine environment. The current ecological impacts of EMFs are unknown but it has been suggested that they may be detected by marine organisms (Inger et al. 2009). In an underwater environment vision is limited by both light availability and turbidity, natural selection therefore favours other sensory modalities such as hearing, chemoreception and electroreception. Animals may rely on natural magnetic fields for orientation or navigation and some animals may be electro-sensitive to facilitate detection of predators/prey or for social or reproductive behaviours. Thus the introduction of anthropogenic EMFs near offshore cabling may interfere with these natural behaviours. The basking shark is part of the class Chondrichthyes who all possess a unique sensory system known as the Ampullae of Lorenzini which consists of an array of individual receptors that function in detecting weak electric fields in the animals underwater environment (Normandeau et al. 2011). In particular, elasmobranchs use their electroreceptors to detect bioelectric fields produced by their natural prey. Basking sharks filter-feed on zooplankton and it is thought they identify energy-rich foraging patches through electroreception (Sims & Quayle 1998; Kempster & Collin 2011).The effects of anthropogenic EMFs on the basking sharks ability to locate prey with their electroreceptors are, however, unknown.

There is also an increasing body of evidence showing that marine vertebrates and invertebrates can sense the earth's magnetic field and they use this information for orientation and navigation (Normandeau et al. 2011). The effects of anthropogenic magnetic fields are of particular interest in those animals that undertake long migrations because if navigation is affected then animals may be displaced from their migratory corridors. This could have serious implications if animals were prevented from reaching their essential feeding, spawning or nursery grounds (Normandeau et al. 2011), alternatively it may also have a positive effect if it acts as a topographic landmark for the animals (Normandeau et al. 2011). A confounding issue is if animals are attracted to anthropogenic EMF sources. If animals use electroreception to identify rich prey patches then the introduction of anthropogenic electric fields in certain areas may result in animals becoming attracted to these areas and thereby reducing the time the animals spend foraging and ultimately their daily energy intake (Normandeau et al. 2011).

Anthropogenic EMFs associated with offshore wind developments will likely affect context specific behaviours in localised areas that are dependent on season and habitat (Normandeau et al. 2011). This use of the development area by basking sharks therefore remains an important consideration because basking sharks appear to favour specific geographic locations for social and mating behaviour. The long term impact of EMFs on basking shark populations may be minor if only a few individuals are affected in this way; however, if enough animals are affected then the population consequences become more significant. Our current understanding of the effects of anthropogenic EMFs on basking sharks does, however, remain limited (Gill, et al. 2005).

ASSESSMENT OF SIGNIFICANCE

There are areas of research that suggest that marine species are more likely to detect magnetic fields from DC cables than AC cables (Normandeau et al. 2011).The primary concern for species, such as basking sharks, that rely on electroreception for finding food is that EMF emissions may result in them becoming confused and will disrupt their foraging behaviour thus reducing their daily energy intake (Normandeau et al. 2011). There is, however, a notable lack of information on whether electrosensitive species are affected by electromagnetic field emissions. The benthic shark (*Scyliorhinus canicula*l) has been shown to avoid electric fields at 1000µV/m out to small ranges which are the maximum predicted fields to be emitted from 3-core undersea 150kV, 600A cables used in offshore wind developments (Gill & Taylor 2001). Unlike the benthic shark, however, the basking shark is pelagic and as such may not be affected by EMFs to the same extent.

Given our limited knowledge of the impact of EMFs on elasmobranchs and the fact that basking sharks are pelagic foragers rather than benthic ones the impact is predicted to be of **minor severity** with only a **very low** proportion of the population being affected and thus is of **minor significance**.

Certainty for these predictions is **probable**.

5.2.2.5 *TOXIC CONTAMINATION*

DIRECT IMPACTS – INGESTION OR ABSOPRTION

Activities undertaken during the lifetime of the wind farm may result in the leaching of sacrificial anodes and antifouling paints into the water. This may lead to a build-up of heavy metals in the environment which may have a negative impact on marine vertebrates such as basking sharks. The accumulation of heavy metals in shark species has been shown to inhibit DNA synthesis, alter heart function, disrupt sperm production and alter blood composition (Watts 2001; Bloomfield & Solandt 2006b). The compound Tributylin (TBT), which is found in anti-fouling paints, has the potential to cause severe damage to basic biological functions and has been found in the kidneys of blue sharks off the Italian coast (Carsolini et al. 1995)

It is difficult to predict the extent of toxic contamination over the lifetime of development, although with appropriate mitigation measures contamination may be minimal and may be quickly dispersed in tidal currents, depending on current speeds.

INDIRECT IMPACTS – BIOACCUMULATION IN PREY SPECIES

The leaching of heavy metal contaminants, such as zinc, copper and aluminium into the environment may also have an impact on prey species. An increase in copper concentrations has been shown to lead to a reduction in total biomass, and number of species, in benthic communities (Beltman et al. 1999). In addition, although the effects of heavy metals on phytoplankton result in a shift towards more metal resistant species, the abundance and species richness of zooplankton decreases substantially (Monteiro et al. 1995). This may have indirect impacts on basking sharks if rich foraging patches are affected and energy intake is reduced.

ASSESSMENT OF SIGNIFICANCE

The introduction of small amounts of leachate into the environment may disperse quickly depending on the tidal action of the development area and therefore the impact would be short-term in duration. As such, it is important that tidal actions and regimes both at the development site and the in the wider area are assessed and understood.

The direct impact of toxic contamination on basking sharks is predicted to be of **major severity** but with a **low** proportion of the population predicted to be affected and therefore is of **minor significance**.

The indirect impact of toxic contamination on prey species is predicted to be of **minor severity** but with a **low** proportion of the population predicted to be affected and is therefore of **minor significance.**

Certainty for these predictions is **probable**.

MITIGATION

Best working practise and published guidelines should be used along with appropriate mitigation measures, such as applying cathodic protection, to ensure that any accidental release of pollutants is unlikely.

5.2.3 DECOMMISSIONING PHASE

The decommissioning phase of the Argyll Array wind farm is yet to be decided and will depend on the choice of turbine structure and the foundation type. As such a detailed assessment of potential impacts that may occur during the decommissioning phase or the mitigation strategies that may be implemented is not currently possible.

We consider that the impacts outlined in the construction phase impact assessment are mirrored by those to be considered in the decommissioning phase. Therefore please refer section **** for the predicted impacts of the stressors likely to be encountered during decommissioning.

Plume modelling for the construction phase is largely believed to represent the worst-case scenario so impact significance from increased suspended sediment for construction is unlikely to change for decommissioning.

Noise impacts are predicted to be highest during the construction phase, although noise monitoring and mitigation strategies are still recommended for the decommissioning phase. It is also worth noting that, due to the increased vessel presence in the area as a result of the decommissioning of the wind farm development, collision risk will remain a significant impact that should be mitigated against.

6 REFERENCES

Arruda, J. A., Marzolf, G. R. & Faulk, R. T. 1983. The role of suspended sediments in the nutrition of zooplankton in turbid reservoirs. Ecology, 64, 1225–1235.

Bailey, H., Thompson, P.M., 2009. Using marine mammal habitat modelling to identify priority conservation zones within a marine protected area. Marine Ecology-Progress Series 378, 279-287.

Beltman, D. J., Clements, W. H., Lipton, J. & Cacela, D. 1999. Benthic invertebrate metals exposure, accumulation, and community-level effects downstream from a hard-rock mine site. Environmental Toxicology and Chemistry, 18, 299–307.

Bloomfield, A. & Solandt, J. 2006a. The Marine Conservation Society Basking Shark Watch Angus Bloomfield and Jean-Luc Solandt Acknowledgments.

Bloomfield, A. & Solandt, J. L. 2006b. Basking Shark Watch 20 year Report (1987-2006).

Booth, C.G., 2010. Variation in habitat preference and distribution of harbour porpoises west of Scotland. PhD thesis. Scottish Oceans Institute, Sea Mammal Research Unit, University of St Andrews: 264 pp.

Carsolini, S., Focardi, S., Kannan, K., Tanabe, S., Borrel, A. & Tatsukawa, R. 1995. Congener Profile and Toxicity Assessment of Polychlorinated Biphenyls in dolphins, Sharks and Tuna collected from Italian Coastal Waters. Marine Environmental Research, 40, 33–53.

Casper, B. M. & Mann, D. a. 2006. Evoked Potential Audiograms of the Nurse Shark (Ginglymostoma cirratum) and the Yellow Stingray (Urobatis jamaicensis). Environmental Biology of Fishes, 76, 101–108.

Casper, B. M. & Mann, D. a. 2009. Field hearing measurements of the Atlantic sharpnose shark Rhizoprionodon terraenovae. Journal of fish biology, 75, 2768–76.

Casper, B. M., Halvorsen, M. B. & Popper, A. N. 2012. Are Sharks Even Bothered by a Noisy Environment ? In: Effects of Noise on Aquatic Life, Vol 730 (Ed. by A. N. Popper & A. Hawkins), pp. 93–97. Springer Link.

Cox, D.R. & Snell, E.J., 1989. Analysis of Binary Data (Second Edition), 2nd Edition edn. Taylor & Francis Ltd Chapman & Hall/CRC.

Embling, C.B., Gillibrand, P.A., Gordon, J., Shrimpton, J., Stevick, P.T., Hammond, P.S., 2010. Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (Phocoena phocoena). Biological Conservation 143, 267 - 279.

Fowler, S.L. 2005. Cetorhinus maximus. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded on 06 December 2012.

Fox, J., Monette, G., 1992. Generalized collinearity diagnostics. Journal of the Acoustical Society of America 87, 178-183.

Francis, M. P. & Duffy, C. 2002. Distribution, seasonal abundance and bycatch of basking sharks (Cetorhinus maximus) in New Zealand, with observations on their winter habitat. Marine Biology, 140, 831–842.

Gill, A. B. & Taylor, H. 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon Elasmobranch Fishes.

Halvorsen, M. B., Casper, B. M., Carlson, T. J., Woodley, C. M. & Popper, A. N. 2012. Assessment of Barotrauma Injury and Cumulative Sound Exposure level in Salmon after Exposure to Impulsive Sound. In: Effects of Noise on Aquatic Life, Vol 730 (Ed. by A. N. Popper & A. Hawkins), pp. 235–237. Boston, MA: Springer US.

Hardin, J.W., Hilbe, J.M., 2002. Generalized estimating equations, 2nd Edition edn. Chapman and Hall CRC

Hart, R. C. 1988. Zooplankton feeding rates in relation to suspended sediment content: potential influences on community structure in a turbid reservoir. Freshwater Biology, 19, 123–139.

Hoelzel, A. R., Shivji, M. S., Magnussen, J. & Francis, M. P. 2006. Low worldwide genetic diversity in the basking shark (Cetorhinus maximus). Biology letters, 2, 639–42.

Inger, R., Attrill, M. J., Bearhop, S., Broderick, A. C., James Grecian, W., Hodgson, D. J., Mills, C., Sheehan, E., Votier, S. C., Witt, M. J. & Godley, B. J. 2009. Marine renewable energy: potential benefits to biodiversity? An urgent call for research. Journal of Applied Ecology, 1–9.

Kempster, R. & Collin, S. 2011. Electrosensory pore distribution and feeding in the basking shark Cetorhinus maximus (Lamniformes: Cetorhinidae). Aquatic Biology, 12, 33–36.

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S. & Podesta, M. 2001. Collisions between ships and whales. 17, 35–75.

Liang, K.-T., Zeger, S.L., 1986. Longitudinal data analysis using generalized linear models. Biometrika 73, 13-22.

MacLeod, K., Fairbairns, R., Gill, A., Fairbairns, B., Gordon, J., Blair-Myers, C., Parsons, E.C.M., 2004. Seasonal distribution of minke whales Balaenoptera acutorostrata in relation to physiography and prey off the Isle of Mull, Scotland. Marine Ecology-Progress Series 277, 263 - 274.

Marubini, F., Gimona, A., Evans, P.G.H., Wright, P.J., Pierce, G.J., 2009. Habitat preferences and interannual variability in occurrence of the harbour porpoise Phocoena phocoena off northwest Scotland. Marine Ecology-Progress Series 381, 297-310.

Monteiro, M. T., Oliveira, R. & Vale, C. 1995. Metal stress on the plankton communities of Sado River (Portugal). Water Research, 29, 695–701.

Myrberg, A. A. 2001. The acoustical biology of elasmobranchs. 31–45.

Normandeau, A., Exponent, Tricas, T. & Gill, A. 2011. Effects of EMFs from undersea power cables on elasmobranchs and other marine species.

Palka, D., 1996. Effects of Beaufort Sea State on the sightability of harbor porpoises in the Gulf of Maine. Reports of the International Whaling Commission 46, 575-582.

Panigada, S., Zanardelli, M., MacKenzie, M., Donovan, C., Melin, F., Hammond, P.S., 2008. Modelling habitat preferences for fin whales and striped dolphins in the Pelagos Sanctuary (Western Mediterranean Sea) with physiographic and remote sensing variables. Remote Sensing of Environment 112, 3400-3412.

Pirotta, E., Matthiopoulos, J., MacKenzie, M., Scott-Hayward, L., Rendell, L. 2011. Modelling sperm whales habitat preference: a novel approach combining transect and folow data. Marine Ecology-Progress Series: 436: 257-272.

Richardson, W. J., Greene, C. R., Malme, C. I. & Thomson, D. H. 1995. Marine Mammals and Noise. San Diego, California: Academic Press.

Sims, D. W. & Quayle, V. A. 1998. Selective foraging behaviourof basking sharks on zooplankton in a small-scale front. Nature, 393, 460–464.

Sims, D. W. 2008. Sieving a living: a review of the biology, ecology and conservation status of the plankton-feeding basking shark Cetorhinus maximus. Advances in marine biology, 54, 171–220.

Sims, D. W. et al. 2005. Basking shark population assessment.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.G., Greene, C.H., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., Tyack, P.L., 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquat. Mamm. 33, 411-521.

Southall, E.J., Sims, D.W., Metcalfe, J.D., Doyle, J.I. , Fanshawe, P, S., Lacey, C., Shrimpton, J., , Solandt, J-L., Speedie, C.D.,. 2005. Spatial distribution patterns of basking sharks on the European shelf: preliminary comparison of satellite-tag geolocation, survey and public sightings data. J. Mar. Biol. Ass. U.K. (2005), 85, 1083^1088

Speedie, C. D. & Johnson, L. A. 2008. 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.

Speedie, C. D., Johnson, L. A. & Witt, M. J. 2009. Commissioned Report No. 339. Basking Shark Hotspots on the West Coast of Scotland : Key sites , threats and implications for conservation of the species.

Vanderlaan, A. S. M. & Taggart, C. T. 2007. Vessel Collisions With Whales: the Probability of Lethal Injury Based on Vessel Speed. Marine Mammal Science, 23, 144–156.

Watts, S. 2001. The End of the Line? Global threats to sharks. San Francisco.

Wilson, B., Batty, R. S., Daunt, F. & Carter, C. 2007. Collision risks between marine renewable energy devices and mammals , fish and diving birds.

Wilson, E. 2000. Determination of boat disturbance on the surface feeding behaviour of basking sharks (Cetorhinus maximus). University of Plymouth UK.