Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland
Volume 2: Cetaceans and Basking Sharks

This report was produced by **SMRU Ltd and Royal Haskoning** on behalf of Scottish Natural Heritage (SNH) and Marine Scotland (MS). It provides guidance and protocols for the conduct of site characterisation surveys and impact monitoring programmes for cetaceans and basking sharks for marine (wave and tidal) renewables developments in Scotland. Four accompanying volumes are also available, covering:

- Vol 1. Context and General Principals
- Vol 3. Seals
- Vol 4. Birds
- Vol 5. Benthic Habitats

At present, the contents of all five reports should be regarded as recommendations to SNH and MS but not as formal SNH or MS guidance. It is the intention of both organisations to prepare a separate, short overview of the documents offering additional guidance on SNH and Marine Scotland's preferred approach to key issues such as survey effort, site characterisation and links to Scottish Government's Survey, Deploy and Monitor policy.

To assist in the preparation of this guidance note, the views of developers, consultants and others involved in the marine renewables sector are sought on the content of this and the accompanying reports. Specifically we would welcome feedback on:

A. The format and structure of the current reports
B. Changes that should be considered
C. Key issues that you would wish to see incorporated within the guidance note.

Feedback should be provided by e-mail to SNH (marinerenewables@snh.gov.uk) by 31 October 2011, marked 'Marine Renewables Guidance Feedback'.

It is hoped that developers and their advisers will find these documents to be a useful resource for planning and delivery of site characterisation surveys and impact monitoring programmes. They may be cited, but any such reference must refer to the draft status of the report concerned and to its specific authors. For this report (Volume 2), the appropriate citation is: **Macleod, K., Lacey, C., Quick, N., Hastie, G. and Wilson J. (2011).** ***Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 2. Cetaceans and Basking Sharks*****. Unpublished draft report to Scottish Natural Heritage and Marine Scotland.**

Queries regarding this guidance should be addressed to:
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CONSULTATION DRAFT

Guidance on survey and monitoring in relation to marine renewables deployments in Scotland.

Vol 2. Cetaceans and Basking Sharks.

This draft report should be cited as:
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Selected Acronyms

AA	Appropriate Assessment
AC	alternating current
BACI	Before-After/Control-Impact
CREEM	Centre for Research into Ecological and Environmental Modelling
CRRU	Cetacean Research and Rescue Unit
CV	coefficient of variation
DAQ	data acquisition devices
DC	direct current
DECC	Department of Energy and Climate Change
DR	data recorder
EAR	Ecological Acoustic Recorder
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EMF	electromagnetic fields
EPS	European Protected Species
FPS	Fixed Point Surveys
GAM	Generalised Additive Model
GMT	Greenwich Mean Team
GPS	Global Positioning System
IM	Impact Monitoring
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
NMEA	National Marine Electronics Association
PAM	Passive Acoustic Monitoring
POD	Porpoise Detector
pSAC	possible Special Area of Conservation
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European Atlantic and North Sea
SEA	Strategic Environmental Assessment
SMRU	Sea Mammal Research Unit
SSPCA	Scottish Society for the Prevention of Cruelty to Animals
TCE	The Crown Estate
TS	Transect Surveys
TTS	Temporary Threshold Shift
USB	Universal Serial Bus
VP	Vantage Point
W&CA	Wildlife and Countryside Act 1981

Table of Contents **Page**

List of Figures **Page**

List of Tables **Page**

1 INTRODUCTION

This Volume discusses the survey and monitoring required for cetaceans and basking sharks. The waters around Scotland are used by a variety of cetacean species, of which seven of the most regularly encountered species have been identified as Priority Marine Features by Scottish Natural Heritage[1] and will be reviewed within this document. It is important to note that this does not represent an exclusive list of species found in Scottish waters. Basking sharks are also listed as Priority Marine Features, and survey methodology for basking sharks has many similarities to that for cetaceans.

This Volume should be read in conjunction with Volume I of this guidance, which 1) introduces the need to survey and monitor; 2) outlines the legislation which drives the statutory requirements to survey and monitor and associated implications for developers and 3) provides guiding principals relevant to all the taxonomic groups.

This Volume should also be read in conjunction with Volume III of this guidance, which focuses on seals and for which there is considerable overlap. Reference may also be required to Volume IV (birds) and Volume V (Benthic ecology).

[1] Draft list of Priority Marine Features for Scottish territorial waters, available http://www.snh.gov.uk/docs/B639755.pdf

2 IDENTIFICATION OF KEY SPECIES AND HABITATS

Although 20 species of cetacean have been listed as occurring in Scottish waters (Gillham and Baxter, 2009) (Table 2.4), many of these species do not occur regularly within Scottish Territorial Waters. Seven of the most regularly occurring have been listed as Priority Marine Features[2]. However, all cetacean species are protected under European Legislation, and consideration should be given to the likelihood of disturbing or injuring any of these species when planning any development or construction activity. Species may be particularly sensitive to disturbance during breeding and calving periods (Table 2.2).

Table 2.4: Cetacean species occurring in Scottish Territorial Waters. The top 7 are identified as Priority Marine Features by Scottish Natural Heritage, the remainder are species sighted less commonly or occasionally in Scottish waters[3]

Common name	Scientific name	Priority Marine Feature?
Harbour porpoise	*Phocoena phocoena*	Y
Minke whale	*Balaenoptera acutorostrata*	Y
Killer whale	*Orcinus orca*	Y
Common dolphin	*Delphinus delphis*	Y
Bottlenose dolphin	*Tursiops truncatus*	Y
White-beaked dolphin	*Lagenorhynchus albirostris*	Y
Risso's dolphin	*Grampus griseus*	Y
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	N –seen regularly in Northern waters
Pilot whale	*Globicephala melas*	N – seen occasionally in Scottish waters
Striped dolphin	*Stenella coeruleoalba*	N – seen occasionally in Scottish waters
Northern bottlenose whale	*Hyperoodon ampullatus*	N – seen occasionally in deeper waters

[2] http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/priority-marine-features/
[3] Cetaceans listed as sighted occasionally in Scottish waters- SNH report 1430, Naturally Scottish – Whales, Dolphins & Porpoises (2009). Available from http://www.snh.org.uk/pdfs/publications/naturallyscottish/whales.pdf

Common name	Scientific name	Priority Marine Feature?
Cuvier’s beaked whale	*Ziphius cavirostris*	N – seen occasionally in deeper waters
Humpback whale	*Megaptera novaeangliae*	N – seen occasionally in deeper waters
Sperm whale	*Physeter macrocephalus*	N – seen occasionally in deeper waters
Blue whale	*Balaenoptera musculus*	N – seen occasionally in deeper waters
Sei whale	*Balaenoptera borealis*	N – vagrant
Beluga whale	*Delphinapterus leucas*	N – vagrant
False killer whale	*Psuedorca crassidens*	N – vagrant
Pygmy sperm whale	*Kogia breviceps*	N – vagrant
Northern right whale	*Eubalaena glacialis*	N – vagrant

Table 2.5: Summary of known calving periods for species listed as Priority Marine Features where data exists.

Species	Known calving period	Reference
Harbour porpoise	April-August	Jefferson *et al*. 2008; Lockyer, 2007
Bottlenose dolphin	May-November	Thompson *et al*. 2011; Evans *et al*. 2003.
Common dolphin	May-September	Murphy *et al*., 2005; Murphy and Rogan, 2006
White-beaked dolphins	July-August	Canning *et al*. 2008
Risso's dolphin	July-December	Atkinson and Gill, 1996
Basking shark	Early summer	Shark Trust Fact Sheet[5]

2.1 Harbour poirpoise

Harbour porpoise (*Phocoena phocoena)* is the most common small cetacean in the eastern north Atlantic and can be seen all around the Scottish coast (Reid *et al*., 2003). Its conservation status assessment within the UK was considered favourable on the basis of the species’ range, population, habitat and future prospects (JNCC 2007). The abundance of harbour porpoises in the Moray Firth and Northern Isles was estimated to be 10,254 (CV=0.36) with a further 12,076 (CV=0.43) in a shelf area from the North Channel to the north the Minch during July 2005 (SCANS-II, 2008). Sightings data collected during surveys off the west coast of Scotland indicate a preference for waters within 15 km of the shore and between 50 and 150m depth (Marubini *et al.,* 2009). There is also a relationship between tidal variables and porpoise distribution with more sightings predicted for high tidal stream speed areas and times of high tide (Marubini *et al.,* 2009).

In UK waters, mating and calving periods are estimated to take place between April and August (Jefferson *et al.* 2008) with a peak around June and July (Lockyer, 2007). In Scottish waters harbour porpoise diet consists predominately of small shoaling fishes from both demersal and pelagic habitats. Porpoises tend to feed primarily on two to four main species e.g. whiting and sandeels in Scottish waters (Santos & Pierce, 2003). Porpoises occur in small groups or singly and frequently use narrow sounds or bays.

2.2 Minke whale

The minke whale *Balaenoptera acutorostrata* is widely distributed from tropical to polar seas. In Europe, it is generally found in coastal waters on the continental shelf from Norway to France and the northern North Sea. Its conservation status assessment within the UK was considered favourable on the basis of the species' range, population, habitat and future prospects (JNCC 2007). Within UK waters, minke whales are most frequently sighted in the north-western North Sea, (e.g. Anderwald and Evans, 2007; Robinson *et al.*, 2009; Tetley *et al.*,2008), the Hebrides (e.g. Macleod *et al.,* 2004) and in the Irish Sea (Northridge *et al.,* 1995; Reid *et al.,* 2003). They are predominately sighted singly or in pairs, although when feeding they may aggregate in groups as large as 10 to 15 individuals (Reid *et al.*, 2003). The abundance of minke whales in the Moray Firth and Northern Isles was estimated to be 835 (CV=1.02) during July 2005 (SCANS-II, 2008).

There appears to be some seasonality in movements, and regular surveys in the Inner Hebrides have shown that minke whales tend to move northward as the summer season progresses, with the areas around Tiree and Coll being most important during May and June (Macleod *et al.,* 2004). These results are similar to those from Northridge *et al.* (1995) who found more minke whales in the Hebrides later in the third quarter of the year.

Minke whales are often sighted feeding around banks, in areas of upwelling or strong currents, and around headlands and small islands (Anderwald *et al*. 2008). In a study of the diet of minke whales stranded along the coast of Scotland, Pierce *et al.,* (2004) found the diet comprised mainly of sandeels and clupeids. Macleod *et al. (*2004) reported that off the Isle of Mull minke whales tend to occur in areas of sandeel habitat in early summer and areas preferred by pre-spawning herring in late summer. This behaviour has also been noted in Shetland during 2010 (K. Hall pers com).

2.3 Bottlenose dolphin

Bottlenose dolphin *Tursiops truncatus* has a worldwide distribution in tropical and temperate seas of both hemispheres. Throughout Europe, most populations are coastally distributed but they also occur offshore. Reid *et al*. (2003) reported large aggregations of bottlenose dolphins in the vicinity of the shelf break off northwest Scotland, southwest Ireland and northwest France. In coastal waters, bottlenose dolphins favour river estuaries, headlands and sandbanks, mainly where there is uneven bottom relief and/or strong tidal currents (Wilson *et al*., 1997). In Scottish waters, bottlenose dolphins occur around the west and east coasts, but with relatively few records on the north coast of mainland Scotland or around the Northern Isles (Thompson *et al.*, 2011). Photo-identification survey data show a lack of significant movement between east and west (Ingram *et al*. 2011). Its conservation status assessment within the UK was considered favourable on the basis of the species' range, population, habitat and future prospects (JNCC 2007).

The Moray Firth region is designated as a Special Area of Conservation (SAC) for bottlenose dolphins, and population estimates include 129 individuals [95% CI = 110-174] (Wilson *et al*. 1999), 74 – 181 individuals (Thompson *et al*., 2004) and 96-144 (Corkey *et al*., 2008) for the period up to 2002. In recent years there has been a range expansion and animals routinely use areas adjacent to the SAC in the southern Outer Moray Firth (Culloch & Robinson, 2008), off the Aberdeen coast (Weir *et al*., 2008) and south to St Andrews Bay (Quick, 2006). Lusseau *et al*. (2006) found evidence of two social communities of bottlenose dolphins in the east Scotland population, one comprised of individuals that have only been seen in the inner Moray Firth and another whose members have been seen both within and out-with the inner Moray Firth. Changes in the distribution of prey resources were the most likely reason given for the apparent expansion in range for the eastern Scotland population (Wilson *et al*. 2004). . Photo-identification studies indicate that there are around 200-300 individual dolphins occurring regularly in Scottish waters (Thompson *et al*. 2011). Estimates from large scale line transect surveys for July 2005 (SCANS-II, 2008) were 412 (CV = 0.86) bottlenose dolphins in a survey block including the Moray Firth and Northern Isles and a further 246 animals (1.04) in a shelf area from the North Channel to the north the Minch.

Parsons *et al*. (2002) found some evidence of population differentiation within UK inshore waters, although sample sizes were small. They identified that within-population genetic diversity was markedly lower in the Moray Firth population than any other sampled region in the British Isles. The calving period appears to extend from May to November. Bottlenose dolphins commonly form groups ranging in size of 2-25 individuals. Groups of several tens or low hundreds of animals have also been observed, although usually in offshore waters (Reid *et al.* 2003).

Bottlenose dolphins have a diverse diet and studies on the Scottish east coast suggest that areas with strong tidal flows are favoured for foraging (Mendes *et al.,* 2002). Santos *et al.* (2001) published dietary information for ten stranded bottlenose dolphins off the east coast of Scotland, the main prey items being cod, saithe and whiting. Hastie *et al*. (2004) found that the east coast bottlenose dolphins exhibit distinctive patterns of habitat use related to foraging behaviour.

2.4 Common dolphin

Common dolphin *Delphinus delphis* has a widespread oceanic distribution in tropical to temperate waters in the Atlantic and Pacific. Its conservation status assessment within the UK was considered unknown (JNCC 2007). In Scottish waters, these dolphins are common around the Hebrides and southern part of the Minch (Reid *et al.,* 2003). MacLeod *et al*. (2005) reported an increase over time in sightings and stranding of common dolphins off the northwest Scottish coast between 1948–2003. They attributed this to an increase in the sea surface temperature in the region. The SCANS-II survey estimated an abundance of 2, 322 (CV = 0.61) common dolphins in a shelf area extending from the North Channel to the north the Minch during July 2005 (SCANS-II, 2008).

The mating/calving period for this species in the Northeast Atlantic extends from May to September (Murphy *et al.*, 2005; Murphy and Rogan, 2006). Group sizes can be very large and usually number at least 10, sometimes up into thousands of animals (Jefferson *et al*, 2008). In European waters common dolphin is known to feed on a variety of fish and squid.

2.5 White-beaked dolphin

The white-beaked dolphin *Lagenorhynchus albirostris* is one of the most abundant dolphin species observed in shelf waters around the UK (Hammond *et al*., 2002), but it does have a more limited range than most of the species present in UK waters.. They are mainly distributed over the continental shelf and in the northern North Sea and adjacent areas, generally in waters between 50m and 100m in depth, and rarely out to the 200m isobath

(Northridge *et al.,* 1995; Reid *et al.,* 2003). Its conservation status assessment within the UK was considered favourable on the basis of the species' range, population, habitat and future prospects (JNCC 2007). White beaked dolphin abundance in the Moray Firth and Northern Isles was estimated to be 682 (CV=0.86) with a further 9,731 (CV=0.91) in a shelf area from the North Channel to the north the Minch during July 2005 (SCANS-II, 2008).

The distribution of white beaked dolphins has been linked to sea surface temperature (SST), local primary productivity and prey abundance (MacLeod *et al*. 2007; Weir *et al*. 2007). Behavioural observations have shown that white-beaked dolphins forage close to the surface (Weir *et al*., 2009). A study on white-beaked dolphins in UK waters found that all sightings were reported in summer and early autumn and that calves were recorded only during July and August (Canning *et al.,* 2008). A dietary study of white-beaked dolphins in Scottish waters identified that fish represented more than 95% of the diet; the most important prey species being haddock and whiting (Canning *et al.,* 2008). Sightings and distribution data indicate that the population off the northern UK may be discrete from other populations in the North Atlantic (Northridge *et al*. 1995).

2.6 Risso's dolphin

Risso's dolphin *Grampus griseus* is found in both hemispheres in continental slope areas from the tropics to temperate regions. In Scottish waters, they are most commonly seen around the Hebrides (Reid *et al.*2003), although the species reaches the northern limits of its regular range in the Northern Isles (Evans, 2008). Very little is known about the diet of Risso's dolphin in western European waters but they are generally assumed to feed on cephalopods (Clarke *et al.,* 1985), and may also consume crustaceans and occasionally small fish. In areas where feeding habits have been studied, the majority of foraging behaviour appears to occur at night (Baird, 2009). Group sizes are usually small (up to 12 animals), but they have been recorded in groups of several thousand. In the UK, calving is likely to occur between July-December (Atkinson and Gill, 1996). There are no abundance estimates for Scottish waters, although at least 12 individuals have been identified in the Minch, western Scotland (Atkinson *et al*, 1999).

2.7 Killer whale

The killer whale *Orcinus orca* has the widest distribution of all marine mammals and is found from the equator to the poles, but is most common in near-shore temperate waters. Most sightings in UK waters are of single animals or groups of less than eight individuals, although groups of up to 100 have been reported (Reid *et al.,* 2003). These large aggregations are generally associated with trawling activities between November and March taking advantage of the mackerel and herring fisheries off northern Scotland, peaking between January and February (Evans *et al.* 2003; Luque *et al.* 2006). In UK waters, killer whales are found along the shelf edge, especially north of Shetland, and in the Pentland Firth as well as inshore waters around Western Isles, where sightings are concentrated around Mull and the Treshnish (Bolt *et al.,* 2009), and in the northern North Sea (Reid *et al.,* 2003). In Shetland waters, sightings show a strong seasonal peak in June-July, which coincides with the harbour seal pupping season (Bolt *et al*., 2009). There are reports of killer whales predating upon grey seals, harbour seals and porpoises around Scotland (Weir 2002; Bolt *et al.,* 2009).

Photo Identification work carried out in both the Northern Isles and the Hebrides has shown that there seem to be distinct populations of killer whales around Scotland. The Hebrides supports a group of 10 individuals which are seen throughout the year. These animals have never been seen in association with the animals sighted around the Northern Isles. To date, 38 individuals have been identified from the Northern Isles group[4]. Killer whales show high levels of specialisation in foraging strategies, with groups showing strong preferences for either fish or other marine mammals as prey. The presence of both fish and seal eating killer whales around Shetland implies that there are at least two distinct groups of animals utilising this area, for at least part of the year.

2.8 Basking shark

The basking shark *Cetorhinus maximus* is the world's second largest fish, and can reach lengths in excess of 11m. Although three species of shark feed by filtering seawater, the basking shark's feeding strategy, known as ram filter-feeding (Sims, 2000), is unique among sharks. In ram filter-feeding, the flow of water through the large open mouth is controlled by swimming speed, unlike the suction feeding methods of whale shark *Rhynocodon typus* and megamouth shark *Megachasma pelagios*. This feeding strategy is thought to dominate key aspects of the biology and ecology of the basking shark (Sims, 2008).

The basking shark is a cold water, pelagic species and is both widely distributed and migratory (Gore *et al.,* 2008). Historically, basking sharks have been the subject of a targeted hunt for at least 200 years and consequently there is some concern over current population levels (Sims, 2008) not least because there are currently no reliable population estimates (Southall *et al*., 2005) and the Northeast Atlantic subpopulation is listed as endangered by the IUCN (Fowler, 2005).

Scotland contains several "hotspots" for basking sharks – sites where they can be consistently observed at the surface, notably the Hebrides and the Clyde Sea (Speedie *et al*., 2009). The vast majority of sightings occur on the west coast of the UK; and numbers of sightings off the east coast are considerably lower. Most basking shark sightings are of solitary individuals although aggregations of 50 or more may occur – presumably in areas of high food availability (Speedie *et al*, 2009). A study examining zooplankton abundance in surface waters found that plankton peaks were associated with peaks in basking shark abundance (Thom *et al.,* 1999). Basking sharks have been found to forage along thermal fronts and actively select areas that contain high densities of large zooplankton (Sims & Quayle, 1998). Sims *et al.* (2003) tagged five basking sharks and found that contrary to popular belief they did not undertake winter hibernations off the shelf edge but rather undertook extensive horizontal (up to 3400 km) and vertical (>750 m depth) movements to utilise productive continental-shelf and shelf-edge habitats during summer, autumn and winter. Movements into shallow waters may also coincide with breeding and pupping periods. Breeding is thought to occur in early summer in British waters[5].

[4] www.northatlantickillerwhales.com
[5] Basking Shark factsheet: http://www.baskingsharks.org/content.asp?did=26603&rootid=6224

3 RELEVANT LEGISLATION

3.1 Wildlife and Countryside Act 1981 and the Nature Conservation (Scotland) Act 2004 (W&CA)

The Scottish Government has responsibility for the conservation and protection of all cetaceans and basking sharks within Scottish waters under the W&CA. This protection was enhanced by the Nature Conservation (Scotland) Act 2004. Under this legislation it is an offence to deliberately or recklessly capture, kill disturb any whale, dolphin, porpoise or basking shark (Box 3.1). This applies within the 12nm limit of UK territorial waters.

Box 3.1.

Schedule 6 of the Nature Conservation (Scotland) Act 2004[6] states that:

Subject to the provisions of this Part, any person who, intentionally or recklessly, disturbs or harasses any wild animal included in Schedule 5 as a—

(a) Dolphin, whale or porpoise (*cetacea*); or

(b) Basking shark (*Cetorhinus maximus*),

shall be guilty of an offence.”

3.2 European Habitats Directive: Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2007 (applicable within the 12nm territorial waters)

All cetaceans are European Protected Species (EPS) and are protected by the EU’s Habitats Directive under Annex IV (species of community interest in need of strict protection). This legislation offers similar protection to the W&CA, and was translated into Scottish law by the Conservation (Natural Habitats, &c.) (Scotland) Regulations 1994. The Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2007 further strengthens the 1994 act, and contains a revision of the disturbance offence for EPS specifically through Regulation 39 (Box 3.2,). Guidance to assist developers in understanding when an EPS licence may be required in relation to cetaceans is presently being drafted by Scottish Government.

[6] Text taken from http://www.opsi.gov.uk/legislation/scotland/acts2004/asp_20040006_en_9
Downloaded on 04/02/10

Box 3.2

39.—(1) It is an offence–

(a) deliberately or recklessly to capture, injure or kill a wild animal of a European protected species;

(b) deliberately or recklessly–

(i) to harass a wild animal or group of wild animals of a European protected species;

(ii) to disturb such an animal while it is occupying a structure or place which it uses for shelter or protection;

(iii) to disturb such an animal while it is rearing or otherwise caring for its young;

(iv) to obstruct access to a breeding site or resting place of such an animal, or otherwise to deny the animal use of the breeding site or resting place;

(v) to disturb such an animal in a manner that is, or in circumstances which are, likely to significantly affect the local distribution or abundance of the species to which it belongs;

(vi) disturb such an animal in a manner that is, or in circumstances which are, likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young; or

(vii) to disturb such an animal while it is migrating or hibernating;

(c) deliberately or recklessly to take or destroy the eggs of such an animal; or

(d) to damage or destroy a breeding site or resting place of such an animal.

(2) Subject to the provisions of this Part, it is an offence to deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean).

3.3 Environmental Impact Assessment

Cetaceans and basking sharks will need to be considered within the EIA for the development, as detailed in Volume I. Although basking sharks are classified as vulnerable worldwide by the IUCN and as Endangered in the North-east Atlantic, the EU Habitats Directive does not list basking sharks on either Annex II or Annex IV, and protection of this species in European waters is limited to national legislation. In addition, cetaceans and basking sharks are listed as UK Biodiversity Action Plan target species and as Priority Marine Features.

3.4 European Habitats Directive: Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (applicable outwith 12nm territorial waters)

Protection of all EPS outwith the 12nm limit is provided by the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (OMR). The Habitats Directive does not contain a definition of the term “disturbance”, but the associated guidelines (Anon, 2007) offer the interpretation that disturbance need not directly affect the physical integrity of a species but can nevertheless have a direct negative effect. The OMR, under Regulation (39 (1) (b)) states it is an offence to deliberately disturb EPS in such a way that it is likely to significantly affect a) the ability of any significant group of animals of that species to survive, breed or rear or nurture their young; or b) the local distribution or abundance of that species.

Anon (2007) recommend a species by species approach because different species will react differently to potentially disturbing activities. Particular consideration should be given to periods of breeding, rearing and migration with regard to disturbance

3.5 Special Areas of Conservation (SACs)

In addition to affording protection to EPS at a species level, legislation that implements the Habitats Directive also protects important habitats, and requires the establishment of a network of sites that will contribute to the protection of the habitats and species listed on Annexes I and II of the Directive. The harbour porpoise and the bottlenose dolphins are two of the species listed on Annex II, meaning that the presence of these species may require the designation of a Special Area of Conservation (SAC).

The SAC designation affords protection to a SAC population and therefore an Appropriate Assessment may be required where an activity’s potential impact footprint does not overlap with an SAC but does overlap with an area or resources used by individuals from that SAC population.

There is currently only one SAC designated for a cetacean species in Scottish waters – the Moray Firth SAC which was designated for bottlenose dolphins (Box 3.3. However, the wide ranging nature of cetaceans may result in this population and those associated with SACs and pSACs in adjacent territories potentially being affected by proposed developments that are a considerable distance away. For example, in the Republic of Ireland there are three SAC designated for cetaceans; Roaringwater Bay and the Blasket Islands for harbour porpoise and Lower River Shannon for bottlenose dolphins.

Box 3.3

The following conservation objectives relevant to marine mammals were outlined for the Moray Firth marine SAC (Scottish Natural Heritage, 2006)

The conservation objectives relevant to marine mammals for the Moray Firth marine SAC are as follows:

- To avoid deterioration of the habitats of the qualifying species (**Bottlenose dolphin *Tursiops truncatus***) or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for the qualifying interest.

- To ensure for the qualifying species that the following are established then maintained in the long term:

• Population of the species as a viable component of the site

• Distribution of the species within the site

• Distribution and extent of habitats supporting the species

• Structure, function and supporting processes of habitats supporting the species

• No significant disturbance of the species

The Habitats Directive (Article 1 (i) defines FCS as follows: The conservation status will be taken as 'favourable' when:

-population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and

-the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and

-there is, and will probably continue to be, a sufficiently large habitat to maintain its population on a long-term basis.

4 POTENTIAL IMPACTS

Many of the potential impacts of wave and tidal energy developments are likely to be the same as those associated with other more established marine industries (such as oil and gas exploration and extraction or construction). However, there are a number that may be specific to each of these new technologies. These have been reviewed in a number of SEA documents (e.g. Faber Maunsell & Metoc, 2007; Aquatera, in prep).

4.1 Construction impacts

4.1.1 Physical injury

Increased vessel traffic during the installation phase of both wave and tidal developments will increase the risk that cetaceans and basking sharks collide with construction machinery and vessels. Ship strikes are a recognized cause of cetacean mortality worldwide, with ships travelling at 14 knots (~7 ms^{-1}) or faster most likely to cause lethal or serious injuries. Vessels involved in the construction work are likely to be travelling considerably more slowly than this, and therefore the risk associated with collision form the vessel is likely to be lower than that posed by commercial shipping activity.

Basking sharks are thought to be particularly susceptible to collision with vessels, even those travelling at speeds considerably lower than 14 knots. Surface feeding sharks very rarely show any reaction to vessels – often appearing relatively unaware of the presence of surface craft, even when they approach within 10 meters of the shark (Speedie *et al*., 2009).

Entanglement in mooring lines or cables also has the potential to cause physical injury during construction. This has been shown to be a particular risk for larger animals such as baleen whales (Clapham *et al*. 1999) and basking sharks (Valciras *et al*. 2001).

4.1.2 Acoustic impacts

Cetaceans use sound extensively to navigate and forage, and for communication and social interactions. This makes them susceptible to anthropogenic noise.

Negative effects that may be caused by the noise associated with the construction and operation of renewable energy developments can broadly be divided into direct physical, chronic stress, perceptual, behavioural, and indirect effects. Individually or cumulatively, these have the potential to lead to population level effects through energetic deficiencies, reductions in individual viability, and direct injury or mortality.

There are likely to be many different sources of anthropogenic noise during construction of wave and tidal stream energy developments. Despite being a potentially uncommon activity for wet renewable deployment, the effects of pile driving during construction have the potential to be significant. Pile driving generates noise with a high source level and broad bandwidth (Richardson *et al.,* 1995) which has the potential to cause auditory damage to cetaceans. Source levels from impact pile driving are about 218-227dB_{pp} re 1µPa@1m with short intense pulses (100-200ms). Most of the energy is below 1kHz, but some components from ramming impulses extend to 100kHz (Evans, 2008). The levels of noise emissions are dependent on a variety of factors including pile dimensions, seabed characteristics, water depth, impact strengths and duration (Diederichs *et al.,* 2008). Physiological impacts of pile driving noise on cetaceans could include temporary or permanent hearing damage or discomfort. Southall *et al* (2007) proposed criteria against which sound exposure levels and peak pressure levels could be assessed for likelihood of inducing Temporary Threshold Shift and Permanent Threshold Shift (TTS and PTS) onset. Thomsen *et al*. (2006) proposed the TTS–zone would be within 1,800m of pile-driving for harbour porpoise. Pile driving noise has been shown to elicit behavioural reactions in harbour porpoise at ranges up to 20km (Madsen *et al*. 2006; Tougaard *et al*. 2009). Bailey *et al*. (2009) concluded that auditory injury in bottlenose dolphins would only have occurred at very close range to pile driving activity (ca. 100m) whereas behavioural disturbance could have occurred up to 50km away,

Pile drilling is much more likely to be employed in the environments suitable for wave and tidal development, however much less information exists on the impacts of drilling. The few data that do exist suggests that pin pile drilling has a much lower impact than piling (Southall *et al*, 2007). Nedwell and Brooker (2008) reported underwater noise measurements during pin pile drilling operations during construction of SeaGen at Strangford Lough. They reported sound pressure levels of 130 dB re 1µPa@1m at a distance of 54m from the drilling operation, and 115 re 1µPa@1m at a distance of 830m.

Additional noise may come from increased vessel activity, construction techniques such as dredging, blasting, trenching, and seismic exploration, or the use of sonar and echo sounders. Depending on their intensity and duration, these noise sources may cause displacement of animals and/or prey, auditory damage, masking of communication signals, foraging interference, and may present perceptual barrier effects to marine mammals.

The hearing characteristics of basking sharks are currently unknown. The hearing bandwidth of the 5 species of elasmobranch which have so far been measured ranges from 20 Hz to 1 kHz, although caution must be applied before applying these data to all species (Casper *et al*., 2010). Few studies have considered the acoustic impact of pile drilling on elasmobranches. It is possible that the primary source of damage to elasmobranchs from pile driving would be barotrauma as a result of the impulsive energy produced when the hammer hits the pile. Although our general understanding suggests only a narrow hearing range with relatively poor sensitivity, the lack of knowledge makes it difficult to evaluate the potential effects that could be associated with chronic exposure to anthropogenic noise (Casper *et al*., 2010).

4.1.3 Contaminant effects

A large scale chemical or hydrocarbon spill associated with a marine energy site has the potential to affect cetaceans and basking sharks in the vicinity. However, due to strict current health and safety procedures during marine construction, the risk of such contamination is likely to be minimal; although the impacts of any spill have the potential to be significant. Construction activities such as drilling or trenching could allow contaminated sediments to be released into the water column.

Pollutants can have direct effects at the time of the spill or release, or they can result in chemical accumulation in body tissues leading to lagged effects on health and breeding success (Ross *et al.*, 1996, Ross, 2002).

4.1.4 Increased turbidity

There is the risk that construction activities such as drilling or trenching can increase turbidity in the water column. Increased turbidity has the potential to affect social interactions and foraging efficiency and may also impact prey species. The potential magnitude of this impact is currently unclear and will depend on the environment (i.e. water flow, seabed type etc) in the development area.

4.2 Operational impacts

4.2.1 Physical injury

The risk of collision is considered to be a key potential impact for cetaceans and basking sharks during device operation. Direct physical interactions with devices have the potential to cause physical injury to individuals with potential consequences at a population level. Although there is considerable lack of empirical knowledge on this risk, it is important to highlight that tidal device rotors in particular, either of the horizontal or vertical axis type, present a threat quite unlike anything that cetaceans and basking sharks have previously encountered.

Baleen whales and basking sharks are generally slow moving with a relatively low degree of manoeuvrability, potentially putting them at a high risk of collision with devices. In contrast, being highly mobile underwater, small cetaceans *should* have the capacity to both avoid and evade wave and tidal devices. However, this is reliant on a number of factors: individuals having the ability to detect the objects, perceiving them as a threat, and then taking appropriate action at a suitable range. Each species' ability to detect devices will depend on its sensory capabilities, and the visibility and level of noise emitted by the device. The potential for animals to avoid collisions with devices will also depend on their body size, social behaviour, foraging tactics, curiosity, habitat use, underwater agility, and the tidal and environmental conditions present at a site.

Collision risk is likely to be highest in fast flowing areas where high approach speeds may delay the time available for animals to react, or impede their navigational abilities.

Entanglement in mooring lines or cables also has the potential to cause physical injury during construction. This has been shown to be a particular risk for larger animals such as baleen whales and basking sharks.

4.2.2 Acoustic impacts

Although operational noise is considered to be less in magnitude than construction noise, potential noise sources during device operation include: rotating machinery, flexing joints, structural noise, moving air, moving water, moorings, electrical noise, and instrumentation noise.

As there are only a relatively small number of devices currently deployed, available information on their acoustic signatures is limited. However, the tidal devices in place appear to emit broadband noise with significant narrow band peaks in the spectrum. SeaGen in Strangford Lough is reported to be comparable to a large vessel underway (Royal Haskoning, 2010b). Although clearly likely to be device specific and dependent upon site characteristics and species concerned, empirical studies have attempted to predict impact zones for cetaceans based on a modelled acoustic signature of a 1MW tidal device. These have predicted that depending on sound propagation conditions, temporary hearing damage could occur if a cetacean were to spend 8 hours within 934m of the tidal device (Faber Maunsell & Metoc, 2007).

Empirical acoustic data for wave devices is lacking. However, the predicted operational noise of wave devices is considered to be lower than for tidal devices and the risk of permanent hearing damage is considered unlikely (Faber Maunsell & Metoc, 2007).

Cetaceans have been shown to exhibit avoidance reactions to underwater noise at levels much lower than the permanent and temporary hearing damage thresholds. It is therefore clear that operating devices have the potential to cause a range of impacts at relatively large ranges, including masking of biologically important sounds such as communication signals, displacement of animals, foraging interference, and perceptual barrier effects.

It should be highlighted that the hearing characteristics of basking sharks are currently unknown but the potential impacts of noise on this species can be inferred from knowledge of other elasmobranches. Hearing abilities among sharks have demonstrated highest sensitivity to low frequency sound (40 Hz to approximately 800 Hz). Free-ranging sharks are attracted to sounds possessing specific characteristics: irregularly pulsed, broad-band (especially below 80 Hz), and transmitted without a sudden increase in intensity. A sound can also result in immediate withdrawal by sharks from a source, if its intensity suddenly increases 20 dB [10 times] or more above a previous transmission (Myrberg, 2001).

4.2.3 Habitat alteration

The physical presence of wave and tidal devices will inherently result in some habitat loss during device operation. However, associated seabed moorings and structures also have the potential to function as artificial reefs or fish aggregating devices. As cetacean and basking shark distribution is influenced by prey distribution and associated prey habitat, this clearly leads to the potential of changes in the distribution of cetaceans and basking sharks. For example, fish have been shown to aggregate under floating structures, which may lead to an increase in prey for marine mammals within the vicinity of a device. Installation of a device may affect oceanographic conditions within the vicinity, for example, increasing water mixing. This may lead to a localised increase of basking sharks in the area which in turn could increase the risk of collision with the device.

The physical structures could also offer enhanced foraging efficiency for some species. For example, in tidal flows physical structures will produce eddies and areas of slack water which small cetaceans in particular could use to shelter when ambushing prey. Furthermore, if devices have moving components, these have the potential to scatter, disorientate or injure prey leading to enhanced foraging efficiency. However, it is currently unclear whether such opportunities would provide enhancements to foraging or would simply lead to the attraction of animals into situations where the risk of collision is increased.

4.2.4 Displacement/barrier effects

Arrays of devices have the potential to create physical or perceptual barriers to important migration or other travelling routes. This will be dependent on geographical location, the number of devices, and how individual devices are spaced relative to one another.

Cetaceans have been shown to exhibit avoidance reactions to underwater noise at relatively low levels and this impact may be more acute for species travelling regularly through narrow tidal channels where tidal devices are likely to be deployed. Although the navigational mechanisms of basking sharks are poorly understood, it is possible that noise or electromagnetic emissions could result in similar barrier effects for this species.

4.2.5 Electromagnetic emissions

Basking sharks may be able to detect the magnetic fields associated with wave and tidal devices. The electricity generated by an energy device is likely to be transmitted to shore via 50Hz high voltage alternating current (AC) or direct current (DC) cable. The electricity transmitted through the cables will emit electromagnetic fields (EMFs). Elasmobranchs respond to EMFs and are thought to use the Earth's magnetic field for migration, whilst they respond behaviourally to electric fields emitted by prey species and conspecifics.

The potential for damage to the electrosensory system is considered low as E fields are only detected over short distances and will be encountered as a voltage gradient in the seawater to which the elasmobranch can respond accordingly. Furthermore, subsea cables are typically laid on or in a soft sediment substratum. Wet renewable devices will typically be anchored to hard substrates with cables likely to be rock armoured due to cable trenching not being possible. There are no data on interactions between basking sharks and existing cables.

Although detection of EMF by cetaceans has not been demonstrated conclusively there is circumstantial evidence that cetaceans can detect EMF (Zoeger *et al*, 1981) and may be negatively affected by it (Kirschvink *et al* 1986). However, the underlying assumption that cetaceans are capable of determining small differences in relative magnetic field strength remains unproven. The effects of cabling could be present throughout all stages of marine offshore energy development.

4.2.6 Contaminant effects

As with the construction phase, contaminant release through spillages or contaminated sediments poses a risk to cetaceans and basking sharks that can have direct effects at the time of the spill or can result in chemical accumulation in body tissues leading to lagged effects on health and breeding success.

4.2.7 Changes in water flow and turbidity

Changes in water flow, turbidity, and wave heights associated with the extraction of tidal and wave energy will potentially impact on cetaceans and basking sharks through indirect effects on prey abundance or distribution. Furthermore, it is currently unclear whether small-scale hydrodynamic vibrations and flow vortices in the water column are used during foraging by these species; these appear to be important for prey detection by other marine mammals (seals).

4.3 Decommissioning impacts

The impacts associated with the decommissioning phase will often be similar to those for construction, and will include increased vibration, noise and turbidity during the removal of structures, along with the risk of collision of animals with vessels, and the risk of accidental spillage of toxic chemicals. Many of the impacts associated with decommissioning are likely to be short term.

4.3.1 Summary of potential impacts

A summary of potential impacts and how they relate to the phase of development and specific devices is shown in

Figure 4.2.

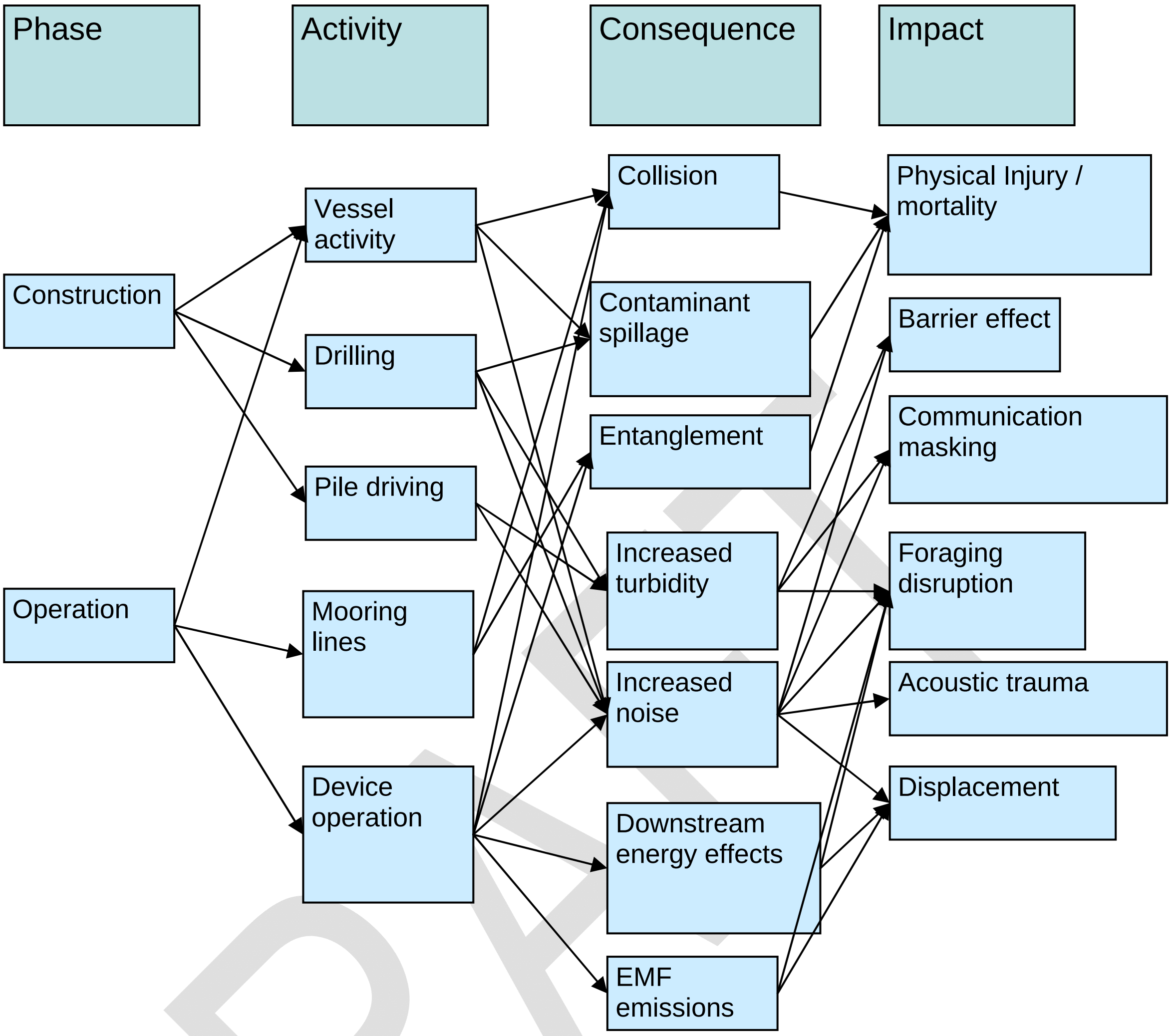

Figure 4.2: The predicted risks for cetaceans and basking sharks associated with wave and tidal energy developments.

5 KEY QUESTIONS TO BE ANSWERED BY MONITORING

An essential first step in the EIA and AA process is establishing the 'impact footprint' of proposed activities. These footprints may comprise of a small proportion of the development area or extend some considerable distance away (noise impacts for example). Survey and monitoring activities must be designed to gather data at the relevant scales in order for an assessment of potential impacts upon SAC and EPS populations to be completed. However, data on the impacts of many activities (and their spatial and temporal scales) is currently scarce. A summary of the key questions to be addressed for EIA, AA and impact monitoring is given in Table 5.1.

5.1 Pre construction: Characterisation

Characterisation data may be required to inform three separate but overlapping processes: to inform an Environmental Impact Assessment; to assess the presence of European Protected Species to determine the relevance of Annex IV of the Habitats Directive; and, to assess the relevance of any development to sites or populations protected under Natura 2000 legislation. In addition, characterisation surveys *should* provide baseline data for the monitoring of construction and post-construction impacts. However, care must be exercised to ensure that characterisation surveys fulfil their primary goal, that all requirements of environmental legislation are fulfilled.

For cetaceans, site characterisation undertaken by the developer for the EIA process must consider the regulations relating to European Protected Species (EPS) and Special Areas of Conservation (SACs). The key questions relating to these are whether the development or associated activities, such as construction, could:

- Kill, injure or disturb European Protected Species?
- Adversely affect the integrity of an SAC?

A. Kill, injure or disturb European Protected Species?

Breaking down question (1) and considering the ways to disturb (refer to Boxes 1 & 2), the primary questions to be answered through characterisation surveys (if they cannot be addressed using available data) are:

- Do EPS occur in the area?
- What is the spatial and temporal distribution of EPS in the area?
- What is the abundance of EPS in the area?

- What are EPS using the area for (e.g. foraging, breeding etc.)?
- Is an EPS license required?

B. Adversely affect the integrity of an SAC?

To assess whether a proposed activity may adversely affect the integrity of an SAC, characterisation surveys will need to establish:

- Does a priority species (Annex II, Habitats Directive) occur in the development site?
- What is their spatial and temporal distribution within the site and the potential impact footprint? (Volume I)
- What is their abundance or relative abundance within the site and the potential impact footprint?
- What do the protected species use the site for?
- Are these animals part of an SAC population?

Answers to these questions will make up the information provided by developers to inform an Appropriate Assessment, which will be undertaken by the competent authority. The Appropriate Assessment must then determine whether the development will affect the integrity of the SAC, as measured against the conservation objectives, which are broadly, the long-term maintenance of:

- The population of the species as a viable component of the SAC
- Distribution of the species within the SAC
- Distribution and extent of habitats supporting the species
- Structure, function and supporting processes of habitats supporting the species
- No significant disturbance of the species.

Basking sharks are protected under the W&C Act and the Nature Conservation (Scotland) Act 2004, which list disturbance to this species as an offence only within territorial waters. To carry out an EIA for this species, the following questions need to be answered by characterisation surveys (assuming data are not already available):

- Are basking sharks present in the area?
- What is the spatial and temporal distribution of basking sharks in the area?

- What is the abundance or relative abundance of basking sharks in the area?

Characterisation data should allow the assessment of the degree and significance of any potential impact upon individuals and populations at both the local and regional levels to be undertaken. In order to do this, an understanding of the effects of potential stressors (e.g. noise) and the spatial and temporal scales of these stressors is required. Knowledge of the 'impact footprint' of an activity is necessary to properly assess the significance of any potential impacts.

5.2 Impact monitoring

The primary aim of post-consent monitoring is to assess the accuracy of predictions made in the ES and AA (if prepared) regarding impacts of the development on the EPS and SAC populations. This is especially important at wet renewable sites where relatively little is known about potential impacts on marine mammals and basking sharks. The secondary aim is to establish whether impacts are occurring as a result of device presence and operation, to enable review of the adequacy of mitigation and to inform future consenting.

Impacts to be considered are:

- Disturbance and/or displacement during construction and deployment
- Disturbance and/or displacement due to presence and operation of devices
- Collision of animals with generating devices
- Interference with movement, i.e. passage / barrier effects
- Acoustic impacts

Data collected during this phase of monitoring should contribute to an assessment of whether the development is having a significant impact that is likely to affect the Favourable Conservation Status of an EPS. It should also enable assessment of the effectiveness of mitigation and feed into an adaptive management plan if appropriate.

Key questions to be answered are likely to include:

- Is there a significant difference in the metric being measured (e.g. relative abundance, area utilization) between baseline and either construction or deployment?
- Is detected change limited to the development footprint?
- Does level of impact change with time or distance from impact site?

- Can any change be attributed to the development's construction or operation?
- Could any change affect the integrity of a SAC?
- Could any impact affect the Favourable Conservation Status of the species?

Table 5.1: Key EIA Questions to be addressed for European Protected Species (EPS), Appropriate Assessment (AA) and Post Consent or Impact Monitoring (IM)

EIA	No	Question
EPS	1	Are EPS likely to occur in the area?
EPS	2	What is the spatial and temporal distribution and abundance of EPS in the area?
EPS	3	What are the EPS using the area for? (e.g. foraging, breeding)
EPS	4	Is an EPS required?
AA	5	Does a qualifying species (Annex II, Habitats Directive) occur in the development site or zone of impact?
AA	6	What is its spatial and temporal distribution and abundance within the site?
AA	7	What is the site used for?
AA	8	Are the animals part of an SAC population?
AA	9	Could any change affect the integrity of the SAC (and, if so, how)?
IM	I	Is there a significant difference in the metric being measured (e.g. relative abundance area utilisation) between baseline and either construction or deployment?
IM	II	Is detected change limited to the development footprint?
IM	III	Does level of impact change with time or distance?
IM	IV	Could any change be attributed to the development's construction or operation?
IM	V	Could any impact affect the Favourable Conservation Status of the species?

6 EXISTING INFORMATION AND DATA SOURCES

The first step in any characterisation will be assessing what information already exists on the distribution and abundance of cetaceans and basking sharks in and around the development area. Adequate data on the distribution, abundance, and status of cetaceans may already exist for some areas and this should be used to inform scoping, EIA assessment and post-consent monitoring. Considerably less information is available on the distribution and abundance of basking sharks. Information from large scale regional or national surveys is particularly important as it enables site specific information, including that from baseline surveys, to be put into a wider context. Existing information for development sites is unlikely to be sufficiently detailed or up to date to negate the need to undertake new baseline survey work. Nevertheless, it may affect the design of baseline surveys, i.e. so that maximum value can be made of existing data.

The UK waters Joint Cetacean Atlas (JCA) (Reid *et al*., 2003) publishes long-term and large scale distribution and relative abundance information from data collected by the JNCC's Sea Birds at Sea Team, the SeaWatch Foundation and the 1994 SCANS survey. A more recent initiative, the Joint Cetacean Protocol, builds on the JCA database and will deliver information on distribution, abundance and population trends of cetaceans in UK waters.

The JCP will consider more recent datasets, including the SCANS-II (Small Cetaceans in the European Atlantic and North Sea) surveys which took place in July 2005 and surveyed the entire European continental shelf. Data were collected for all species but abundance could only be estimated for harbour porpoise, common dolphin, bottlenose dolphin, white-beaked dolphin and minke whale. The spatial resolution of the SCANS-II surveys is coarse and the amount of survey effort in each survey block is low. Therefore, the usefulness of these data to inform developers on species distribution (and abundance) at comparatively small-scale development sites is limited. Additionally, there is no seasonality to the SCANS data.

The Crown Estate have commissioned a number of surveys as enabling actions for Round 3 wind and Round 1 wave and tidal developments and these data may provide additional information on density and distribution of some cetacean species.

Specific to Scottish waters, multiple groups carry out cetacean research projects. In particular, Aberdeen University has been conducting research in the Moray Firth for decades, particularly on the SAC population of bottlenose dolphins (e.g. Wilson *et al*. 1997; Wilson *et al*., 2008). Additionally, several non-governmental organisations carry our surveys of Scottish waters and collate sightings data of cetaceans e.g. the Hebridean Whale and

Dolphin Trust (Hebridean waters) and the Whale and Dolphin Conservation Society (Moray Firth). On the southern coast of the Moray Firth, the Cetacean Research and Rescue Unit (CRRU) carry out visual and photo-identification surveys of cetaceans (e.g. Robinson *et al*., 2009). Several reviews of these existing data have been undertaken for SEAs and individual developments. A study commissioned by SNH to review abundance and behaviour data available for cetaceans and basking sharks in Pentland Firth and Orkney Waters is currently in preparation (SNH, 2011). Scottish Natural Heritage is a key supporter of many such projects and is therefore, a useful point of contact, for relevant information.

Sightings data on the distribution of basking sharks in UK waters is collated by the Marine Conservation Society and Shark Trust. Additionally, the University of Plymouth has conducted focussed long-term research projects on basking shark behaviour using telemetry (e.g. Sims and Quayle, 1998; Sims *et al*., 2003). Details of basking shark hotspots in the west of Scotland were collated for, and published by, SNH in 2010 (Speedie *et al.,* 2009).

There are a number of review documents which collate existing sources of data on marine mammal distribution and relative abundance and can provide a good source of information. These include the Strategic Environmental Assessment (SEA) documents initiated by the Department of Energy and Climate Change (DECC), and publications commissioned by SNH.

Sources of information on national/regional cetacean populations and potential impacts of marine renewables:

- Reid et al. (2003) Atlas of Cetacean distribution in north-west European waters http://jncc.defra.gov.uk/page-2713#download
- Joint Cetacean Protocol http://jncc.defra.gov.uk/page-5657
- SCANS-II Final Report. http://biology.st-andrews.ac.uk/scans2/inner-contact.html

The SNH website is a valuable source of species information.

http://www.snh.gov.uk/protecting-scotlands-nature/

- SNH publications available from: http://www.snh.gov.uk/publications-data-and-research/publications/
- The most recent compilation of information on bottlenose dolphins in Scottish waters:

http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=1727

- Marine Spatial Plans and Regional Local Guidance where available may have information on cetacean populations in specific areas e.g. http://www.scotland.gov.uk/Resource/Doc/295194/0096885.pdf
- Marine Renewables SEA http://www.seaenergyscotland.co.uk/ In particular the sections dealing with marine mammals: http://www.seaenergyscotland.net/public_docs/ER_C9_MarineMammals_final.pdf and noise: http://www.seaenergyscotland.net/public_docs/ER_C17_Noise_final.pdf
- The Dept of Energy and Climate Change offshore SEAs http://www.offshore-sea.org.uk/site/, SEA documents available from http://www.offshore-sea.org.uk/site/scripts/sea_archive.php

Sources of information on basking sharks in Scottish waters:

- SNH review of basking shark hotspots on the west of Scotland http://www.snh.org.uk/pdfs/publications/commissioned_reports/339.pdf
- The Shark Trust - for national and regional sightings. http://www.sharktrust.org/sd/default.asp

1.

7 STUDY DESIGN

7.1 Introduction

Sound study design is essential to ensure that surveys and data collected are fit for purpose, robust and scientifically defensible. Objectives need to be clearly defined and monitoring should be designed with particular questions in mind.

There is an important distinction between characterisation surveys, surveys which provide a baseline for monitoring ongoing change and post impact monitoring surveys. There are likely to be similarities between the methods required for each but there will also be differences, generally relating to the precision of the resulting estimates or the scale over which data are collected.

Although this volume presents the main issues to be considered in planning monitoring studies for cetaceans and basking sharks, and provides detailed information on suitable methodologies and protocols, each project should be individually assessed and an appropriate monitoring programme developed.

7.2 Spatial scale

The size of proposed wet renewable sites in relation to the range of cetaceans and basking sharks is relatively small. Monitoring impacts that may cause changes in density and abundance local to the development will require survey areas to capture both the development site and expected impact footprint. The installation of wet renewables may cause temporary disturbance of animals and a movement away from the activity – impact monitoring designs must consider the scale of such movement. Additionally the potential size of any impact of wave and tidal devices on marine mammals may have a much larger footprint than the development site itself due to the propagation of noise through the marine environment or downstream impacts on benthic habitats and fish populations. The use of buffers beyond the boundaries of a development site is often incorporated in a Before After Gradient design for impact monitoring. Study design for monitoring cetaceans and basking sharks should extend beyond the development site and the exact extent of this should be informed by the likely impact footprint and the sensitivity of the population.

The results of monitoring cetaceans and basking sharks in relatively small areas will be difficult to put into context of the population without some large scale background population-level data. The SCANS surveys take place during summer approximately every 10 years (1994, 2005 to date) and are currently the main source of regional and national scale cetacean data[7] (Hammond *et al*. 2002; SCANS-II 2008). Full analysis of the Joint Cetacean Protocol data should also provide annual and seasonal density estimates for key species throughout the UK[8] and should provide important contextual information. However until such analyses have been completed, more frequent regional coverage may be required. The marine environment is also inherently variable and teasing apart observed changes in animal density due to environmental shifts rather than the development activity needs consideration in the analytical approach.

7.3 Temporal scale

Surveys for site characterisation needs to be carried out over a long enough period to ensure that the data collected are representative of the area and reflect the seasonal variation in the natural system. Cetacean and basking shark numbers fluctuate throughout the year and monthly surveys are recommended to track this. Inter-annual variation in cetacean distribution and density may also be valuable in assessing the importance of a site. However, to adequately characterise this, survey effort over several years would be required. For characterisation surveys monitoring abundance and distribution of marine mammals and basking sharks, an initial year of baseline data should be collected prior to consent application with the possibility of a further year's data collection for areas of particular importance to these species.

If not combined with site characterisation surveys, the impact monitoring "baseline" needs to be carried out immediately prior to the installation period and the same considerations as for site characterisation are required – that the surveys are frequent enough and cover a long enough period to adequately characterise natural variation in numbers and distribution in order to detect a change out with this natural variation. Impact monitoring needs to be carried out through all stages of the sites' development and for a long enough period to ensure that a change above levels of natural variation can be detected should it occur as result of an impact. The exact frequency of sampling depends on the location of the site, the amount of data collected at each sampling period, the metric being measured (in particular it's variability) and the survey method used. More detail on this is given for individual survey methods in the protocols section.

[7] Basking sharks were also recorded
[8] There are 3 phases of data analysis for the JCP; Phase II and III include analyses of data off Scotland and are due for completion mid-2012.

7.4 Effort and uncertainty

The distribution, behaviour and abundance of cetaceans and basking sharks are highly variable, both temporally and spatially. All measurements of these have an associated uncertainty which results from both the variation in the system and from error in the measurement. The confidence one has in making decisions based on data from any survey will be closely associated with the uncertainty surrounding any estimates or comparisons.

Replicate samples are necessary to estimate this uncertainty; the number of replicate samples required will depend on the overall abundance of the species of interest in an area and the variability. Some standard approaches can be taken to decide how much effort is required. For both line transect and vantage point data, existing data from an area, or a short pilot study can provide information on likely encounter rates to design a survey with appropriate effort to generate sufficient sample sizes to allow precise estimates of abundance and to detect any impacts. For example, for line transect surveys the amount of survey effort (L) required to achieve a density estimate with a defined coefficient of variation (CV, measure of uncertainty) in a study area of known encounter rate (ER) can be calculated from:

$$L = \frac{b}{CV(\hat{D})^2} X \frac{1}{ER} \qquad \text{(eqt. 1)}$$

The value of *b* has been shown to be fairly stable (Eberhardt 1978) and the recommended value for planning purposes is 3[9] (see Survey Design in Buckland *et al*. 2001 and references therein).

In general, surveys that generate a lot of data (sightings or acoustic detections) tend to generate more precise metrics i.e. have a low CV. The results of characterisation surveys should play an important role in providing an estimate of density with its associated CV to inform the design of subsequent impact monitoring that will allow defined levels of change to be detected. The more effort expended during both types of monitoring, the tighter the estimates of variability. In Figure 7.1, ca. 1300km of survey effort over a year could be achieved during monthly 2-day boat based surveys of a site, assuming 6 hours of surveying per day at 10 knots. If the encounter rate was 0.02 animals/km then an annual estimate of density could be expected to have a CV of approximately 0.34 (i.e. 34%). If 7 days of surveying effort were achieved during each month, then the CV of the annual density estimate could be as low as 0.13.

[9] It can be directly estimated from pilot survey data if available.

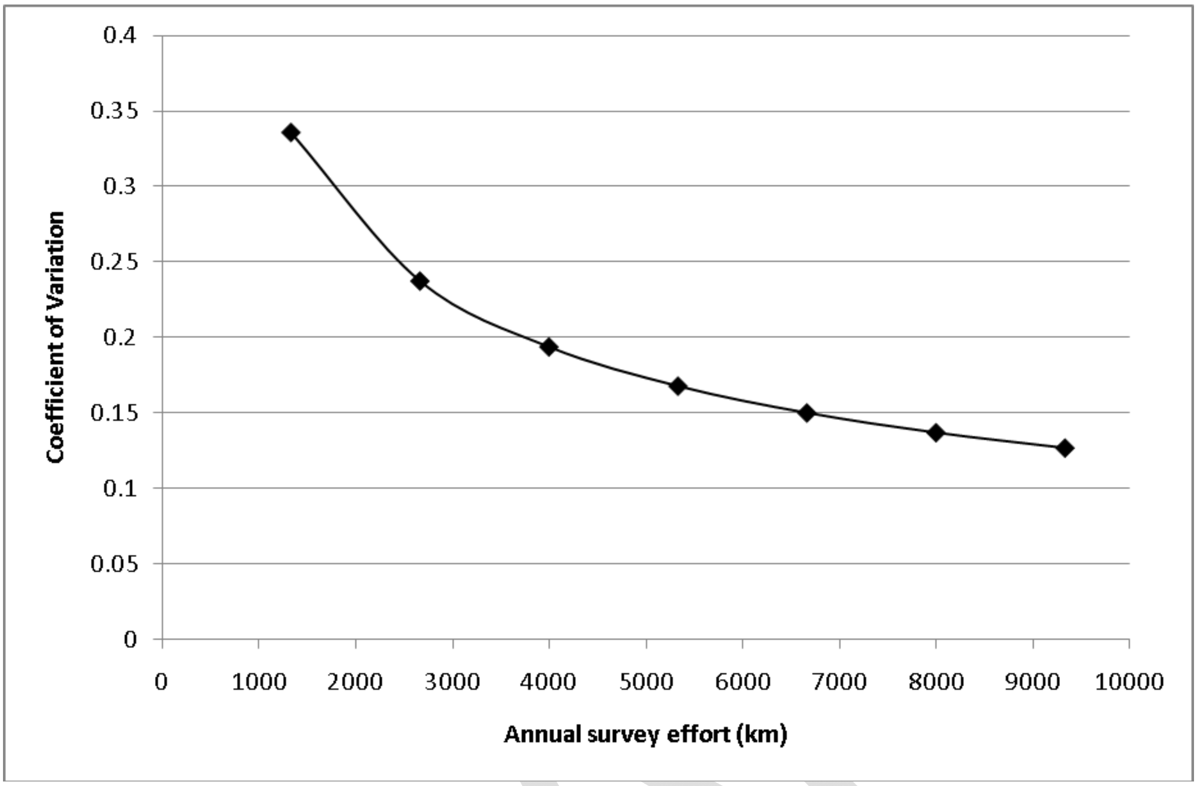

Figure 7.1 Relationship between effort and total CV for a boat-based harbour porpoise monitoring survey. Circles on the plot indicate CVs and effort calculated from assuming increasing number of days of survey effort per month from 1-7 days with an average of 6 hours of effort per day at 10knots. Effort is accumulated over 12 months of surveys and the CV of an annual density estimate calculated. Encounter rate of 0.02 harbour porpoise/km was used for the calculation of CV.

Power to detect changes between consecutive samples is dependent on a number of parameters including the CV of the metric of interest (e.g. density), the duration of the monitoring period, the magnitude of change between samples and the significance level. Figure 7.2 demonstrates that larger changes between consecutive samples can be detected with greater power for the same amount of survey effort. In general, power to detect change is likely to be low over a monitoring period of a few years unless the magnitude of change per annum is high and annual CV is low; in Figure 7.2, there is a power of ca. 0.8 (certainty is 1) to detect a 20% decline per annum over a 4 year monitoring period comprising monthly one week boat-based surveys[10].

[10] These figures should not be used for planning purposes and are used here only to demonstrate the relationships. A site-specific power analysis can be carried out using values of the estimation parameters (such as encounter rate, magnitude of change, significance required) specific to the development.

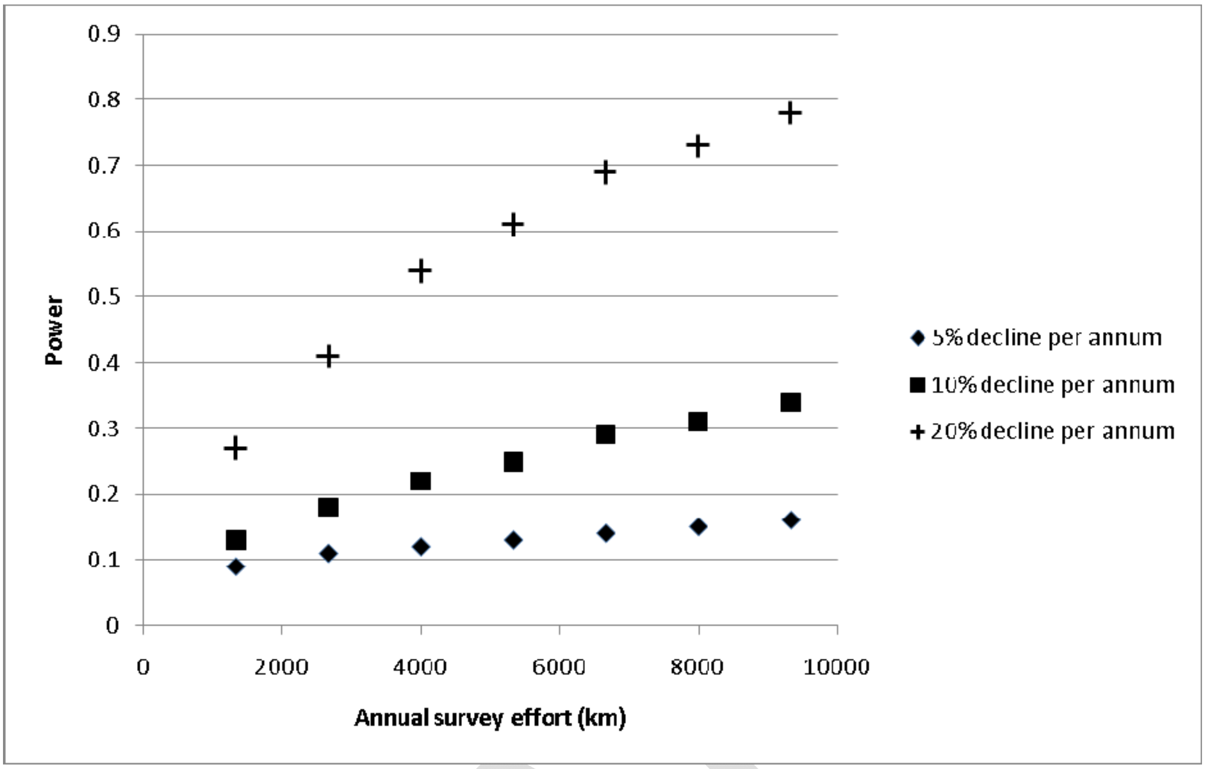

Figure 7.2 Relationship between power and effort for harbour porpoise monitoring for difference levels of %change in the abundance per annum. Power was calculated using TRENDS software (Gerrodette 1993) for a 4 year monitoring period with annual monitoring and a one-tailed significance level (alpha) of 5%, assuming exponential decline and that CV was constant with abundance. CV was calculated from equation 1 assuming an encounter rate of 0.02 animals/km.

The power to detect changes also differs between monitoring methods and those that generate larger sample sizes (for example ‘continuous’ monitoring of acoustic detections by static passive acoustic monitoring devices versus sightings from a survey over a relatively limited period of time) will have increased power; note however, that acoustic detections cannot easily be related to numbers of individuals.

It is important to consider that encounter rates of birds will generally be higher than marine mammals in wet renewable sites in coastal areas and therefore consideration must be given to the differential effort that may be required for surveys for birds and marine mammals.

Further detail on the likely effort required and how to assess it is given for specific protocols in later sections of this volume.

7.5 Encouraging collaboration

Given the spatial considerations described above, and the fact that many sites with potential for marine renewable developments tend to be clustered together, it makes sense for surveys for marine mammals to be carried out collaboratively over the entire region – this will ensure that the surveys are carried out and information gathered over appropriate ecological scales and will also provide data appropriate for cumulative impact assessment over several deployments. This will also reduce costs for individual developers and prevent competition for scarce resources such as survey platforms and experienced observers. This is particularly appropriate for boat and aerial based surveys of marine mammal abundance and distribution at sea where survey designs can cover large geographical ranges encompassing several potential development sites and appropriate ‘buffers’.

The value of collaborative surveys was stressed by SMRU Ltd in a document to Crown Estate (TCE, 2010). This report also concluded that the success of collaboration will rest in large part with the Developers, and whether each can obtain the information they need in a time frame that fits their schedule.

7.6 Adaptive management

Given the relative novelty of the marine renewable industry and the uncertainties surrounding the impacts of marine renewables on marine mammals, an adaptive management approach is likely to be required. An adaptive management approach is a process for achieving development in light of such uncertainties by continual ongoing evaluation of impacts and feedback of results. This approach has been used successfully at Strangford Lough in North Ireland (see Case Study, Section 7.7). Adaptive management programs should be developed to fit a particular project’s scope and location and address its environmental impacts. As the industry develops and stakeholders and regulators become more certain about the impacts, monitoring requirements can develop and become more prescriptive. The following sections describe and discuss the methodologies that should be considered as part of the monitoring programme.

7.7 Case Study: Marine Mammal Monitoring at Marine Current Turbines SeaGen tidal turbine, Strangford Lough, Northern Ireland.

Background

The SeaGen tidal device is the world's first commercial scale tidal stream generator. It was installed in April 2008 and was connected to the grid in July 2008. The device comprises twin 16m diameter rotors which begin to generate electricity at current speed greater than $1m.s^{-1}$. Maximum rotational speed is limited to 14 rpm, resulting in a peak rotor tip speed of $12m.s^{-1}$. Pre-installation environmental monitoring commenced in May 2004 and the Environmental Statement was submitted to the regulatory authority, the Environment and Heritage Service in Northern Ireland in June 2005. A full environmental baseline report was submitted to EHS (now the Northern Ireland Environment Agency, NIEA) in August 2006. An adaptive management strategy was developed which incorporated a series of monitoring programmes with the aim of detecting, preventing or minimising environmental impact attributable to the turbine installation and operation. This programme is managed by Royal Haskoning with scientific input from Queens University Belfast and the Sea Mammal Research Unit and SMRU Ltd, University of St Andrews. Continual review and feedback of the results of this programme by an independently chaired working Science group have allowed subsequent relaxation of tiers of mitigation and increased confidence in the absence of detrimental effects on the habitats, species and physical environment of Strangford Lough.

Marine mammal monitoring

Strangford Lough holds a population of breeding harbour seals (*Phoca vitulina*) and there are also regular sightings of harbour porpoise (*Phocoena phocoena*) in the Narrows and inner Lough. The EIA process identified uncertainty surrounding potential risks to marine mammals within the Strangford Special Area of Conservation. The main uncertainties related to collision impacts, barrier effects and disturbance/displacement of marine mammals from the Lough and Narrows.

Active Sonar

As part of the adaptive management and mitigation system, a study of the effectiveness of active sonar for detecting marine mammals around the turbine was included. This system provides real-time sub surface imagery of marine mammals and other large marine animals within 80m of the turbine. Results indicate that marine mammals and other 'targets' can be detected in a tidally turbulent water column in real time. Targets which are likely to travel close to the turbine elicit an emergency shut-down of the turbine. This system is monitored remotely 24/7 throughout operation by human observers as a real-time collision mitigation strategy. The turbine can be stopped by the Active Sonar Operator in approximately 3 seconds.

Concurrent trials with a pile-based MMO determined that approximately half of the sightings detected by the MMO at the surface were also detected by the sonar, and it is reasonable to assume that the degree of detection below the surface layers is considerably higher than this. Currently data from this system is being examined by SMRU Ltd to investigate the effects of turbine activity on close range movement of targets. However at present the current sonar system is unable to perfectly distinguish between marine mammal targets and other targets such as diving birds and as such it is difficult to interpret resulting data. In addition the requirement for precautionary shut downs complicates the interpretation of close range interactions A more updated sonar system is currently being trialled on SeaGen and automatic target recognition tracking software is under development.

Acoustic monitoring of harbour porpoise

Levels of harbour porpoise activity have been monitored throughout the development programme using TPODS. TPODS are self contained submersible units which detect vocalisations. A daily rate of Detection Positive Minutes (DPM) is used as a proxy for porpoise activity levels in the vicinity of each TPOD. Initially 10 TPODS were deployed in Strangford Lough in 2006. Since then some losses have occurred but 4 have been consistently deployed in the Narrows.

Over 1,900 days worth of data have been collected. Detection rates were generally low with higher rates of detection in the inner Lough than in the Narrows. There has been a significant decrease in detections at locations in the eastern side of the Narrows throughout the operational phase compared to baseline, although those on the west site have not changed. Throughout the latter stages of the operational monitoring period (Summer 2010 onwards) there have been some indications of a decline in porpoise detections in the inner Lough although current analysis is ongoing to determine whether this could be as a result of declines in TPOD sensitivity or variations in sampling effort over this period. Changes in the recorded click rates could have several causes. It could be a result of a decrease in the number of animals using an area, animals spending less time within an area or the same number of animals echolocating less often than previously or could be due to small changes in recording operations.

Marine mammal carcass monitoring

Throughout the first year of commissioning and operation a programme of shoreline surveillance was carried out by Queens University Belfast. This covered a pre-defined area of the Strangford Narrows and immediate coastline and surveys were carried out weekly. Any marine mammal carcasses discovered within the surveillance area were reported to NIEA and underwent post mortem examination. Weekly surveys were discontinued mid way through 2010 although NIEA continue to monitor and manage all stranding events. No post mortem examination to date has found any evidence of any connection with the SeaGen turbine.

Vantage point observations

Shore based visual surveys for marine mammals and birds have been undertaken regularly since the baseline phase of the project and have continued throughout installation and operational phases. These consisted of monthly observation periods, stratified to provide coverage over a range of tidal states and times of day.

Analyses of these data involved fitting statistical models to determine the relationships between sightings rates and environmental, spatial and temporal variables. The year, time of day, tidal phase and spatial location all had a significant effect on relative abundance although no trends in abundance were apparent between baseline, installation and operational phases of the development.

The natural variability the system is high and this was reflected in a high variability in sighting rates, particularly for less abundant species. This presents difficulties for detecting fine scale changes in species distributions. Simulation studies were carried out to quantify the probability of detecting an effect, over varying effect sizes and over different monitoring periods. The results from these suggest low power to detect changes in harbour porpoise abundance, regardless of the length of the monitoring period. Even large effects, say a reduction in abundance of 20%, have only an approximate probability of detection of 0.28 after 6 months of monitoring for porpoises. These values are indicative of the large degree of natural variation in the system and large increases in survey effort would be required to improve the power of the monitoring scheme. Power is increased with increased sample size, either through longer monitoring or more comprehensive sampling.

8 SURVEY METHODS FOR ESTABLISHING THE CHARACTERISATION CONDITIONS OF A WET RENEWABLES SITE FOR CETACEANS AND BASKING SHARKS

8.1 Introduction

The need for characterisation surveys should be assessed after a thorough scoping study of available data. It is envisaged that, for most sites, surveys will be needed because available data are absent or at too coarse a scale to be informative. Available data should be used for planning the characterisation surveys; it will be useful for deciding on the most appropriate technique, how much effort will be required to obtain an adequate sample size and how frequent surveys need to be carried out. Importantly, existing data can also highlight seasonal and/or annual variability in the "populations" present.

There are a range of well-established methods for surveying marine mammals (Table 8.1) (Evans and Hammond, 2004; Diedrichs *et al*. 2008; Boyd *et al*., 2010; TCE, 2010), and analysing the resulting data. The primary data of interest for characterisation monitoring related to marine renewable energy will be: species present, distribution and abundance; these data will be required for the Environmental Statement and any Appropriate Assessment to be carried out. In many cases, the methods also allow for collection of other data that can be interpreted in the context of habitat use. An additional question that needs to be addressed by an Appropriate Assessment is whether the animals present in the area are part of an SAC population; techniques available to address this are restricted primarily to photo-ID studies and telemetry. There is only one SAC in Scottish waters for bottlenose dolphins, in the Moray Firth. The range of these animals has extended over the last decade with animals moving as far south as St Andrews Bay. However, studies to date suggest that movement of SAC animals from the east to the west coast along the northern Scottish coast is limited (Thompson *et al*. 2011). Therefore, the occurrence of SAC bottlenose dolphins at Northern Isles and west coast wet renewable sites will be unlikely. There is the possibility of future SAC designations including cetacean species as a qualifying feature/s.

Telemetry methods have not been widely used in the UK for cetaceans (attempts have been made to tag minke whales off the west coast of Scotland and in the Moray Firth[11]) and Home Office licence requirements would probably prohibit their use, at least in the foreseeable

[11] http://www.crru.org.uk/minke.asp

future. For this reason, telemetry is not considered a viable monitoring tool for cetaceans in this report and is discussed only in the context of studying basking sharks.

The most basic metric that the characterisation surveys will generate is presence/absence of the different species. All methods will also provide data on distribution, which describes where the animals are and when they are there. Abundance data may provide estimates of either relative or absolute abundance, with both usually estimated using distance sampling methods (Buckland *et al*. 2001). In estimating absolute abundance, it is necessary to estimate the proportion of animals that are missed during the survey on the transect line (the detection probability on transect line or sampling point, notated as *g(0)*). If detection probability is not estimated, then abundance estimates can still be compared over time, but the estimates will be *relative*, and care will need to be taken to standardise as many aspects of the survey as possible for comparisons to be valid. Not estimating g(0) has more serious implications for impact monitoring (see Section 9).

Acoustic monitoring for marine mammals all rely on passive (rather than active) acoustics – referred to as PAM (Passive Acoustic Monitoring). These methods record the acoustic signals produced by the animals. Acoustic survey techniques are popular because they are less labour-intensive and are not as limited by weather conditions as visual techniques. Beyond sea state 4 it becomes very difficult to observe cetaceans, especially small species such as porpoises. However, many cetaceans can be reliably detected using passive acoustic methods and the technique can be used to collect reliable data up to sea state 5. Passive acoustics can allow extended survey duration when visual surveys are not possible (e.g. at night and during winter months). There are currently two systems in use for carrying out passive acoustic monitoring of cetaceans: towed hydrophone arrays (e.g. Leaper *et al*. 2000) and static autonomous acoustic data loggers (e.g. Mellinger *et al*. 2007). It is important to realise that only vocalising animals will be detected. Not all EPS can be reliably detected by acoustic methods. In the UK, they are used most successfully on the harbour porpoise and can be used to indicate their presence, distribution and relative abundance in an area.

The visual and acoustic methods described above can be divided into two sampling approaches: Fixed Point Surveys (FPS) and Transect Surveys (TS). FPS record detections from a fixed point, whether it be a vantage point survey from a headland (point transects) or a POD on the seabed (point counts) (see protocols for further explanation). TS are conducted from a moving platform (ship or aircraft) and detections are recorded (visually or acoustically) along a single/set of line transects.

Methods for assessing the distribution of basking sharks are varied and can range from tracking or tagging individual animals (e.g. Southall *et al*., 2005*;* Lacey *et al.,* 2010) to large scale surveys (e.g. Speedie *et al*., 2009). One major problem associated with conducting visual surveys for basking sharks, is that these methods rely on individual sharks spending sufficient time at the sea surface to be observed. It is currently not known what proportion of the population exhibit “basking” behaviour, how often it is exhibited, or whether it is undertaken in all habitats – consequently there may be significant bias associated with assessments of distribution. Where basking sharks do not appear at the surface their presence may go unrecorded (Southall *et al*., 2005). The behaviour of basking sharks occupying waters that are well-stratified is different from that of sharks occupying tidal front regions (Sims *et al*., 2005). This results in different sightings frequencies in different habitats. The probability of sighting a basking shark may be 60 times higher in a frontal area than in a well stratified zone (Sims *et al.,* 2005).

Table 8.1: Monitoring methods used to address characterisation monitoring questions at inshore and offshore wave and tidal sites for cetacean. Methods marked ‘ † ’ are also applicable to basking sharks.

Primary Assessment type	Monitoring Objective	Monitoring Method						
		Strandings†	Vantage Point †	Line transect surveys †	Towed Array	Autonomous acoustic monitoring*	Photo-ID**	Telemetry† * *
EPS licence, Appropriate Assessment or EIA	Species present	☆	☆	☆	☆	☆		
	Density/ abundance		☆	☆	☆	☆	☆	
	Habitat Use		☆	☆	☆		☆	☆
AA only	Connectivity with SAC						☆	☆

* May or may not be useful for multi-species assessment depending on technology used.
** used with a target species in mind, such as bottlenose dolphin (photo-ID) and basking shark (telemetry).

8.2 Fixed Point Surveys

8.2.1 Vantage point surveys

Vantage point observations are undertaken by an experienced observer who undertakes dedicated watches from an elevated position, such as a cliff or headland overlooking the study site. Depending on the methods and equipment used, vantage point observations can be relatively cheap, and they are certainly one of the most non-invasive of the visual observation choices. For this reason, they are often used in behavioural studies for coastal cetacean species as researchers can observe behaviour of animals without disturbing them (e.g. Hastie *et al.* 2004).

The main limitation to this survey type is the extent of reliable visual observations which can be made over the entire study site. Depending on the species of interest the effective search radius can vary from 2 - 5km (small cetaceans, e.g. 2km for harbour porpoise in Koschinski *et al* 2003) to ~10km for large cetaceans with conspicuous blows (e.g. humpback whales; Noad *et al*., 2008). This approach is also dependent on the presence of a suitable elevated observation site; the higher the elevation the further the distance that can be searched.

With a few notable exceptions, fixed-point observations in isolation cannot produce estimates of absolute abundance. However, with auxiliary data to model detectability, it is possible to establish relative abundance and therefore trends over time (Section 12.1.7). Where sites are amenable to VP surveys, this approach can answer the key questions relating to EPS; whether EPS are present, their temporal and spatial distribution and also information on habitat use. VP surveys could detect Annex II species and prompt further investigation to satisfy an Appropriate Assessment. The pros and cons of vantage point surveys are given in 8.2.

Table 8.2 Pros and cons of vantage point surveys (adapted from TCE, 2010).

Pros	Cons
• Inexpensive (compared to boat based or aerial methods) • Observers not influencing behaviour of animals • Can provide spatial and temporal data on usage and distribution • Can collect data for pinnipeds, cetaceans and sea birds using the same approach • Established analysis frameworks • Can be extended to assess long-term trends	• Generally not possible to estimate abundance • Experienced observers are required • Weather restricted • Need to find a suitable site/vantage point • Often confined to coastal strips or channels i.e. near shore sites • May need more than 1 VP

8.2.2 Autonomous acoustic data loggers

The POD[12] is an autonomous device incorporating a hydrophone and a hardware data-logger, which detects cetacean echolocation clicks. Dedicated software processes these detections and filters out unwanted noise from other sources. The newest version of the POD, the CPOD, can detect odontocetes which vocalise within the 20-160kHz range (all except sperm whales). PODs can differentiate between porpoise and dolphin clicks; however, the software is not yet able to differentiate between dolphin species. PODs only log detections from animals that are actively echolocating. Therefore they can currently only provide a crude proxy for the number of porpoises and dolphins recorded; and in isolation they cannot be used for estimating absolute or relative abundance. Validation of the POD data may be possible when combined with sighting information from concurrent visual surveys. POD data can be used to provide information on diurnal and seasonal variation and inter-annual trends in detection rates. They are powered by batteries and can log continuously for up to 4 months. They are a useful tool for looking at behaviour of animals in response to marine activities and have been used extensively to monitor the impact of wind farms on harbour porpoises in Denmark, Germany and Holland (Carstensen *et al*. 2006; Brandt *et al*. 2011).

PODs need to be anchored, either to the seabed or an existing buoy, and the hydrophone floats upright in the water column. This presents one of the main problems with this system as many PODs are lost in trawling, through theft and severe storms. The current maximum

[12] http://www.chelonia.co.uk/.

water depth for deployment of PODs is 500m (Trengenza *pers.comm.*), well within the depths of development sites currently being considered. Ambient noise, particularly in fast flowing tidal sites, may be problematic to their use. The detection range is generally about 300m but this will potentially be affected by ambient noise. Overall, the use of static acoustic monitoring devices such as PODs is a cost effective, non invasive method of long term acoustic data collection.

There are several other autonomous acoustic data loggers available for monitoring marine mammals (see Table 8.3) for pros and cons of the method). Cornell Pop-Ups[13] record raw data and can be deployed on the seabed up to depths of 6000m. The device consists of a microprocessor, hard disk for data storage, acoustic communications circuitry and batteries. An external hydrophone is connected to the internal electronics through a waterproof connector. At the end of the survey the Pop-Up separates itself from its mooring using an acoustic release system and "pops up" to the surface for retrieval (e.g. Swift *et al.* 2002)

The Ecological Acoustic Recorder (EAR)[14] is another acoustic data logger which monitors sound (both biological and anthropogenic) in the sea for up to a year at a time (Lammars *et al.,* 2008). There are 2 versions of EARs; one of which can be deployed at depths of up to 500m and another which is restricted to up to 36m deep. The EAR is a microprocessor-based autonomous recorder that periodically samples the ambient sound field and also automatically detects sounds that meet specific criteria. They are anchored to the sea-bed and have an acoustic release system similar to the Pop-Up.

Table 8.3: Pros and cons of autonomous static acoustic data loggers (taken from TCE, 2010).

Pros	Cons
• Stationary click detectors provide high temporal resolution • Data collection can be relatively inexpensive • Long-term data sets can be collected • Data can be used to monitor relative abundance if click rates are assumed to be constant over time	• Methods to estimate abundance are not well developed • High frequency vocalisations have a limited detection range of approximately 200m • Devices require retrieval to obtain the data • No background noise compensation • Limited ability for most designs to provide detection range

13 http://www.birds.cornell.edu/brp/hardware/pop-ups
14 http://www.pifsc.noaa.gov/cred/eartech.php

8.3 Transect Surveys

8.3.1 Visual Line Transect

Line transect surveys are often considered the standard for estimating density and abundance of cetacean populations (see Buckland *et al.*, 2001). A survey area is defined and a set of pre-determined transect lines are surveyed. During the survey, observers record the perpendicular distance to each of the sightings together with data on the species and group size. By recording distances to sightings, a detection function can be fitted and an effective width of strip that has been searched estimated; this corrects for animals missed by observers further away from the transect line. The method generates unbiased density and abundance estimates when three key assumptions are met:

1. Animals on the transect line are detected with certainty, (i.e. they are detected with probability 1, or the detection function at zero distance *g(0)* = 1);
2. Animals are detected at their initial location, prior to any responsive movement to the survey platform; and
3. Distances and angles from the observer to the objects of interest (e.g. porpoises) are measured accurately (e.g. using angle boards and reticle binoculars).

The first, and most critical assumption, is almost always violated because cetaceans and basking sharks spend considerable amounts of time below the surface which means they are missed by observers. Observers may also miss animals simply because they weren't looking in the right direction or an animal surfaced behind a wave. In either case, when g(0) does not equal one, density will be underestimated. Double-observer methods (Buckland *et al*. 2004) allow for empirical estimation of g(0) but both the field and analysis methods are relatively complex. As noted in section 8, one major problem associated with visual surveys for basking sharks (whether aerial or ship based) is that these methods rely on individuals spending sufficient time at the surface to be observed. In areas where basking sharks do not appear to bask, their presence is likely to go un-recorded. For the purpose of developers gaining consent, conventional distance sampling methods will generally provide appropriate density estimates for characterisation. However, in the context of impact assessment density and abundance estimates produced using g(0)=1 should be considered *minima*.

The probability of detecting an animal on the transect line, g(0), is normally assumed to be 1 (certain detection), but for marine mammals, which spend a proportion of the time below the surface, this assumption is not generally valid. Double observer methods are needed to accurately calculate the g(0) value specific to each species and survey but this is not always practical due to limited space on some survey platforms or additional cost. However, they have been successfully employed on a relatively small survey boat to estimate abundance for bottlenose dolphins in the Cardigan Bay SAC (Pesante *et al*. 2008). The influence of differing g(0) values on the abundance estimates generated are demonstrated in Figure 8.1. The detection probability used in analyses will have a key influence on resulting abundance estimates.

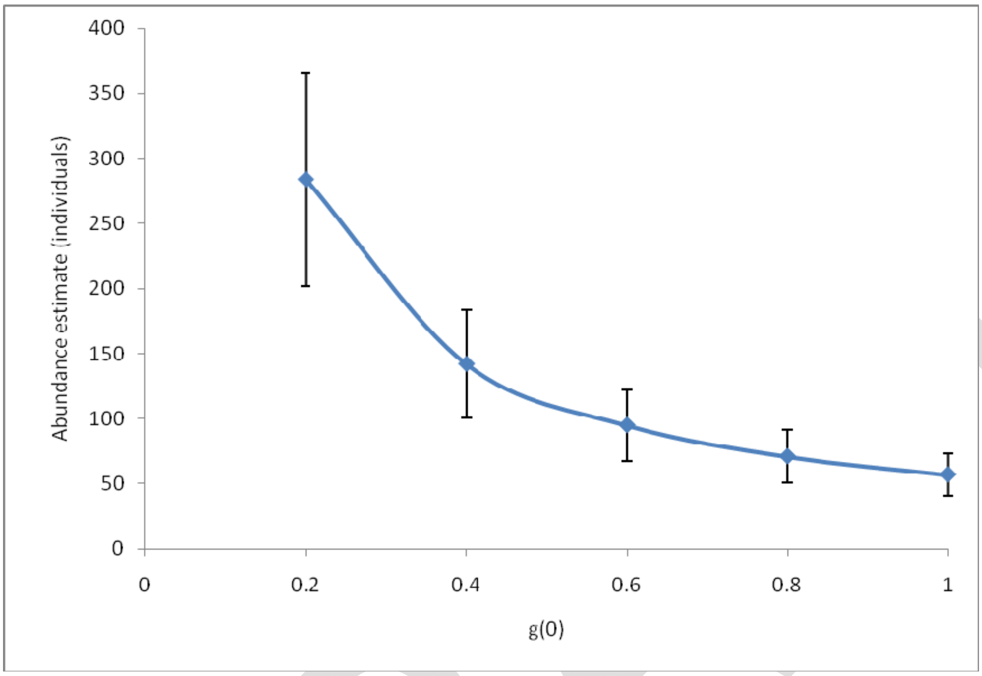

Figure 8.1: Example estimates of abundance based on different g(0) values. The estimate of g(0) for harbour porpoise from SCANS- II range boat-based surveys was just 0.22.

If analyses assume that detection probability of harbour porpoise (or other species) on the transect line is certain, density and abundance estimates will be negatively biased. The implications of this in terms of the application of these estimates for monitoring change through time are limited, providing it is reasonable to assume that g(0) would be consistent over all the surveys. However, there are implications when using the estimates to assess the number of animals that may be impacted by a particular activity or development as it is likely that considerably more animals would be exposed to a potentially harmful activity than an abundance estimate based on g(0)=1 would suggest. It would therefore be prudent to at least apply a published estimate of g(0) when assessing any potential impact.

Assumption (2) is a particular issue for boat-based surveys as many cetacean species are known to respond to the presence of boats. Attraction results in positive bias in abundance estimates whilst vessel avoidance results in negatively biased estimates. These are not insurmountable problems, but generally require auxiliary data collection involving some sort of double-observer method (Hammond *et al*. 2002) or record of animal heading for each sighting (Palka and Hammond, 2001). Aerial surveys do not suffer from problems associated with responsive movement.

Line-transect methods can be conducted from boats and aircraft. A constraint common to all visual line-transect surveys, regardless of platform choice, is that surveys need to be conducted in fair weather conditions. The detection of cetaceans is heavily dependent on weather conditions, particularly Beaufort sea state[15] since an increasing number of white caps or breaking waves tends to obscure the most common sighting cues. Sighting surveys should be discontinued when sea state is above Beaufort 4 for ships and Beaufort 3 for aircraft (Hammond *et al.* 2002). Obviously surveys can only be conducted during daylight hours, which impose further time-restrictions. When weather conditions are suitable, a great deal of ground can be covered quickly by air compared to ships. Compared to ship surveys, charter costs for aircraft are relatively cheap.

Free and increasingly sophisticated DISTANCE software (Thomas *et al*., 2009)[16] facilitates data analysis and also includes some useful survey design tools (see Strinberg *et al*., 2004).

Line transect surveys are a broad-brush technique that allow data to be collected for all species of cetacean and also basking sharks (Table 8.4 for pros and cons). This approach will inform on the presence, distribution and also abundance/relative abundance of EPS within the area. The same information can be collected for Annex II species in the area and would provide characterisation data for the Appropriate Assessment. It is also possible to undertake seabird surveys from a shared survey platform, but with separate dedicated teams of observers used for collecting the marine mammal and seabird data.

[15] See http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html
[16] http://www.ruwpa.st-and.ac.uk/distance/

Table 8.4: Summary of pros and cons of visual line-transect surveys for cetaceans (adapted from TCE, 2010).

Pros	Cons
Line-transect surveys	Line-transect surveys
• Data allow for estimation of absolute or relative density & abundance • Can provide information on distribution • Can be long-term • Can cover entire range of population	• Can be expensive (depending on spatial and temporal scale required) • Restricted by weather conditions and to daylight hours • May be difficult to implement (especially boat-based) during operational phases of wave/tidal sites
Boat-based line-transect surveys	Boat-based line-transect surveys
Offshore and near-shore • Additional data can be collected • Well established and robust methods for assumption violations, especially for large vessels Near-shore only • Small boats can take advantage of good weather in some circumstances	Offshore and near-shore • Large vessels expensive • Responsive movement Near-shore only • Small boats range-restricted • Small boats reduced effective strip width and survey team size/effectiveness for line-transects • Small boats highly constrained by weather
Aerial line-transect surveys	Aerial line-transect surveys
• Fewer issues with responsive movement • Can cover large areas quickly • Can take advantage more readily of good weather windows • May already be taking place to carry out bird surveys	• Logistical limitations • Responsive movement may be a problem for some aircraft types or some species • Height limitations around wind farms

High definition cameras are being increasingly used to capture video or stills images along aerial line transects to provide bird data for estimating density and abundance (Burt *et al*. 2009). Marine mammals are also detected during HD-photography surveys and Thaxter (2009) generated abundance estimates from these detections (porpoises, dolphins and seals). No analysis has been made to compare marine mammal estimates from simultaneous data collection from both HD-photography and observer surveys of the same area, as has been done for birds (Burt *et al*. 2010). Species identification remains an issue for marine mammals; porpoises seem distinguishable from dolphins (e.g. Hexter, 2009; 2009a) yet species-ID beyond “dolphin” seems more difficult. There are also acknowledged difficulties in accounting for animals not at the surface (availability bias) and while these issues are not insurmountable, they do not appear to have been resolved yet (Thaxter and Burton, 2009). Further work is therefore needed before HD-photography can be recommended as a preferred and primary monitoring technique (TCE, 2010).

8.3.2 Towed hydrophone array

A hydrophone array can be towed behind a survey vessel to detect vocalisations of cetaceans in the area and is often deployed concurrently with visual observations. A summary of the advantages and disadvantages of towed arrays are presented in 8.5.

Sounds detected by the hydrophones are digitised and detected by automated click and whistle detection software. This can be monitored in real time by a trained observer but will also require detailed offline analysis. Triggers and filters built into the software parameters can be used to filter out some ambient noise. This works particularly well for constant noise sources – such as ship engine noise or electrical noise from onboard equipment.

Within UK waters, this technique is applicable mainly to odontocetes including the harbour porpoise, for which it is particularly useful. Porpoises can be detected at a range of approximately 200m. Bottlenose dolphins and other odontocetes can also be detected, at ranges of approximately 400m. Species identification of harbour porpoises and sperm whales is possible using the automated detection algorithms and work is ongoing to develop classifiers to automatically detect dolphin species (e.g. Gillespie and Caillat, 2008). This technique is not applicable to baleen whales within UK waters.

Data collected can yield relative abundance estimates for harbour porpoises, and presence data for all odontocete species.

Table 6.5 Pros and cons of towed hydrophone array surveys

Pros	Cons
• Data are independent of daylight and most weather conditions • Can provide high spatial resolution data	• Methods to estimate abundance are only developed for harbour porpoises and sperm whales; species identification is currently difficult for other species • Performance is dependent on the noise level of the vessel • High frequency vocalisations have a limited detection range of approximately 200m

8.4 Other methods

8.4.1 Photo-ID

Mark-recapture analysis using photographs of long-lasting natural marks on cetaceans has substantially increased biologists' abilities to monitor movement patterns and population changes for many species (see Evans and Hammond 2004 for a review). However for wide ranging cetacean species it is often impossible to monitor over the entire range of the species and broad scale systematic surveys provide limited power for detecting core habitats. This is especially true if animals are sparsely and unpredictably distributed or are part of a small population. In areas where animals show some degree of regularity of occurrence, targeted photo-identification studies may provide better information (see Thompson *et al*. 2011).

Photo-identification is a non-invasive technique which utilises the fact that different individuals within a population have distinctive markings which enable them to be distinguished from other individuals within that population. For cetaceans, features such as nicks in the dorsal fin or tail fluke and marks on the body surface are used (Figure 8.2). These features are captured photographically during encounters with individuals and kept as a permanent record along with associated information. Photo-ID data can be used to estimate population parameters such as size, status and residency; individual life history parameters such as survival or calving intervals/success; and assess connectivity between different development sites (to assess the potential for cumulative effects) and also between development sites and SACs.

Credit: Kate Grellier

Figure 8.2: Typical markings used to identify individual dolphins.

In Scotland, the main cetacean species for which photo-ID has been used are bottlenose dolphins (e.g. Wilson *et al*. 1999), Risso's dolphins (e.g. Atkinson *et al*. 1999), killer whales (e.g. Foote *et al*. 2009) and minke whales (e.g. Robinson *et al*. 2007). The technique has also been used on other marine vertebrate species in the UK such as basking sharks (Speedie, 2000).

In the context of characterisation studies, photo-ID would be most appropriate to answer questions pertaining to population size (using mark-recapture analysis) and the presence of individuals from a SAC population within/near to the development site. Photographs of animals within the site could be compared with existing catalogues of SAC animals (i.e. Moray Firth bottlenose dolphins) to establish whether they "belong" to an SAC population. An alternative approach would be to assume that all individuals present do belong to the SAC population.

8.5 Collision risk of cetaceans and basking sharks

The risk of collision is a key issue for wet renewable sites and a lot of site characterisation work may be directed at assessing this risk. Both tidal and wave devices pose collision hazards to seals. Tidal devices with rotating turbines are deemed the most likely cause of injury or death to seals that collide with them. However, the surface components of wave devices are not risk free as cetaceans have to surface to breathe and basking sharks spend periods swimming at the surface.

Collision risk models are being developed to assess the magnitude of risk posed to marine mammals in the vicinity of wet renewable devices. Wilson *et al.* (2007) developed a model to assess risk between a rotating turbine device and harbour porpoises (amongst other species). The model is based on common ecological predator-prey encounter rate models and requires information on the density of the animals per cubic metre in the locale of the turbine, the velocities of both the animal and turbine blades and also the encounter radii of the animals and the turbine blade. However, present models have two main problems associated with them. They assume that marine mammals are randomly distributed, randomly moving objects within the water mass; this assumption is unlikely to be true in many of the areas where wave and tidal energy developments will be sited. Secondly they effectively predict the number of animals being in close proximity to devices, but do not include the likelihood of impact i.e. they do not account for any responsive movement that animals might take to avoid collision. Adoption of this model without consideration of these issues has a large risk of misleading results which limits the practical application of these models to managing collision risk within the industry.

To be useful, models need to incorporate information on how animals utilise the water column, for example what depths they are known to forage at and whether this increases their probability of encountering a particular (tidal) device. They should also incorporate information on how animals transit areas designated for development. Also, accurate strike rates from existing devices will be crucial to inform future empirical predictions of avoidance rate.

The potential for direct impacts (injury and mortality) through collision could be considered more directly “quantifiable” than disturbance or displacement effects and the effects of predicted “removals” may be considered in a management framework, such as Potential Biological Removal (PBR). The PBR was developed by the US National Marine Fisheries Service in response to the US Marine Mammal Protection Act requirements, primarily as a management tool for marine mammal takes (e.g. Wade 1998). It is designed to assess the number of individuals that can be ‘safely’ removed from a population in addition to natural mortality without having any negative population consequences and relies on this extra mortality being directly measurable. There are alternative approaches to the PBR; one such alternative which has been well tested and developed over decades is the International Whaling Commission’s Catch Limit Algorithm which is central to the Revised Management Procedure. Additionally, the SCANS-II project developed a management tool specifically geared for managing cetacean ‘take’ as a result of bycatch to avoid population declines (Winship & Hammond 2008). It is possible that predictions of mortality related impacts from marine renewables may feed into the PBR management approach in future or that the Regulators may use an alternative approach to setting thresholds for ‘takes’ in relation to a deploy and monitor strategy for consenting. Research is currently ongoing by SMRU and CREEM at the University of St Andrews.

9 MONITORING METHODS TO ESTABLISH IMPACTS OF CONSTRUCTION AND OPERATION OF WAVE AND TIDAL DEVICES

9.1 Introduction

To quantify the impact of construction and operation of wave and tidal devices on cetaceans and basking sharks it may be possible for the data collection initiated in establishing the characterisation to continue through construction and into operation. However, as discussed in Section 8.3.1, specific questions about the potential impacts of development activities being undertaken must be answered, as well as how any potential impacts may vary over different spatial and temporal scales. It is essential that monitoring is targeted towards the consent conditions and key questions of relevance to the development and existing methodologies may need to be amended or additional methods incorporated to properly assess any impacts. Methods that can be used to investigate impacts are given in Table 9.1 and Table 9.2.

The use of standardised methodologies will ensure consistency and allow comparisons between different developments.

There is very little data regarding the interaction between individual animals and devices or device arrays. Dedicated study of animal interactions with devices and utilisation of development areas may therefore provide valuable information for device installation and operation and, indeed, be a pre-requisite for informing the consenting process for future developments of similar technologies in environmentally sensitive areas. Given the uncertainties about predictions of direct impacts of wave and tidal devices on marine mammals at the pre-consenting impact assessment stage, careful consideration needs to given to the ability to rapidly detect and mitigate against these should they occur.

9.2 Disturbance and/or displacement during construction, deployment and operation of device(s)

Monitoring for disturbance and displacement effects during construction, deployment and operation should focus on measuring changes in abundance and distribution of animals present in the study area during the construction phase and operational phases. The methods appropriate for monitoring changes in distribution and abundance (relative or absolute) are vantage point surveys, line transect surveys and static acoustic monitoring (see Characterisation monitoring sections). These methods may also provide information on displacement caused by the barrier effect of installations or activities.

Vantage point surveys (section 12.1) can be used to monitor relative abundance within the development site throughout all stages of development. Rather than just recording sightings, the protocol could include the need to track individuals using a theodolite or video-range method to assess barrier effects of installation activities or the presence of an operational device (s). The collection of a series of positional "fixes" of the study animal at different points in time yields a series of data points which can be used to reconstruct a trackline for the animal and swim speed. This provides a quantitative mechanism for gauging behaviour of individuals around devices. Video-range tracking is well suited to monitoring basking sharks as they generally spend long-periods of time swimming slowly at the surface, allowing detailed movements to be logged. Cetaceans tend to be fast moving, spending limited time at the surface and are not easy to track. However, the method was used from ships during the SCNAS-II surveys to track harbour porpoise with some success (SCANS-II, 2008). Video-range techniques can be conducted from a vantage point or boat and a protocol is given in section 12.8.

Additionally, the VP survey could include targeted focal follows to collect fine-scale individual/group behavioural data. This can be interpreted in the context of disturbance caused by noise and/or physical presence of the devices or analysed to assess time-energy budgets. The technique has been successfully employed for bottlenose dolphins in Scottish waters (Quick & Janik, 2008; Quick *et al*., 2008). However, in reality focal follows are extremely difficult and probably not practical for harbour porpoise.

Line transect surveys (12.3) from boats could be problematic to implement during the construction and operation phase of wet renewable sites. Some devices could cause navigational obstacles making it difficult to adhere to a designed set of survey transects. Surveying from the air would not suffer the same problems. Line transects must be properly designed to ensure that there is enough survey effort within the monitoring period(s) associated with each phase to generate precise estimates of density. Precise measures will allow changes to be detected more readily than estimates with a great deal of uncertainty. If estimates of g(0) were generated from the characterisation surveys, then providing survey techniques and platforms are the same, they can be used during the impact monitoring surveys to correct density and abundance estimates for animals missed on the transect line.

Autonomous acoustic data loggers (12.2) could be deployed throughout all stages of wet renewable site development to monitor impacts. Their positioning within the site would have to be agreed upon with knowledge of where the devices are to be sited. However, deployment at tidal sites is challenging because the device will need to be anchored to the seabed to withstand strong tidal races. Data collection may also be hindered by loud flow noise over the hydrophones in such areas. The benefits of this approach are that data can be collected over long time periods and can monitor changes in acoustic activity and usage within the area. Currently, these methods do not generate numbers of individual animals.

Photo-ID studies being used to monitor coastal bottlenose dolphins can be used to look for changes in abundance of animals in the area. Photographs should also be cross-referenced with existing photo-ID catalogues to determine whether the animals are part of the SAC population. The method could also contribute data on new injuries to the animals coincident with the operation of devices.

Telemetry studies are not routinely used for cetacean studies in the UK. However, they are used extensively for monitoring seals (see Volume III) and can provide information on at sea distribution, usage and behaviour.

9.3 Collision monitoring of cetaceans and basking sharks during operation of device(s)

The risk of collision is a key issue at wet renewable sites. Both tidal and wave devices pose collision hazards to cetaceans and basking sharks. Tidal devices with rotating turbines are deemed the most likely cause of injury or death to cetaceans that collide with them. However, the surface components of wave devices are not risk free as cetaceans have to surface to breathe and basking sharks spend periods swimming at the surface.

In addition, tracking or visualisation technologies may be used to detect and track animals in close vicinity to devices; passive and active sonar techniques can be used to provide information on the interactions between marine mammals and marine renewable devices (particularly tidal devices). The use of sonar technology in detecting animals around turbines is a relatively new technique and protocols and systems are currently being developed and validated (Royal Haskoning, 2010b). However, ongoing trials at Strangford Lough have been encouraging in demonstrating that mobile targets such as marine mammals can be detected in a tidally turbulent water column in real time. Work is currently underway in the development of automated target recognition and tracking software for use with active sonar imaging of animals around marine energy devices. This development is essential for cost effective integration of active sonar in impact monitoring and mitigation schemes.

Underwater video or photography (tests at OpenHydro, EMEC) provide a potential means of identifying direct collision events with devices under certain conditions (daylight with good underwater visibility). Furthermore, if a ‘deploy and monitor’ strategy is adopted by regulators it will be very important for developers to be able to detect and identify collision events using strain gauges or accelerometers engineered directly onto tidal device rotors, or by monitoring variations in the rotor speed; these techniques are currently being used but have so far not been validated in the field. Developers will also need to be able to identify the species concerned in any collisions – this will involve a combination of passive acoustic monitoring to identify echolocating cetaceans and active sonar or visual/video monitoring to identify seals. These particular applications have not been practically tested in field conditions although work is ongoing at SMRU and SMRU Ltd to develop these technologies.

Another means of monitoring injury and mortality due to collision with wet renewable devices is through standardised stranding schemes and the collection and examination of any carcasses found in the study area. Coastlines adjacent to proposed wet renewable sites should be monitored for stranded animals and carcasses recovered and necropsied to determine common cause of death. Areas of search must be defined given information on local current flow patterns and the likelihood of recovering carcasses. In some areas it may not be feasible to cover the entire range of potential sites of eventual carcass recovery. These data will serve as a baseline to subsequent impact studies where carcasses may show signs of injury as a consequence of collisions with wet renewable devices. In Scotland, reports of stranded cetaceans should be made via the Scottish Agricultural College's Veterinary Investigation Centre at Inverness[17]. If the animal(s) are alive, then the Scottish Society for the Prevention of Cruelty to Animals must be contacted with a view to keeping the animal alive and re-floating.

9.4 Acoustic impacts on sensitive species

Noise disturbance impact monitoring during construction and operation should focus on measuring changes in abundance and distribution of animals present in the study area during device installation and operation. Methods that allow measurement of ambient noise would also inform interpretation of observed changes. When monitoring the impacts of noise it is important to consider the potential range that the sound source could spread to; in such case, applying a gradient survey design rather than BACI might be preferable (see Volume I (Overview, approach and generic advice) of this guidance document).

[17] SAC Veterinary Services, Drummondhill, Inverness, IV2 4JZ, **Tel.** 01463243030

Table 9.1: Monitoring methods used to address impact monitoring questions at inshore and offshore wave and tidal sites for cetaceans and basking sharks.

Monitoring Objective	Monitoring Method							
	Vantage Point	Video-range	Boat-based line transect	Aerial line transect (single/double platform)	Autonomous acoustic monitoring*	Photo-Id**	Telemetry**	Stranding schemes (and carcass recovery)
Species present	☆		☆	☆	☆	☆		
Density/abundance	☆		☆	☆	☆	☆	☆	
Distribution	☆	☆	☆	☆	☆	☆	☆	
Behaviour		☆						
Injury/mortality								☆
Communication/masking					☆			
Barrier effects	☆							
Origin of individuals						☆	☆	

** used with a target species in mind, such as bottlenose dolphin (photo-id) and basking sharks (telemetry)

Table 9.2: Summary of methods available for the monitoring of renewable device impacts on cetaceans. Note that we are not advocating the adoption of all these methods for a monitoring programme, rather these are the range of methods available for selection. The suitability of each would be dependent on the concerns, conditions and constraints of the individual development site.

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
Vantage Point	Presence/ absence	Binoculars/ telescope Theodolite Inclinometer Video-range	Suitable elevated vantage point Visual observation- continuous scan Even sampling of spatial and/or temporal factors influencing detection	Seasonally and annually if natural variability is to be established At-least one in each development phase	Very wide range of metrics may be gathered so very dependent upon questions being asked and data being collected.	Permissions may be needed to access VP. Very dependent upon suitable VP being available. Amount, type and quality of data it is possible to collect declines dramatically with reduced VP suitability and distance of survey area from shore. Data from second survey platform required to estimate detection function if absolute abundance estimates required.
	Distribution					
	Relative abundance					
	Habitat use					
	Behaviour					
Autonomous Acoustic Data loggers	Presence/absence	AADL eg. CPOD Batteries Boat-winch Moorings	Gradient/BACI design	Continuous (need regular servicing)	Regression analyses	Consider navigational issues, licence requirements, local environment when positioning static devices
Line Transect	Relative abundance	Platform (ship, aircraft)	Randomly located	Seasonally and	Baseline: Distance	Ships and aircraft need to

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
visual surveys***	Density Abundance	Inclinometer (aerial) Reticle binoculars (ship) Angleboard (ship) Data recording software and laptop	lines Various layouts (zig-zag, parallel)	annually if natural variability is to be established At-least one in each development phase Intensive surveying within short periods may be more appropriate than regular surveying over extensive periods or throughout the year	Sampling analyses Statistical tests between point estimates eg. Z-test Regression analyses	be suitable. 'Piggybacking' surveys onto bird surveys may result in sub-optimum data. Survey design using Distance can significantly increase survey efficiency (reducing costs) and survey robustness. Understanding and application of standard methodologies for surveying and data analysis essential.
Photo-ID	Presence/absence Abundance Connectivity	Small manoeuvrable boat Digital SLR & 200+MM autofocus lens GPS Note-taking materials	None specific – but area covered must be sufficient to sample population in question	Population estimates may require 2 days per month or more concerted effort during shorter periods. Question dependent.	Matching & grading photographs Matching across catalogues Estimator for abundance e.g. Petersen	

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
Active Sonar and Underwater Photography	Approach distance to turbine , impacts	In development	N/A	N/A		Technology very much still in development.
Carcass recovery	Species present	Trained observers Equipment for moving animals Vets	Established stranding network	Dedicated monthly coastline surveys or before and after activities/ phases of key interest (e.g. construction?)	Species composition over time Cause of death over time in conjunction with development phases	Attributing death to a particular device or activity may be difficult.
	Cause of death					
	Movement /behaviours					
	Time-energy budget					

* Not everything listed will be required in all cases. Depends on specific approach

** See under individual protocols for process for establishing appropriate effort

*** See Table 8.4 for Pro's and Con's of boat and aircraft survey platforms

10 DOWNSTREAM IMPACTS, DATA GAPS AND MITIGATION

10.1 Downstream impacts – Prey abundance

A potential issue with wet renewable installations is that they alter the movement of water affecting down-stream conditions, changing the distribution and extent or structure, function and supporting processes of habitats that support a species of concern. For cetaceans the ultimate impact of such degradation may be the loss or reduced density of key fish stocks. In order to assess potential down stream effects it is essential that during the EIA process, regular discussions take place between the developer and the regulator to determine the EIA requirements. In this way potential issues can be identified early and baseline survey and monitoring put in place to address any concerns raised.

10.2 Data gaps

Monitoring of wet renewable sites is relatively small-scale when considered in the context of the range of most cetacean species in Scottish waters. Interpretation of distribution and abundance data collected during characterisation and impact monitoring will be complicated without larger-scale data with which to compare. Environmental data on an appropriate scale are also important and can be used in analyses (see 12.3.1.7). Understanding background variability in the animals' habitat will be important for teasing out any effects from the development.

The National Cetacean Surveillance Strategy intends to conduct large-scale population level monitoring of cetaceans at six-yearly intervals and such information would be important in putting findings at development sites in context. However, regional data collected more frequently might also serve to better understand cumulative impacts of neighbouring development sites.

The behaviour of cetaceans around wet renewable devices can only be inferred from that around comparably sized structures. It is assumed that harbour porpoises, at least, should be able to detect devices using echolocation and as agile swimmers, take necessary avoidance action (if they perceive it as an object that needs to be avoided). Species that don't actively echolocate, such as minke whales, may have more difficulty in detecting devices in the water; but this is simply unknown.

The impact footprint of wave and tidal devices will vary from a few km^2 for small scale developments to 10's of km^2. The impacts of these developments on the coastal ecosystem are not well understood, and even less so for marine mammals. The impact footprint, considered in the context of noise disturbance, may vary with the different phases of development; expanding during construction and shrinking to a comparably narrow buffer around the devices once they are in operation. The spatial extent of impacts needs further investigation.

Telemetry and photo-ID data on marine mammals are the main sources of information available to explore connectivity between development sites. Understanding connectivity is particularly important for SAC populations and existing telemetry data and usage maps can inform decisions about the placement of sites and likelihood of including SAC individuals. However, sample sizes from telemetry studies are generally small and more effort may be required to answer the questions of interest to the developer and Regulator alike. Telemetry techniques have not been applied to cetaceans in the UK generally; photo-ID can provide data on the home ranges and movements of animals but such projects generally have to run for a long period of time before the necessary data can be collected.

10.3 Mitigation

Mitigating against the potential for negative impacts of wet renewable sites on cetaceans and basking sharks can begin at the site selection stage. Best practice should include avoidance or exclusion of developments from core home ranges (Dolman and Simmonds, 2010). Planning installation phases out with key times of the year may also lessen the potential for impacts; most calving periods for cetaceans in UK waters are during the summer months but do extend into spring and autumn for some species (see Table 2.5).

Monitoring has a crucial role in mitigation. Monitoring data designed to assess impacts will also feed into a mitigation plan and adaptive management.

11 COMBINING MARINE BIRD AND MARINE MAMMAL SURVEYS

The main cost to developers for boat based surveys is the cost of chartering a suitable vessel. Collecting seabird and marine mammal data from a single platform is very cost effective and logistically easier for the developer. Ship-based seabird surveys have been carried out using the European Seabirds At Sea (ESAS) methodology for several decades (e.g. Reid et al., 2003; COWRIE 2004). Marine mammal sightings are also routinely recorded using ESAS methods. However, due to differences in the encounter rate and behaviour of marine mammals it is important that a standard line transect survey method is used for marine mammals rather than ESAS methods. Whilst marine mammal and seabird surveys can be effectively carried out using the same platform, it is important that surveys for birds and marine mammals are conducted by specific staff trained for that purpose and that the two surveys are conducted simultaneously but separately with no interference between them. It is also important that there is a large enough observation platform for the two teams on the survey vessel. If cetacean acoustic data are also of interest then a hydrophone array can be towed from the same vessel; factors affecting "noisiness" of the vessel (such as propeller type) should be checked before charter. Surveys that intend to collect data on both marine mammals and birds must be designed to ensure that survey effort is sufficient to provide adequate information on the species of interest with the lowest (and most variable) expected encounter rate.

Where surveys are unlikely to produce sufficient data for key species it may be necessary to conduct separate species specific surveys (.e.g. tracking studies for some seabirds, the use of PAMs for some cetaceans). The identification of an appropriate survey area must be based upon the species or taxonomic group with the greatest potential impact footprint of the development, and still allow these data to be placed in a local or regional context. Temporal variation may also differ between taxonomic groups therefore survey frequency considered adequate for characterising bird use of an area may not be suitable for marine mammals. Generally speaking, this may result in a marine mammal species of interest (if any are present) being the key determinant of survey effort and survey area. The recommended conditions for ESAS surveys and marine mammal surveys are up to and including Beaufort sea-state 4. Weather windows for survey should be as good as possible, and so whole periods of sea-state 3-4 should be avoided if bird and marine mammal surveys are being combined. A sea-state greater than 2 limits the chances of recording porpoises, and so, although a sea-state 4 is the upper limit, the lower the sea-state the better for cetacean surveys.

There is also good potential for shore-based VP surveys to target birds and marine mammals using the same surveyor as a single field exercise, though surveys of the two taxonomic groups should not be simultaneous. Depending on the requirements of the site this might be done alternating relatively short watch periods (scans) aimed at one group with periods aimed at the other. The amount of time spent surveying and the frequency of survey can be therefore be adjusted in light of the expected encounter rates and variability of each taxa independently.

Digital imaging aerial surveys can survey both birds and marine mammals. As this methodology is relatively new and developing very rapidly as present we recommend that contact is made with the relevant service providers on the ability of this method to survey both taxonomic groups. This should then be discussed with SNH and Marine Scotland prior to surveys commencing.

11.1 Sharing benthic data

Data collected during benthic survey work, including bathymetry, depth profiling, acoustic and relevant interpretation data should be made available to the survey and monitoring teams responsible for marine mammal. An understanding of the benthic environment is important for identifying areas of rich feeding grounds for the top predators, such as where upwelling causes plankton and nekton to move to the top of the water column.

The creation of a joint database would also be beneficial to allow scientists to access each other's data sets easily.

12 SURVEY AND MONITORING PROTOCOLS FOR CETACEANS AND BASKING SHARKS

These protocols are a guide only and adjustments will be required for each development site as site specific issues arise. Protocols are provided for the following methodologies:

1) Fixed point methods

- Vantage Point (VP) surveys;
- Autonomous acoustic data loggers (e.g. PODs);

2) Line transect methods

- Boat surveys;
- Aerial surveys;
- Towed hydrophone array;

3) Other

- Photo-ID;
- Carcass recovery; and
- Video-range tracking

12.1 Vantage point surveys

12.1.1 Survey Design

The observer needs to be flexible and able to carry out observations at all times of day, states of tide and suitable weather conditions. It must be possible for the observer to search the entire area using the necessary equipment from the designated vantage point (VP) or points. The survey area is a hemispherical shape extending from the vantage point to offshore waters encompassing the whole of the tide/wave site.

For vantage point surveys, effort is measured as time spent searching the area. The amount of survey effort should be based on knowledge of the expected encounter rate. This may be available from existing data or can be gleaned from conducting a short pilot survey. From the encounter rate (number of sightings per unit effort), the total time spent searching to collect enough data for analysis can be estimated. For impact monitoring where the objective is to detect change, the minimum sample size for analysis may not be sufficient to generate the required precision to give adequate power to detect changes.

Depending on the temporal resolution required of the metric of interest, effort can be accumulated over days, months etc. to achieve the desired sample size. Blocks of effort will be grouped into 'watches' and these should be distributed evenly over the course of the sampling period to avoid bias e.g. by always sampling particular states of the tide or time of day.

12.1.2 Site selection

In order to successfully carry out VP monitoring for cetaceans the key factor is access to a suitably elevated platform; this is usually a cliff or hilltop. The higher the vantage point the further the observers can see but there is a limit to how far away small cetaceans can be sighted given the height of the vantage point. For example, Hastie (2000) found that an area extending to 5km offshore was the sighting limit for small cetaceans when the vantage point was on a cliff top of 90m above sea level. However, this methodology is only suitable for very nearshore/coastal developments. Also be aware that there may be blind spots, such as close in shore at the base of the cliff, that may need to be covered using other methods or viewed from addition VPs. The VP needs to be easily accessible to observers carrying heavy equipment and the land owner's permission must be obtained before initiating any work.

Exposure is an important factor to consider. A more sheltered site can be more comfortable for the observers, which will be beneficial in terms of their concentration and ability to maintain constant and effective searching. In some situations it may be useful to construct a shelter/hide but landowner or planning permission is also required.

Identification of a suitable control site would be beneficial for comparison with the tidal/wave site. Identifying genuine control sites is difficult but monitoring of an additional, comparable site(s) would at least supply contextual data for the development site.

12.1.3 Equipment and other resources

The basic equipment requirements are a set of binoculars. A mounted telescope or 'big-eye' binoculars should be used for scanning the distant areas of the survey area and lower power binoculars used for the inner area. The equipment used will be site dependent. At some sites, a theodolite can be used, but at others, such as those where the ground is boggy, this will not be possible. The equipment used also depends on the species of interest. .

Land based observations are usually undertaken with a telescope and/or 'Big-Eye' binoculars. This equipment increases detection distance and enables species identification at greater distances. In some cases it may be appropriate to use a theodolite which, when placed in a known geo-referenced position, can provide accurate positional information of sighted animals (see for example; bottlenose dolphin tracking in Bailey and Thompson, 2006; harbour porpoise tracking in Koschinski *et al*. 2003). Using a digital theodolite, linked to a laptop running custom software such as Pythagoras[18] or Cyclops[19], researchers can plot and track animals in real time. Another tool often used is a digital inclinometer which, when used in conjunction with compass binoculars to record locations of sightings, provides robust estimates of distance from the observer, essential for Distance analysis.

Data recording/entry should be done either in the field into an access database for example or recorded into paper forms or a dictaphone.

12.1.4 Personnel

Observers carrying out VP monitoring should be trained in marine mammal identification and have a biology/ecology background. For health and safety reasons, two observers should watch at more hazardous sites (e.g. cliff edges). At all times the observer should have good communication links to a base and should call in/out when on site.

12.1.5 Procedures

The marine mammal observer will collect sightings information during watch periods (for example 4 hour blocks). The number of watches per day is dependent on the length of each watch and the number of daylight hours with good light for surveying; more watches will be possible during summer days than winter. During watches the observer will undertake visual ‘scans’ of the entire survey area. A number of scans will be carried out during a watch. A typical scan might be 15 minutes long but it is area dependent. Scanning can be carried out using a combination of telescope and/or binoculars and the observer will scan from left to right, slowly and steadily.

To ensure even coverage of the survey area, it can be divided into near, mid and far sub areas. The appropriate search equipment should be set at a suitable declination angle depending on the region to be scanned. The first part of the scan should examine the furthest parts of the observational area with a telescope/ Big Eyes, then the mid-area and finally, using binoculars or the naked eye to examine the nearest shore area. For consistency, each scan should take approximately the same amount of time. It is important not to scan immediately to a known area of marine mammal activity. In order to closely examine animal behaviour in the near shore area it may be useful to observe this area using

[18] http://www.tamug.edu/mmrp/Software/pythagoras/Index.html,
[19] http://www.brahss.org.au/pages/research/vadar-cyclops-tracker.php ,

the telescope also. There should be a short rest period between scans to record data and reduce observer fatigue.

A sighting is defined as an observation of a marine mammal made during a scan. There may be occasions where marine mammals are seen before a scan commences and these should be recorded as ‘incidental’ sightings.

Calibration of positional data should be carried out to correct for any errors in angles measured to the sightings. Calibration of the locations can be carried out using a boat based differential GPS system; the boat should be manoeuvred around the study area and the locations calculated using the tripod angles and compared to the GPS locations.

12.1.6 Data recorded

Sightings will be recorded in the ‘far’ and ‘near’ scans of the area into a Dictaphone. Critical data are the species, number of animals, and the declination and horizontal angle to the sighting (and from which observation tool) so their position can be estimated. Behavioural data would also be of interest. Observer effort must be collected accurately and core fields are the site location, date, start and end time of watch periods, time of any effort changes, time of high and low tide and the names and number of observers. Environmental data can influence the sightings data collected so it is important to record and account for as many variables thought to affect the probability of detecting cetaceans as possible. As environmental conditions can change rapidly, this data should be noted at the start of each scan. Once weather conditions deteriorate above Beaufort Sea state 4, heavy rain, or thick fog the watch should be abandoned.

12.1.7 Data analysis

The data set comprise sightings, effort and environmental data. Vantage point survey data can be analysed to, primarily, provide information on distribution and ‘relative’ abundance of marine mammals in the study area. The data can also be analysed in conjunction with habitat variables (e.g. depth, tidal state) to look at relationships between these and animal distribution using a modelling approach (e.g. Generalised Linear Models (e.g. Mcculloch, 2000), Generalised Additive Models (e.g Hastie, 1990).

The ability of observers to sight cetaceans decreases with increasing distance from the VP. How detectability changes with distance from the VP can be tested by augmenting VP surveys with boat based surveys along transect lines placed perpendicular to the coast. The boat based data is then used to calibrate the VP observations and generate a 'correction' factor to correct the relative abundance estimates. For impact monitoring, this approach takes into account detectability, thereby allowing genuine changes in relative abundance to be detected rather than misinterpreting changes caused by other factors affecting detectability only. This is a more robust approach to impact assessment.

12.2 Autonomous Acoustic Monitoring (e.g. PODs)

12.2.1 Survey design

The number of PODs/other static devices will be based primarily on the size of the development area and the detection distance of the device (e.g. 200-300m porpoises and >500m for dolphins for the TPOD). There needs to be adequate coverage of the site and placement should take into account the key questions to be answered. It would be desirable to spread PODs throughout the survey area. If they are being deployed for impact monitoring in a gradient design, then spacing between consecutive PODs would increase with increasing distance from the site. For habitat studies, PODs should be located in different habitat types which may differ in seabed topography, distance from coast, or sediment type. PODs can be deployed for a period of months and many can be deployed to cover larger areas. The location of the devices should remain the same throughout the monitoring period.

12.2.2 Site selection

When selecting a site for deployment of CPODs the following issues must be considered:

- Navigational hazards,
- Fisheries conflicts,
- Licensing issues,
- Water depth and mooring capabilities,
- Substrate type.

Local knowledge will be invaluable in determining adequate mooring and deployment positions of PODs. In gravelly (noisy) substrates it may be required to place the PODs nearer the surface to reduce ambient noise interference.

12.2.3 Equipment and other resources

- PODs
- Software freely available on www.chelonia.co.uk
- Batteries

- Boat with winch for deployment
- Moorings – ropes, chains, weights, surface buoys/lights

The installation of static autonomous acoustic devices in Scottish waters will require a licence. The licence requirements depend on the deployment locations. Ultimately, consent is required from Marine Scotland. If they are to be placed within the jurisdiction of a harbour authority, permission needs to be sought from them. In other areas an application for a CPA (Coast Protection Act) licence from Marine Scotland (within 12nm only) will be required, as the devices may be deemed hazards to navigation. If the surface marker for the device has a light on it (e.g. this may be a condition enforced by the harbour authority), then the Northern Lighthouse Board also need to be informed. The area of seabed for attachment of the devices must be leased from the Crown Estate and a Notice to Mariners issued in collaboration with the UK Hydrographic Office.

12.2.4 Personnel

Little training is required to deploy and retrieve a POD. The devices must be handled carefully to prevent damage. Downloading and interpreting the data, however, requires some knowledge and previous experience would be essential.

12.2.5 Procedures

Full details on POD software and deployment issues are available on www.chelonia.co.uk. In areas with high vessel activity or high densities of dolphins and porpoises the PODs may need to be serviced more regularly due to the memory filling up. PODs should be tested before deployment to ensure they are all operating correctly and all of the same sensitivity. The devices should be both “bench” and “wet” tested prior to deployment.

12.2.6 Data recorded

Key data to record are the date and time of deployment and retrieval of devices. Additionally, the positions of PODs/devices needs to be recorded. The PODs record, process and store the target acoustic data (i.e. animal clicks and vocalisations). It is good practice that the PODs, and therefore data, be retrieved periodically (e.g. 3 months). Regular retrieval of PODs insures against the potential for loss of data in the event of POD loss/failure.

12.2.7 Data analysis

The most basic metric derived from PODs is the presence of harbour porpoise and delphinids over time. The data are also used to generate an ‘index of abundance’ expressed as Detection Positive minutes/hours/days, which is dependent on animal density in the study area. These metrics can be related to habitat variables, such as diurnal and tidal states. As yet, POD metrics do not equate to animal abundance. There are major issues still be resolved including how to account for the probability of detecting cues, the rate at which animals produce cues and the proportion of false positive detections (Marques *et al*. 2009).

In some coastal areas it may be possible to validate POD data by carrying out simultaneous vantage point watches/ boat-based surveys. This is particularly useful in areas of high species diversity as PODs can only distinguish between phocoenid and delphinid detections. To date, delphinid species cannot be distinguished (i.e. it is difficult to distinguish bottlenose dolphin clicks from those of common dolphins).

As POD software is constantly undergoing development it is important to always note which software version is being used to analyse data.

12.3 Visual Boat-based surveys

12.3.1 Survey design

Achieving unbiased density estimates using distance sampling methods relies on a survey design that gives even coverage probability[20] throughout the survey area. A continuous zig-zag sampler (line transect) is generally used for boat-based surveys; such a design limits the amount of time lost surveying due to transiting between parallel line transects. However, the type of sampler will also depend on the size and shape of the area; parallel lines may be more suitable for small areas. In general the transects should run perpendicular to the coastline so that monitoring is conducted out over the environmental gradient (e.g. changes in depth) rather than along it. The freely available software DISTANCE 6 (Thomas *et al*. 2009) can be used to fit different designs using different samplers and amounts of effort. Strindberg *et al* (2004) give an overview of survey design for distance sampling.

The available resources often limit the amount of survey effort that can be planned; for example, the length of time the boat is available, which is often dependent on available funding. Given a certain number of days for surveying and knowing the vessel's cruising speed, an achievable amount of survey effort (length of transect) can be calculated allowing for survey downtime due to bad weather. Survey design needs to be based on existing data within the area of interest from which the expected number of sightings per unit of survey effort (generally length of transect searched) can be calculated. This encounter rate is then

[20] The coverage (or inclusion) probability at an arbitrary location within the survey region is the probability of it falling within the sampled portion of the survey region (Thomas et al. 2009)

used to determine what the required length of transect would be to achieve a target sample size. Buckland *et al*. (2001) recommend that at least 60-80 sightings are required for distance sampling analysis. This amount of effort can be accrued over months or years. The same set of transects should be surveyed each time.

The number of sightings also greatly affects how precise the final estimates of density and abundance will be. Therefore, when planning impact monitoring in particular, it is crucial that estimates are precise; precise estimates have greater power to detect a given magnitude of change over a defined period when compared to less-precise estimates. So, the amount of effort may be calculated given a target CV and known encounter rate (from previous surveys) (refer to 7.4).

12.3.2 Boat Specification

The boat will have an observation platform, ideally at least 5m above sea level, with an unobstructed forward 180 degree view. The platform must be able to accommodate three cetacean observers at any one time. A cruising speed of 10 knots is optimal for cetacean surveys. The platform needs to be stable; avoid vessels with shallow drafts or flat bottoms. Angle boards (see below) will need to be fixed to the observation platform; this can generally be done on the guard rail. They must be horizontal and the zero lined up such that it is parallel to the bow.

12.3.3 Equipment and other resources

Observers will need waterproof binoculars (7x50s are commonly used) that are fitted with an eyepiece reticle for measuring sighting distances; the reticle measurements can be converted to true radial distance after the survey. The observation platform height and observer height above the water is needed in order to make these conversions. An angleboard (a simple compass rose with rotating pointer) will also be needed to record sighting angle; there is an example to download at http://jncc.defra.gov.uk/images/Angleboard_2011.jpg, however, the board should ideally be marked in 1° increments for accurate angle measurement. Data may be recorded real time in a laptop computer running data collection software, such as Logger (IFAW, 1995) or on pre-printed paper recording forms; these should also be taken as a back-up if a computer is being used in case of laptop failure. Separate forms for sighting data and effort and environmental data will be needed. Dictaphones can be used but should not be relied on; on windy days, the recording quality may be poor. A hand-held GPS for recording the location of sightings will also be needed.

12.3.4 Personnel

Good observation skills cannot be learnt on a training course; they can only be acquired through the accumulation of experience at sea conducting survey work. Less experienced observers should always be teamed with at least one experienced observer. At least 3 observers should be used and operate on rotation. If there is a fourth, then this allows regular rest intervals. However, this may not be necessary on short surveys. Training of experienced observers prior to the survey should be given to ensure that the specific survey protocol and use of equipment is fully understood.

12.3.5 Survey procedures

Observers will operate in rotation through 3 positions on the observation platform: starboard, port and data recorder (DR). Observers should normally search with naked eyes from the ship to the horizon. Searching constantly through binoculars limits the field of view of the observers and limits potential for sightings, especially for smaller species such as harbour porpoise.

Each observer searches from 90 ^{o} abeam of the vessel to 10 ^{o} over the transect line (i.e. on the other observer's side). This ensures good coverage of the transect line where all animals that are present are assumed to be detected. At the start of the survey, the DR should complete the effort and environmental data and continue to update this regularly (e.g. every 30 minutes) throughout the survey and whenever survey effort or sighting conditions change.

When a sighting is made, radial distance and angle must be measured immediately; the theory assumes these measurements are of animals at the location when first sighted. The information is relayed to the DR who also notes the time and/or GPS position of the sighting. Species, group size and additional information can then be relayed to the data recorder. After all the information has been recorded, the observers should resume normal searching behaviour. At the end of the survey, the DR should take a final location and complete the effort and environmental data.

12.3.6 Data recorded

There are 3 main data types: effort, environmental and sightings. The effort data is usually measured as "distance spent searching". Effort, primarily GPS location or GMT time, should be recorded at the start and end of each survey period. It should also be recorded periodically (e.g. every 30 minutes) and when sighting conditions change throughout the survey period. Sighting conditions are grouped under the environmental data and should include seastate, swell, glare and visibility. These should be recorded periodically and when conditions change. The key sightings data include the time/GPS location of the sighting, species, sightings angle and distance, and group size. If time allows, ancillary data on behaviour, for example, can also be recorded.

12.3.7 Data analysis

If data have been collected on paper forms, this needs to be entered into electronic spreadsheets. If data have been collected in real time electronically, this needs to be validated – checked for missing values, mistakes etc. Validated data should be reformatted for analysis.

Sightings can be mapped in a Geographical Information System to show the distribution of sightings; however, interpretation of these sightings needs to be done in conjunction with the effort data.

The Distance software (Thomas *et al.* 2009) is commonly used for analysis of distance sampling data to generate density and abundance data. However, a specialist with thorough understanding of distance sampling should undertake the analysis. Data collected from a well-designed survey will generate density and abundance estimates; they will be biased low unless methods have been used to estimate the detection function on the survey transect line.

Model based methods (such as Hedley *et al.* 2004) may be particularly useful for analysing both characterisation and impact surveys. This approach generates continuous density surfaces by fitting a Generalised Additive Model (GAM) to the counts of animals on legs of survey effort against a set of predictor variables. The predictors are environmental variables, such as water depth and seabed sediment. The advantage of this approach for impact analyses is that predictors that represent the development activity can be included. The model will then indicate which variables have a statistically significant effect on animal density. The approach requires environmental datasets with adequate temporal and spatial resolution for analyses. This approach has the potential to highlight where changes in animal density are due to environmental shifts, features of the development or a combination.

12.4 Visual Aerial survey protocol

12.4.1 Survey design

Unlike shipboard surveys, aerial line transect surveys are often based on a series of parallel lines throughout the survey area. Compared to ships, aircraft can cover large areas in a relatively short time period. They are well suited to surveying coastal waters but coastlines with steep cliffs and inlets would require a very experienced pilot. The principles for survey design are the same as those for boat-based surveys; they both rely on line transect methods. The freely available software DISTANCE 6 (Thomas *et al*. 2009) can be used to fit different designs using different samplers and amounts of effort.

12.4.2 Aircraft specification

Typical aircraft suitable for aerial surveys should be high-winged, twin engine and have bubble windows. The latter feature enables observers to have a good view of the transect line beneath them, which enables them to maximise detections on the transect line. For cetacean surveys, the plane will fly at a constant height (600 feet = 183m) and speed. The flying altitude for cetacean surveys is generally higher than the recommended altitude for most seabird surveys (i.e. 80m, Camphuysen *et al*. 2004).

12.4.3 Equipment and other resources

For distance sampling surveys from aircraft, an inclinometer is used to measure the angle of declination to the sighting when it is abeam; this can be converted to perpendicular distance from the transect line given the flying altitude of the aircraft at the time of the sighting. Data are entered real-time into a laptop which is linked to a GPS for continual recording of effort. There is also a "sightings button" that the DR will press when a sighting is made and the GPS position will be instantaneously recorded. Paper forms can also be used as a back-up and an external hard drive should be available for daily electronic data backup. Communications between the observers, data recorder and pilot is through intercom. An experienced pilot is crucial, as are experienced cetacean observers.

12.4.4 Personnel

Experienced observers and pilots only should be used for aerial surveys. Generally, there will need to be space for two observers and a data recorder, in addition to the pilot.

12.4.5 Procedures

In general, surveys are carried out in seastate 3 or less (especially important for areas where harbour porpoise are the main species) and good visibility (not <1km) (SCANS-II, 2008). A total of 2 observers should be used for the survey. One will sit at each of the port and starboard bubble windows. A data recorder will also be onboard, generally seated next to the pilot and therefore unable to see the observers. Communication between the observers and the pilot is through intercom. Data entry is generally carried out real-time in a data logging software run on a laptop computer. Effort and environmental data are recorded at the start of the survey, at regular intervals, when sighting conditions change and at the end of the survey.

When a sighting is made, the observer will immediately inform the data recorder ("sighting left/right") and the logging software can record the sighting time and location. The key information to record is species, group size and angle of declination using the inclinometer when the sighting is abeam. The observers' commentary to the data recorder should be kept brief so as to clear the intercom should another sighting be made or for the pilot's use.

12.4.6 Data recorded

The 3 types of data recorded are sightings, effort and environmental. For aircraft surveys, turbidity and glare are also important environmental variables to record as they affect the ability of observers to sight cetaceans. The main sightings data are species, group size and angle of declination; without these data and an accurate record of survey effort they cannot be analysed to generate density estimates.

12.4.7 Data analysis

If data have been collected on paper forms, this needs to be entered into electronic spreadsheets. If data have been collected in real time electronically, this needs to be validated – checked for missing values, mistakes etc. Validated data should be reformatted for analysis. The Distance software (Thomas *et al.* 2009) is commonly used for analysis of distance sampling data to generate density and abundance estimates. However, a specialist with thorough understanding of distance sampling should undertake the analysis. Both design based and model-based methods are appropriate (see previous section).

Sightings can be mapped in a Geographical Information System to show the distribution of sightings; however, interpretation of these sightings needs to be done in conjunction with the effort data.

12.5 Towed Hydrophone Array Protocol

12.5.1 Survey design

Passive acoustic monitoring is often carried out concurrently with boat based visual line transect surveys and so survey design will not be covered again here – this protocol pertains only to the deployment and utilisation of Passive Acoustic Monitoring (PAM) equipment.

12.5.2 Site selection

As previously noted, this type of data collection is usually carried out in conjunction with visual surveys, and so the site is likely to be selected on the basis of wider criteria than required for PAM. The water depth is an important consideration for towed array surveys as there is generally a minimum in which they can be used without risking the hydrophone hitting the seabed. The depth at which the end of the hydrophone array will sit in the water column depends on both the length of the tow cable and the speed of the towing vessel. For example, a 400m array can tow at more than 20m depth on a survey boat doing 8 knots, so care must be taken in shallow areas.

It is also worth noting that the cable extends for some distance behind the towing vessel, and so consideration must be given to navigational hazards to avoid entangling the array.

12.5.3 Equipment and other resources

There are many different hydrophone arrays available. When selecting, care must be taken to choose hydrophone elements which are sensitive to the frequencies utilised by the marine mammal species of interest. Commonly, 2 hydrophone elements are used on one towing cable, but arrays with more elements are available. Arrays may also contain depth sensors, accelerometers, and GPS receivers depending on the specification. A depth sensor may be desirable in shallower coastal areas to monitor the towing depth of the array.

An amplifier box powers the hydrophone and may also contain some sound cards. Usually, data acquisition devices (DAQ) are incorporated into the amplifier box and are required to sample the data. The best sound card choice depends on the desired sampling rate (sampling rate must be at least twice the highest frequency of interest). The soundcards incorporated in a laptop will not be adequate for successful PAM.

A computer is needed with enough ports for connection to the selected DAQ devices, and external data storage devices. It can be either a high end laptop or a PC depending on the available space on board the survey vessel. The computer will run the PAM software. Pamguard (Gillespie *et al*., 2008; Gillespie *et al*., 2009) is widely used and is freely available for download from www.pamguard.org. This software provides the ability to acoustically detect, localize and classify a variety of cetacean vocalisations. It is user configurable to allow for array design and desired survey parameters. A GPS feed is required for Pamguard. This can be either via a USB GPS device, a handheld, or the NMEA feed from the survey vessel. All data are referenced to a Microsoft Access database. Microsoft Office is also therefore required.

A power source will be required to run the hydrophone array, amplifier box and computer. Depending on the selected hydrophone array and amplifier box this may be mains power or batteries.

Depending on the length of survey, the sampling rate, and whether the creation of real-time recordings is required, some external data storage may be necessary. This commonly takes the form of USB hard drives.

12.5.4 Personnel

An experienced operator is required to set up PAM equipment, troubleshoot and to carry out analysis. If set up and working correctly, day to day operation is straightforward. A Pamguard training course is available (http://www.pamguard.org/training.shtml) but no certification is required.

12.5.5 Procedures

Before commencing the survey, Pamguard software should be configured appropriately for the desired species and the current array selection. Online help files and tutorials are available from www.pamguard.org.

Hydrophones can be towed either directly behind the vessel, or out from a davit from the side, depending on the vessel. The method of tethering the hydrophone will vary depending on vessel, but consideration must be given to manoeuvrability of the vessel and health and safety requirements during deployment and retrieval. The deck cable will be run from the "wet" hydrophone cable to the "dry" electronics equipment which is ideally located inside, or is at least stored in a water proof box. Once deployed, the hydrophone can be towed for the remainder of the survey providing water depth is adequate. In order to reduce interference from vessel noise the hydrophones are usually towed some distance behind the vessel (e.g. 200 or 400m).

12.5.6 Data recorded

Two types of data are available as a result of PAM surveys depending on the analysis requirements and data storage constraints.

Recordings: recordings can be made from the hydrophones of all noise detected. This can be done for the duration of the survey, or a sampling cycle can be set up to record at pre-determined intervals. Depending on the number of channels being used, the sampling rate and the duration of the survey, this can quickly become a large amount of data and may require the use of external storage devices (Box 12.1). The collection of continuous acoustic data provides the opportunity for more extensive offline data analysis.

Detection files: Pamguard also utilises automated detection algorithms which can detect specified cetacean vocalisations. These are saved as files and can also be used for analysis. This has a lower storage space requirement, but is reliant on the detector working correctly as the actual hydrophone signals are not recorded anywhere.

Box 12.1 Calculating the data storage requirement for different sampling regimes.

Data volume =
(Number of channels) * (bytes per sample)* (samples per second) * (hours per day) * (days on survey)

12.5.7 Data analysis

Automatic detection algorithms incorporated into the software allow straightforward preliminary identification of cetacean vocalisations. These can be assessed manually (by visualising the waveforms, frequencies etc) to verify species. Currently, species that 'click' can be readily identified (harbour porpoise, sperm whales and beaked whales). The software is being upgraded to incorporate whistle detection algorithms for determining dolphin species. All acoustic detections can be converted to an 'encounter rate' (detections/km) providing effort data has been recorded. Click data (from harbour porpoises) collected from a well-designed line transect survey can also be analysed in Distance to generate density and abundance estimates. However, this requires an additional, time consuming processing stage to get bearing and range information to individual click trains (Target Motion Analysis).

12.6 Photo-ID

12.6.1 Survey design

Conventional, mark-recapture studies are carried out over a defined area covering a standardised route. This ensures that any bias in individual detection probabilities is minimised. However as analysis techniques have developed, it is also possible to carry out opportunistic surveys where no predefined route is used. Either of these approaches is valid and will generally be determined by resources such as time and money. For example opportunistic survey effort to maximise captures in core habitat to characterise a site may be preferable to the same effort covering a larger proportion of the population range to assess connectivity or displacement linked to impact assessment. If the aim is to maximise captures for individuals the opportunistic method may be more appropriate. However if the required outcome is coverage of the area, the systematic approach may be better.

12.6.2 Site selection

Photo-Identification studies should be carried out in targeted areas where encounter rates of individuals are likely to be high. Because a small boat is often used, they are ideal for coastal locations where targeted effort will provide robust data on seasonal and inter-annual patterns of occurrence. If conducting photo-identification studies further offshore, an appropriate support boat may be needed.

12.6.3 Equipment and resources

An appropriate small manoeuvrable boat, with the necessary MCA coding and safety equipment should be used. This boat should have a secure platform or area for the photographer to stand. This platform should provide an unobstructed view from the front of the vessel. The boat needs to be set up to allow easy communication between the photographer and the rest of the crew.

The boat should be equipped with a GPS and a hand held GPS should be taken as a back up. Any local charts and information should be on board. In some areas permissions for transit may be needed and should be checked prior to departure.

An appropriate digital SLR camera with a fixed or zoom lens (e.g. 200mm or 70-200mm) should be used. The camera should contain a good sized memory card (2-4GB) plus a spare card and spare battery. The camera should be housed in a shock proof case and be secured when in use and during transit. Multiple copies of datasheets should also be taken along with guidance sheets on how to fill them out. Binoculars may also be useful although should not be used to search with during transit.

12.6.4 Personnel

A skilled and experienced person should be responsible for taking the photo-identification images. If possible this person should have prior knowledge of the population and area to maximise the data collection. A skilled boat driver with experience of manoeuvring safely and responsibly around the target species and knowledge of the photo-identification techniques should be used. This person should have the necessary skipper qualifications to ensure safe running of the vessel. A further one or two personnel can be used as spotters or note takers to help with initial spotting of groups and keeping track of animals during encounters.

If work is carried out on an SAC population at least one person undertaking the survey will need to be named on an Animal Scientific Licence granted by SNH, and an EPS licence may also be required.

12.6.5 Procedures

All surveys should be carried out in Beaufort Sea State 3 or less (to maximise the chance of spotting and being able to follow animals) and good light (to maximise picture quality). Spotters should be positioned around the boat to ensure individuals are scanning different areas. Ideally spotters should cover from 90˚ abeam of the vessel to the bow. The photographer should not be at the photography platform during searching. Spotters should search with the naked eye while transiting through the area at about 20 knots. When animals are sighted, the boats should slow down in enough time to ensure the animals are approached in a way that minimises disturbance. The boat should never pass through a group and should always exercise care when around animals. If animals appear disturbed by the boat, and the boat is unable to get close to the animals, the approach should be aborted. Once the boat is close enough to the group, ensure all necessary information is noted down and the photographer should take their position and begin taking photos.

Photograph the dorsal fin (most cetaceans) making sure that the whole of the relevant part of the animal is in the picture, the fin is parallel to the camera, and the height of the fin image is >10% of the field of view (see Thompson *et al*. 2006). Only high quality images will be useful for most analyses. If possible try to photograph both the left and right hand sides of the animal and try to photograph every individual in the group (e.g. don't just focus on those which approach the boat, or have the most obvious markings). At the end of the encounter record the necessary data and either slowly move away from the animals or let the animals move away from you. Ensure you take a spacer photograph of e.g. the engine or a person, so that individual encounters can be easily distinguished during analysis.

12.6.6 Data recorded

During each survey the survey route should be recorded automatically from the boat's GPS. In addition, a record of the personnel involved, the weather conditions, including sea state and sighting conditions and the camera equipment used should be recorded. During the trip a 30 minute record of weather conditions should be routinely recorded. On encounter with groups, start times and GPS locations should be accurately noted. An estimate of the group size and composition (i.e. presence of calves) should also be made. During the encounter any information on behavioural states, changes in group sizes or notable individuals should be recorded. Any changes in weather conditions should also be noted down as they happen.

Photographs of all members of the group should be taken. Once the encounter has finished an accurate end time and GPS locations should be recorded, along with an estimation of whether the photographer feels that photos of every group member were obtained.

12.6.7 Data analysis

All photographs must be graded for quality and only high quality photos should be used in any analysis. These high quality photos should then be matched, where possible, to an existing catalogue for the population of interest. Photo-identification data on individual animals can be used for mark-recapture analysis to estimate abundance. This analysis is carried out using both the capture histories of marked individuals, i.e. information on whether an animal was sighted or not during a particular period, and information on the proportion of unmarked individuals. This period is generally temporal (days, months or years), but the resolution of capture histories will depend on the longevity of the data set. Ideally, multiple recaptures of tens of individuals over months or years will provide more information. Mark-recapture analysis methods are well established and photographic identification using natural markings of cetaceans is used worldwide. However, considerable difficulties in the application of mark-recapture techniques to estimate cetacean abundance still exist and must be considered during the analysis of photo-identification data. There are a wide variety of mark-recapture models available, all of which have different underlying assumptions. To provide the most robust analysis, it is necessary to match the collected data to the most appropriate model through consideration of these assumptions. This is particularly important when surveys designs are more opportunistic, because a non standard approach may result in certain individuals being more likely to be captured (photographed) in some locations and times than others. This introduces differences in capture probability between individuals and violates the standard assumptions of conventional mark-recapture models. Although most mark-recapture software is freely available, it is recommended that a specialist with a thorough understanding of mark-recapture techniques undertake the analysis.

Geographic information on dolphin encounters can be mapped in a Geographic Information System to show the distribution of dolphin encounters. Information on group sizes, composition and behaviour can also be assessed to provide further population information.

12.7 Stranding and carcass recovery

12.7.1 Survey Design

When using strandings data in impact monitoring studies, it is important to initiate the strandings scheme early in the project to make sure that there is baseline data to compare to. Coastal areas should be systematically searched with a team of observers. The search period should be defined at each site and the same amount of effort carried out at each survey replication. The frequency of searches could take into account the local hydrographic conditions and consider the probability of stranding events. Previous stranding data for the area might also inform this. The perceived risk in terms of the number of renewable devices in the area will also influence the sampling frequency. Sites with many devices may be expected to have greater potential to cause injury/mortalities and hence stranding than an area with a single device. The search area needs to include the area between the high water tide line and low water tideline. Surveys should be carried out on a falling tide or at low water.

12.7.2 Site selection

Areas of search must be defined given information on local current flow patterns and the likelihood of recovering carcasses. Local knowledge and strandings records for the region may be useful in identifying likely areas where stranded animals may be found. Resources should be focussed in areas where perceived risk (of collision and consequent stranding events) is greatest.

12.7.3 Equipment and resources

Logistical support and equipment for moving live animals and collecting carcasses is crucial. Pre-designed data sheets and clipboard will be used for recording data. There may be systems in place locally to retrieve carcasses/specimens or to co-ordinate rescue attempts and these should be adhered to. The observers should have a mobile phone to contact the coordinator to make arrangements for carcass collection if needed. A digital camera to document the carcass is also useful and a tape measure for taking body measurements.

12.7.4 Personnel

The recovery of all or any part of an EPS must only be undertaken under licence. Whilst SNH and the SAC have a licence that allows others to assist in the retrieval of samples, this can only be undertaken through instruction by SNH or the SAC.

The stranding scheme should have a Coordinator to plan the survey schedule, oversee the data collection and to make the arrangements for carcass recovery and necropsy. This should be in line with any local arrangements already in place. In Scotland, Bob Reid of the

Scottish Agricultural College generally carries out necropsies of stranded marine mammals.[21]

A network of observers is required to carry out the standardized, regular coastline searches for stranded animals. The level of effort on these surveys must be consistent throughout the impact monitoring study. When a carcass is found, its position should be determined as accurately as possible, ideally by noting the precise map reference or by using a handheld GPS. If appropriate, the body should be secured or moved to higher ground to prevent it being washed away for inspection later by the nominated vet.

As many carcasses as possible within the area/s of interest should be necropsied. The cause of death can then be ascertained. If carcasses cannot be retrieved, then as much biological information on the condition of the animal should be recorded. Samples may also be taken e.g. blubber for ancillary analyses.

An animal found alive should be reported to the SSPCA (Scottish Society for the Prevention of Cruelty to Animals) with a view to keeping the animal alive and returning it to the sea.

It should be remembered that diseases can be transmitted from the dead bodies of mammals to humans, so care should be taken and no contact made with the animal until the appropriate protective clothing, such as thick rubber gloves, is available. This, along with the other risks associated with working with large live or dead mammals (heavy lifting, working near water etc) should be assessed prior to any work starting.

12.7.5 Data recorded

The time and location at the start and end of the survey period should be recorded, together with the names and number of observers. The carcass location, species (if possible), number of carcasses and body condition should be described as far as possible. Body length, useful for determining the age of the specimen, should also be measured.

12.7.6 Data Analysis

In the context of impact monitoring, the key information to discern is the cause of death.

[21] http://www.sac.ac.uk/consulting/services/s-z/veterinary/scottishmarinestranding/about/

12.8 Video-range tracking for basking sharks

12.8.1 Survey design

Video-range tracking can be carried out from any boat with a suitable platform, and so can be used in wave sites that are some distance offshore. However, the presence of a boat may influence the behaviour of the study animals. The technique has been successfully used for tracking basking sharks, which are shown to be relatively undisturbed by the presence of slow moving vessels (Speedie *et al*., 2009). Alternatively, the method can be used from a suitable vantage point.

12.8.2 Site selection

Areas around the UK for focused studies of basking sharks are problematic to identify. However, concentrations of basking sharks do occur in Scottish waters at certain times of the year, especially off the west coast of Scotland. Where known 'hot spots' coincide with areas identified for development, then targeted basking shark studies should be undertaken.

12.8.3 Equipment and other resources

Binoculars will be required for scanning for animals from the observation platform. A 7x50 magnification pair is suitable.

The video-range technique requires a digital video camera and a pair of binoculars fitted with a magnetic compass. These should be mounted together in a frame, and aligned so that the operator can look through the binoculars and read the compass, whilst the camera is capturing footage of the same view. If boat based, the technique relies on calculating the position of the focal animal relative to the position of the survey vessel, and consequently requires a detailed record of the position and heading of the survey vessel at each point a fix is made to the animal/group. This can be achieved in a number of ways, including the use of the software program "*Logger*" – a free data logging program developed for cetacean research, which can be downloaded from http://www.ifaw.org/sotw. This program can receive NMEA format position data from a number of sources including ships navigation instruments, a hand held GPS unit, or a USB GPS receiver. The software can then record the position of the ship at given intervals. For tracking, an interval of around 4 seconds or less is recommended. This software program can also be used to log a number of other data sets, including weather, observer status, and sightings of animals.

In addition, a computer is required for analysis, and sufficient storage capacity for multiple hours of video recording should be available.

12.8.4 Personnel

See Vantage Point protocol. For the photo-grammetric method, two experienced observers are required. Analysis is straightforward but may require a short period of training before commencement.

12.8.5 Procedures

It is recommended that a test set-up be carried out before the commencement of fieldwork to ensure that all operators are familiar with the equipment. Calibration may also be necessary. If conducting the technique from a vantage point then cliff height and reference points should be known and selected prior to commencement.

Dedicated searches for basking sharks should be carried out by two trained observers. It is recommended that the "Logger" software is started as soon as searching begins. Once a shark is sighted, the tracking process can begin. The operator should view the focal animal through the binoculars mounted on the frame with the video camera. The camera should already be aligned so that the view captured by the video camera is the same as that viewed by the observer when looking through the binoculars. Ensure the video camera is turned on.

The operator should ensure that the focal animal stays as central to the field of view as possible whilst keeping the horizon is visible within the frame at all times.

Bearings to the shark should be recorded whenever the shark changes direction, or every minute if the direction is constant. This can be done by reading them aloud from the binocular compass – which will be picked up by the video recorder. A commentary of what the focal animal is doing is also useful to have during analysis.

Other factors to record onto the audio commentary include: behaviour, which parts of the shark are visible above the water, how many sharks are in the area, changes to environmental conditions, sun glare.

Tracking can continue as long as possible, but should stop if there are too many sharks in the area to keep track of the focal shark successfully.

The purpose of this tracking is to get high resolution behavioural data, and so a large number of fixes is desirable. Basking sharks can spend many hours at the surface, and so are an excellent candidate species for this technique. Fixes should be made every minute, or whenever a marked change of direction is noted. Individual tracking will be more appropriate as basking sharks do not exhibit cohesive group behaviour. In aggregations of large numbers, care must be taken to ensure the fix is taken of the same animal each time.

Distances to focal animals using the video-range method are calculated from photographic images by measuring the angle of dip from the horizon to the object from images taken from a known height with a calibrated lens. Consequently, lens calibration is fundamental to the technique and should be carried out first of all. A few seconds of footage of a circle of known diameter will suffice. The focal lens should then remain unchanged for the duration of the track. Calibration shots should ideally be taken at the beginning and end of a tracking session to account for accidental changes to focal length. Any deliberate alterations to focal length should be accompanied by calibration footage. A brief trial period may be required to establish the optimum focal length before tracking commences in earnest. Observer eye height must be recorded for use in calibration.

Each track will present the behavioural data for one individual on one day, and so replicates over different tidal states, and times of day will be desirable. For tracks in the presence of renewable devices, a variety of tracks during operation and not during operation should also be investigated.

12.8.6 Data analysis

Lens calibration involves measuring the number of pixels on the video image that correspond to a known angle subtended at the lens. These methods have been subjected to extensive calibration tests to assess their accuracy (Gordon, 2001; Leaper & Gordon, 2001).

Once the footage has been downloaded, it should be assessed. Measurements of shark position can be made from any frame containing the shark, the horizon and the bearing recorded onto the audio. The distance to the shark from the vessel can be measured by counting pixels following calibration.

The track can be constructed using the “logger” software by plotting the positions of the shark relative to the vessel’s trackline. Total distance travelled can be calculated as the sum of distances between observed locations, and swim speed can be established as well as providing a measure of behaviour in a given area.

12.8.7 Length analysis:

In addition to measuring locations, measurements from images can also be used to estimate body length. This has been applied to whale species (Gordon, 1990) and can also be adapted for use with basking sharks. The technique relies on measuring the distance to easily identifiable parts of the animals’ body and using angles measured from these to convert to lengths. This can be done for all images of sharks taken in which the shark is parallel to the tracking operator and the horizon, and two body parts (either tip of snout, dorsal fin or caudal fin) are visible above the surface (Figure 12.1).

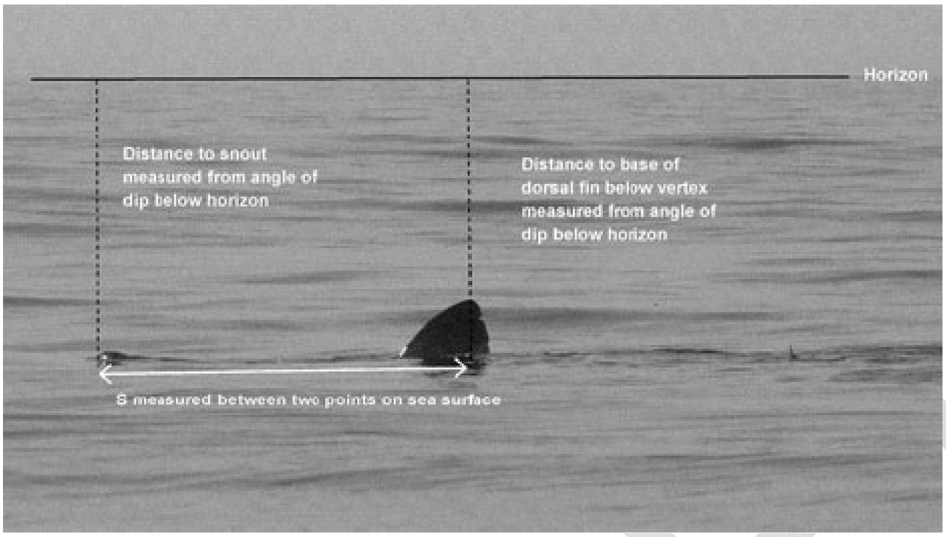

Figure 12.1: Example of measurement of snout to dorsal length. In this case, the tail fin appears to be at a different angle to the rest of the body and so would not be included for length measurement. Taken from Lacey *et al*., 2010.

Total body length can then be made following comparisons with Matthews and Parker (1950) which gives detailed measurements of basking shark morphometrics from carcasses from Scotland.

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Wilson, B. Batty, R. S., Daunt, F. and Carter, C. 2007. Collisionrisks between marine renewable energy devices and mammals, fish and diving birds.Report to the Scottish Executive. Scottish Association for Marine Science, Oban,Scotland, PA37 1QA

Wilson, B., Hammond, P. and Thompson, P.M. 2008. Estimating size and assessing trends in coastal bottlenose dolphin population. Ecological Applications 9 (1): 288-300

Winship, A., Berggren, P. and Hammond, P. 2008. Management framework to assess the impact of bycatch and recommend safe bycatch limits for harbour porpoise and other small cetaceans. Appendix D1.1 to Small Cetaceans in the European Atlantic and North Sea (SCANS-II). Final report to the European Commission LIFE Nature programme on project LIFE04NAT/GB/000245.

13.1 Websites

13.1.1 Legislation

Marine Renewables SEA http://www.seaenergyscotland.co.uk/

In particular the sections dealing with marine mammals:

http://www.seaenergyscotland.net/public_docs/ER_C9_MarineMammals_final.pdf

and noise: http://www.seaenergyscotland.net/public_docs/ER_C17_Noise_final.pdf

The Dept of Energy and Climate Change offshore SEAs http://www.offshore-sea.org.uk/site/

SEA documents available from http://www.offshore-sea.org.uk/site/scripts/sea_archive.php

Marine Spatial Plans and Regional Local Guidance where available may have information on cetacean populations in specific areas e.g. http://www.scotland.gov.uk/Resource/Doc/295194/0096885.pdf

http://www.opsi.gov.uk/legislation/scotland/acts2004/asp_20040006_en_9

13.1.2 Species Information

Draft list of Priority Marine Features for Scottish territorial waters, available http://www.snh.gov.uk/docs/B639755.pdf

http://www.snh.org.uk/pdfs/publications/naturallyscottish/whales.pdf

Reid *et al*. (2003) Atlas of Cetacean distribution in north-west European waters.

http://jncc.defra.gov.uk/page-2713#download

SCANS-II Final Report. http://biology.st-andrews.ac.uk/scans2/inner-contact.html

Joint Cetacean Protocol http://jncc.defra.gov.uk/page-5657

North Atlantic Killer whales: www.northatlantickillerwhales.com

Minke whales http://www.crru.org.uk/minke.asp

Bottlenose dolphins in Scottish waters:http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=1727

Basking sharks
http://www.snh.org.uk/pdfs/publications/commissioned_reports/339.pdf

Basking Shark factsheet:
http://www.baskingsharks.org/content.asp?did=26603&rootid=6224

13.1.3 Acoustic Devices

Chelonia (PODs) http://www.chelonia.co.uk/.

EARs http://www.pifsc.noaa.gov/cred/eartech.php

POP-Ups http://www.birds.cornell.edu/brp/hardware/pop-ups

13.1.4 Software

http://www.ruwpa.st-and.ac.uk/distance

http://www.tamug.edu/mmrp/Software/pythagoras/Index.html,

www.pamguard.org

http://www.ifaw.org/sotw