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Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland
Volume 3: Seals

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 2. Cetaceans and Basking Sharks
- 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 3), the appropriate citation is: **Sparling, C., Grellier, K., Philpott, E., Macleod, K., and Wilson, J. (2011).** ***Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 3. Seals*****. Unpublished draft report to Scottish Natural Heritage and Marine Scotland.**

Queries regarding this guidance should be addressed to:
marinerenewables@snh.gov.uk

CONSULTATION DRAFT

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

Vol 3. Seals.

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Selected Acronyms

AA	Appropriate Assessment
ANOVA	Analysis of Variance
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
ER	Encounter Rate
GAM	Generalized Additive Model
GPS	Global Positioning System
IM	Impact Monitoring
MPA	Marine Protected Areas
NERC	Natural Environment Research Council
PBR	Potential Biological Removal
PRIMER	Plymouth Routines In Multivariate Ecological Research
SAC	Special Area of Conservation
SCOS	Special Committee on Seals
SEA	Strategic Environmental Assessment
SMRU	Sea Mammal Research Unit
SRDL	Satellite Relay Data Loggers
SSPCA	Scottish Society for the Prevention of Cruelty to Animals
SSSI	Site of Special Scientific Interest
TCE	The Crown Estate
VP	Vantage Point

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[1] http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365

1 INTRODUCTION

This Volume discusses the survey and monitoring for two species of seal commonly recorded in Scotland. This guidance relates to the characterisation of wave and tidal development sites, the pre-consent identification and assessment of likely impacts, and the post construction monitoring of these. It does not consider any impacts associated with cable routing or landfall.

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 principles relevant to all the taxonomic groups.

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

2 IDENTIFICATION OF KEY SPECIES AND HABITATS

Two species of seal are found around the coast of the UK: grey seals *Halichoerus grypus* and harbour (also known as common) seals *Phoca vitulina*. There are occasional sightings in Scotland of Arctic seal species including ringed, hooded, bearded and harp seals.

Grey and harbour seals spend time on land to breed, moult and to rest between foraging trips but differences in their annual cycles determine how and when routine monitoring surveys are carried out. Both species are most conveniently monitored when they are on land.

2.1 Grey seal

The grey seal is the larger of the two UK species with adult females weighing approx 130-250kg and adult males often weighing over 300kg. Grey seals are only found in the North Atlantic and have three population centres: the North-west Atlantic, the North-east Atlantic and the Baltic Sea. Approximately 37% of the world population of grey seals is found in Britain with approximately 90% of these breeding in Scotland, mainly in the Hebrides and in Orkney (SCOS, 2009).

Grey seals are generalist, benthic feeders and forage over the continental shelf, usually at depths between 100 and 200m. In the UK, their diet consists mainly of sandeels and other species which live on or close to the seabed, although this varies both seasonally and regionally (Hammond & Grellier, 2005; Hammond & Harris, 2006). Telemetry data shows that grey seals spend approximately 40% of their time at or near terrestrial haul-out sites, 12% of their time foraging and the remainder travelling between foraging areas and haul-out sites (McConnell *et al.,* 1992; McConnell *et al.,* 1999). Foraging trips usually last between two and five days but they may be as long as 30 days. Around the coasts of Scotland, most grey seals feed within 50 km of their haul-out site (McConnell *et al.,* 1999, McConnell et al 2009.) but some feeding trips may be up to several hundred kilometres offshore. Individual grey seals make repeated trips to the same offshore area from a specific haul-out site, although they also routinely move large distances between haul out sites (McConnell et al, 2009).

In Scotland, adult female grey seals aggregate between September and early December to breed at traditional colonies on remote, uninhabited islands and coasts where they give birth to a single white-coated pup. Pups are suckled for approximately three weeks. After weaning their pups, the females mate and depart to sea. Pups remain on the breeding colony for up to two weeks after weaning before departing to sea. Breeding colonies vary greatly in size from only a few pups being born in a season to several thousand at the largest colonies. Mature seals of both sexes are usually faithful to particular breeding colonies and may return to within 10-100m of previous breeding location in successive years (Pomeroy *et al.,* 2000). Grey seals also come ashore in large numbers to moult, between December and April.

Grey seals in Scotland are currently monitored at two different times during the year. Annual surveys (both aerial and ground count) during their September to early December breeding season, determine the numbers of pups born at the main breeding colonies. Grey seals are also counted during aerial surveys in August which are primarily for moulting harbour seals. Although some areas are surveyed annually in August (Firth of Tay, Shetland and Moray Firth), most parts of Scotland are surveyed approximately once every four to five years. Details of surveys techniques are provided below (See 8.1 Aerial Survey and 8.2. non-aerial survey).

Pup production estimates for breeding colonies in Scotland are reported annually by the Sea Mammal Research Unit (Duck 2009; SCOS 2009). Additionally, Scottish Natural Heritage (SNH) ground count (see 8.2) pups born on the Isle of Rum, on South Ronaldsay and at colonies in Shetland; the Forth Seabird Group ground count pups born on the islands of the Firth of Forth.

Grey seal distribution during their breeding season is very different to their distribution during the summer months. Grey seals are counted during all harbour seal surveys, in June, July and August. Although these summer grey seal counts are not used (yet) for population estimation, they do provide information on the location of haul-out sites used by grey seals between foraging trips.

The Scottish grey seal population has increased since the early 1960s. Along with this increase, the number of colonies that are monitored annually has also increased.

Pup production data from these surveys are used to estimate the total size of the grey seal population[2] the best estimate of the total population associated with all annually monitored colonies in 2009 was 106,200 (95% CI 82,000-138,700) individuals (SCOS 2010, in prep). Overall, grey seal pup production in Scotland continues to increase but at a reduced rate compared with previous decades (Duck, 2009). In some areas (e.g. Inner and Outer Hebrides) pup production has not increased since at least 1992 and may have slightly declined. The indications are that the UK grey seal population is approaching its upper limit. There are six Special Areas of Conservation (SAC) designated for breeding grey seals in Scotland which are all monitored annually as part of the pup production monitoring programme (Table 2.1).

Table 2.1: Grey seal pup production estimates for colonies in the main island groups in Scotland surveyed in 2008 (Duck 2009)

Location	2008 pup production
Inner Hebrides	3,356
Outer Hebrides	12,712
Orkney	18,765
Isle of May and Fast Castle	3,346
All other colonies	3,441
Total (Scotland)	41,600

Grey seals are listed on Annex II of the EU Habitats Directive. The six SACs account for approximately 36.7% of pups born in the UK (**Table 2.2**). There are also a number of grey seal SSSIs including Fetlar in Shetland (very few pups in recent years), the Green Holms in Orkney and the 'Small seal isles in the Western Isles' which includes Shillay (Sound of Harris), Coppay, Haskeir, Gasker and Causamul. Together these SSSIs produced 1713 pups or 4.1% of pups born in the UK in 2008 (SMRU unpublished data).

[2] Further information on the estimation and modelling processes used by SCOS is available from http://www.smru.st-andrews.ac.uk/documents/341.pdf

Table 2.2: Summary of features of SACs designated for grey seals, and their contribution to UK pup production. Data from the Sea Mammal Research Unit

SAC	Brief description	Percentage of annual pup production contributed
Berwickshire and North Northumberland Coast (Farne Islands)	Long established colony in the north-east of England, forms part of an SAC that extends into south-east Scotland	2.8%
Faray and Holm of Faray, Orkney	Combined, were previously the second largest breeding colony in the UK	6%
Isle of May, Firth of Forth	Largest east coast breeding colony of grey seals in Scotland, and 5th largest in the UK	4.0%
Monach Islands, Outer Hebrides	Largely undisturbed breeding habitat. These islands hold the first and third largest UK breeding colonies.	20.2%
North Rona, Outer Hebrides	Very remote island rarely visited by humans. This used to be the third largest breeding colony in the UK, now 14^{th}	1.6%
Treshnish Isles	Remote chain of uninhabited Hebridean islands and skerries.	2.0%

2.2 Harbour seal

Harbour seals are one of the most widely distributed of all pinniped species and are found along most coastlines in the northern hemisphere. There are five recognised subspecies with *Phoca vitulina vitulina* occurring around Europe (Jefferson *et al*., 2008). Harbour seal males and females do not differ greatly in size and are quite hard to differentiate. Adult males weigh around 100kg and females are slightly smaller. Approximately 4% of the world population of harbour seals *Phoca vitulina* and 30% of the population of the European subspecies (*P. v. vitulina*) is found in UK waters, with approximately 85% of these occurring in Scotland (SCOS, 2009).

Like grey seals, harbour seals are generalist benthic feeders and normally forage within 40-50km of their haulout sites, consuming a variety of prey including sandeels, whitefish, herring, sprat, flatfish and octopus (SCOS, 2008).

Harbour seals are much more widely distributed around the coast than are grey seals, occurring particularly in more sheltered areas, hauling out on areas of rock, sandbanks or mud exposed at low tide. Pregnant females do not aggregate to breed but give birth to a single pup in very small groups, some time between late May and early July, usually below the high water mark. Having moulted their white coat while in the uterus, pups are able to swim almost immediately (SCOS, 2008). Females lactate for approximately four weeks and then mate in the water.

Harbour seals regularly haul-out on land in a pattern related to the tidal cycle. Individuals are generally faithful to particular haul-out sites both within a season and from year to year (Thompson, 2008). The greatest and most consistent numbers of harbour seals are found on land during their annual moult between July and September with a peak in August. Because harbour seals are so dispersed during their breeding season, it is not practical to estimate pup production for large areas, never mind the whole of Scotland. Instead, surveys are carried out in August when harbour seals spend longer periods ashore to moult.

Harbour seals are also surveyed aerially using different techniques depending on the substrate the seals are occupying. On east coast sandbanks, they are quite easy to locate and fixed-wing surveys using hand-held oblique digital photography is the most cost-effective method. On rocky shores, harbour seals are very well camouflaged and these areas are surveyed using a helicopter equipped with a thermal imaging camera. Seals are quite hot when moulting and are readily detected with a thermal imaging camera at distances up to 3km. Digital images of most groups of seals are also recorded to verify species identity and numbers in haul-out groups.

Harbour seals are widespread around the west coast of Scotland and throughout the Northern Isles and the Hebrides. The Firth of Tay, Firth of Forth and the Moray Firth represent most of the distribution on the east coast. Large declines have been documented in harbour seal populations in parts of Scotland since 2001 (Lonergan *et al* 2007) and surveys carried out between 2006 and 2009 have confirmed the magnitude of these declines (SCOS, 2009). Major declines have now been documented in harbour seal populations around Scotland with declines of up to 70% since 2000 in Orkney, Shetland, the Moray Firth and the Firth of Tay.

Surveys have also confirmed that there has been a lower but sustained decline in the Outer Hebrides, of around 3% per year since 1996. In contrast, recent surveys of the west coast of the Highland and Strathclyde Regions have confirmed that populations in these areas have not shown similar declines (Duck & Thompson, 2009).

Harbour seal surveys are expensive and therefore the aim is generally to survey the entire Scottish coastline every four to five years, although the Moray Firth and the Firth of Tay are surveyed annually. In response to recent declines, survey effort has been increased. An attempt was made to survey the entire Scottish (and English east coast) in August 2007. In addition, Orkney was surveyed in 2006, 2007 and 2008 (SCOS 2009). The overall harbour seal count for Scotland between 2006 and 2008 was 19,771 animals (SCOS, 2009). This figure does not represent the size of the total population for Scotland as an unknown number of seals will be at sea at the time of the survey and therefore not counted[3]. Moult counts of harbour seals are used as an index of total population size.

Harbour seals are listed on Annex II of the EU Habitats Directive. There are currently eight SACs designated for harbour seals in Scotland which together hold 13.1% of harbour seals counted in Scotland and 10.8% of harbour seals counted in the UK (**Table 2.3)**.

[3] For more details on the methods used to survey harbour seals, please refer to Duck & Thompson, 2009, available from www.**smru**.st-andrews.ac.uk/**documents**/**341**.pdf

Table 2.3: Summary features of SACs designated for harbour seals and their contribution to the overall UK August counts of harbour seals (using data up to and including 2009)[4].

Special Area of Conservation (SAC)	Brief description	Percentage of UK August count
Ascrib, Isay and Dunvegan, North-west Skye	A complex of skerries, islets, undisturbed mainland shores and offshore islands in north-west Skye	3.6%
Dornoch Firth and Morrich More, Moray Firth	Part of the most northerly large estuary in Britain and supports a significant proportion of the inner Moray Firth population. Has declined in recent years	0.7%
Eileann agus Sgeiran Lios Mór (Lismore), Argyll & Bute	A composite site comprising five groups of small offshore islands and skerries	2.5%
Firth of Tay and Eden Estuary, Fife and Tayside	Part of the east coast population of common seals that typically utilise sandbanks. Substantial decline.	0.5%
Mousa, Shetland	The large rocky tidal pools on the island are of particular importance, as they are frequently used by the seals for pupping, breeding and moulting, and provide shelter from the exposed conditions on the open coast. Substantial decline	0.4%
Sanday, Orkney	Nearshore kelp beds that surround Sanday are important foraging areas for the seals, and the colony used to be part of a very large surrounding population in the Orkney archipelago. Substantially declining population in Orkney since 2001.	1.3%
South-east Islay Skerries, Argyll & Bute	The south-east coastline areas are extensively used as pupping, moulting and haul-out sites by the seals	2.7%
Yell Sound Coast, Shetland	The most northerly UK site selected for harbour seals. A number of important harbour seal haulout sites are just outside the bounds of the SAC. Decline since 2001	0.5%

Harbour seal SSSIs include: Eynhallow (Orkney) and north Fetlar (Shetland).

[4] http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365

3 RELEVANT LEGISLATION

In neither Scotland nor the UK are grey and harbour seals afforded the protection given to cetaceans by either the Wildlife and Countryside Act 1981 or the Nature Conservation (Scotland) Act 2004. Nor are grey or harbour seals European Protect Species, although they are listed on Annex II of the EU Habitats Directive. There are currently six designated SACs for grey seals in Scotland and eight for harbour seals (**Table 2.2** and **Table 2.3**).

3.1 Habitats Directive

The SAC designation affords protection to a SAC population and therefore an Appropriate Assessment may be required where an activity's potential impact footprint overlaps with either an SAC, or an area or resources used by individuals from that SAC population. In the case of seals, this would mean where the activity's potential footprint overlaps with transit routes or foraging areas used by seals from an SAC.

3.2 Environmental Impact Assessment

Seals will need to be considered within the EIA for the proposed development, as detailed in Volume I.

3.3 The Marine (Scotland) Act 2010

The Marine (Scotland) Act 2010 came into force in January 2011 and introduces seal-specific legislation replacing the Conservation of Seals Act 1970 as it applies in Scotland. Part 6 of the Marine (Scotland) Act (Conservation of Seals) directly prohibits the killing, injuring or taking of any seal at any time, except under licence or for animal welfare concerns. Sea fisheries, salmon fisheries and salmon netsmen can apply for a seal management licence to shoot seals to protect fish, fisheries and gear. The Act also introduced a new regulation making it an offence to harass a seal, either intentionally or recklessly, at a designated haul-out site and this should be considered in the EIA process along with the presumption against killing, injuring or taking of seals.

In addition, the Act grants powers to Scottish ministers to designate an area as a 'seal conservation area' in consultation with NERC. It also introduces the power to designate

Marine Protected Areas (MPAs) including seal foraging areas. However, at present it is unclear how these new powers/regulations will be incorporated into the EIA process.

3.4 Seal Conservation Areas

The Marine (Scotland) Act 2010 introduced Seal Conservation Areas (replacing Seal Conservation Orders or CO's). This was in response to local declines in harbour seal numbers to provide additional protection for vulnerable local populations. Ministers must not grant a licence unless they are satisfied that there is no satisfactory alternative and that the granting of the licence will not be detrimental to the maintenance of the harbour seal population at a favourable conservation status. The two existing CO's which were introduced under the conservation of Seals Act 1970 (the Conservation of Seals (Scotland) Order 2004 which protects both species year-round in the wider Moray Firth from Wick to Fraserburgh, and the Conservation of Seals (Scotland) Order 2007 which protects seals in the Northern isles and the Firths of Forth and Tay) continue in the form of Seal Conservation Areas. Additional provision was made for a Seal Conservation Area for harbour seals in the Western Isles.

Seven 'Seal Management Areas' have been defined by Marine Scotland based on advice from SMRU (SCOS 2010, in prep). These are East coast, Moray Firth, Orkney and North coast, Shetland, Western Isles, West Highlands and South-West Scotland.

4 POTENTIAL IMPACTS

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

An essential first step in the EIA and AA process is establishing the size of the 'impact footprint' of proposed activities. These impact footprints may be comprised of a small proportion of the development area or extend some considerable distance (noise impacts for example). Impact footprints may also vary in lifetimes, with some activities resulting in long-term impacts such as habitat degradation, and others such as installation noise in shorter-term impacts. The effects of both of these upon species of concern may be equally important however. Survey and monitoring activities must be designed to gather data at relevant geographical and temporal scales that will allow potential impacts to be detected. However, data on the scale and severity of impacts are scarce in some cases and an important part of construction and post-construction monitoring should be the robust assessment of the degrees and scales of impacts.

4.1 Construction impacts

4.1.1 Physical injury

Increased vessel traffic during the installation phase of both wave and tidal developments presents an increased risk of seals colliding with construction machinery and vessels. Interactions between ships and seals are generally perceived as being rare events (but see Swails, 2005). However, since 2008 dead seals with characteristic spiral injuries have been reported from sites on the UK east coast and in Northern Ireland[5]. The most likely cause of death is associated with seals being drawn through ducted (or cowled) propellers such as a Kort nozzle or some types of Azimuth thrusters. Such systems are common to a wide range of ships including tugs, self propelled barges and rigs, various types of offshore support vessels and research boats (Thompson *et al* 2010). The numbers of seals found would be unlikely to have a significant impact on large seal populations, but may have rather more of an impact on small populations which may be already declining. There is no way of

[5] http://www.smru.st-and.ac.uk/documents/366.pdf

estimating what proportion of the casualties are being washed ashore. It is unlikely that all the mortalities are being recorded so any estimate of the impact will represent a minimum impact. Only a small proportion of the 30,000+ seals that die each year are washed ashore, therefore we cannot rule out the fact that we may only be observing part of a more general and widespread process (Thompson *et al* 2010). Due to the potential severity of impact for some populations, it is possible that strict restrictions and requirement for mitigation options from developers using DP vessels, particularly in areas near designated sites or with a declining seal population, may be applied. These conditions may only be relaxed following greater understanding of what is attracting seals to be close to DP vessels or development of mitigation that removes this risk. There is also the potential for mooring lines or cables to cause physical injury during construction, although this risk is likely to be less than that associated with entanglement with fishing gear.

4.1.2 Acoustic impacts

Seals use sound (both in air and underwater) for communication and social interactions, making them susceptible to effects of anthropogenic noise. In air, seals hauled out on land could be disturbed by the noise produced during installation (and operation) of devices. Both species of seal are sensitive to disturbance when out of the water and will return to the water if disturbed. Seals are most sensitive to disturbance, especially repeated or prolonged disturbance, during their breeding season when mothers must establish a bond with new-born pups. Disruption of this bond can lead to increased pup mortality as mothers may abandon their pups. Seals may also be sensitive to repeated disturbance when moulting. At this time of the year they spend longer periods out of the water to enable their hair follicles to produce new hair more quickly. Repeated disturbance can lead to a prolonged moulting interval. This may impose additional energetic costs, but there is no information on the level of such costs. Outside the breeding season seals are less tied to specific haulout sites and may be able to relocate to avoid further disturbance.

In water, there are likely to be a range of sources of anthropogenic noise during construction of wave and tidal stream energy developments. However, the potential effects of pile driving during construction are likely to be of most concern, although the use of pile driving for wet renewable installation is likely to be minimal. 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 seals. Source levels from impact pile driving depend on the size of piles and the substrate, but may be around 218-227dB_{pp} re 1µPa@1m (Mueller-Blenkle *et al*, 2010). Pile driving produces short intense pulses (100-200ms) with the majority of the energy below 1kHz, but with some components up to 100kHz (Evans, 2008). Physiological impacts of pile driving on seals could include temporary or permanent hearing damage or discomfort. Permanent hearing damage may be a concern at a distance of 400 m from any pile driving activities for harbour seals (Thomsen *et al*, 2006). There is limited available data on the behavioural responses of seals to pile driving. Studies looking at haul out behaviour and at sea distribution of seals during different stages of construction of Danish wind farms have been inconclusive (Edren et al. 2004; Tougaard et al 2006).

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 suggest that pin pile drilling has a much lower impact than piling. 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 sources 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 intensity and duration, these noise sources may cause displacement of animals and/or prey, auditory damage, acoustic masking of communication signals, foraging interference, and may present perceptual barrier effects.

4.1.3 Contaminant effects

A large scale chemical or hydrocarbon spill at a marine renewable energy site is unlikely. However, any spillage has the potential to affect seals in an area. Young animals may be at increased risk as they may be less able to avoid spillages (e.g. the oil spill in south Wales in the 1970's saw few adults but large numbers of young grey seal pups affected on Ramsey Island). However, due to strict current health and safety procedures during marine construction, the risk of pollution is likely to be minimal.

There is a very small risk that construction activities such as drilling or trenching could allow contaminated sediments to be released into the water column, although it is unlikely that developments will be sited in areas where sediments are heavily contaminated. In most high tidal and wave energy sites this is unlikely to be a major problem. Any pollutants released 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 (Ross et al., 1996, Ross, 2002).

4.1.4 Increased turbidity

Vision plays a role in prey capture and during social interactions underwater for seals. These processes could be impaired by construction activities such as drilling or trenching increasing turbidity in the water column. Any such effect will be geographically and temporally limited but there is a small risk. The magnitude of any such impact is currently unclear and will depend on the environment (i.e. water flow, seabed type etc) in the development area. In the high energy areas where wave and tidal devices will be situated, it is likely that materials released into the water column will be rapidly dispersed.

4.2 Operational impacts

4.2.1 Physical injury

The risk of collision is currently perceived as a key potential impact for seals 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 no direct observational data to allow us to quantify this risk, it may be noted that tidal device rotors in particular, either of the horizontal or vertical axis type, present a threat quite unlike anything that seals have previously encountered.

Although the mechanisms that seals use to navigate and avoid objects are poorly understood, it is likely that a seal's ability to detect devices will depend on 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, previous experience and underwater agility. Collision risk is likely to be highest in fast flowing areas where high approach speeds limit the time available to detect and avoid a device. Larger individuals may also be at greater risk due to lower manoeuvrability than smaller individuals or species.

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, tidal devices appear to emit broadband noise with significant narrow band peaks in the spectrum, the noise produced by SeaGen in Strangford Lough is reported to be comparable to a large vessel underway (Royal Haskoning, 2010b). Modelling work carried out by SMRU Ltd and summarised in Royal Haskoning (2010b) predicted that short term exposure to SeaGen noise is unlikely to cause auditory damage to seals. Seals would need to remain within 100m of SeaGen for several hours to suffer temporary damage and would need to be within 30m of SeaGen for 24 hours. These scenarios are considered to be unlikely. Seals have been shown to exhibit avoidance reactions to underwater noise at levels much lower than the permanent and temporary hearing damage thresholds (e.g. Kastelein *et al*., 2006); SMRU Ltd predicted that noise from an operating SeaGen had the potential to cause behavioural avoidance responses up to 600 metres from the device, although data collected during a telemetry study by SMRU Ltd demonstrated seals frequently occurring within this distance of the turbine while it was operational (Royal Haskoning, 2010b). Operating devices therefore 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.

4.2.3 Habitat alteration

The physical presence of wave and tidal devices will inherently result in habitat change during device operation. However, associated seabed moorings and structures have the potential to function as artificial reefs or fish aggregating devices. For example, fish have been shown to aggregate under floating structures (Gooding & Magnuson, 1967). As seal distribution is influenced by prey distribution and the associated prey habitat, this clearly leads to the potential of changes in the distribution of seals.

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 seals 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 for opportunistic predators such as seals. 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 travelling routes between haul out and foraging areas for seals. This will be dependent on geographical location, the number of devices, and how individual devices are spaced relative to one another. Seals have been shown to exhibit avoidance reactions to underwater noise at relatively low levels (Götz and Janik, 2010) and this impact is likely to be most acute for species travelling regularly through narrow tidal channels where tidal devices are likely to be deployed. This has the potential to alter foraging behaviour and haul out use and may lead to increased individual energy expenditure which has the potential to have population level effects. Although there is some evidence emerging from work at Strangford Lough that harbour seals and harbour porpoises are still regularly transiting the narrows despite the presence of an operating tidal turbine (see Case Study, Section 7.7).

4.2.5 Contaminant effects

As with the construction phase, contaminant release through spillages or contaminated sediments poses a risk to seals that has 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.

4.2.6 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 seals through indirect effects on prey abundance or distribution. Furthermore, there is evidence that small-scale hydrodynamic vibrations and flow vortices in the water column are important for prey detection and navigation by seals (Dehnhardt *et al* 2001).

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: The predicted risks for seals associated with wave and tidal energy developments.

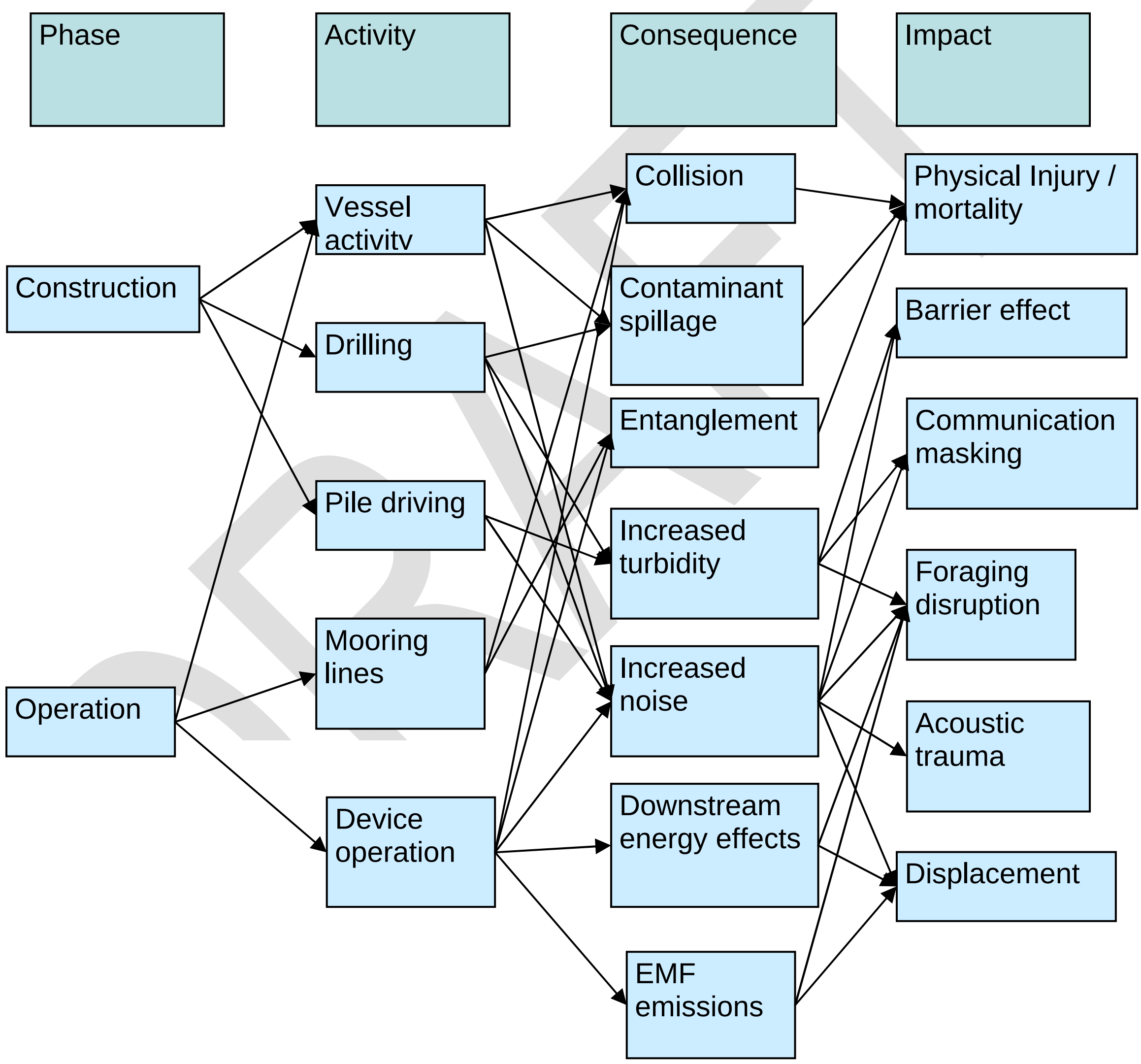

Figure 4.2: The predicted risks for seals associated with wave and tidal energy developments.

5 KEY QUESTIONS TO BE ANSWERED BY MONITORING

5.1 Pre construction: Characterisation

Survey data may be required to inform two separate but overlapping processes: to inform an Environmental Impact Assessment and to assess the relevance of any development to sites or populations protected under Natura 2000 legislation (Habitats Regulations Assessment (HRA) including Appropriate Assessment (AA)). In addition, characterisation surveys *may* provide baseline data for the monitoring of construction and post-construction impacts of the work. However, care must be exercised to ensure that characterisation surveys fulfil their primary goal, that the requirements of environmental legislation are fulfilled ahead of the consenting process.

For seals, the key considerations for the developer in order to obtain consent are the completion of an EIA, and the regulations relating to Special Areas of Conservation (SACs)

The key questions for site characterisation to inform the EIA process are:

- Do grey or harbour seals occur in the development site or its impact footprint?
- What is their spatial and temporal distribution and abundance within the site or its impact footprint?
- What do they use the site for?

The answers to these questions will help to identify potential impacts and determine their nature, extent and magnitude and likely significance.

In addition to 1-3 above, the key questions for the AA process are:

- Are these animals part of an SAC population?
- Could the proposed activity affect the integrity of the SAC?

A programme of monitoring needs to be designed which answers these questions and provides the information necessary for an Appropriate Assessment which will determine whether the development will affect the integrity of the SAC. It is important to note that given the wide ranging nature of seals, development need not be located within a seal SAC for it to impact upon such a site, or its seal population, and for an AA therefore to be necessary.

SAC site integrity is 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

The development site characterisation data should allow an assessment of the degree and significance of any potential impact upon individuals and populations at both the local, management area and regional levels. 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. Without knowledge of the 'impact footprint' of an activity, it may not be possible to apply the correct survey or monitoring methods at a scale relevant to the proposed development.

5.2 Impact monitoring

The primary aim of post-consent impact monitoring is likely to be assessment of the impacts of the technology deployed at the site on individuals, and testing the predictions made during the impact assessment. Potential impacts that should be considered include:

- Injury, disturbance and/or displacement during construction and installation
- 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 – injury and disturbance

The metrics which need to be measured to assess each impact may differ. Data collected during this phase of monitoring should also contribute to a confirmation of the accuracy of the Appropriate Assessment of the impact of the development on the designated features of the relevant SAC/SACs. Monitoring data should also be used to assess the effectiveness of mitigation and should feed into an adaptive management plan. Where uncertainties exist about any impacts, monitoring should be designed to rapidly identify an impact should it occur, allowing appropriate mitigation to be implemented.

Key questions to be answered for each impact are likely to include:

- Is there a significant difference in the metric being measured (e.g. relative abundance) between site characterisation and either construction or operational phases of the development? For example where displacement or disturbance of seals due to a development has been identified as a potential impact, a monitoring study can be put in place which assesses whether there is a significant change in the abundance or distribution of seals present in the area between the baseline and the installation and operation stages of the development. Similarly, where a potential for barrier effects has been identified during the assessment stage, a monitoring study would aim to measure the number of transits of seals past or through the development site and compare this metric between baseline and operation periods.
- Does the level of impact change with time or distance from impact site?
- Can any change be attributed to the development's construction or operation?
- Could change in any of the monitored metrics affect the integrity of a SAC?
- Could any impact affect the Favourable Conservation Status of the species?

Table 5.1: Key questions to be addressed for EIA, Appropriate Assessment (AA) and Impact Monitoring (IM)

Task	Number	Question
EIA	1	Do grey or harbour seals occur in the development site or its impact footprint?
EIA	2	What is their spatial and temporal distribution and abundance within the site or its impact footprint?
EIA	3	What is the site used for?
EIA	4	Is there likely to be a significant change in their abundance, distribution or habitat use in the vicinity of the development site or impact footprint?
EIA	5	What would be the significance or implications at the population level of any changes that occur?
AA	6	Do grey or harbour seals occur in the development site or its impact footprint?
AA	7	Are the animals part of an SAC population?
AA	8	Could any change affect the integrity of the SAC (and, if so, how)?
IM	I	Is there a significant difference in the metric being measures (e.g. relative abundance, area utilisation) between baseline and either construction or deployment/operation?
IM	II	Is detected change limited to the development footprint?
IM	III	Does level of impact change with time or distance from impact site?
IM	IV	Can any change be attributed to the development's construction or operation?
IM	V	Could any change affect the integrity of a SAC (and, if so, how)?
IM	VI	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 seals in and around the development area. Adequate data may already exist for some areas, there are considerable amounts of existing information on the distribution, abundance, and status of seals and this should be used to inform scoping, EIA assessment and post-consent monitoring. 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.

Scotland-wide information on seal distribution and abundance is available from annual aerial surveys carried out by SMRU. This information is presented annually by SMRU in a report to SCOS (http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=411).

There is also a dataset of at-sea movement information from various telemetry deployments on both grey and harbour seals around Scotland (e.g. McConnell *et al* 2009, Cunningham *et al* 2009, Sharples *et al* 2009, SMRU Ltd, 2010. Work is ongoing at SMRU funded by DECC and Marine Scotland to make these datasets more readily available for use by the marine renewables industry. Examination of this dataset should be made to establish whether adequate data already exist in the region of interest to inform the EIA or HRA processes. This will depend on the area of interest and the spatial and temporal resolution of data required.

Sources of information on Scottish seal populations and potential impacts of marine renewables:

- Annual SMRU advice to SCOS (Special Committee on Seals): http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=411
- McConnell et al, 2009. http://www.offshore-sea.org.uk/consultations/Offshore_Energy_SEA/OES_GreySeal_report.pdf
- SMRU Ltd, 2010 http://www.snh.org.uk/pdfs/publications/commissioned_reports/441.pdf
- SNH sitelink website – source of information about seal populations at designated sites:

http://gateway.snh.gov.uk/portal/page?_pageid=53,910284,53_920288&_dad=portal&_schema=PORTAL

- Marine Spatial Plans and Regional Locational Guidance where available may have information on seal populations in specific areas e.g. http://www.scotland.gov.uk/Resource/Doc/295194/0105824.pdf and 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/

7 STUDY DESIGN

7.1 Introduction

Study design is essential to ensure that surveys and data collected are fit for purpose and 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 is collected.

Although this volume presents the main issues to be considered in planning monitoring studies for seals, 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 seals 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 seal distribution at sea should extend beyond the development site and the exact extent of this should be informed by the likely impact footprint, the sensitivity of the population and the local geography.

Monitoring undertaken by developers should address impacts at the appropriate regional level (development site and the expected impact area) and on individuals. In the case of seals, the main monitoring for abundance is generally carried out at haul out sites and determining the impact footprint will require consideration of the extent of movement between haul out sites. It is difficult to be prescriptive about the likely size of buffer for monitoring haul out sites but this will depend on the distribution of haul out sites at the regional (Seal Management Area) level and their designation status.

The results of monitoring seals in relatively small areas will be difficult to put into context of the population, without some large scale background population-level data. The regular large scale surveys for seals undertaken by SMRU may provide at least some of this contextual framework, but more frequent repeats of surveys may also 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 need 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. Seal numbers fluctuate throughout the year and monthly surveys are recommended to track this. Seal abundance and distribution also vary across an area in relation to tide and time of day so where possible, survey effort should be stratified across these. Inter-annual variation in seal abundance and distribution may also be important in assessing the importance of a site for seals. However to adequately characterise this, survey over several years would be required. For characterisation surveys monitoring abundance and distribution of marine mammals, 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 seals.

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 seal numbers and distribution in order to detect a change outwith this natural variation. Impact monitoring needs to be carried out through all stages of the site's 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.

7.4 Effort and uncertainty

The distribution, behaviour and abundance of seals 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 seals 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 which will allow the design of appropriate effort to generate sufficient sample sizes to allow estimates of abundance and to detect any impacts.

Some standard approaches can be taken to decide how much effort is required. 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[6] (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.

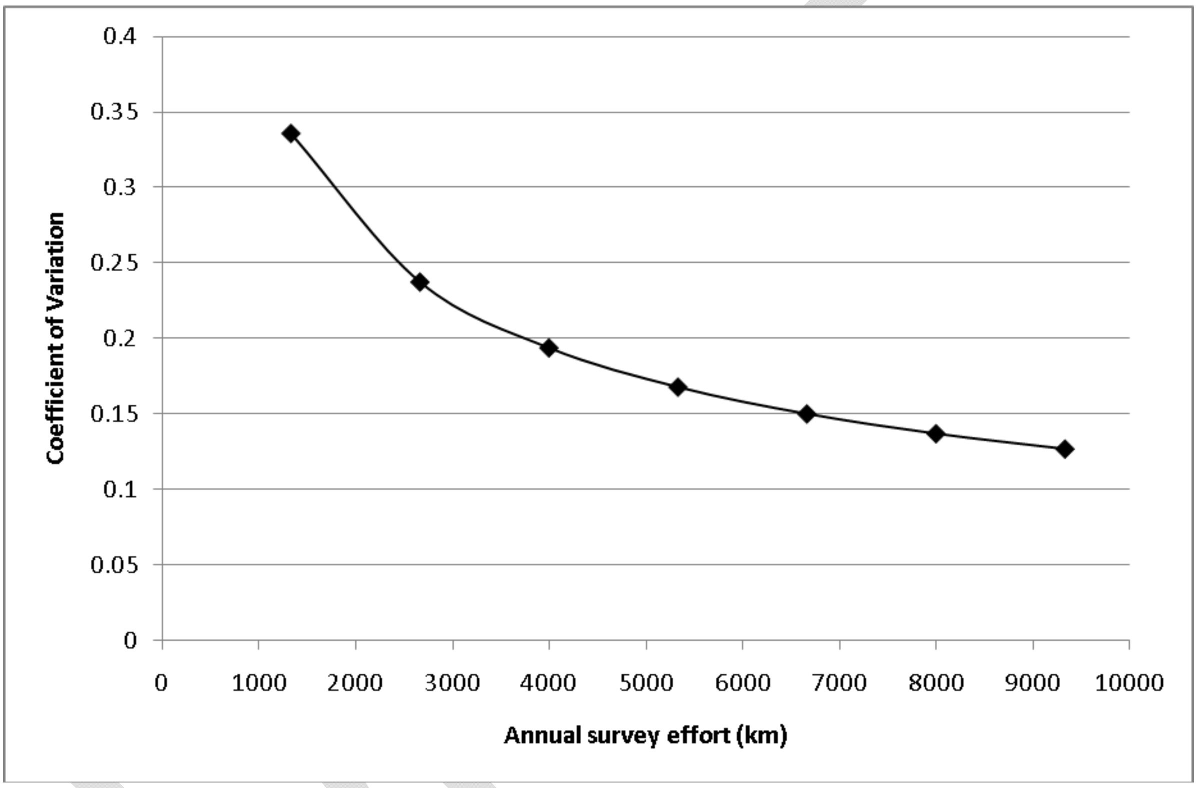

Figure 7.1 Relationship between effort and total CV for a boat-based monitoring survey. Circles on the plot indicate CVs and effort calculated from assuming increasing number of days of survey effort per month from 1-7 days with an average of 6 hours of effort per day at 10knots. Effort is accumulated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

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

Figure 3 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[7].

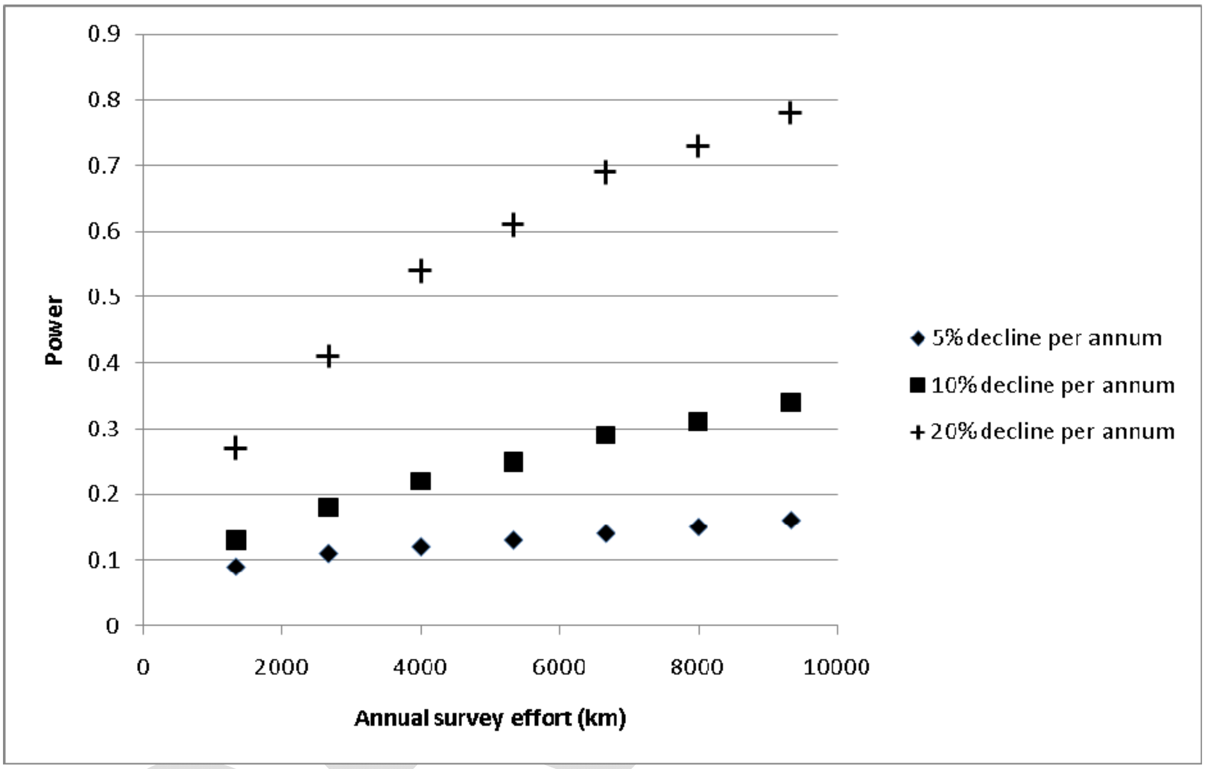

Figure 7.2 Relationship between power and effort for monitoring for difference levels of %change in the abundance per annum. Power was calculated using TRENDS software (Gerrodette 1993) for a 4 year monitoring period with annual monitoring and a one-tailed significance level (alpha) of 5%, assuming exponential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

The same principles apply for vantage point surveys – encounter rates observed for seals during vantage point surveys at various marine renewable sites can vary substantially with sightings rates varying from up to 10 seals/hour to <0.1 seals per hour. CV's in daily

[7] 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

sightings rates across the year are generally high (80-150%). The proportion of harbour seal positive days at Strangford Lough varied between 80 and 100% depending on the year and the associated power for detecting change was high (generally above 80% probability of detecting a change within three to six months.) In contrast the proportion of grey seal positive days at the same site varied between 25 and 75% resulting in a much reduced power to detect change as part of an impact monitoring programme.

It is important to consider that encounter rates of birds are generally higher than marine mammals in the coastal areas surveyed using vantage point methods and therefore consideration must be given to the differential effort that may be required for surveys for birds and marine mammals.

Inter-individual variation coupled with a relatively small sample size make uncertainty and variability a particular problem for telemetry studies. Increasing effort however means tagging more animals which has implications for disturbance at haul out sites as well as for cost.

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'. Seasonal counts at a network of linked haul out sites could also be carried out efficiently by helicopter and the cost split amongst all the developers in a region. This is likely to be more cost effective than multiple

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parameters (such as encounter rate, magnitude of change, significance required) specific to the development.

boat based counts of individual haul outs which are not co-ordinated in terms of temporal coverage.

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.

Telemetry

A tagging study was implemented by SMRU and SMRU Ltd to answer questions relating to the impact of the turbine on movements of harbour seals in and out of the Lough. Three separate deployments took place: March-July 2006 during the pre-installation baseline period; March-July 2008 during the installation period; and March-July 2010 during the operational period. In each deployment, 12 seals were captured at haul outs in the Narrows and Lough and fitted with GPS phone tags which collect relatively high resolution location data and transmit these through onboard mobile phone modems. An analysis was carried out to test the hypothesis that the turbine does not act as a barrier to the movement of seals through the channel. The deployment in 2010 was coincident with periods of continuous operation interspersed with periods when it was not operating. This allowed an assessment of the effects of turbine operation on the transit behaviour of individual seals. Comparisons between years was complicated by the relatively small numbers of animals tracked, the high level of individual variability in behaviour and the fact that individuals provided differing amounts of data. The transits made by each individual cannot be treated as independent data points in comparisons of the overall behaviour of groups of animals.

The study generated over 2500 seal-days of track data. The major feature of the data is that there is a broad degree of consistency between years, all showing a high degree of variability between seals, but a high degree of consistency within seals. In all three years some seals transited past the turbine site regularly whereas others never transited the narrows. Transit rates were therefore highly variable between individuals but overall mean transit rates were similar across the three years. This individual variation created large confidence intervals for transit rates and when 2010 data was examined no difference was detected in transit rate between periods when the turbine was operating compared to when it was not. To remove this individual variation, the ratio of transit rates during operation relative to non operation was calculated for each individual separately and this suggested that individual seals significantly reduced the rate at which they passed the turbine when it was operating. This reduction ranged from 10% to 50% with an average reduction of 20%.

Visual inspection of the distribution of transit locations suggested they differed between years with a distinctly bimodal distribution appearing in 2010 with peaks in transits occurring approximately 250m either side of the turbine, However as with the between year transit rate comparison, differing numbers of transits between individuals complicated any statistical comparison of these distributions. This pattern of 'local avoidance' was similar regardless of turbine operation suggesting that it was not directly related to noise or moving turbine rotors per se.

This study identified two main factors which contribute to uncertainty and thus reduce our ability to detect changes: interpolation error between the GPS fixes and the high rates of inter-individual variation in behaviour. A method for interpolation is required which takes into account dive behaviour and bathymetry to increase certainty in reconstructed animal tracks. More frequent, high quality location fixes are required for investigating small scale or localised behaviour in relation to marine renewable energy devices or for collecting baseline information on small scale behaviour to inform risk assessments.

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.

Aerial surveys

Aerial surveys have been carried out annually since 2006 to determine the overall number of harbour seal adults and pups, and the locations of their haul out sites between Carlingford Lough and Belfast Lough, including Strangford Lough. All aerial surveys were carried out by SMRU and were by helicopter using a thermal imaging camera. The helicopter operated at a height of 150-250m and a distance of 300-500m offshore to ensure that seals were not disturbed from their haulout sites. All surveys were conducted within +/- 2hrs of the local low tide times occurring between approximately 12:00hrs and 19:00hrs. Surveys were not carried out on rainy days as the thermal imager cannot 'see' through heavy rain and because seals abandon their haulout sites and return to the water in medium to heavy prolonged rain. Seals were counted using a thermal imager (Barr and Stroud IR18) with a dual telescope (x2.5 and x9 magnification). The imager was mounted on a pan and tilt head and operated out of the helicopter window. High resolution digital photographs are also taken to confirm species i.d. and provide a back up count.

Aerial surveys are carried out during both the annual moult (August) to provide a standard index of population size and during the pupping season (June-July) to estimate production as a proxy for current status. These data are then used in conjunction with monthly boat based surveys to track short term changes in seal haulout use and numbers. Despite a decreasing trend in harbour seal numbers region wide since the early 2000's, there have been no changes in population status since the installation and operation of SeaGen.

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. For harbour seals there was evidence that distribution of seals in the vicinity differed between periods where the turbine was operating relative to when it was not, but no change in overall abundance was detected.

The natural variability of 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 that the monitoring scheme has relatively high power to detect changes in the most common species – the harbour seal – a drop of 50% in seal numbers would be detected with high probability (0.88) within a month of the current monitoring scheme. However the same simulations demonstrated low power to detect changes in grey seal and 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. For grey seals a 20% decrease in abundance would only be detected with a probability of 12%. 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 – thereby reducing the probability of missed animals within the survey region.

8 SURVEY METHODS FOR SITE CHARACTERISATION AND ESTABLISHMENT OF PRE-INSTALLATION BASELINE CONDITION OF A WET RENEWABLES SITE FOR SEALS

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 may 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.

Data should be sufficient to inform a quantitative assessment of the magnitude and significance of any potential impacts identified at the scoping stage. It should also be considered at this stage whether surveys for site characterisation also need to provide a sufficient baseline against which post-consent monitoring data can be compared.

There are a range of well established survey methods for collecting information on seal abundance, distribution and behaviour, and some standard methods for analysing the resulting data (Table 8.1). The primary data of interest for characterisation of a marine renewable energy production are:

- Species present;
- Their distribution and abundance on land;
- Their distribution and abundance at sea;
- Their movements through the area of interest and connectivity with other areas
- What the land or sea areas are used for; and
- How the above vary seasonally and between years (and in the case of tidal energy developments, most likely how they vary over different states of the tide).

These data are required for the Environmental Statement and Appropriate Assessment. 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 questions related to connectivity are restricted primarily to photo-ID studies and telemetry.

Table 8.1: Monitoring methods used to address site characterisation at inshore and offshore wave and tidal sites for seals.

Primary Assessment type	Monitoring Objective	Monitoring method					
		Aerial survey of haul outs	Ground/boat counts of haul outs	Vantage Point surveys	Boat based line transect surveys	Photo-ID	Telemetry
EIA and AA	Species present	☆	☆	☆	☆		
	Density/ abundance	☆	☆		☆	☆	
	Habitat Use					☆	☆
AA only	Connectivity with SAC					☆	☆

8.1 Aerial surveys

The surveys carried out annually by SMRU for the purposes of monitoring Scottish populations of grey and harbour seals have been discussed briefly in Section 2 and shall be considered further here. Although individual developers are unlikely to carry out surveys of such scale, the data from these surveys are likely to provide valuable pre-consent information on the distribution and abundance of seals in and around development sites or development impact footprints. Annual pup production data exist for all major grey seal breeding colonies (SCOS 2009, 2010 figures in prep). With the exception of the Moray Firth and the Firth of Tay, SMRU generally survey the whole of the Scottish harbour seal population every five years although in response to the observed declines around the UK survey effort has increased. Between 2007 and 2009, the entire Scottish coast was surveyed and some parts of Strathclyde and Orkney were repeated. Additional funding from Scottish Natural Heritage (SNH) allowed completion of a third consecutive survey of Orkney. Data from these surveys are available annually in the publicly available SCOS reports.

Although it is unlikely that developers will be required to carry out large scale aerial surveys for site characterisation, there may be areas where data from these surveys are not sufficient to fully characterise the abundance and distribution of seals within an area. This may particularly be the case for assessing seal abundance and distribution in an area outwith the times of year normally monitored by SMRU. In such circumstances developers may need to consider undertaking surveys of haul out sites within the vicinity of their site and aerial surveys may be the most appropriate method, especially if large areas need to be covered. Given the likely concentrations of areas being leased for wet renewable development, and the wide ranging behaviour of seals, developers would benefit from a collaborative approach. This would avoid replication of effort and provide cost efficiencies. Aerial surveys have several advantages over ground- or boat-based surveys (Table 8.2). Large areas can be covered quickly, visibility of haul-out sites is not limited by topography, multiple haul-out sites can be visited sequentially in a time frame incompatible with movement of seals between them, and disturbance is less of an issue than with boat- or land-based counts. In addition, photographic or video records can be kept for verification. Aerial survey techniques can be cost effective for site characterisation if data is required over a relatively large area despite the labour and equipment resources required, especially if a collaborative approach is adopted.

The scale at which aerial surveys are undertaken is extremely useful for putting local abundance into a regional context, particularly as seals move over fairly large areas and cannot be considered discrete populations at the scale of most wave and tidal developments. It also may be important to consider that the relationship between haul out counts and total population size is likely to vary spatially and seasonally. Data on haul-out behaviour and how it changes seasonally, from telemetry studies, can be used to provide correction factors to account for the proportion at sea when the counts are made (Sharples *et al* 2009).

Table 8.2: Pros and cons of aerial surveys of seal haul-out and pupping sites

Pros	Cons
• Cost effective for large areas (compared to boat based or land-based methods) • Can collect data from a large area relatively quickly • Observers not influencing behaviour of animals • Can provide large-scale spatial and temporal trends • Established analysis frameworks • Long term monitoring data from other sources (SMRU) readily available and may be incorporated to provide context.	• Restricted window of opportunity for surveys each year. • Data on Grey and Harbour seal pupping collected in different seasons • Requires different approaches in different habitats/different species • Well trained and experienced surveyors and pilots required. • Specialised imaging cameras may be required. • Desk-based processing of images to extract data may be time consuming. • Weather restricted

8.2 Land- or boat-based counts at haul-out sites

Boat-based or land-based counts of seals at haul out sites can be carried out as an alternative to aerial survey and are the method likely to be chosen for site characterisation on the scale of most wet renewable developments. Small boats provide access to parts of the coast inaccessible by land. Counts are often made with the use of binoculars. With the exception of counts during the grey seal breeding season these are limited to optimal parts of the tidal cycle (2 hours either side of low tide) and are often highly weather dependent (boat surveys more so than land-based counts). Counting from either land or boat can be limited by topography in that all seals may not be visible. In addition, the oblique view from boat or land may mean that closer seals obscure further seals, resulting in less accurate counts. However, in some locations boat or land counts can provide accurate, easily repeatable information on seal numbers. Due to the necessary proximity of observers to the haul outs these types of surveys may result in more disturbance than aerial surveys. They also only provide coverage of a relatively small area and can be time consuming to undertake. Counts at haul out sites at or close to designated haul outs may require a licence from SNH.

The same issue of variation in the proportion of seals hauled out, described above for aerial surveys, is also relevant here and, similarly, telemetry derived information on haul out behaviour can be used to estimate the proportion of seals at sea. However, unlike aerial surveys, it is less costly to carry out repeat counts with greater frequency thus providing a mean estimate with an associated measure of variation. The precision of this estimate will increase with more repeat counts. Surveys can be repeated on a monthly basis to derive information on seasonal variation in seal abundance.

As with aerial survey these methods only give information on distribution and abundance of seals on land and give no information on the distribution of seals at sea.

8.3 Vantage point survey of seals at sea

Presence, relative abundance and distribution of seals in waters around wet renewable sites can be monitored using land based observations undertaken by an experienced observer who carries out detailed watches from an elevated position onshore overlooking the study site. Vantage point surveys can be relatively cheap and non-invasive. The main limitation however, is the distance of the site from shore and the extent of reliable visual observations which can be made over the whole study site from a single point (Table 8.3). It is unlikely that shore based observations will be useful at sites situated much more than 1-2km from a suitable vantage point. Fixed-point observations in isolation cannot produce estimates of absolute abundance but, given sufficient effort, can provide information on relative abundance and how this changes seasonally and with other factors such as time of day, state of the tide etc. If effort is sufficient, these surveys can be used throughout the life cycle of a project to monitor for changes through time. Providing a suitable vantage point is available shore-based visual observation is likely to be the most widely used and informative method for surveying seal abundance and distribution at wet renewable sites.

Vantage point surveys can also be used to collect positional data to provide information about distribution within a site – this can give information on how animals are using a site, and how this use varies spatially and temporally and may be important for identifying times and areas of particular importance, which in turn may inform issues of project design.

Abundance and distribution of seals in relation to the tidal state may also be important for assessing the potential for collision impacts of tidal developments.

Depending on the nature of the site, additional data can be collected to allow corrections for differences in detection probability with distance from the observation point. A discrete set of boat based line transect surveys can be carried out concurrently with a subset of shore based observations, or where the region of interest is a narrow sound with land on either side of it (e.g. many areas of high tidal flow are narrow areas of water) double observer trials with an observer on each side of the channel can be used. Once detection probability has been established and accounted for, conventional distance sampling methods can be used to estimate absolute abundance of seals using the area. This may be important for quantifying and assessing magnitude and significance of impacts in a risk assessment framework.

Data on behaviour can also be collected from vantage points – this can be used to answer questions relating to habitat use. Information on habitat use will be important for informing impact assessment, for example whether animals use an area primarily for feeding vs. transiting through will have different implications for the potential effects of displacement or barrier impacts. Information on transit rates will also potentially be useful for assessing collision risk. Pilot studies may be required to ascertain likely encounter rates to inform the design of the monitoring surveys to ensure that the amount of effort over the sampling period is adequate to sufficiently characterise the site.

Vantage point surveys can have multiple objectives, for example, in addition to carrying out standard scans to record sightings and estimate relative abundance, the protocol could also include tracking individuals using a theodolite or video-range method to monitor movements of seals. 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 which is cheaper than telemetry but will provide much less data.

Table 8.3: Pros and cons of vantage point surveys.

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/impact monitoring	• Generally not possible to estimate abundance unless additional methods are employed • 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

8.4 Boat based surveys of seals at sea

Line transect surveys are often considered the standard for estimating density and abundance of cetacean populations (see Buckland *et al.*, 2001) although they have not been routinely used to estimate density and abundance of seal populations (but see Herr et al 2009 for a rare example). This is generally because seals can be counted when on land and therefore their populations estimated with much more ease than cetaceans by restricting surveys to periods and locations where seals predictably occur on land. It is also a common belief that seals are less likely to be ‘spotted’ at sea during visual surveys. Where seals spend their time at sea has generally only been studied using telemetry. This is because a direct link can be made between where seals are on land and where they go at sea. Sophisticated analytical techniques have been developed for scaling up data on at sea movements and distributions from a small number of tagged individuals to give estimates of how the density of seals varies spatially (Matthiopoulous et al 2004, McConnell et al 2009). Where telemetry data is not available for a site or is based on only a few tagged individuals, it may be more cost effective to use boat based surveys to determine the likely distribution and abundance of seals at sea.

By adopting the same techniques as used during line-transect surveys for cetaceans and giving consideration to analytical issues relating to availability and detectability of seals during surveys, it should be possible to carryout boat based surveys to answer questions relating to seal abundance and distribution in areas of interest to marine renewable energy developments. Very little work has been done assessing the ability of line transect seal sightings data to estimate abundance and at sea distribution of seals. An exception to this is a study using data collected during aerial line-transect surveys for an assessment of harbour porpoise distribution in German waters (Herr et al 2009). This study demonstrated that seal sightings could be used to estimate abundance and model density despite sightings rates being relatively low (329 sightings over 52,000km of effort over a 6 year period.)

In terms of seal sighting probability, there may be an issue of a lack of sighting cues such as blows or conspicuous surface behaviour such as tail slapping or breaching. However there is little empirical basis upon which to judge this. A study using line transect surveys in Cardigan Bay, Wales, reported sightings rates of seals that are comparable with cetaceans: sightings rates of grey seals were intermediate between those of harbour porpoise and bottlenose dolphins, and g(0) was higher for grey seals than for harbour porpoise (Reay 2005). Although the proportion of the body available to be seen while at the surface may be lower than for cetaceans, seals often spend considerable periods of time at the surface and may be available for detection less frequently but for longer periods of time when they are at the surface.

An additional consideration for seals is that they spend a proportion of time on land and therefore not at sea and available for counting during these surveys. Estimates of abundance and distribution must take this into account, particularly where surveys are used to monitor change – estimates of abundance will be underestimates if the proportion of animals onshore is not accounted for. The proportion of time animals spend hauled out varies seasonally and with the tide (e.g..Thompson et al 1998, Sharples et al 2009) so the seasonal and tidal distribution of survey effort must be spread to cover all states equally to avoid bias in estimates. Stratification of data by different states may be possible but this will depend on sightings rates and sample sizes. 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 are measured accurately (e.g. using angle boards and reticle binoculars).

The first, and most critical assumption, is almost always violated because seals spend considerable amounts of time below the surface which means they are missed by observers (availability bias). Observers may also miss animals simply because they weren't looking in the right direction or an animal surfaced behind a wave (detection bias). In either case, when g(0) does not equal one, density will be underestimated (see section 8 of Volume II (cetaceans and basking sharks). Double-observer methods (Buckland *et al*. 2004) allow for empirical estimation of g(0) but both the field and analysis methods are relatively complex. Availability bias can be corrected for using information from telemetry derived information on dive behaviour (e.g. harbour seals generally spend around 80% of their time submerged while at sea (Fedak et al 1988, Bekkby and Bjorge 2000). There are very few empirical estimates of g(0) for seals, surveys in Cardigan Bay using double observer methods estimated a g(0) of 0.82-0.93, indicating that detectability is reasonably high for grey seals. For the purpose of developers gaining consent, conventional distance sampling methods will generally provide appropriate density estimates. It is important that the survey be repeatable and that sources of bias, if they cannot be eliminated, are at least consistent throughout. However, because of the inherent variability in abundance estimates, trends can be difficult to detect, requiring several years of repeat surveys. This reinforces the need for standardised methods to be used, so that estimates from different years may be compared.

Assumption (2) is a particular issue for boat-based surveys for cetaceans, 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). It is less clear how seals may respond to the presence of boats but it is likely that some response may occur. Aerial surveys do not suffer from problems associated with responsive movement.

Line-transect methods can be conducted from boats and aircraft (Table 8.4). 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[8] since an increasing number of white caps or breaking waves tends to obscure the most common sighting cues

[8] See http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html

(most sighting surveys should be discontinued when sea state is above Beaufort 4). The relationship between sea state and seal detection is less clear, although it is likely that probability of detection diminishes in a similar manner, although the longer periods seals spend at the surface between dives may make this less obvious. Obviously surveys can only be conducted during daylight hours, which imposes 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)[9] 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 marine mammals and also basking sharks. This approach will inform on the presence, distribution and also abundance/relative abundance of seals within the area. 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. It is important if a shared platform is to be used for collecting data on multiple taxa, that the survey design and effort is based on the least abundant taxa, otherwise the surveys will not generate adequate sightings of less abundant species for analysis (see section 7.4).

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). Comparisons between the seabird density estimates generated from this approach compared to traditional aerial surveys using observers have also been made (Burt *et al*. 2010). Marine mammals are also detected during HD-photography surveys and Thaxter and Burton (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. Species identification may be a key issue during aerial surveys for seals. Herr et al (2009) noted that grey seals and harbour seals could not be distinguished during aerial surveys of the North Sea. The importance of this issue will depend on the likely presence of each species in the area. 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).

[9] http://www.ruwpa.st-and.ac.uk/distance/, page viewed July 14, 2009.

Table 8.4: Summary of pros and cons of visual line-transect surveys for seals.

Pros	Cons
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 • Currently very limited use with seal data. • Impacts of availability bias currently unclear
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 reduce effective strip width and survey team size/effectiveness for line-transects • Small boats highly constrained by weather
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 or cetacean surveys	• Logistical limitations • Responsive movement may be a problem for some aircraft types or some species • Can't identify to species

8.5 Photo ID

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 seals, pelage patterns are used. 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 and pupping intervals/success; and for assessing connectivity between different development sites (to assess the potential for cumulative effects) and also between development sites and SACs. Photo ID has been used in Scotland for both harbour (Mackey *et al.* 2008; Thompson and Wheeler 2008) and grey seals (Harrison *et al*. 2006).

8.6 Telemetry

Telemetry devices are used to gain information on the at-sea location and behaviour of seals. Information can be gained on haul-out bouts and on dive characteristics as well as characteristics of the at-sea environment itself. For example tags can collect data on salinity or temperature which provides contextual information to help interpret behaviour. Locations of animals and their behaviour while at sea, plus terrestrial haul-out bouts can be used in conjunction with counts of groups on land to construct relative habitat usage maps. Telemetry data can also inform the geographical extent of boat and aerial surveys. Proportion of time hauled out (=being available to be counted at a haul-out) may also be derived from the haul-out information provided by telemetry which can help translate counts at haul outs to estimates of total population size.

Telemetry studies can answer several questions relating to characterisation, providing information on how animals use a site (Table 8.5). For example, information on how seals transit areas of high tidal flow will have important implications for the degree of collision risk with tidal turbines. Telemetry can also link usage of areas at sea with particular haul out sites (e.g. are they from a nearby SAC if the development site itself is not in an SAC). There are a variety of seal telemetry devices available, such as the GSM/GPS tag which provides high quality GPS locations and individual dive and haulout records.

A wide variety of information relevant to monitoring studies may be obtained using telemetry:

- At-sea usage maps
- Passage transits and activity levels in the proposed development site and impact footprint

- Haulout behaviour (to calibrate haulout counts into local population estimates).

- Linkage between the marine areas where the impact is focussed and the haulout sites used by animals after visiting these impact areas. This indicates which haulouts are likely to be most affected by a change in seal usage at a given impact area.

- Haulout fidelity and network transition rates. These will indicate the required geographical extent of haulout counts.

An important issue to consider in telemetry studies is that there must be a large enough sample to make inferences about these metrics at the population level. There is frequently considerable variation in behaviour between individuals and this variation means that larger samples have to be employed in order to detect change. However, prolonged catching effort may cause local disturbance. In practice 10-12 tags per deployment may be a reasonable compromise between data requirements and cost.

Another important consideration is the frequency at which location fixes are attempted. If information on very fine scale habitat use is required (i.e. the way in which seals transit an area rather than just wanting to know if they transit it at all) then tags need to record location as often as they can as interpolating between location fixes to reconstruct animal tracks has some degree of error/uncertainty associated with it.

An additional consideration is that telemetry studies must be carried out under licence as the techniques involved in telemetry come under the Animals (Scientific Procedures) Act 1986. The regulations involve three levels, the regulation of person, project and place. All work must fit in under a project licence – granted to a suitably qualified and experienced individual. The project licence outlines detailed justification for the work and the numbers and types of animals likely to be used. Amongst other things the licensing procedure demands that the work be absolutely necessary i.e. could not be extrapolated from other methods. The project licence also details the regulated procedures which may be carried out. All individuals carrying out these procedures must hold a personal licence, which may be granted after a defined series of training.

Table: 8.5 Pros and cons of Telemetry.

Pros	Cons
• Large amount of data on animal location collected • Usage maps can be produced • Data on connectivity can be collected • Dive profiles (and behaviour) data can be collected • Data can be collected on habitat use to inform collision risk modelling • Data on interactions with installed devices and device arrays can be collected. • Observers not influencing behaviour of animals • Can provide spatial and temporal data on usage and distribution • Not weather restricted • Established analysis frameworks • Data can help correct haul out counts to account for proportion of animals at sea	• Expensive • Only a small (potentially unrepresentative) proportion of population tagged • Limited life of tags • Catching of animals for tagging can be difficult. • Home Office licence required for catching and tagging. • Very experienced team required • Not possible to estimate abundance • Animals tagged at haul out sites may not enter area of interest • Location data resolution may not allow small-scale movement of animals in proximity to devices/ arrays to be determined • Data analysis and interpretation highly specialised

8.7 Collision risk of seals

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 seals surface to breathe and spend periods of time 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 seals transit areas earmarked for development. This information can be gained from a combination of telemetry studies and vantage point observations. Collecting data on the fine-scale behaviour of seals around operational devices as well as 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. The PBR approach is being used as part of the seal licence system in Scottish waters (SCOS, 2009) to manage seals with the Seal Management Units. It is possible that predictions of mortality related impacts from marine renewable may feed into this management approach in future or that the Regulators may use a similar approach to setting thresholds for 'takes' in relation to a deploy and monitor strategy for consenting.

9 MONITORING METHODS TO ESTABLISH IMPACTS OF CONSTRUCTION AND OPERATION OF WET RENEWABLE DEVICES

9.1 Introduction

In order to quantify the impact of construction and deployment of wave and tidal devices on seals and to ensure that proposed mitigation is sufficient, monitoring will focus on detecting change in a number of defined metrics. These metrics will be directly related to key questions defined at the impact assessment stage. In practice this is likely to mean that some aspects of the data collection initiated in establishing the site characterisation will continue throughout construction and operation phases of the development. Additional methods may also be incorporated and existing methodologies be amended to accurately measure impacts. Consideration must be given to the ability of the monitoring scheme to detect change of a given magnitude. Consideration must also be given to the scale of the monitoring scheme to ensure that data is captured at a scale appropriate to the scale of impact. In addition, given 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 be given to the ability to rapidly detect and mitigate against these should they occur. A summary is provided in Table 9.1.

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

Monitoring for disturbance and displacement (including barrier) effects during construction and deployment should focus on measuring changes in abundance and distribution of animals present in the study area during the construction and operational phases. The methods appropriate for monitoring changes in distribution and abundance (relative or absolute) are vantage point surveys, boat or aerial line transect surveys, haul out counts and telemetry (see Site characterisation Section 8 for further details).

The nature of disturbance related impacts (e.g. 'barrier' effects, long term displacement from an area) will be very site specific and such monitoring programmes should be designed with the particular characteristics of a site in mind. For example, changes in the transit rates of tagged seals may be used as a metric to compare between deployments during site characterisation and operational stages to answer questions relating to barrier effects. Similarly to answer questions relating to displacement, changes in local abundance and distribution may be difficult to assess in terms of significance at the population level without data from surveys at regional and national scale.

Repeated haul out counts (Section 8.2) can be undertaken to assess changes in relative abundance at or use of haul out sites during construction or operational phases. Haul out counts may also provide an opportunity to search for injured animals that may have been involved in collisions with devices or associated infrastructure.

Although, as discussed in Section 8.1, it is unlikely that individual developers will be required to carry out aerial surveys over large areas, nonetheless the scale that annual SMRU aerial surveys are carried out at may be useful for providing context - for example, it may be important to relate changes in numbers at a haul out site local to a development, to a region wide trend to avoid wrongly attributing a negative impact to the development. Similarly it may be possible to relate a decrease in one part of the region to an increase in another, allowing an assessment of the significance of a local decline. However aerial surveys are expensive to repeat and therefore mostly provide a single count 'snapshot' with low precision. They therefore have a limited ability to assess seasonal variation or to detect change due to a single development. Cunningham *et al* (2010) showed that harbour seal counts around the coast of Scotland have a co-efficient of variation of around 15%. Cunningham *et al* (2010) also demonstrated that it would take around 14 years of surveys to detect a change in the harbour seal population of 5% per year using current single count methodology.

Telemetry (Section 8.6) can provide high spatial and temporal resolution data on animal movement in and around a development site during construction and operation/ non operation of a device. Telemetry data can provide simple metrics such as transit rate and locations, and in certain situations enable the production of usage maps. However, it must be noted that telemetry studies are likely to involve a very small proportion of the population of interest and that these individuals may not be representative of the wider population.

Vantage point surveys can also provide some information on how behaviour around a site changes if individuals are tracked using theodolite or video-range method to monitor changes in swimming behaviour in response to construction activities or the presence of an operational device (s).

9.3 Collision monitoring during operation of device(s)

Given current uncertainties about the collision risk posed by marine renewable devices, monitoring of collisions during operational stages is likely to be an important aspect of monitoring and mitigation for marine renewable energy developments, at least in early stages of the industry until more data can be collected and the risk of collision reassessed. Tracking or visualisation technologies may be used to detect and track animals in close vicinity to existing devices; underwater video and passive and active sonar techniques can be used to provide information on the interactions between seals 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. 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. Telemetry studies have to date lacked the fine scale resolution required to assess near field interactions with devices although the development of tags which allow high resolution 3-D accelerometry tracking while seals are in the vicinity of devices is currently being considered at SMRU.

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 echolating 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. Carcass surveys carried out prior to developments 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 seals should be made via the Scottish Agricultural College's Veterinary Investigation Centre at Inverness. If the animal(s) are alive, then the Scottish Society for the Prevention of Cruelty to Animals should be contacted.

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

Monitoring Objective	Monitoring Method						
	Carcass recovery	Vantage Point	Boat-based surveys	Aerial Survey of haul out and breeding sites	Photo-Id**	Telemetry	Active Sonar
Species present	☆	☆	☆	☆		☆	
Density/abundance		☆	☆	☆	☆		
Productivity		☆		☆			
Distribution		☆	☆	☆		☆	
Behaviour		☆	☆			☆	
Injury/mortality	☆					☆	
Barrier effects		☆					☆
Connectivity of SAC					☆	☆	

10 SUMMARY OF SURVEY AND MONITORING METHODS

Table 10.1: Summary of protocols available for the monitoring of renewable device impacts on seals. 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
Aerial surveys of haul outs and pupping sites	Presence/absence Distribution Relative abundance Productivity	Aircraft Camera Infra-red camera	Survey extent, species and season dependent. Image resolution and infra-red camera substrate, species and data requirement dependent. Haul outs surveys 2 hours either side of low tide.	4-5 times annually for pupping season (grey seals) and moult period (harbour seals). If haul-out data required, increased frequency for each development phase.	Statistical tests of differences between means counts e.g. ANOVA	Suitable for large areas. Specialised activity. Management of large numbers required. Extraction of data from images and data QA time consuming.
Non-aerial surveys of seals at haul outs (boat and land-based)	Presence/absence Distribution Relative abundance	Boat Binoculars/ telescope	Very dependent upon site characteristics. Two hours either side of low tide.	Monthly if seasonal variation required. Frequent during brief periods if season-specific usage or impact monitoring data required.	Statistical tests of differences between means e.g. ANOVA	More appropriate for smaller, discrete areas. Disturbance potential.

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
Telemetry	Relative distribution At-sea usage Dive profiles Connectivity with SAC's	Range of tags and loggers available. Appropriate tag dependent upon site/ area constraints and metric/s of interest.	Question driven and dependent upon desired metric.	Once per project phase. Continuous data acquisition during device lifetime. Device lifetime variable (2-9 months).	At-sea usage maps Comparison of at various metrics between years/ phases. usage/transits/trip metrics	Expertise and Home Office licence required for deployment. Relatively small number of individuals tracked. Combination with other data sets e.g. haulout counts Devices lost during annual moult.
Vantage Point	Presence/absence Distribution Relative abundance Habitat use	Binoculars/telescope Theodolite Inclinometer	Suitable elevated vantage point Visual observation-continuous scan Even sampling of spatial and/or temporal factors influencing detection/distribution – tide, time of day etc.	Monthly and over multiple years if natural variability is to be established	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.

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
Line Transect visual surveys***	Relative abundance	Platform (ship, aircraft) Inclinometer (aerial) Reticle binoculars (ship) Angleboard (ship) Data recording software and laptop	Randomly located lines Various layouts (zig-zag, parallel)	Seasonally and 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	Baseline: Distance Sampling analyses Statistical tests between point estimates e.g. Z-test Regression analyses	Ships and aircraft need to 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.

Method	Metric	Equipment required*	Survey design	Suggested monitoring interval**	Analyses	Comments
Photo-ID	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	Dependent upon sightings rate and re-capture rate, as well as question being asked.	Matching & grading photographs Matching across catalogues Estimator for abundance e.g. Petersen	Highly weather dependent. Large amount of effort may be required due to low encounter rates, low re-capture rate, poor observation platform/ site
Carcass recovery	Species present Cause of death	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, operation)	Species composition over time. Cause of death over time in conjunction with development phases	Attributing death to a particular device, site or activity may be difficult. Some site geography make this method impractical

* 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 for comparison of pros and cons of boat based and aerial surveys

11 DOWNSTREAM IMPACTS, DATA GAPS AND MITIGATION

11.1 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 seals, the ultimate impact of such degradation may be the loss of key fish stocks. In order to assess potential down stream effects and resulting potential indirect impacts on seal populations it is essential that during the EIA process, regular discussions take place between the marine predator specialists and ocean modelling, benthic habitat and fish specialists. In this way any potential issues can be identified early and site characterisation and monitoring put in place to address any concerns raised. The monitoring methods adopted are likely to be similar as the consequences of the indirect impacts are likely to be similar to direct impacts – e.g. changes in distribution and abundance of seals. However attributing changes to indirect rather than direct impacts will require ancillary information on concurrent changes in benthic and fish populations.

11.2 Data gaps

Annual surveys of seals in Scottish waters are currently undertaken by the SMRU. Surveying the entire harbour seal population is not possible annually, instead only certain haul outs are covered with a complete "census" every five years or so. Harbour seal numbers at certain haul outs have shown signs of decline in recent years; for example, numbers are down by 40% at Orkney haul outs. The level of monitoring of these sites has now been increased but this exemplifies the fact that large declines can happen within relatively short monitoring intervals. There may be cases for enhanced strategic monitoring at other sites around the Scottish coastline, particularly in areas where marine renewable developments may be concentrated.

How seals behave around wave and tidal devices is relatively unknown. The Strangford Lough tidal turbine site has been monitored from its conception and seals within the area have been studied using a variety of methods (see Case Study).

11.3 Mitigation

There are numerous SACs for seals in Scottish territorial waters and adjacent UK sites. The best method of mitigating against impacts of wet renewable sites on seals would be to avoid developing sites within (or near to) these areas. However, telemetry data show that seals are far ranging and it is probable that animals from SACs will transit through wet renewables sites even when they are some distance away from the SAC concerned.

Installation of devices in the vicinity of breeding sites should avoid the pupping season if possible as disturbance can cause mothers to abandon pups. Installation should also avoid moulting periods as disturbance during the moult has the potential to impact significantly on the energy budgets of seals (Paterson *et al*, submitted).

Whether or not a real-time mitigation is required for collision impacts is a subject of debate and any decisions made by the regulators for individual developers will depend on the characteristics of the site and the outcomes of site characterisation data collection and collision risk assessment. A tiered approach may be considered

The layout of devices within a development site should allow passage of animals through the area. At present however, there is little information available on the interactions between animals and single devices or device arrays to properly determine the degree to which developments may act as barriers to movement. Recent evidence from tagged seals at Strangford Lough demonstrated an apparent degree of local avoidance of the turbine up to approximately 250m when transiting past the turbine (See Case Study).

12 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.

13 SURVEY AND MONITORING PROTOCOLS FOR SEALS

The protocols outlined below are guidelines only and should be adjusted as required for each development site according to any site or device specific issues. Protocols are provided for the following methodologies:

- Aerial survey of haulout sites;
- Non aerial (boat and land based) haul out surveys;
- Vantage Point Surveys;
- Boat based surveys;
- Visual aerial Surveys;
- Telemetry;
- Photo-ID; and
- Carcass Recovery.

13.1 Aerial survey

Although contemporary data from grey seal breeding and harbour seal breeding and moult surveys should be available for site characterisation, there may be need for additional data collection where coverage is not available or information is required for other times of year. SMRU monitor all main grey seal breeding sites annually so this is more likely to be the case for harbour seal haul outs which have not been recently surveyed by SMRU, or for haul out abundance and distribution at times of the year other than the moult or breeding for both harbour and grey seals. Therefore the protocols provided here focus on surveys for counting animals at haul outs.

13.1.1 Survey design

Aerial survey for seals can be carried out using a number of different recording techniques. These include:

- fixed-wing aircraft with large-format vertical photography (primarily breeding grey seals) fixed-wing aircraft with oblique hand-held photography (can be used for both species on sandbanks)

- helicopter equipped with a thermal imaging camera (harbour seals)

- helicopter with oblique hand-held photography (can be used for both species but not used routinely)

The survey method used is entirely dependent on what is being surveyed. Harbour seals (and grey seals outside their breeding season) are restricted to a narrow section of coastline (which may be extremely convoluted) with greater numbers on shore at low tide than at high tide. Seals on sandbanks are considerably more visible than seals on rocky shores. In general, species identification of individual seals is possible due to their different thermal profile, size, head-shape, and coat pattern and group structure when hauled out.

Where seals haul out on sandbanks, as in the large east coast estuaries, seals are quite visible and can most efficiently be surveyed from a (small) fixed-wing aircraft using hand-held oblique photography. Where seals haul out on rocky shores, they can be remarkably well camouflaged and very difficult to detect. For these areas, surveys are carried out by helicopter equipped with a thermal imaging camera. Harbour seals are particularly warm when moulting as their peripheral circulatory system is open to encourage hair production.

Procedures will be determined by the species, particular questions to be answered and the characteristics of the area to be surveyed.

The majority of haul out seal surveys around rocky coastlines are undertaken using a helicopter that operates at a height of 150-250m and a distance of 300-500m offshore to ensure that seals are not disturbed from their haulout sites. The Sea Mammal Research Unit also currently uses a Piper Aztec PA-27 (http://www.gilesaviation.com/index.html) to undertake grey seal surveys. A hole in the floor of the plane allows the use of a specially mounted Linhof wide format aerial survey camera.

All haul out surveys are conducted within +/- 2hrs of the local low tide times occurring between approximately 12:00hrs and 19:00hrs.

13.1.2 Aerial survey equipment and other resources

The majority of harbour seal surveys are conducted using thermal imagery from a helicopter. Use of a thermal imaging camera enables seals, which appear as “hot spots”, to be detected against the relatively cool background of rocks or sand and provides the most efficient way of surveying large areas of coastline. Harbour seals are counted using the thermal imager (e.g. Barr and Stroud IR18) with a dual telescope (x2.5 and x9 magnification). Both the thermal image and a ‘real’ image (e.g. Canon MV3i digital video camcorder) are displayed continuously on a monitor, and simultaneously recorded to a digital video recorder.

13.1.3 Aerial survey personnel

Two trained field staff are required to conduct these harbour seal surveys (in addition to the pilot) one to operate the imager and one to record the sightings and take images.

13.1.4 Aerial survey data recording

Developed colour positive films are marked up using a light table to exclude overlap between frames and to prevent double counting of pups. The number of pups is counted on a frame by frame basis from the magnified images viewed under a microfiche. During surveys of breeding sites any new births are also recorded (indicated by the presence of placenta, often with gulls feeding) as well as any pups that are suckling from their mothers.

During surveys, in addition to the real-time digital video recording, the location, time, species and number of seals is recorded directly onto Ordnance Survey 1:50 000 maps. In addition, large groups of seals are photographed using a digital SLR camera with an image-stabilised 70-300mm zoom lens to enable more accurate counts to be made at a later time.

13.1.5 Survey effort

Seals are relatively wide ranging and therefore the extent of the area surveys will be informed by the availability of existing data on haul out location and connectivity. The maximum area covered in any one survey is likely to be constrained by the size of the area that can be covered within the time frame that precludes movement between haul out sites. This will vary depending on the location of alternative haul out sites but is likely to be within one or two days. The frequency of survey will depend on the precision required – surveys for impact monitoring will require a greater precision than surveys for characterisation. See, for example, Cunningham et al (2010.

13.1.6 Survey data analysis

Counts of seals from surveys provide a minimum estimate of population size. Timing of moult is dependent on age and sex class, but estimates indicate that between 50 and 70% of the population may be ashore at this time. SMRU are currently undertaking a telemetry study to estimate the percentage of population hauled out during the moult surveys. The percentage of seals hauled out will vary seasonally and regionally and between species but it may not be possible to correct for these variations (will be dependent on coverage of telemetry data for the area and season) so confidence intervals around estimates may be large. Repeat counts over multiple surveys will provide a mean estimate with associated variation in the number of seals using a haul out. Standardising the tidal and diurnal conditions will allow this variability to be minimised as much as possible.

13.2 Non-aerial (boat and land based) surveys of seals at haul outs

13.2.1 Survey design/site selection

Boat or land based counts are likely to be used where knowledge of seal distribution/abundance is required for relatively small, discrete local areas. Survey design will be highly dependent on the characteristics of the site(s), the size of any potential impact footprint and the objective of the monitoring. For example, survey design will vary in temporal resolution between a study which aims to provide minimum estimates of the number of seals using a particular haul out site at a particular time of year compared to a study which aims to characterise seasonal variation in the use of a haul out site.

Small boats provide access to coasts inaccessible over land, or where topography may preclude land-based counts. Counts from boats are made by direct observation usually with the aid of binoculars. Work from small boats is highly susceptible to poor weather conditions.

Land based surveys will be restricted to accessible areas. Land-based counts are usually made with the aid of a telescope. Weather is less of an issue than for boat based counts.

13.2.2 Resources

Surveys can be conducted from a small outboard powered boat (and associated safety equipment – life jackets etc) with appropriately qualified driver with experience of approaching and driving around seal haul outs. Observers will need binoculars (boat-based surveys) or telescopes (land-based surveys).

13.2.3 Protocol

The observation point for the haul out should be approached carefully to avoid disturbance of animals. Weather and tide states should be recorded. The number of individuals of each seal species should be counted, with sex or age class also recorded where possible. Seals in the water next to the haul out should be counted but a distinction made between these and animals hauled out. Counts should be constrained to 2 hours either side of low tide. Individuals with brands or flipper tags should also be noted along with any individuals showing signs of injury. Counts should be repeated at least three times during the visit to ensure they are accurate. For large or dispersed sites haul outs can be broken down into sub-units for counts to be undertaken separately before combining into single haul out counts.

13.2.4 Effort

The reason for the surveys will dictate the amount of effort required. For example, for site characterisation surveys it will be important to determine how abundance fluctuates seasonally and therefore monthly surveys would be recommended. If, however, the question relates to numbers of pups born at a particular site then weekly (if not more regular) counts would need to be made over a shorter period. An initial assessment of the variation in numbers of animals present at a haul out can be carried following a small number (5-10) of ‘trial’ counts, allowing the number of surveys required to be estimated.

13.3 Vantage Point (VP) Surveys

Vantage point surveys are particularly useful for assessing coastal site use by marine mammals. They are also useful when it comes to assessing device avoidance and barrier effects provided that comparable data have been collected during a baseline period. Vantage point surveys have been used at several marine renewable energy sites, for example Strangford Lough (Royal Haskoning, 2010a), EMEC (Mackenzie et al 2010) and Sound of Islay (Scottish Power Renewables, 2010).

13.3.1 Survey Design

To characterise and account for variation related to environmental variables such as tide and time of day, sampling should be stratified by the state of the tide and time of day. It must be possible for the observer to search the entire area using the necessary equipment from the designated vantage point (VP). The survey area is a hemispherical shape extending from the vantage point to offshore waters encompassing the whole of the tide/wave site.

In general, observations are carried out in Beaufort Sea State 3 or less so that the quality of the data is not compromised. Wind can sometimes be a problem for equipment stability too (e.g. theodolites/telescopes mounted on tripods) as can other weather conditions for observation e.g. heavy rain, fog. Observations will need to be carried out often enough so that there are enough replicates of each of the variables – tide, time of day etc. Employing comparable effort to pre- and post-consent monitoring is also important.

13.3.2 Site selection

The key factor in order to be able to carry out VP monitoring is access to a suitably elevated platform (usually a cliff or hilltop) overlooking the area which needs to be observed. The higher the vantage point the further the observers can see but there is a limit to how far seals can be seen. Hastie (2000) found that an area extending to 5km offshore was the sighting limit for a vantage point 90m above sea level. Detection probability dropped off beyond about 400m from a vantage point 10m above sea level at Strangford Lough. This methodology is only suitable for collecting data relating to nearshore/coastal developments. 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 when selecting a site to observe from. A sheltered site can be more comfortable for observers which will be beneficial in terms of maintaining concentration and enabling watches to be carried out over longer periods. In some situations it may be useful to construct a shelter/hide (with landowner permission).

13.3.3 Effort

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), and the variability in this over time, 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 effort must be sufficient to generate the required precision to give adequate power to detect changes. For example at Strangford Lough, survey effort of approximately 25-30 hours per month was calculated to be sufficient to pick up a change in harbour seal abundance of 50% with high probability (88%) after 1 month of monitoring. This is because harbour seals are sighted relatively frequently during these surveys. Similar survey effort however was not adequate for detecting a similar change in grey seal abundance – a 50% change in grey seal numbers would only have 12% chance of detection after 6 months of the same scheme. During a year-long monitoring programme at Billia Croo in Orkney, sightings rates of seals are relatively low (Mackenzie *et al*, 2010) and seals were seen on less than half of all survey days. Subsequently effort was required to be much higher, at almost 80 hours per month and the probability of detecting a 50% drop in relative abundance over 6 months of monitoring was 70%.

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.

13.3.4 Equipment and other resources

The basic equipment requirements are a set of binoculars or telescope. A 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. If device-specific interaction data are required, focal follows of an individual or group could be undertaken using a theodolite. An alternative to using a theodolite is video ranging equipment or the use of an inclinometer and binoculars with inbuilt compass. Data recording/entry should be done into paper forms or a dictaphone in the field and into an Access database, for example, once back in the lab. In some situations it may be possible to record direct to a database in the field.

13.3.5 Personnel

Observers carrying out VP monitoring should be experienced in marine mammal identification. 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.

13.3.6 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 daily watches will be possible during the summer 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 this will be 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 further 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 near 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 the telescope also. There should be a short rest period between scans to record data and take breaks thereby reducing observer fatigue.

A sighting is defined as an observation of a seal made during a scan. There may be occasions where seals 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 angles compared to the GPS locations.

13.3.7 Data recorded

Survey effort should be equally distributed over all states of tide and time of day. Care must be taken that survey effort is not always concentrated at certain times of day. Environmental data can influence the sightings data collected so it is important to record and account for as many relevant variables as possible. As environmental conditions can change rapidly, this data should be noted at the start of each scan (i.e. about every 15 minutes). Once weather conditions deteriorate (to over sea state 4, heavy rain, or thick fog) the watch should be abandoned. Start and end times of all watch periods must also be recorded.

The time of each sighting must be recorded together with key information on species, number and the positional information. Basic behavioural information can also be recorded for each sighting.

13.3.8 Data analysis

The data collected will comprise sightings, effort and environmental data. Vantage point survey data can be analysed to provide information on distribution and relative abundance of marine mammals in the study area. The data can also be analysed in conjunction with environmental, temporal, spatial and habitat variables (e.g. depth, tidal state) to look at relationships between these and animal distribution using a modelling approach (e.g. General Linear Models, General Additive Models and Mixed Models). This modelling framework can be easily adapted to incorporate information on installation and operation to detect change which may be attributable to impacts of devices.

Estimates of relative abundance can be improved by incorporating a correction for animals missed by the VP observers. How detectability changes with distance from the VP can be tested by carrying out a subset of surveys concurrently with boat based surveys along transect lines placed perpendicular to the coast or by carrying out double observer trials where the topography allows. 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. Accounting for differences in detectability would be essential to be certain about any changes in distribution occurring.

13.4 Line Transect Survey protocols

It is unlikely that line transect surveys would be carried out for seals alone, in practice surveys would be carried out for cetaceans and seals using exactly the same protocols. The protocol described below is identical tot that in the cetaceans volume.

13.5 Visual Boat-based surveys

13.5.1 Survey design

Achieving unbiased density estimates using distance sampling methods relies on a survey design that gives even coverage probability[10] 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.

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 should 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 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 sufficiently precise; more 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 section 7.4).

13.5.2 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 marine mammal observers at any one time. A cruising speed of 10 knots is optimal for marine mammal 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.

13.5.3 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

[10] 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)

sighting angle and should be marked in degree divisions. 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 may be needed if Logger is not being used. It is good practice to have a hand-held for back up anyway.

13.5.4 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 (two observers and 1 data recorder) 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.

13.5.5 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.

Each observer searches from 90 ^{o} abeam of the vessel to 10 ^{o} over the transect line (i.e. on the other observers side). This ensures good coverage of the transect line where all animals that are present are assumed to be detected (but see Section 8.4). 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.

13.5.6 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.

13.5.7 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. Density surfaces are also useful for site characterisation as they can highlight areas of particular importance for animals and can allow assessment of likely overlap between the development impact footprint and potentially allow for the quantification of the magnitude of impacts. This approach may also be useful for informing issues of project design.

13.6 Visual Aerial survey protocol

13.6.1 Survey design

Unlike shipboard surveys for marine mammals, aerial line transect surveys are almost always 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.

13.6.2 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 seabird surveys (i.e. 80m, Camphuysen *et al*. 2004).

13.6.3 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.

13.6.4 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.

13.6.5 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). 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.

13.6.6 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.

13.6.7 Data analysis

Analysis of visual line transect data collected during aerial surveys can be analysed in much the same way as data collected during ship-based surveys (see section 12.4.7).

13.7 Telemetry

Applying tags to wild animals requires those doing the work to hold a Home Office licence in accordance with the Animals (Scientific Procedures) Act 1986 (due to the animal capturing and handling involved). Any developers requiring the information which can be derived from telemetry studies to be carried out will therefore need to do so in partnership with a group which holds the relevant skills and Home Office Project Licence.

13.7.1 Survey design

Telemetry can be useful for measuring seal occurrence in, or use of, specific areas, as well as providing information on connectivity between designated areas and other areas. Telemetry can also help quantify transit rates through channels, the proportion of time spent within an area of interest or buffer zone around a specific site. Other metrics are also useful when comparing the behaviour of animals over time at the same site to inform impact monitoring (e.g. probability of hauling out, trip duration and extent in response to a development).

13.7.2 Data collection

Examples of commonly used telemetry devices can be found at http://www.smru.st-andrews.ac.uk/Instrumentation/pageset.aspx?psr=339 and http://www.wildlifecomputers.com/Products.aspx?ID=-1. Two main types, developed by SMRU, are used on seals in the UK – Satellite Relay Data Loggers (SRDLs) and GPS phone tags. Location information can be computed using the global Argos satellite system (SRDLs) or GPS (GPS phone tags) and relayed by the Argos system (SRDLs) or the GSM mobile phone network (GPS phone tags).

The longevity of SRDLs is typically one year, but this may be extended with software modifications, however deployments on seals are limited to a year as the tags fall off during the annual moult. GPS phone tags do not last this long but provide higher resolution spatial data than SRDLs do - GPS phone tags are usually programmed to attempt a location every 10-20 minutes (whereas only one location per day is provided by SRDLs). Detailed dive data are also collected by GPS phone tags. Although it depends on the purpose of the study, seals are often tagged after their annual moult (August for harbour seals, February/March for grey seals). GPS phone tags are likely to be the most appropriate choice for monitoring seals in relation to consenting and impact monitoring at marine renewable sites. This is because they generate higher resolution, more spatially accurate data and are more suited to measuring the fine scale movements of seals around renewable energy devices.

13.7.3 Protocols

Detailed protocols for tag deployment are not provided here due to the licensed nature of the work.

13.7.4 Effort

Seals are often tagged after their annual moult (August for harbour seals, February/March for grey seals) in order to maximise the length of possible data collection. Deciding when to deploy GPS phone tags will be more time-specific because these tags do not last for as long as the SRDLs (approximately a year).

In terms of the number of animals which need to be tagged in a deployment from a single site/area it should be noted that no matter how many animals are tagged, they will always be a sample of the population which is assumed to be representative. In general half a dozen or so tags should be deployed from a single site as a minimum. Inter-individual variation in behaviour is often high in telemetry studies and this may restrict the ability to detect change in metrics such as transit rate – for example the rates that individual seals transited past the SeaGen turbine in Strangford Lough varied from zero to over 8 times a day which meant that annual average transit rates had very wide confidence limits and would require a very large change to be detected from tag data (See Case Study). Males and females may behave differently (e.g. Thompson *et al.* 1998) so this should also be taken into account. In some areas/seasons it may be logistically very difficult to catch animals and it may not be possible to deploy the full complement of tags.

13.7.5 Data analysis

Currently at SMRU standard approaches are undertaken for analysis of the track data collected from the GPS/GSM tags. The tracks of each individual are split into trips. A trip begins when the seal is greater than 1 km from its departure haulout site for at least an hour. It finishes when the seal next hauls out. Trips are indexed by the haulout site of departure. Hourly tidal phases (0 High Water, 90 Ebb, 180 Low Water, 270 Flood and 360 High Water) are calculated from tidal heights at the closest secondary tidal ports.

This processing provides the basic information to:

- Estimate passage transits and activity levels in the vicinity of a structure
- Examine haulout behaviour (to calibrate haulout counts for use in local population estimates)
- Assess linkage between areas where the impact is focussed and haulout sites used by animals before/after visiting these impact areas. This indicates which haulouts are likely to be most affected by a change in seal usage at a given impact area.
- Assess haulout fidelity and network transition rates. These indicate the required geographical extent of haulout counts.

13.7.6 At-sea usage estimation

Usage maps can be constructed from telemetry data and haul out counts to describe the relative at-sea distribution of a population of seals departing from a haulout site or group of haulout sites. The current usage estimation method used by SMRU is based on a case-control development of Matthiopoulos *et al*.'s (2004) technique. The method constructs haulout-specific usage maps by averaging individual usage. The maps are then scaled by the number of individuals counted at each site and combined into an aggregate map of usage – these give an indication of the predicted density at sea and can assist in the process of assessing and quantifying likely impacts by highlighting areas of particular importance for seals. Currently software development is underway at SMRU to incorporate habitat variables in this modelling to improve predictions. Unfortunately, at-sea usage patterns cannot easily be statistically compared between years/tag deployments due to problems of serial correlation in the data. Instead, the year can be modelled as a binomial variable using a generalized additive model (GAM). This approach to usage mapping is still under refinement and its power to detect change is being evaluated.

13.8 Photo-ID

13.8.1 Survey design

Photo-ID is potentially useful for assessing connectivity between haul out sites and the extent of site fidelity of seals using an area. The main objective will be to devote sufficient effort in order to survey as many individuals as possible. The survey targets specific seal haul-outs where individuals are concentrated and photographs can be taken. Visits to haul-out sites will be undertaken either side of high tide when animals are more likely to be hauled out.

13.8.2 Site selection

Photo-ID can be carried out in most haul-out areas but they must able to be approached relatively closely, by boat or by land without disturbing seals away from the haul out.

13.8.3 Equipment required: Land-based methods

In general, seal photo-ID is undertaken from land. If sites are not accessible by land, then a small boat may be needed. A tripod and suitable combined telescope/camera system (e.g. Mackey *et al*. 2008) are required as are all the usual datasheets and note-taking materials.

13.8.4 Personnel

- A skilled, experienced person is required to take the photo-ID images.
- If working on an SAC population, at least one person undertaking the survey will need to be named on an Animal Scientific Licence granted by SNH.

13.8.5 Protocol

- A suitable site close enough to where the animals occur will need to be found – the range is likely to be 10m-200m depending on the camera equipment being used, visibility and availability of a suitable observation site or hide. It is important to fill the frame with the image to get as good quality shots as possible.
- Photograph the head/neck (sometimes whole body shots are used too) making sure that the whole of the relevant part of the animal is in the picture. Only high quality images will be useful for some analyses.

13.8.6 Effort/frequency of survey

In order to generate enough sightings and resightings of animals, visits to haul out sites will need to be relatively frequent. Depending on the numbers of seals using a haul out site, monthly haul out visits may suffice if sampling the population to assess whether individuals use/continue to use a particular haulout site during/between years.

13.8.7 Data analysis

- Download images and make a back-up copy.
- Grade the images for quality (see Thompson *et al*. 2006 for a good example of image quality grading criteria used for bottlenose dolphins).
- Match animals to those from catalogues of previously photographed individuals from the relevant geographical areas, if they exist. An experienced person is required for this task and matches should be independently verified by a second skilled person. An alternative to this is to use an automated matching system e.g. that developed and described by Hiby and Lovell 1990. Automated matching if often used where patterns are complicated or the number of potential animals is large. It reduces the number is images which need to be examined by eye.
- If working at a new site, a catalogue will need to be built up from scratch. Bear in mind that animals identified at a new site may have previously been seen at other sites and already be present in existing catalogues.
- Enter information in a well designed database from which it can easily be extracted in a suitable format e.g. as a capture matrix.

13.9 Stranding surveys and carcass recovery

13.9.1 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. Local knowledge may be useful in identifying likely areas where stranded animals are likely to be found; in fact local stranding networks and schemes may already be in place for the area and these are valuable sources of data. Information on current and tidal patterns in the area will also help identify the appropriate search area. 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, whilst predictive models based on local currents and tides may identify areas with a greater probability of strandings. The perceived risk in terms of the number of renewable devices in the area, will also influence the sampling frequency. Sites with many devices in proximity (e.g. within 50 km) of a haulout 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.

13.9.2 Equipment and resources

Predesigned data sheets and clipboard will be used for recording data. 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.

13.9.3 Personnel

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. In Scotland, Bob Reid of the Scottish Agricultural College generally carries out necropsies of stranded marine mammals[11].

13.9.4 Procedure

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 SAC vet.

As many carcasses as possible, with obvious signs of injury (that may or may not have been caused by wet renewable devices) 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. of blubber for ancillary analyses. This will be useful in highlighting any seals found with spiral injuries and ensure the correct reporting of these.

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.

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

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.

13.9.5 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.

13.9.6 Data Analysis

In the context of impact monitoring, the key information to discern is the cause of death and whether it can be attributed to any impact related to the renewable energy development activities.

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14.1 Websites

SCOS (http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=411).

Annual SMRU advice to SCOS (Special Committee on Seals): http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=411

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SMRU Ltd, 2010 http://www.snh.org.uk/pdfs/publications/commissioned_reports/441.pdf

SNH sitelink website – source of information about seal populations at designated sites: http://gateway.snh.gov.uk/portal/page?_pageid=53,910284,53_920288&_dad=portal&_schema=PORTAL

Marine Spatial Plans and Regional Locational Guidance where available may have information on seal populations in specific areas e.g. http://www.scotland.gov.uk/Resource/Doc/295194/0105824.pdf and 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/

Piper Aztec PA-27 (http://www.gilesaviation.com/index.html

Examples of Telemetry devices can be found at http://www.smru.st-andrews.ac.uk/Instrumentation/pageset.aspx?psr=339 and http://www.wildlifecomputers.com/Products.aspx?ID=-1

http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365

Further information on the estimation and modelling processes used by SCOS is available from http://www.smru.st-and.ac.uk/documents/341.pdf

For more details on the methods used to survey harbour seals, please refer to Duck & Thompson, 2009, available from http://www.smru.st-and.ac.uk/documents/341.pdf .

http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365

http://www.smru.st-and.ac.uk/documents/366.pdf

http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html

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