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

**Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland**
**Volume 5: Benthic Habitats**

This report was produced by **Graham Saunders Marine Ecology** 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 benthic habitats and species 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 3. Seals
- Vol 4. Birds

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 5), the appropriate citation is: **Saunders, G., Bedford, G.S., Trendall, J.R., and Sotheran, I. (2011).** ***Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 5. Benthic Habitats*****. Unpublished draft report to Scottish Natural Heritage and Marine Scotland**.

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CONSULTATION DRAFT

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

## Vol 5. Benthic Habitats.



*This draft report should be quoted as:*
Saunders, G., Bedford, G.S., Trendall, J.R., and Sotheran, I. (2011). *Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 5. Benthic Habitats*. Unpublished draft report to Scottish Natural Heritage and Marine Scotland.

**Selected Acronyms**

| | |
|---|---|
| AA | Appropriate Assessment |
| AGDS | Acoustic ground discrimination systems |
| ANOSIM | Analysis of similarities |
| ANOVA | Analysis of Variance |
| BAP | Biodiversity Action Plan |
| BACI | Before After Control Impact |
| BAG | Before After Gradient |
| CCW | Countryside Council for Wales |
| CEFAS | Centre for Environment, Fisheries & Aquaculture Science |
| CPA | Coast Protection Act |
| DECC | Department of Energy and Climate Change |
| EIA | Environmental Impact Assessment |
| FEPA | Food and Environment Protection Act |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| IM | Impact Monitoring |
| JNCC | Joint Nature Conservation Committee |
| Marlin | Marine Life Information Network |
| MDS | Multi dimensional scaling |
| MESH | Mapping European Seabed Habitats |
| NBN | National Biodiversity Network |
| PCA | Principle Components Analysis |
| PRIMER | Plymouth Routines In Multivariate Ecological Research |
| PSA | Particle Size Analysis |
| ROV | Remotely Operated Vehicle |
| SAC | Special Area of Conservation |
| SCUBA | Self Contained Underwater Breathing Apparatus |
| SEA | Strategic Environmental Assessment |
| SIMPER | Similarity Percentages |
| SNH | Scottish Natural Heritage |
| SSSI | Site of Special Scientific Interest |
| UKBAP | United Kingdom Biodiversity Action Plan |

**Table of Contents** **Page**

**List of Figures** **Page**



**List of Tables** **Page**

# 1 INTRODUCTION

This Volume discusses benthic species and habitats of potential concern when considering potential impacts of wave and tidal devices in Scotland and addresses survey and monitoring guidance methodology and protocols in relation to these. SNH has proposed a number of priority marine features of conservation importance in Scotland, upon which this guidance focuses when considering monitoring protocols to detect potential impacts of wave and tidal devices in Scotland. In addition, Annex I Habitats designated under Natura 2000 have been considered for their international importance, and BAP habitats and species, and SSSI intertidal habitats are considered for their national importance.

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

This Volume will also be relevant to Volumes II (Cetaceans and basking sharks), III (Seals) and IV (Birds) of this guidance, where an understanding of the benthic environment is important for identifying areas of rich feeding grounds for the top predators.

# 2 IDENTIFICATION OF KEY SPECIES AND HABITATS

## 2.1 SNH Priority marine features

In the waters around Scotland, a wide range of benthic habitats and species are present. Scottish Natural Heritage has identified several as priority marine features in Scottish waters[1] of which nine habitats and eight species are considered, herein, to have the potential to be impacted by the deployment of wave and tidal devices due to their proximity to potential development sites. Priority habitats and species are presented in Tables 2.1 and 2.2 respectively, and discussed below.



[1] http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/priority-marine-features/

### Table 2.1. Priority habitats identified by Scottish Natural Heritage

| Priority feature name | Specific important biotopes and species included within this (common name) | Specific Important biotopes and species included within this (scientific/biotope name) |
|---|---|---|
| Blue mussel beds | *Mytilus edulis* beds on sublittoral sediment | SS.SBR.SMus.MytSS |
| | Intertidal *Mytilus edulis* beds on mixed and sandy sediments | LS.LBR.LMus.Myt |
| | *Mytilus edulis* and *Fabricia sabella* in littoral mixed sediment | LS.LSa.St.MytFab |
| Coldwater coral reefs | *Lophelia* reefs | SS.SBR.Crl.Lop |
| Flame shell beds | *Limaria hians* beds in tide-swept sublittoral muddy mixed sediment | SS.SMx.IMx.Lim |
| Horse mussel beds | *Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata | SS.SBR.SMus.ModCvar |
| | *Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata | SS.SBR.SMus.ModHAs |
| | *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata | SS.SBR.SMus.ModT |
| Kelp and seaweed communities on sublittoral sediment | Kelp and seaweed communities on sublittoral sediment | SS.SMp.KSwSS |
| Maerl beds | Maerl beds | SS.SMp.Mrl |
| Maerl or coarse shell gravel with burrowing sea cucumbers | *Neopentadactyla mixta* in circalittoral shell gravel or coarse sand | SS.SCS.CCS.Nmix |
| Northern seafan communities | *Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock | CR.MCR.EcCr.CarSwi |
| | Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tide-swept circalittoral rock | CR.HCR.XFa.SwiLgAs |
| | Northern sea fan | *Swiftia pallida* |
| Tide-swept algal communities | Fucoids in tide-swept conditions | LR.HLR.FT |
| | *Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment | IR.HIR.KSed.XKHal |
| | Kelp and seaweed communities in tide-swept sheltered conditions | IR.MIR.KT |
| | *Laminaria hyperborea* on tide-swept, infralittoral mixed substrata. | IR.MIR.KR.LhypTX |

### Table 2.2: Priority Species identified by Scottish Natural Heritage

| Species |
|---|
| A tube anemone *Arachnanthus sarsi* |
| Pink soft coral/ pink sea fingers *Alcyonium hibernicum* |
| White cluster anemone (*Parazoanthus anguicomus* |
| Crayfish, crawfish, spiny lobster *Palinurus elephas* |
| A feather star *Leptometra celtica* |
| Iceland cyprine *Arctica islandica* |
| Fan mussel *Atrina pectinata* |
| Heart cockle *Glossus humanus* |

### 2.1.1 Blue mussel *Mytilus edulis* beds

*Mytilus edulis* is highly intolerant to substratum loss, however recoverability is high (depending on successful recruitment events). Intermediate intolerance to smothering is predicted as it is believed that a proportion, particularly young mussels, are able to avoid smothering while others may be suffocated and starve. As with habitat loss, recoverability from smothering is high. *M. edulis* has low intolerance to changes in suspended sediment, as well as decreased flow rate and wave exposure. *M. edulis* beds are found in moderately strong to weak tidal streams where potential reductions in water flow may result in increased sedimentation and reduced food supply. Intermediate intolerance to physical disturbance is expected with high recoverability (MARLIN, 2008).

### 2.1.2 Coldwater coral *Lophelia pertusa* reefs

This is a deep water habitat and is not generally expected within the environments suitable for the wave and tidal devices considered within the scope of this guidance. However, *Lophelia* reefs occur as shallow as 50m in Norwegian fjords and so can not be fully ruled out although they are expected to be in depths greater than 70m around Scotland. Substratum loss within a *Lophelia* reef would cause destruction of the reef and recoverability is low due to their slow growth rate (1.2mm per year, Fosså *et al.,* 2002), potentially several hundreds to thousands of years. *Lophelia* is expected to have high intolerance to substratum loss (as with most coral species) and low intolerance to smothering and changes in suspended sediment. The cold water coral is predicted to have intermediate intolerance to decreased flow rate but to be tolerant to decreased wave exposure (Tyler-Walters, 2008a).

### 2.1.3 Flame shell *Limaria hians* beds

*Limaria hians* beds are often found on mixed muddy gravel and sand substrates in the tide swept narrows of sea loch entrances but have also been found in coastal locations with suitable tidal flow and substrate. The beds are difficult to distinguish as they are usually overgrown or overlain by other benthic species and the individuals are hidden within debris ‘nests’ created by aggregating seabed material with their byssal threads. Establishment of the presence of *L. hians* beds usually requires a close examination of the consistency of the seabed substrata and a lifting of a visibly loose surface layer, which may extend to approximately 5cm depth. *L. hians* has been found from low water to around 100m depth. Substratum loss within areas of flame shell beds will cause the removal of the ‘nest’ and the species will have high intolerance to this, with low recoverability (depending on recruitment from the surrounding area). Intermediate intolerance to smothering is predicted due to the species ability to swim and move away from unfavourable conditions, however a layer of around 5cm of silt would be expected to reduce the flow of water through the bed required for food and oxygen. Intolerance is intermediate to decreased water flow rate and tolerant to decreases in wave exposure. (Tyler-Walters, 2008b).

### 2.1.4 Horse mussel *Modiolus modiolus* beds

*Modiolus* beds are usually found on mixed substrates in moderately strong currents, generally on open coasts but also in tide swept channels. Loss of substrate within *Modiolus* beds would cause destruction to the bed and so intolerance is high. An intermediate intolerance to smothering is predicted due to the requirement for water flow through the bed for food and to remove wastes. Intermediate intolerance to decreased water flow rate is also predicted, although the horse mussel bed is considered tolerant to decreased wave exposure (Tyler-Walters, 2008c).

### 2.1.5 Kelp and seaweed communities on sublittoral sediment

Found on shallow sublittoral sediment and mixed substrata in sheltered areas this habitat primarily includes *Saccharina latissima* and *Chorda filum*. Substratum loss would remove the seaweeds resulting in a high intolerance, however re-colonisation would also occur rapidly on any hard substratum that becomes available. Smothering will block light penetration and cause physical damage and rotting of *S. latissima* resulting in high intolerance. The impact of smothering on *C. filum* would depend on the life cycle stage during which the smothering occurs, resulting in intermediate intolerance. Due to the preference for sheltered environments this habitat is not expected to be affected by decreased wave exposure or current flow. Physical disturbance is expected to cause intermediate intolerance. The species associated with this habitat can live in areas of high turbidity and so are expected to be tolerant (or have low intolerance) to increased suspended sediments despite the reduction in light penetration which may cause a reduction in growth rate (White, 2006; White and Marshall 2007).

### 2.1.6 Maerl beds

Maerl species, including *Lithothamnion coralloides*, *L. glaciale* and *Phymatolithon calcareum* are found in coarse clean sand and gravel on the open coast or in tide swept channels of marine inlets. Substratum loss would cause removal of the maerl beds which are unlikely to re-establish if fully removed. The maerl life span is around 20 to 100 years but a maerl bed can be thousands of years old, often consisting of many layers of older, dead maerl, laid down over many years, lying below a thinner living surface layer. Smothering would cause a loss of light penetration to which maerl is highly intolerant. Due to the very slow growth rate of maerl species they are also expected to be highly intolerant to physical disturbance. No direct effect is expected from decreased wave and current flow rate, to which maerl should not be sensitive. However if this results in increased siltation the maerl beds will suffer (Jackson 2003; 2007a; 2007b; 2008a and 2008b). Maerl beds provide a suitable habitat for diverse flora and fauna. A change in the wave or current regime could potentially have a significant effect on the species associated with this biotope. Change in water flow, smothering or substratum loss would cause a major decline in the species richness of maerl beds (Jackson, 2008a)

### 2.1.7 Maerl or coarse shell gravel with burrowing sea cucumbers *Neopentadactyla mixta*.

*Neopentadactyla mixta* living in circalittoral gravel is found predominantly on the west coast of Scotland. The cucumber is highly intolerant to substratum loss. Suspended sediments interfere with the feeding strategy of *N. mixta*. However, the species is predicted to have high tolerance to smothering due to the species' ability to move itself up to the surface of the sediment, above the initial smothering layer. Given sufficient oxygen, this species can tolerate large periods without feeding (Jackson 2008c).

### 2.1.8 Northern sea fan *Swiftia pallida* communities

Generally found on circalittoral bedrock. The community has high intolerance to substratum loss and smothering, intermediate intolerance to decreased water flow rate and is tolerant to wave exposure. (Durkin, 2008). While micro-siting should ensure no devices will be placed on this habitat, vessel anchors and chains could cause physical disturbance to sea fans on vertical rock.

### 2.1.9 Tide swept algal communities

Found on wave exposed to wave sheltered hard substratum with strong tidal currents. The community has high intolerance to substratum loss but is tolerant to smothering due to the tide-swept nature of the habitat allowing the rapid removal of sediments. The community has intermediate intolerance to decreased water flow rate because the community structure would change. Where this habitat occurs in sheltered areas, a decrease in wave exposure will be of little significance (Tyler-Walters, 2008d).

### 2.1.10 A tube anemone Arachnanthus sarsi

A tube dwelling anemone, found in sand and mud at 10m to 36m depth. Current records include the west coast of mainland Scotland and the Hebrides. This species has high intolerance to substratum loss, however it also has very high recoverability. The species has low intolerance to smothering and intermediate intolerance to decreased flow rate. The anemone is tolerant to decreased wave exposure (Wilson and Wilding, 2009).

### 2.1.11 Pink soft coral/ pink sea fingers *Alcyonium hibernicum*

Found on vertical or overhanging rock between 1m to 30m with at least moderate water movement and shelter from wave action. No assessment of sensitivity is available for this species. However, it is expected to be intolerant to substratum loss and physical disturbance and, due to the rare nature of the species, it could be expected that recolonisation would be limited and bare spaces could be recolonised by other species such as *Alcyonium digitatum*. Increased smothering and suspended sediments, and decreased water flow rate and wave exposure may interfere with the food supply for the filter feeding polyps. While no devices will be placed on this habitat, vessel anchors and chains could cause physical disturbance to pink soft coral on vertical rock.

### 2.1.12 White cluster anemone Parazoanthus anguicomus

This colonial anemone is found in western and northern Scotland, generally in deep water (up to at least 400m) but also in shallow coastal waters (Wilson, 2008). It can be found encrusting on sponges, corals and hard substratum such as rocks or wrecks, and favours vertical/near vertical or overhanging rocks and other dark places such as caves. While no devices will be placed on this habitat, vessel anchors and chains could cause physical disturbance to the areas colonised by the anemone on vertical rock.

### *2.1.13* Crayfish, crawfish, spiny lobster *Palinurus elephas*

*Palinurus elephas* lives on exposed circalittoral rocky reef habitats within crevices and gullies, at depths of around 5m to 70m. This is a highly tolerant species and due to its mobility it is expected to be displaced by most impacts. *P. elephas* has a hard exoskeleton and so most physical disturbance is not expected to cause death, although some physical harm may occur. The intolerance has therefore been estimated as low (Jackson *et al*. 2009).

### 2.1.14 A feather star Leptometra celtica

The majority of the records for this species are from sealochs and sheltered habitats, however *Leptometra celtica* has also been recorded by ROV in The Minch and other more exposed locations. The feather star generally lives on shell gravel but can be found on a variety of sediment types, from around 40m to over 1000m depth. No assessment of sensitivity is available for this species. However, given its slightly mobile characteristics, ability to live as dense populations and filter feeding strategy it is expected to have similar sensitivities to the brittlestar *Ophiothrix fragilis*, including high sensitivity to substratum loss and smothering. However, recoverability from these impacts would also be high. Some degree of water movement is required for filter feeding but the level of change to currents caused by tidal devices is not expected to be significant to this species. This species is expected to be tolerant of a wide range of wave exposures.

### 2.1.15 Iceland cyprine Arctica islandica

Found predominantly on sublittoral firm sediments including level offshore areas and living infaunally in the sediment, *A. islandica* uses a short siphon for feeding and respiration. Smothering will limit feeding and cause the species to respire anaerobically. Recovery is predicted to be moderate and intolerance intermediate. The mollusc is highly intolerant to substratum loss with low recoverability. A low level of intolerance is expected following a decrease in water flow rate and tolerance for decrease in wave exposure (Sabatini and Pizzolla, 2008).

### 2.1.16 Fan mussel Atrina pectinata

Mostly recorded in west and northern Scotland in lower intertidal and subtidal mud, sandy mud and gravel. A number of records of this species are deemed to be out of date as some date back to mid 1900s and even 1800s and the distribution is believed to have declined significantly, potentially due to fishing activities using mobile gear. However, recent records from 2005 show the species in Loch Duich, on the west coast of Scotland and, more recently, in 2008, by Marine Scotland in the Sound of Canna (http://data.nbn.org.uk/). The fan mussel was also recorded in the Eynhallow Sound, Orkney in 1999. *Atrina pectinata* lives embedded in the sediment and so substratum loss is predicted to cause a very high intolerance with very low recoverability. Adults protrude part of themselves out of the sediment thereby reducing the impact of smothering; however juveniles are expected to be smothered. The recoverability is likely to be low and so the overall sensitivity has been assessed as high. The fragile shell is easily damaged by physical disturbance and the recoverability is very low, resulting in a very high intolerance. This mollusc is known to occur in weak to moderate currents and sheltered areas and so impacts may be limited to downstream effects (Tyler-Walters and Wilding, 2009).

#### 2.1.17 Heart cockle *Glossus humanus*

*Glossus humanus* is found in soft sediments (sand, sandy mud and mud) in deep waters with limited or no disturbance of the bottom sediments (Owen, 1953) and is therefore expected to be of limited significance to the scope of this study. Known records of this species are on the west coast of Scotland in Loch Linnhe/ Loch Eil, east and west Skye, south east Lewis and Loch Ewe. These records were all made between 1989 and 1995 (http://data.nbn.org.uk/). *Glossus humanus* is a suspension feeder and so could be expected to be sensitive to smothering and increased suspended sediments. The species is extremely sensitive to any form of vibration. The shell is thin and can be extremely fragile, particularly in smaller specimens (Owen, 1953).

## 2.2 Annex I habitats

Benthic habitats and species are protected under both UK European legislation, and this is further discussed in Volume I, Section 2. Under the Habitats Directive, several SAC Annex I habitats listed incorporate marine benthic habitats. Further information on these features is available from http://jncc.defra.gov.uk/ .

Any development proposed within SACs will need to demonstrate that no associated impact has affected the site integrity of any Annex I habitats. This may depend on several factors, including the size of the designated feature, the magnitude of the potential effect on the designated feature, and the longevity of the effect. Some of this information may be provided by the existing monitoring data for the feature.

Several Annex I features are not likely to be impacted by wave or tidal energy developments due to their locations, and are not considered further. These are estuaries, lagoons, leaking gas structures and mud and sandflat not covered by water at low tide.

The following Annex 1 habitats are designated features for SACs which may potentially be impacted by the deployment of wave or tidal devices in Scotland. SACs designated for these habitats are identified in Section 2.6.

### 2.2.1 Sandbanks which are slightly covered by sea water all the time

Sandbanks which are slightly covered by sea water all the time consist of sandy sediments that are permanently covered by shallow sea water, typically at depths of less than 20m below chart datum (but sometimes including channels or other areas greater than 20m deep). These may be affected by the deployment of tethered or anchored wave devices as a result of changes to wave climate influencing sediment processes. The habitat comprises distinct banks (i.e. elongated, rounded or irregular 'mound' shapes) which may arise from horizontal or sloping plains of sandy sediment. Where the areas of horizontal or sloping sandy habitat are closely associated with the banks, they are included within the Annex I type.

Shallow sandy sediments are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms. Mobile epifauna at the surface of the sandbank may include shrimps, gastropod molluscs, crabs and fish. Sand-eels, *Ammodytes* spp., an important food for birds, live in sandy sediments. Where coarse stable material, such as shells, stones or maerl, is present on the sediment surface, species of foliose seaweeds, hydroids, bryozoans and ascidians may form distinctive communities.

### 2.2.2 Reefs

Reefs are rocky marine habitats or biological concretions that rise from the seabed. They are generally subtidal but may extend as an unbroken transition into the intertidal zone. Intertidal areas are only included within this Annex I type where they are connected to subtidal reefs.

Two main types of reef can be recognised: those where animal and plant communities develop on rock or stable boulders and cobbles, and those where structure is created by the animals themselves (biogenic reefs).

The greatest variety of communities is typically found where coastal topography is highly varied, with a wide range of exposures to wave action and tidal streams. Exposure to wave action has a major effect on community structure, with extremely exposed habitats dominated by a robust turf of sponges, anemones and foliose red seaweed. The presence of enhanced tidal streams often significantly increases species diversity. The strength of tidal streams varies considerably and can be very strong, with 8-10knots (4-5ms$^{-1}$) or more through tidal rapids or in sounds.

In contrast to the variety of rocky reefs, there is somewhat less variation in biogenic reefs, but the associated communities can vary according to local conditions of water movement, salinity, depth and turbidity. The main species which form biogenic reefs in Scotland are blue mussels *Mytilus edulis*, horse mussels *Modiolus modiolus*, ross worms *Sabellaria* spp., the serpulid worm *Serpula vermicularis*, and cold-water corals such as *Lophelia pertusa*.

#### 2.2.3 Large shallow inlets and bays

Large indentations of the coast, generally more sheltered from wave action than the open coast. They are relatively shallow (with water less than 30m over most of the area), and in contrast to estuaries, generally have much lower freshwater influence.

Large shallow inlets and bays vary widely in habitat and species diversity according to their geographic location, size, shape, form and geology. The degree of wave exposure can also vary considerably and the range of plants and animals associated with this habitat type is wide. Larger sites tend to encompass the greatest variety of constituent habitats and have the greatest potential for maintenance of ecosystem integrity.

In the sublittoral zone, more exposed rocky coasts support forests of kelp *Laminaria hyperborea.* Communities of ephemeral algae and maerl (including *Phymatolithon calcareum*, *Lithothamnion corallioides and Lithothamnion glaciale*) may be present on wave-exposed or tide-swept coasts.

A particular feature of rias and fjards is the presence of sublittoral rock in conditions of strong tidal flow but negligible or no wave action. Particular growth forms of sponges and ascidians, as well as specific biotopes, occur in these unusual conditions.

## 2.3 SSSI Habitats

The UK has also identified a series of important benthic ecological sites under the Wildlife and Countryside Act 1981, under which Sites of Special Scientific Interest (SSSIs) are designated. SSSIs are exclusively intertidal and are only considered relevant here to seabed mounted oscillating wave energy convertors, where SSSI reef features could be vulnerable to changes in wave climate.

## 2.4 UK Biodiversity Action Plan habitats and species

UKBAP priority habitats and species do not have any legal site status, but, whilst SAC designation is not dependent on the presence of specific UKBAP habitats, examples of these habitats may be found within SAC or SSSI sites (Faber Maunsell and METOC 2007) and they are included in SNH's list of priority habitats and species, which are outlined in Section 2.1 UKBAP habitats and species may be one of the features used to identify potential Marine Protected Areas under the Marine (Scotland) Act, 2010.

Ten habitats and 10 species are identified herein which have the potential to interact with wave and tidal devices in Scottish waters (Table 2.3). Further information on them is available from the UK BAP website (http://www.ukbap.org.uk ).

## 2.5 Summary of relevant protected or priority benthic habitats and species

Table 2.3 lists benthic habitats and species which may be affected by either wave or tidal energy developments and identifies the importance afforded to each feature (as an SNH priority, a UK BAP priority or an Annex 1 feature). In addition, an appraisal of the potential risk of interaction has been estimated, considering the following:

1. Sensitivity (based on tolerance and recoverability, sourced from, and further details available at http://www.marlin.ac.uk );

2. Vulnerability (the likelihood of the species encountering an effect, based on maps of species/ habitat descriptions sourced from http://www.marlin.ac.uk ); and

3. Risk of effect occurring (sensitivity against vulnerability).

This table provides an overview risk and identifies features of highest potential sensitivity, however, each effect is dependant of factors including location and device characteristics, and **must** be assessed on a site specific basis. It should also be noted that where a risk is identified as high, appropriate mitigation and monitoring techniques can be used to mitigate potential effects.

**Table 2.3 Relevant protected or priority habitats and species, their designations, sensitivity and vulnerability, and the risk of effect to each (ranked as High, Medium and Low)**

| | | Listed under | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | EIA legislation | | | EIA and Natura 2000 legislation | | | |
| | | SNH priority | SSSI (intertidal) | UK BAP | Annex 1 | Sensitivity (tolerance and recoverability) | Vulnerability (Likelihood of encounterment) | Risk of effect |
| Species | *Alcyonium hibernicum* | ✓ | □ | | | H | L | M |
| | *Atrina pectinata* | ✓ | □ | | | H | L | M |
| | *Glossus humanus* | ✓ | □ | | | H | L | L |
| | *Arachnanthus sarsi* | ✓ | □ | ✓ | | M | L | L |
| | *Palinurus elephas* | ✓ | □ | ✓ | | L | H | M |
| | *Leptometra celtica* | ✓ | □ | | | L | M | L |
| | *Parazoanthus anguicomus* | ✓ | □ | | | M | M | M |
| | *Arctica islandica* | ✓ | □ | | | M | M | M |
| | *Lithothamnion corallioides* | habitat | | ✓ | | H | H | H |
| | *Phymatolithon calcareum* | habitat | | ✓ | | H | H | H |
| | *Edwardsia timida* | | | ✓ | | H | M | M |
| | *Atrina fragilis* | | | ✓ | | H | H | H |
| | *Dermocorynus montagnei* | | | ✓ | | M | L | L |
| | *Fucus distichus* | | | ✓ | | M | M | M |
| | *Amphianthus dohrnii* | | | ✓ | | M | L | M |
| | *Swiftia pallida* | habitat | | ✓ | | M | M | M |
| habitat | Blue mussel (*Mytilus edulis*) beds | ✓ | □ | ✓ | reef | L | M | M |
| | Coldwater coral reefs (*Lophelia* reefs) | ✓ | □ | ✓ | reef | H | L | M |
| | Horse mussel (*Modiolus modiolus*) beds | ✓ | □ | ✓ | reef | H | M | H |
| | Maerl beds | ✓ | □ | ✓ | | H | H | H |
| | Maerl or coarse shell gravel with burrowing sea cucumbers (*Neopentadactyla mixta*). | ✓ | □ | | | H | M | H |
| | Flame shell (*Limaria hians*) beds | ✓ | □ | ✓ | | M | H | M |
| | Kelp and seaweed communities on sublittoral sediment | ✓ | □ | | | M | L | L |
| | Northern sea fan communities | ✓ | □ | | | M | M | M |
| | Tide swept algal communities / Tidal rapids /Tide swept channels | ✓ | □ | ✓ | | M | L | L |
| | *Sabellaria spinulosa* reefs | | | ✓ | reef | L | H | M |
| | *Sabellaria alveolata* reefs | | | ✓ | reef | L | L | L |
| | Sublittoral sands and gravels | | | ✓ | Sandbanks / LSI&B | L | H | M |
| | Fragile sponge and anthozoan communities on subtidal rocky habitats | | | ✓ | reef | M | H | H |
| | reefs (rock or biogenic) | | ✓ | | ✓ | H | H | H |

| | | Listed under | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | EIA legislation | | | EIA and Natura 2000 legislation | | | |
| | | SNH priority | SSSI (intertidal) | UK BAP | Annex 1 | Sensitivity (tolerance and recoverability) | Vulnerability (Likelihood of encounterment) | Risk of effect |
| | Sandbanks slightly covered by seawater at all times | | | | ✓ | M | M | M |
| | large shallow inlets and bays | | | | ✓ | M | M | M |

## 2.6 Areas of Known Importance

Table 2.4 details the areas identified as key sites of importance for marine benthic ecology in the study area (Faber Maunsell and METOC 2007). They have been identified based on their designated status, or whether they are specifically named in the UKBAP for the relevant priority habitat. However, important habitat types will certainly exist outside of these key areas, and the benthic ecology will need to be assessed in more detail on a project specific level for specific developments. Designated sites should be researched for each potential development, to capture any recently designated or candidate areas. Current information is available from the JNCC[2] and SNH[3] websites. Further information on benthic habitats (and other interests) within areas of wave and tidal power resource in Scotland is contained in Government's Regional Locational Guidance[4].



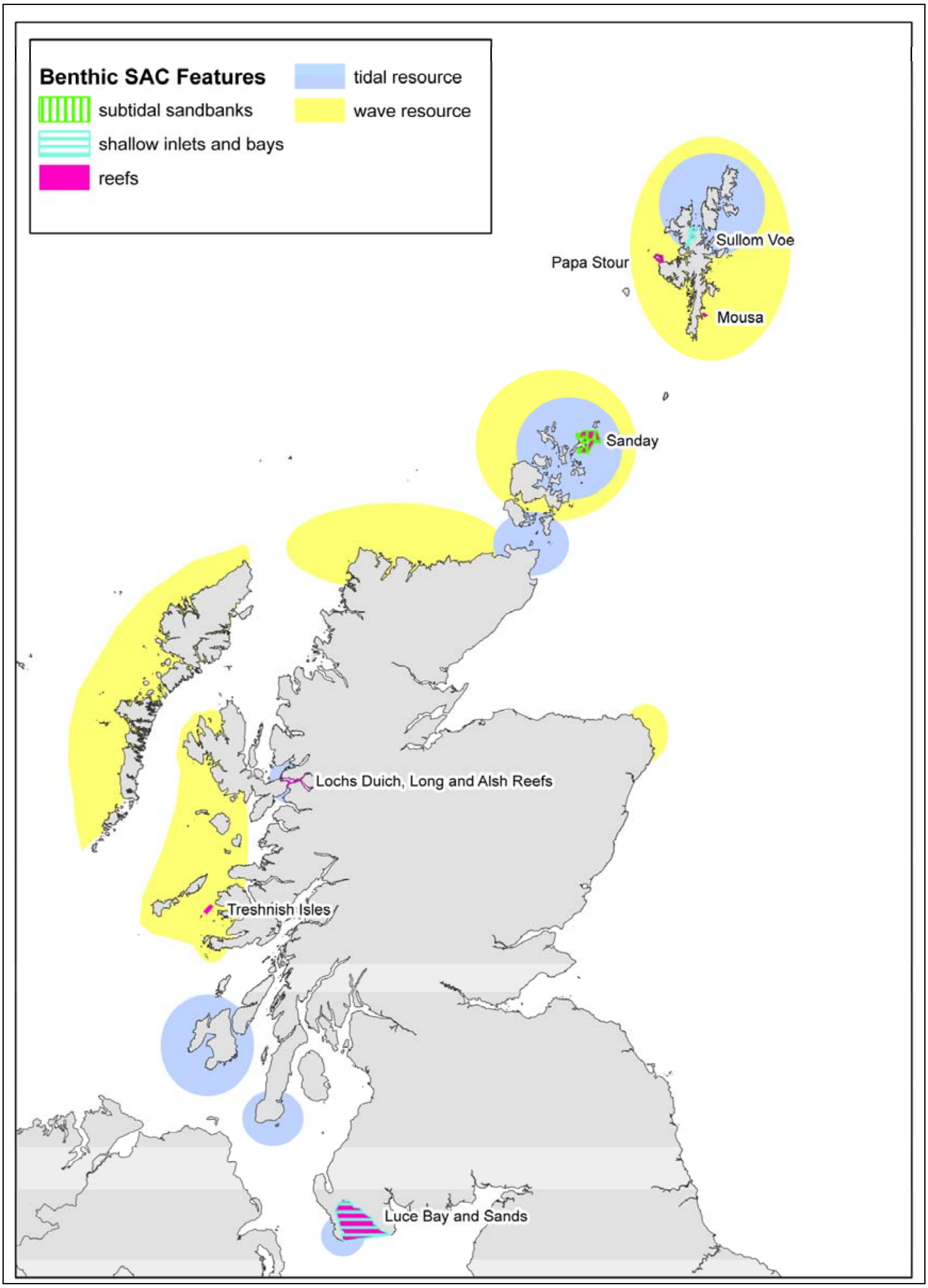
[2] http://www.jncc.gov.uk/page-4
[3] http://www.snh.gov.uk/protecting-scotlands-nature/
[4] http://www.scotland.gov.uk/Publications/2010/09/17095123/0

**Table 2.4 key sites of importance for marine benthic ecology relevant to wave and tidal developments (source: updated from Faber Maunsell and METOC 2007)**

| Site Name | Habitat Directive Primary Reason for Site Designating | Qualifying (but not primary) Features | Potential Resource Area | Protected Status | UKBAP Features |
|---|---|---|---|---|---|
| Papa Stour | Reefs; Submerged/ partially submerged sea caves | None | Wave | SAC / SSSI | Sublittoral sands and gravels |
| Sanday | Reefs | Sandbanks which are slightly covered by sea water all the time; Mudflats and sandflats not covered by seawater at low tide | Wave and tidal | SAC / SSSI | Reefs Intertidal mudflats and sandflats Sublittoral sands and gravels; Horse mussel beds |
| Sullom Voe | Large shallow inlets and bays | Coastal lagoons; Reefs | Tidal | SAC | Saline Lagoons; Reefs |
| Mousa | Species | Reefs; Submerged or partially submerged sea caves | Wave | SAC SAC / SSSI | Reefs Sublittoral sands and gravels; ; Sea Caves |
| Sound of Barra | Sandbanks which are slightly covered by seawater all the time | None | Wave and tidal | pSAC | Sublittoral sands and gravels *Zostera marina Maerl beds* |
| Loch Laxford | Large shallow inlets and bays | Reefs | Wave | SAC / SSSI | Reefs |
| St Kilda | Reefs; Sea caves | None | Wave | SAC / SSSI | Reefs; Sublittoral sands and gravels; Sea Caves |
| North Rona | Species | Reefs; Submerged or partially submerged sea caves | Wave | SAC / SSSI | Reefs; Sublittoral sands and gravels; Sea Caves |
| Loch Duich, Alsh and Long Reefs | Reefs | None | Tidal | SAC | Reefs; Subtidal sandbanks *Modiolus modiolus Phellia gausapata* (nationally scarce species) |
| Sound of Arisaig | Sandbanks which are slightly covered by sea water all the time | None | Wave | SAC | Reefs; Sublittoral sands and gravels ; Maerl beds |
| Firth of Lorn | Reefs | None | Wave and tidal | SAC | Reefs |
| Treshnish Isles | Reefs | None | Wave | SAC | Reefs |
| Loch Sunart | Terrestrial habitats | Reefs | Wave | SAC / SSSI | Reefs; Intertidal mudflats and sandflats Seagrass beds |
| Loch Creran | Reefs | None | Wave | SAC | *Serpula vermicularis* reefs ; *Modiolus modiolus* reefs |
| Luce Bay | Large Shallow inlets and bays | Sandbanks which are slightly covered by sea water all the time; Mudflats and sandflats not covered by seawater at low tide; Reefs | Wave | SAC / SSSI | Reefs; Intertidal mudflats and sandflats; Subtidal mudflats and sandflats; Shallow inlets and bays |

Figure 2.1 below identifies where the wave and tidal resources in Scotland overlap with marine habitat SACs and their designated features.

Figure 2.1 Natura 2000 Sites with relevant features, and their proximity to potential wave and tidal resources (Source: APBmer. 2009; Faber Maunsell and METOC, 2007)



# 3 RELEVANT LEGISLATION

Further details on statutory requirements for survey and monitoring of wave and tidal developments are discussed in Volume I, Section 2. Those relevant to benthic ecology are summarised below.

## 3.1 Special Areas of Conservation (SACs)

The Habitats Directive protects important habitats, and requires the establishment of a network of sites that will contribute to the protection of the habitats listed on Annex I. Further details on this legislation and the protection it affords Annex I listed habitats is provided in Volume I, Section 2.2.

The SAC designation affords protection to a SAC habitat and therefore an Appropriate Assessment may be required where an activity's potential impact footprint overlaps with an SAC.

## 3.2 SSSIs

Intertidal SSSIs are protected under the Wildlife and Countryside Act 1981 and therefore developments with a potential to affect these habitats must consider this legislation during project development, as detailed in Section 2.4, to ensure the interest(s) of the site(s) are not harmed. SSSIs are also afforded protection under the Nature Conservation (Scotland) Act 2004. Intertidal SSSIs are of relevance for near shore wave devices, where a change in wave patterns is potential.

## 3.3 Environmental Impact Assessment

Benthic habitats and species will need to be considered within the EIA, should this be required, as detailed in Section 36 of the Electricity Act 1989 (Volume I, Section 2.1). This would include all habitats and species listed as Annex 1, SSSI or UK or local BAP designations.

## 3.4 Licences

Under the Marine (Scotland) Act 2010 a Marine Licence will be required for wave or tidal devices placed on the seabed or intertidal. A Marine Licence will be required for developments placing materials on the seabed, and applies to all such wave and tidal developments, regardless of scale. Environmental Information is required to support any application and this may include EIA and associated data. These licences are further discussed in Volume I, Section 2.1.

# 4 POTENTIAL IMPACTS

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

## 4.1 Construction phase

### 4.1.1 Habitat loss

During the construction phase, the movements of support vessels such as jack up barges and the deployment of anchors will cause a temporary loss of benthic habitat. The footprint of each device and the export cables will present a long term loss of habitat. The direct habitat loss associated with the footprint of a device is dependant on the method employed to secure it to the seabed. Devices incorporating piling, particularly pin-piling, technology may have a very small footprint, for example the SeaGen tidal turbine has a footprint of 3.1$m^2$ per device (Royal Haskoning, 2007), whereas devices held by gravity bases will generally have a larger direct footprint.

### 4.1.2 Increased suspended sediments

During construction works, sediment may be suspended in the water column, with potential to increase turbidity and reduce light penetration. This can have an impact on light dependant species such as algae. Natural variation in turbidity can occur with season, and storms while land run-off can increase turbidity in coastal areas. Areas of wave and tidal resource are high energy environments and impacts caused by construction are likely to be rapidly dispersed.

### 4.1.3 Smothering

Coarse suspended sediments should settle out of suspension within a relatively short distance, depending on the nature of the sediment and the strength of water movement. Any fine particles produced during drilling are expected to rapidly disperse. Where appreciable amounts of sediments are able to settle out of suspension, sessile organisms may be vulnerable, particularly filter feeders and maerl beds. Maerl beds are particularly sensitive to impacts associated with changes in suspended sediment levels (Faber Maunsell and METOC, 2007). In high energy sites, the substrate is expected to be coarse, commonly ranging from gravels to rock, which would return to the seabed quickly without any significant translocation. Any fine sediment that is present, for example, as a mobilised sub-surface layer, is likely to be dispersed rapidly with no significant impact.

### 4.1.4 Contamination

It is unlikely that high energy sites in Scottish waters will have any significant build up of contaminated sediment. Any impact would be potentially similar to that of smothering, with contaminants more likely associated with finer sediments because of their superior adsorption properties.

Accidental spillage of fuel from construction vessels is another potential impact. However, in a high energy environment, a spillage would be expected to disperse rapidly and have minimal impact on the benthic environment. Where devices are positioned close to the shore, the intertidal zone and nearshore areas will be more vulnerable to such a spillage than benthic habitats at offshore sites.

### 4.1.5 Vibration / noise

Noise disturbance can occur from the presence of vessels, potential drilling activities, piling, anchoring and positioning of gravity based structures, along with acoustic disturbance from survey activities. Noise must be placed in the context of the existing receiving environment, as commercial shipping, sites of industry or other sources of marine noise may already be present in the area. Noise disturbance effects may cause mobile species to move away from the immediate proximity of the construction area over the short term, but the impact is likely to be highly localised and temporary.

### 4.1.6 Introduction of non native species

Non-native species can be transported within ballast water of construction vessels, on the surface of vessels and platforms, or may have already colonised a device structure if stored in the marine environment prior to transport to the site. The introduction of non native species can change the biodiversity of the area, with potential to cause secondary impacts on ecology and other users such as aquaculture.

### 4.1.7 General physical disturbance

Physical disturbance may occur during construction, particularly in areas of sensitive habitat, through the placement of clump weights, mooring lines and buoys or anchor lines and chains landing on or dragging along the seabed either as part of the device itself or for anchoring survey vessels.

## 4.2 Operation phase

### 4.2.1 Habitat alteration

Theoretically, the extraction of energy from the tidal system could impact upon the benthic ecosystem through change to the existing current regime. To date, industry experience of tidal devices in UK waters, although limited, has shown no changes to benthic ecology that are attributable to devices, with all detected change being considered natural (Royal Haskoning, 2010). During operation of a wave device, the extraction of wave energy may alter wave exposed habitats. Based on limited existing projects and modelling studies, it is estimated that the extent of impact on wave energy can extend up to 20km from the wave device (Faber Maunsell and METOC, 2007). Maerl beds and *Modiolus* beds are highly sensitive to decreases in wave energy (Faber Maunsell and METOC, 2007).

### 4.2.2 Increased suspended sediments

The impact of suspended sediment is expected to be minimal. Eddies caused by a tidal device altering the flow of water may re-suspend sediment but impacts should be slight and localised.

### 4.2.3 Smothering

Smothering of benthic communities could impact upon vulnerable and sensitive species, such as maerl.

### 4.2.4 Colonisation of structures

Colonisation of the structures may increase local reef extent although the size of the devices may limit the significance of this. It has been hypothesised (R Holt, Countryside Council for Wales, pers comm.) that an artificial substrate could alter the nature and composition of the species present and may enable non-native species to colonise and potentially spread using the devices as 'stepping stones' to other areas. An example of this type of impact is presently receiving attention from the Countryside Council for Wales (CCW) as they seek to remove the non native ascidian *Didemnum vexillum* from north Wales and consider the potential for further transmission of that and other invasive species. *D. vexillum* has recently been recorded from one location in Scotland.

### 4.2.5 Contamination

Benthic species may be exposed to materials such as paints, hydraulic fuels and antifouling compounds originating directly from the devices. Accidental spillages from maintenance vessels could also occur but there should be less potential for this due to the reduced number of vessels involved in maintenance.

### 4.2.6 Littoral habitat modification

The sheltering effect of inshore wave devices may change the exposure regime shoreward of the device and subsequently modify the natural seashore community. A change in incident wave character can affect the delivery of food and other nutrient sources, modify the gas composition of arriving seawater, restrict the arrival of propagules, reduce the wetting of surfaces and limit the foraging capabilities of some predators (Murray *et al.* 2006,). A potential outcome of significant wave shadowing effects could be an increase in intertidal algal cover and a progressive competitive exclusion of exposure tolerant species. This may be of importance for species established at their geographical limit in Scotland, such as the BAP seaweed species *Fucus distichus*.

### 4.2.7 General physical disturbance

The extent of the impacts associated with mooring chains used for wave devices during operation will vary depending on the design used. A dead weight mooring system would have a relatively small and spatially limited, interaction with the seabed, in contrast a catenary mooring system relies on the weight and movement of a longer and heavier chain to maintain the device position and orientation, potentially resulting in a significantly larger impact footprint for seabed habitats.

### 4.2.8 Vibration/ noise

Noise disturbance can occur from the presence of maintenance vessels, and from device activity. This must be placed in the context of noise already present in the receiving environment.

## 4.3 Decommissioning impacts

The impacts associated with the decommissioning phase of a project will typically be similar to those for construction and will include smothering, loss of substrate and vibration and noise during the removal of structures, along with potentially causing accidental contamination by toxic substances. The removal of devices is also likely to alter the local current flow, with associated impacts on the surrounding biotopes. Many of the impacts associated with decommissioning are likely to be short term.

## 4.4 Summary of potential impacts

The interactions between wet renewable devices and benthic species and habitats are summarised in Table 4.1, which identifies how the different types of devices have potential to impact the benthic habitats and species during construction, operation and decommissioning.

Table 4.1 impacts associated with different devices during construction, operation and decommissioning.

| Operation | Construction | Decommissioning | Impact | Source | Device relevance | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Floating point attenuator | Point absorber | Oscillating wave surge converter | Horizontal axis turbine |
| ✓ | ✓ | | Direct loss of seabed area | Device footprint, anchor blocks | ✓ | ✓ | ✓ | ✓ |
| ✓ | | ✓ | Contamination | Accidental spillages, fuel oil, antifouling, construction debris | ✓ | ✓ | ✓ | ✓ |
| ✓ | ✓ | ✓ | Smothering effects | Excavation/ piling/ dredging, grouting | | | ✓ | ✓ |
| ✓ | ✓ | ✓ | Scour/ loss of substrate | Device structure | ✓ | ✓ | ✓ | ✓ |
| ✓ | ✓ | ✓ | Introduction of non-native/invasive species | Device transport to site, use of internationally sourced service vessels and platforms, colonisation of devices | ✓ | ✓ | ✓ | ✓ |
| ✓ | ✓ | ✓ | Vibration/noise | Piling, drilling, anchoring, acoustic surveys, | ✓ | ✓ | ✓ | ✓ |
| ✓ | | | Impedance of current flow (energy removal) | Introduction of structure, operation of turbine(s) | | | | ✓ |
| ✓ | | | Change in current regime/turbulence | Introduction of structure, operation of turbine(s) | | | | ✓ |
| ✓ | | | Change in wave exposure regime on shore habitats | ‘Wave shadowing’ by device | | | ✓ | |
| ✓ | ✓ | ✓ | General physical disturbance | Clump weights/ mooring lines & buoys/ anchor lines and chains, construction debris | ✓ | ✓ | ✓ | ✓ |

# 5 KEY QUESTIONS TO BE ANSWERED BY MONITORING

Survey and monitoring activities must be designed to gather data at the relevant scales in order for an assessment of potential impacts upon both SAC habitats and other habitats or species of note to be completed. However, data on the impacts of many activities (and their spatial and temporal scales) is scarce in some cases and an important part of construction and post-construction monitoring should be the robust assessment of any impacts.

## 5.1 Pre-construction: Baseline

During the EIA process, the key considerations for the developer in order to obtain consent are:

Are there any benthic habitats or species of note present (i.e. priority, rare, protected, invasive etc)?

What is the spatial distribution and abundance of these species in the area?

How will these habitats or species be affected by the development?

What would be the significance or implications of any damage or loss incurred?

## 5.2 Post construction: Monitoring

Following deployment of a device or an array, post consent monitoring is required to assess the impacts of the development on the benthic habitats and species. Data collected during this phase of monitoring should contribute to an assessment of the accuracy of the impact predictions made in the EIA (and AA if relevant), and to meet licence conditions. Monitoring data can also be used to assess the effectiveness of mitigation and should feed into an adaptive management plan.

Key questions to be considered are:

Is there a significant change in the broad benthic community structure that can be attributed to the device installation?

Is there a significant change in the biotope distribution that can be attributed to the device installation?

Is there a significant change in the intertidal community structure or biotope distribution that can be attributed to near shore wave device installation?

Is there a significant change in abundance of dominant or characterising benthic species that can be attributed to the device installation?

Has the device modified the flow dynamics, scour patterns or turbulence character of the area in such a way to have caused a change in benthic community structure?

If changes in the flow dynamics, scour patterns or turbulence do occur, have they caused a change in biotope distribution?

Data collected during this phase of monitoring should therefore contribute to an assessment of whether the development is having a significant impact that is likely to affect the integrity of an SAC, Annex 1 habitat feature, priority or UKBAP habitat or species. Table 5.1 outlines the key questions which should be addressed in relation to benthic habitats and species.

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

| Task | No | Question |
|---|---|---|
| EIA | 1 | Are there any benthic habitats or species of note present (i.e. priority, rare, protected, invasive, etc.) |
| EIA | 2 | What is the spatial distribution of these species or habitats? |
| EIA | 3 | How will these habitats or species be affected by the development? |
| EIA | 4 | What would be the significance or implications of any damage or loss incurred? |
| EIA/AA | 5 | Does a SAC with priority habitat (Annex 1, Habitats Directive) occur in the proposed development's footprint of impact? |
| AA | 6 | Will the proposed development affect the integrity of the SAC (and, if so, how)? |
| IM | I | Is there a significant change in the broad benthic community structure that can be attributed to the device installation? |
| IM | II | Is there a significant change in the biotope distribution that can be attributed to the device installation? |
| IM | III | Is there a significant change in the intertidal community structure or biotope distribution that can be attributed to near shore wave device installation? |
| IM | IV | Is there a significant change in abundance of dominant or characterising benthic species that can be attributed to the device installation? |
| IM | V | Has the device modified the flow dynamics, scour patterns or turbulence character of the area in such a way to have caused a change in benthic community structure? |
| IM | VI | If changes in the flow dynamics, scour patterns or turbulence do occur, have they caused a change in biotope distribution? |

# 6 EXISTING INFORMATION AND DATA SOURCES

Table 6.1 below summarises the key data sources available for benthic habitats and species to assist with desk based reviews.

**Table 6.1** Key data sources for benthic habitats and species

| Data Source | Location | Notes |
|---|---|---|
| Scottish Government Regional Locational Guidance | http://www.scotland.gov.uk/Publications/2010/09/17095123/0 | Analysis by Marine Scotland of areas proposed for wave and tidal development as part of the Saltire Prize leasing round, including designated sites, seabed characteristics and BAP priority habitat records |
| Mapping European Seabed Habitats (MESH) | http://www.searchmesh.net/ | Combines and harmonises hundreds of individual seabed mapping studies and allows access to them on a web-based GIS platform. |
| National Biodiversity Network (NBN) Gateway | http://data.nbn.org.uk/ | Repository for all U.K. biodiversity information, holding a comprehensive collection of species data for terrestrial and marine species. |
| Marine Recorder Database | http://esdm.co.uk/MarineRecorder/index.html | All information on marine species and habitats collected by, or on behalf of, UK. Government Agencies is eventually transferred to the MR database. |
| Marine Scotland Interactive | http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/ | User-friendly portal for access to all forms of spatial data held by Marine Scotland including bathymetric data and geographically referenced seabed video and photographic records. |
| Admiralty charts | UK Hydrographic Office http://www.ukho.gov.uk/Pages/Home.aspx | Indication of seabed topographical complexity, usually with a coarse account of the nature of the seabed as a substrate type. This may include the presence of biogenic features. Multi-beam echo sounder (MBES) surveys will be also required to provide further information for developers. |
| Government Agencies and other organisations | UK Conservation and Environment Agencies.<br><br>UK Fisheries and marine management bodies. | Seabed and shore surveys are commissioned by Government Agencies and other organisations on a regular basis |
| Local knowledge | | Local communities tend to have an exceptionally good awareness of the nearshore habitats around their coasts, particularly where inshore fishing activity occurs. In addition, at inshore sites, where devices are to be placed in relatively shallow water, useful information may be available from local recreational divers or anglers. |

# 7 SITE SPECIFIC INFORMATION FOR BENTHIC HABITATS

The selection of survey techniques, choice of equipment, spatial extent and intensity of survey will depend on a range of factors which will need to be carefully evaluated by experienced surveyors as part of the initial survey planning process. Site specific information required for the benthic environment is outlined below:

## 7.1 Type of device(s)

The type of device under consideration, together with its means of deployment and eventual physical interaction with the seabed, will strongly influence the anticipated impact footprint. In addition, each type of device may have possible impacts that are remote or 'downstream' from the site of deployment, but related to the environmental conditions which the device is designed to exploit. These impacts range from potential biota change resulting from the direct removal of energy by tidal or wave devices, through to contaminant dispersal or scour and smothering effects as a consequence of the strong tidal or wave transport conditions at the site.

## 7.2 The projected position of the device(s)

The expected eventual seabed position and dimensions of the device(s), together with any mooring blocks, anchor points, or any other seabed structure should be established, where possible, as an integral part of survey planning. However, it is appreciated that in some cases this may not be achievable, because the planned surveys may themselves represent the first detailed data collection available to inform layout.

The placing of these structures will necessarily result in the direct loss of species and habitats at the foundation locations and the presence / absence or distribution / extent of any priority marine features will have to be established.

## 7.3 The total predicted area of impact

The extent of predicted impact over which a survey should cover will depend on a number of factors including the spatial scale of the development, the number and concentration of devices, and the predicted magnitude of disturbance caused by the construction process.

The impacts associated with the type of device (see above) will, however, need to be combined with the nature and geographical extent of possible ‘downstream’ or indirect effects. Moreover, there will be a need to identify a ‘buffer zone’ within which an impact is considered highly unlikely but still possible. Beyond this zone no discernable impact would be expected, allowing the identification of suitable locations for reference or control stations for the evaluation of impact effects. Reference stations may be confidently established in situations where the impact(s) of the devices are obviously directional (for example, the impact of the installation and operation of a tidal turbine is likely to be only along the axis of the tidal flow), and a measurable effect is not likely to occur laterally, even quite close to the devices themselves (this approach was successful in Strangford Lough (Royal Haskoning, 2010)). Substrate, community and depth will also need to be similar to the area of concern for a reference station to be suitable. A down-stream reference station can also be established if modelling data for current modification or suspended sediment transport is available. The size of the buffer is dependant on several factors, including the number and types of device, the length and operating depths of any moorings, local current speeds, incident wave energy etc, along with the value and sensitivity of the potential receptor environment. It is recommended that pre-installation hydrological modelling of the conditions over the proposed development area should be carried out and predictive calculations of the movement of sediments and contaminants made based on pre- and post-installation scenarios. This will provide a basis for defining the downstream transition zone beyond which no impact is predicted and therefore the minimum extent of an appropriate buffer zone.

## 7.4 Physical conditions

The physical environmental conditions of the development location, including depth (see below), will strongly dictate the selection of survey and monitoring methods. By definition, each site is characterised as a high energy environment, either subject to strong wave action or substantial tidal flow, presenting considerable challenges for the development of a technically achievable survey plan. Prior knowledge of the subtidal topography, tidal regime (e.g. presence and duration of a slack tide) and degree of exposure to wave action will help establish methods and equipment most appropriate for a particular location. Diver operations, for example, will be difficult in currents of 0.5 – 1.0 knot, due to the effort needed to maintain position or swim against such water movement. Beyond the range 1.0 – 1.5 knots, divers are unable to manoeuvre effectively and issues of safety become a significant concern.

## 7.5 Depth of the device(s)

The maximum depth of the seabed around the proposed development will influence the range and types of the habitats and species present and influence the choice of survey and subsequent monitoring techniques. Operating depths of up to 30m would allow the use of divers without on-site recompression chamber support, improving the ability to obtain detailed species and habitat data and thus a greater statistical precision. Beyond 30m, a requirement for a recompression chamber and complex gas mixes, becomes prohibitive and only survey techniques incorporating remote sampling are possible.

## 7.6 Predicted substrate type and heterogeneity

Although a benthic survey is designed to supply information on the biota and associated substrata as part of the determination of habitat distribution, prior intelligence on the expected variability and distribution of substrata will greatly improve the ability of a survey design to deliver an accurate description of the benthos. Different substrata require different sampling techniques and the application of the appropriate technique at an early stage will save considerable time and effort. This is particularly true if sediment sampling is under consideration, since repeated deployment on an unsuitable substratum will supply no data at all and may damage the sampler itself. In general, the use of a drop-down video system is the best option when little or no information is available for the location.

## 7.7 Type/range of species and habitats present in the locality

While it is unlikely that the specific area selected for each development has received previous biological study, it is possible that highly relevant information exists from surveys undertaken nearby, or from local knowledge associated with marine–related activities such as fishing. Advance knowledge of the habitats and species expected to be present in that area, particularly where protected or priority features are reported to be established, might influence the survey design such that a greater emphasis could be directed towards confirming that such features exist and at what density.  Site characterisation data must be collected at the earliest possible stage, using acoustic and appropriate ground truthing methods, to determine the nature of the seabed, to enable more detailed consideration of the design of a monitoring baseline survey.

# 8 STUDY DESIGN

Due to the range of conditions, the largely hostile environment and limited accessibility, designing a benthic sampling programme with sufficient power to detect ecologically important change in biological communities is fraught with difficulties and the adoption of inappropriate methods will often result in a great deal of wasted time and effort. Moreover, at present, the effects of placing renewable devices in the marine environment are largely unknown, with almost no field data from which comparative assessments of successful monitoring designs can be made. There are therefore no ‘off the shelf’ rules or strategies that can be automatically applied to each type of device, although some elements of the protocols used in the more mature offshore oil and gas industries will clearly be relevant.

A detailed discussion of benthic sampling design and analytical methods is beyond the scope of this document and the reader is referred to literature that specifically deals with these disciplines, such as Kingsford and Battershill, (2000), Bakus, (2007), Eleftheriou and McIntyre (2005) and Murray *et al.* (2006). It is, however, appropriate to examine the options and associated thought processes that should be applied when attempting to tailor a survey and subsequent monitoring programme to a particular device.

## 8.1 Are methods incorporating statistical analyses necessary ?

A methodology that includes a high level of statistical integrity will almost always be an initial aspiration of a monitoring design, but the correct application of statistical tests will also considerably increase effort and therefore time and financial commitments. Monitoring designs incorporating this level of analytical detail, while providing scientifically rigorous results are, in some cases, likely to greatly exceed the requirements of the overall programme. The specific monitoring objectives, together with the local biological context, should be carefully considered. In many instances, for example, detailed quantitative monitoring studies of unremarkable epibenthic communities may be justifiably substituted by simple and rapid remote video/photography surveillance programmes that are able to visually confirm that each community remains present and largely unmodified throughout the development area. This would constitute the minimum survey and monitoring effort but would be appropriate at all locations where the seabed is characterised by low species abundance and/or diversity and where priority marine features are not present.

## 8.2 Use of population-based parameters

A common approach to examining change in benthic communities, particularly where they are ecologically complex and diverse, is to concentrate sampling resources at the population level, selecting the abundance (or some other univariate attribute, such as size frequency distribution) of a restricted sub-set of species as a descriptor, or indicator, of the state of the wider community. The selection of such species may simply reflect the presence of a group of conspicuous, easily identified and quantified taxa, while others may be considered to be of particular ecological importance, perhaps as key community structuring elements (known as keystone species).

The use of individual species or small groups of species as indicators or keystone organisms for impact assessment is an attractive option, particularly where these are listed as priority or protected species. The adoption of a select group of species also greatly reduces the need for specialist taxonomic skills among the survey team, while reducing the overall time required for field sampling.

It should be recognised, however, that when populations are of low abundance or have a patchy distribution, the ability to detect a statistically significant change is almost always going to be very restricted. Moreover, changes in the abundance of one or a small number of species may not necessarily be representative of the ecological health of the benthic community and must always be treated with a degree of caution.

If, however, a good case can be made for such an approach, either because there are species present that are both abundant and well-documented as good indicators, or if there are limited opportunities for other types of monitoring strategies, then this route could potentially provide reasonably clear signs of an absence or presence of an impact. The statistical determination of change from this type of monitoring design will be dependent on the method of quantification and overall spatial design, but is usually relatively simple to perform, commonly incorporating analysis of variance (ANOVA) or a non-parametric equivalent.

If priority species are present at the site, they should not automatically be considered for this type of study, since, as indicated above, they may not necessarily be of a suitable abundance or distribution to detect change beyond a complete absence. In this situation a better approach might be to consider their relationship or similarity with other, more abundant species, such as a preference for similar habitats and conditions and accept these taxa as a proxy for the continued presence of the priority species.

Experience at the SeaGen tidal turbine site in Strangford Lough (Royal Haskoning, 2010) has shown that common turf-forming species, such as the hydroids *Sertularia* spp. and *Tubularia* spp. form extensive and seasonally stable features which are relatively easy to quantify as a percentage cover. These, together with other common sessile species (e.g. the bryozoan *Flustra foliacea*) are easily recognised and likely to be ubiquitous in high energy environments and could be used as effective indicators for a range of development impacts.

## 8.3 Use of community-based parameters

The use of community level analyses, incorporating the whole assemblage present in a habitat, is widely considered to provide a more statistically credible measure of an ecosystem response to an anthropogenic impact when compared to simple species abundance counts. There is, however, an inevitable cost in terms of sampling effort, with significantly greater time required for either *in situ* surveys, or for sample processing, which must be accepted to ensure that the additional data are adequately gathered and utilised. When considering the use of whole-community metrics, there should be a high degree of confidence that a large proportion of the species present in the community can be consistently and accurately identified throughout the duration of the monitoring programme. This would necessarily require the services of one or more skilled benthic taxonomists who should ideally be members of a recognised quality assurance scheme, supported by a regular external auditing programme.

Sediment sampling by grabs or cores is most amenable to community-level analyses because quantitative 'snapshots' of the infaunal community can be obtained and carefully identified and enumerated in a laboratory. Quantitative sampling of epifaunal/epifloral species is more challenging because it is either achieved *in situ* or is derived from remote images, presenting issues of time limitations or sub-optimal image resolution. For these reasons, epibiota data are often a mix of a quantitative and semi-quantitative format which can present some problems when attempting to apply statistical testing for community change.

The most commonly-used community level metric is diversity which can be expressed either as species richness (i.e. number of species or taxa present per unit area) or as an index, which integrates species richness with individual abundance. Various indices are routinely used for impact assessment, each differing in the degree of proportional influence exerted by dominant or rare species and their ability to reflect evenly distributed species composition. A comprehensive description of diversity indices is given in Krebs (1999).

Of the range of diversity indices used in ecological studies, the Shannon-Wiener index is the most frequently used by aquatic biologists and is almost routinely calculated as part of an environmental impact assessment. Other indices often applied to the benthos include Simpson's index, Margalef's index and Pielou's evenness index. Because each have their perceived strengths and weaknesses, depending on the characteristics of the communities being examined, it is probably advantageous to simultaneously apply and compare a suite of indices. This is an easy task, since there are a range of computer applications which will instantly calculate all of them when presented with tabulated species-abundance data. The most commonly used is probably the DIVERSE routine incorporated into the PRIMER package (Primer-E Ltd., Plymouth Marine Laboratory.)

Diversity values are usually calculated for each sample and replicate means are examined using univariate statistics (e.g. ANOVA) to determine temporal or spatial differences among sampled communities. Note that the purpose of this test is to determine whether there is a *difference* in diversity that can be attributed to the development and not whether there has been a comparative *reduction or loss* of diversity. An increase in diversity does not necessarily correlate with an increase in environmental quality. It has been demonstrated that, in some cases, a minor or intermediate anthropogenic impact may modify a previously stable community structure such that opportunities for previously excluded species are provided which may then elevate species richness and affect individual abundance. In addition, it is also important to be aware that the relationship between species richness and impact stresses on a community may be non-linear and a detected change in a diversity index may only be apparent after the changes in the biota have become severe (Murray *et al.*, 2006).

Multivariate analytical methods provide a means of examining change within the entire community beyond the constraints of a single index value. Multivariate methods effectively retain and use the information collected on all sampled species allowing a more comprehensive assessment of the community interaction and complexities that are responsible for spatial and temporal differences.

Three types of analysis are commonly used in benthic community surveys. These are cluster analysis, non-metric multidimensional scaling (MDS) and principle components analysis (PCA). All of these use species-abundance data to calculate similarities between pairs of samples.

Cluster analysis uses an algorithm to construct a dendrogram displaying the similarities between samples and groups of samples. In the context of impact monitoring it is predominantly a visual tool that usefully shows patterns of similarity (or dissimilarity) between samples, grouping them into discrete clusters. It is especially useful for determining and categorising distinct community structure across a site and for confirming that replicate samples do indeed contain identical assemblages. Cluster analysis becomes less useful and sometimes misleading if there is a continuous gradation of community structure across the sample area.

MDS is an ordination technique that uses rank distances to visually display similarities between samples in two or more dimensions of unitless space. It is often used for benthic community analysis, being particularly well-suited to datasets that do not conform to multivariate normality and is therefore able to cope with frequent zero occurrences of species. MDS, like cluster analysis, is able to show where samples correspond or diverge, indicating possible temporal community change due to natural or anthropogenic factors. MDS is widely considered to be the best ordination technique available, although it can become misleading when the differences between samples diminish (measured as stress values). In general, it is recommended that both MDS and cluster analysis are routinely carried out and the results are viewed in combination. A further, very useful, statistical test can be performed on the ranked similarity matrix used to construct the MDS ordination. Analysis of similarities (ANOSIM) which is roughly analogous to the univariate ANOVA can be used to test whether statistically significant differences exist between replicate sample groups. Statistical power, as with other statistical tests, decreases with a decreasing number of replicates and an ability to detect a significant difference is completely lost below four replicates, so if ANOSIM is expected to form part of the impact analysis a sample design with greater than four replicates per sample station will be an essential prerequisite.

PCA is also an ordination technique, in which plots of samples are displayed in two or more dimensions, while attempting to arrange them along a meaningful continuum or gradient which represents the most influential source or 'principal component' of the variation between them. PCA carries particular advantages over other multivariate techniques such as its ability to accept and combine species-abundance data with environmental data expressed in different units. Because PCA axes have units it is possible to calculate statistical correlations between axes and original environmental variable (e.g. contamination or other anthropogenic disturbance gradients) and to correlate sample groups such as sites, to species abundance or other data. PCA does, however, suffer from a range of limitations (see McGarigal *et al*. (2000) and Clarke and Warwick (2001)) which, among others, restricts resolving power. It is generally considered to be most effective when applied to narrow environmental gradients.

All of the methods mentioned above are computationally complex and can really only be carried out using a computer. The PRIMER (Plymouth Routines In Multivariate Ecological Research) software package incorporates all of the above, together with a number of other applications that are designed to facilitate the analysis of ecological and other environmental data. A comprehensive examination of multivariate methods together with detailed instruction in the use of PRIMER can be found in Clarke and Warwick (2001)

## 8.4 Size of sample unit

The selection of sample unit size is a complex and often-debated issue, but in most monitoring programmes the primary factors are:

- size of the organisms under investigation
- the presence of and scale distribution patterns (patchiness etc.)
- the available resources (time, manpower, cost)

In general, benthic sediment sampling is relatively standardised because of the need for purpose-built grabs, together with a relatively long history of utilisation in academic studies and environmental impact surveys. Here, sample area depends on the type of grab but broadly ranges between $0.05m^2$ to around $0.3m^2$, with $0.1m^2$ being the most common. Core sampling is more variable, particularly since it is sometimes used for sampling very small organisms, but the most commonly used size for diver-obtained (and intertidal) macrofaunal core samples is a 10cm diameter tube penetrating to 20 cm depth.

Sampling of the epibenthos is rather less standardised, predominantly because of the greater organism size ranges, habitat complexity and varying abundance over different spatial scales. For most quantitative monitoring strategies, the quadrat is the basic sampling unit used. The size of the selected quadrat is principally dictated by the size of the largest species that is being counted, although in many cases the quadrat is sub-divided to aid greater precision in counting smaller species. Andrew and Mapstone (1987) and Eleftheriou and McIntyre (2005) both examined the problems associated with quadrat size selection, strongly recommending that quadrat size is selected on the basis of the requirements of the individual survey, rather than attempting to apply ‘off the shelf’ methodologies obtained from scientific literature.

By way of practical advice, Andrew and Mapstone (1987) go on to suggest that the size of sampling unit should be approximately one order of magnitude larger than the organisms being counted. Bakus (2007), in proposing an additional rule of thumb, advocates selecting the size of quadrat that will not give frequent yields of zero counts of individuals. In very broad terms, when applied to species commonly encountered in North Atlantic and North Sea the range of quadrat sizes are likely to include:

- 10cm x 10cm – cryptic species, barnacles, small molluscs;
- 50cm x 50cm – many intertidal species, common conspicuous epiflora and epifauna; and
- 3m x 3m – sea urchins and other large echinoderms, corals and large sponges.

Note that there is no particular reason for quadrats to be square, beyond perhaps a convenience during fabrication. Bakus (2007), after reviewing a range of studies utilising various shapes, indicates that rectangular sample plots are more efficient and provide slightly better population estimates than square or round plots.

## 8.5 Sample Replication

Sample replication is a necessity for almost all of the types of univariate statistical analyses (and a range of multivariate methods) regularly applied to benthic studies. The power to detect change increases with the addition of a greater number of replicates. The provision of too few replicates can very easily render a monitoring programme ineffective because a statistically significant difference is beyond the power of the method, or is at a level that is little better than a coarse visual assessment. Conversely, too many replicates, although never undesirable from an analytical perspective, will inevitably increase time and financial commitments. These could be considerable in the case of grab sampling, where the processing of each sample requires substantial laboratory time and specialist taxonomic skills.

The determination of what constitutes an appropriate level of replication is a difficult task when presented with a site from which very little is known about the distribution and natural temporal variability of benthic communities. A pre-installation survey, if conducted in a systematic manner, will provide a broad indication of the density and distribution of possible target species and habitats, but it cannot give a definitive figure for the number of replicates needed to detect a statistically significant impact. The only way to reliably achieve this is to carry out a pilot study prior to installation and perform power analysis[5] on the results. This in itself may be a significant undertaking, but is essential if the primary aim of a monitoring programme is an indisputable statistical robustness. The pilot study will necessarily be an accurate representation of the eventual planned monitoring strategy, perhaps scaled down, but capturing the full range of sample variation present across the site. Alternatively, the full pre-installation programme could be initiated and the statistical power determined from this at the risk of having to revise and repeat the fieldwork if the results are unsatisfactory.

Prior to carrying out power analysis, decisions will have to be made on the acceptable parameters under which undesirable change will be judged to have occurred, namely the power, significance level, and effect size. The adoption of a power of 80% is conventionally considered the minimum acceptable to reliably avoid a failure to detect a real difference and a significance threshold of 5% is almost universally accepted as the maximum for ecological studies, although each can be modified to reflect the level of concern for a particular habitat or species. The effect size (e.g. detectable change in individual abundance) requires a crucial examination of what constitutes both an ecologically significant and unacceptable change within the context of the development and may require input and consultation with regulatory authorities, particularly where priority features and/or designated areas are involved.

The spatial scale separating replicate ‘reference’ stations from ‘impact’ sites is also an issue that needs to be carefully considered. An examination of impact will ideally compare against reference samples collected outside of the probable zone of impact. Although a reference site will be selected for its similarity in terms or substrate and biological community it may be some distance away from the nearest impact sampling site. If a statistically significant difference in, for example, species abundance is detected, the hypothesis that this is due to an anthropogenic disturbance effect cannot technically be supported. An equally valid hypothesis is that samples separated by this distance exhibit this difference as a consequence of natural spatial variability. The sampling strategy that gives rise to this situation is commonly referred to as ‘pseudoreplication’ because the replicate units provide information on sample variability only at the scale of the replicates themselves and not at the scale of the full sampling programme. It is corrected by ensuring that there are several reference and impact stations with similar distances between them, thus accounting for natural community variability within a selected substrate or habitat type.

[5] Note that power analysis is most often applied to univariate statistical tests and there are a wide range of computer applications that will quickly calculate one of the five variables, given the other four. Multivariate power analysis, although possible, is both computationally complex and usually requires specialist statistical decisions on many of the input parameters.

Finally, it is probably worth emphasising here that replication is only required where a sampling programme is designed for rigorous statistical analysis. Comparative analyses are still possible using multivariate ordination techniques to assess similarity and in some cases this may be adequate to simply confirm that the infaunal community composition and structure has remained broadly similar.

## 8.6 Integration with existing sample programmes

There may be some occasions when existing and ongoing benthic surveys are being undertaken within or adjacent to the development area. This is liable to be extremely rare, but is most likely to occur in locations where sites have been identified for designation as marine protected areas or Marine Natura Sites. Existing SACs, in particular, carry an obligation to report on the condition of the qualifying features every six years and therefore there is an implicit requirement to maintain a site condition monitoring programme. Whilst the objectives of such a programme are different to an impact monitoring strategy, there are likely to be obvious overlaps of interest if the qualifying features incorporate benthic elements.

At the initial survey planning stage, existing monitoring data, even if it is outside the development area, will provide valuable details on the possible presence and distribution patterns of priority species. This will be important since the proximity of a Natura site automatically raises the possibility of a need for an Appropriate Assessment. This aside, however, the presence of an existing monitoring programme provides opportunities for integration and the development of a mutually beneficial adoption of common reporting targets.

Each SAC will already have a series of attributes and targets for each feature present, with the implication that if the target is not achieved then the feature may be judged to be in unfavourable condition, triggering some form of management action to restore the condition. Some of these targets may relate directly to conditions that could change as a result of a device installation (e.g. sediment granulometry or extent and abundance of a particular reef-forming species) and it may therefore be prudent to examine the existing condition monitoring methodology to find ways of incorporating a similar, or at least, compatible set of targets as part of the impact assessment's suite of formal 'key questions'. An example might be a SAC condition monitoring target of no more than a 10% change in the granulometric character of sediments (allowing for natural variability). By adopting the existing methodology and incorporating some (or all) of the SAC monitoring stations, the development monitoring programme simultaneously demonstrates that the development has had no adverse effect on that particular SAC attribute and that the area of the SAC that falls within the possible zone of impact is likely to achieve favourable condition status at the next reporting milestone.

# 9 SURVEY METHODS FOR SITE CHARACTERISATION AND ESTABLISHMENT OF PRE INSTALLATION BASELINE CONDITION OF A WET RENEWABLES SITE FOR BENTHIC HABITATS AND SPECIES

A pre-installation benthic survey will always be necessary unless the full extent of the development area has previously received substantial survey attention of a type and intensity appropriate for determination of the biological character of the area. A very small proportion of Scotland's inshore areas have undergone this type of detailed survey, (predominantly for conservation or academic purposes) and the expectation is that a comprehensive survey will be required in almost all cases. Indeed, the Scottish Renewables SEA notes that the potential benthic impacts for devices are not well studied or understood, and goes on to say:

"*…Most of the seabed within the [SEA] study area has not been mapped and biologically surveyed using up-to-date acoustic methods supplemented by video ground-truthing. It is therefore recommended that benthic communities are surveyed prior to device installation, both to provide information on the benthic ecology of the site to allow for any species or habitats considered to be sensitive to significant impacts to be taken into account and avoided during site selection, and to provide a baseline against which monitoring of subsequent impacts can take place.*"

An effective pre-installation benthic survey will provide:

- a substrate distribution map of the seabed (and seashore where required) within the predicted area of impact;
- a broad-scale map of the spatial arrangement of the biological communities or biotopes within the predicted area of impact enabling site characterisation;
- an account of the presence and abundance of habitats and species that are either protected or are indicated to be of UK or Scottish concern, including the location and broad extent of discrete populations or communities
- an indication of the possible monitoring targets and potential obstacles that may impede or prevent the use of particular methods or equipment

It is important to undertake the planning of a pre-installation survey with a degree of care and foresight, since the information collected may be required to fulfil both the immediate need for an account of the biological character of the area (site characterisation), and also contribute, directly, to the pre-installation baseline or reference condition necessary for a subsequent monitoring programme. An example of integrating a pre-installation survey plan with the later monitoring programme might be the design of a drop-down video survey in support of the broad-scale mapping strategy. In this case, the number of sample drops and the selection of a statistically robust survey design could, in itself, constitute a monitoring baseline for evaluating change across some of the seabed elements.

It may also be prudent to examine the full range of survey activities that will take place in support of the site identification and characterisation process. In some cases clear opportunities for the integration and 'dual-use' of some hydrological and geological techniques may be identified, perhaps, to provide supporting or corroborative evidence for the presence of particular habitats and species. The use of acoustic survey techniques, for example, is common to both the physical and biological mapping processes and an investment in simultaneously considering the requirements for both purposes could reduce the time and effort expended on the deployment of such equipment.

The majority of expected impacts - and thus the pre-installation benthic survey planning and methodological requirements - are likely to be similar across device types. The methods available for the characterisation of the benthos in such hostile environments are limited and more likely to be determined by the practicalities of cost, anticipated substrate type(s) and physical conditions rather than device type.

When attempting to establish the biological character of a location, the methods being considered broadly fall into two categories: destructive - usually requiring the removal of samples for subsequent analysis; or non-destructive - generally involving remote imaging or in-situ observation. For assessment of sedimentary habitats, the use of destructive sampling, such as grabs or cores is unavoidable. In the majority of situations where this equipment is deployed, communities are widely distributed, resilient and unlikely to be damaged by the removal of samples.

Habitats and species associated with hard substrata are more vulnerable to physical damage and are usually surveyed by non-destructive methods, such as remote video and photographic systems or direct diver observation. Some remote imaging methods, such as camera-mounted sleds, are also capable of damaging epifauna and flora and even the use of devices designed to remain above the seabed, such as drop-down imaging systems may often collide with the seabed when being operated in difficult sea conditions or over a topographically complex seabed. For this reason, particular care should be taken in equipment selection when planning a survey methodology that is likely to encounter reef/bed-forming, delicate or slow growing species.

An examination of the fisheries interest for the site may also be undertaken using investigative demersal fishing gear. The catch from this activity will also contain a bycatch of other benthic organisms which should be recorded (or retained for later taxonomic identification) and incorporated into the benthic data inventory. It should be recognised, however, that demersal trawls are known to be very inefficient when sampling epifauna and do not retain the fauna with the same level of effectiveness as dedicated benthic trawls, such as beam and Agassiz trawls.

Individual survey methods are discussed in more detail in the following sections.

## 9.1 Acoustic mapping

For environmental purposes it is vital that adequate verification (ground truthing) of the substrates and habitats is carried out. This can take the form of remote video or stills from drop-down, diver or ROV or direct samples of the seabed using grabs, cores or other direct sampling devices. Information on seabed topography generated from swath systems can be used to detect seabed features such as Annex 1 features or BAP habitats.

Collection of remote acoustic data can assist in the deployment strategy for direct sampling and ensure sufficient samples are collected at appropriate locations.

### 9.1.1 Survey Design

The majority of remote acoustic surveys are designed using a series of parallel survey lines with some additional cross tracks for quality assurance purposes, the spacing between these can be altered depending upon the outputs required and the operating environment. If the survey is carried out using IHO standards, (IHO, 2008), then linespacing and cross tracks will be determined by these standards, if the survey is carried out solely for environmental purposes, then IHO standards should be referred to and followed where possible. Each of the remote acoustic systems is available in various fixed acoustic frequencies on which they can be operated and the choice of these depends upon the outputs required and the operating environment.

For baseline survey, it is recommended that a suite of acoustic systems are deployed that at a minimum combines an Acoustic Ground Discrimination System (AGDS) with either a swath bathymetric system or sidescan. A combination of swath bathymetry along with single beam AGDS is likely to be most appropriate and provide sufficient data for environmental baseline and monitoring purposes. These systems can be deployed simultaneously and in an efficient manner in terms of survey strategy. They will provide 3D bathymetric data, sidescan sonar/backscatter images and data on the physical composition of the seabed. These data will enable an overview of the seabed habitats and their distribution to be developed together with a digital terrain model of the seabed to identify specific features or habitats of potential conservation interest and enable any effects such as sediment movements, accretion or scouring which may influence the seabed environment to be detected. It should be noted that other acoustic systems may be required for purposes other than environmental survey (e.g. geology, engineering, archaeology and sediment dynamics) and it may be that data from these will provide additional or supplementary data for environmental interpretation.

IHO standards may be applied to the survey line design but if these are not employed and complete coverage of the survey area is required, it is advisable to plan for at least 25% overlap between adjacent swath tracks and the line spacing should be planned to provide this. This prevents gaps in the coverage and compensates for any deterioration of the data towards the extremities of swaths. 25% overlap is often sufficient for environmental purposes too but the overlap can be increased up to 100% (complete overlap between adjacent port and starboard tracks) if it is important that there are no blind spots in the data in the shadow of high seabed features. Also, tracks run at right angles should be collected to reduce the possibility of non-detection of features due to ensonification from just one direction. Orientation of the lines is of particular importance for sidescan sonar for the detection of features: linear features (such as sand waves) oriented across the tracks may go undetected but be very conspicuous when tracks are run in line with the features. Cross track lines are important to ensure features are not missed.

The problem of detection of features being sensitive to track orientation, which is important for sidescan, is less of an issue for swath bathymetry since the features are detected from depths rather than backscatter images. However, there is still a requirement for some cross-tracks to be run with swath bathymetry as a quality check on the data.

The area to be surveyed should encompass the whole site in question and additionally cover a 'buffer zone' around the site which may be impacted during installation or operation of an array. An area which is likely to be unaffected should also be included within the survey, to provide a reference or control area. The entire survey area will be dependent upon the tidal and current regimes at the location of each array but should be large enough to encompass areas affected during one spring tidal cycle.

For environmental purposes, it is vital that adequate verification (ground truthing) of the substrates and habitats is carried out. This can take the form of remote video or stills from drop-down, diver or ROV or direct samples of the seabed using grabs, cores or other direct sampling device. However, information on seabed topography and generated from swath systems can be used to detect certain seabed features which may be important for conservation status, such as Annex 1 features or BAP habitats, for example. The acoustic data will assist in the design of the sampling regime and enable the range of substrates and habitats to be sampled efficiently and effectively.

## 9.2 Grab sampling

The primary method of establishing the biological community composition of sedimentary habitats is by recovering sediment samples using a grab. Grabs are lowered to the seabed from a stationary vessel and a sample is usually obtained by automatically or manually operating some form of mechanism that closes the jaws of the grab. A wide range of grabs have been developed with varying capabilities in terms of recovery of different sediment types, penetration depth, volume reproducibility and reliability. It is beyond the scope of this document to discuss the relative merits of each grab type and a more detailed review can be found in Eleftheriou and McIntyre (2005).

In general, most commonly used grab types will obtain adequate samples from sediments ranging from muds to medium sands. While coarse sand and mixed gravel may also be sampled, the success of obtaining a full or complete sample is variable and might be substantially reduced.

The devices most frequently used for UK marine survey work are the van Veen grab, the Day grab and the Hamon grab.

The van Veen grab is acknowledged as a good all-round option and has been adopted as the standard by some organisations, notably for benthic surveys in the Baltic Sea. It is simple and quick to deploy and its long lever arms provide a substantial jaw closing force, but they also make it cumbersome to manoeuvre on a ship’s deck and will sometimes cause it to be pulled onto its side before closing if the vessel is drifting.

The Day grab is also a popular choice because it is also simple to use and is known to sample efficiently due to its greater weight which improves sediment penetration. In addition, the grab mechanism is incorporated into a metal frame which keeps the grab level on the seabed and prevents it from toppling over.

The Hamon grab utilises a rectangular scooping action and is considered to be particularly effective in coarse, loose sediments, although is reported to be the least successful of the three at maintaining consistency where comparative quantitative sampling is required (Eleftheriou and McIntyre, 2005).

Both the van Veen and the Day grab commonly collect a sample of around $0.1m^2$ of sea bed, while the Hamon grab usually recovers a larger sample of around $0.29m^2$.

Because grab samples essentially collect a snapshot of an entire infaunal community which can be later analysed in detail in a laboratory the data generated from this method can provide a level of biological detail, substantially beyond what can be achieved for epibenthic habitats. A full account of infaunal community composition is possible, with fully quantitative species abundance data that can subsequently be used to calculate diversity metrics if required. These data can also be further aggregated to assign biotopes, although the current sedimentary classification system for sublittoral communities is widely acknowledged to be incomplete and it is not unusual to arrive at community types that do not conform to a recognised biotope. For future comparative purposes it is prudent to always retain the raw species abundance data for each sample as this may serve as a baseline for a subsequent monitoring programme.

The type of infaunal community present at any location is determined by a range of influences, the most prominent of which is likely to be the granulometric character of the sediment. It is common practice to retain a sub-sample from each grab[6] for particle size analysis (PSA) and this is likely to be an essential element of the post-installation monitoring where sedimentary habitats form a major feature of the area, since modification of the hydrology of the site may initiate a change in sediment transport and thus modify the grain size distribution of the site.

Similarly, where chemical contamination of sediments is a concern, a grab sub-sample, correctly taken and stored to prevent cross-contamination, provides the necessary material to establish background or reference levels prior to installation. The grab itself may also

[6]Note that some guidelines suggest that PSA subsamples should only be obtained from grabs specifically deployed for sediment samples and not from those retained for biological analyses.

have to be constructed of a specific material, such as stainless steel, for the sampling of some contaminants.

Grabs are necessarily heavy and bulky pieces of equipment and therefore require vessels equipped with adequate lifting gear and of a suitable size from which they can be safely deployed. In addition, samples are usually wet-sieved on board the vessel to separate the biota from the sediment to reduce the inconvenience of handling and transporting unwanted bulk, while also preventing unnecessary physical damage to the biological material before reaching the laboratory. Sufficient deck space will have to be available to allow this activity alongside the grab deployment and recovery. Even with a suitable vessel, grabs are very difficult to deploy successfully in moderate current speeds or large swell and generally require relatively calm seas and slack tides as the optimal conditions for obtaining good samples.

Although grab samples potentially provide a complete description of community character at any given sample station, a major constraint on the use of this method is the considerable amount of effort required to process each sample, rendering the task both time-consuming and expensive. The retained animals have to be painstakingly removed from the remaining benthic debris before being identified and enumerated by an expert taxonomist. Depending on the number of samples, this process commonly requires a period of several weeks or months, before the results are available for analysis. Time and cost can be saved by reducing the size of the processed samples by sub-sampling, accepting a reduced level of taxonomic identification or allowing a semi-quantitative level of enumeration, each of which could still permit an adequate biological characterisation of each sample station, but may compromise any future statistical analyses. These options may, therefore, be more sensibly considered at the monitoring, rather than the pre-installation survey, stage since the loss of such information may be later regretted if a subsequent monitoring programme experiences problems in detecting community change.

The sieve mesh size that is used will also influence the time and cost of sample processing. The most commonly used mesh sizes are 0.5mm and 1.0mm, with the latter most frequently used for general habitat characterisation and the former if much more detailed analyses are required. The differences in retention abundance and species richness can be significant and may vary between sediment types. In general, though, a 1.0mm mesh size should be adequate for the pre-installation survey and a subsequent assessment of community change.

It is important to recognise that we still know very little about the pattern of natural community change in sublittoral infaunal communities in particular and demonstrating change due to human impacts (unless they are very obvious) may yet prove to be a difficult task. For this reason, some early effort should be made to identify locations where comparable communities may be found both within and outside the zone of impact, thus allowing the use of reference stations to identify non-installation related community change.

### 9.2.1 Survey design

The pattern of grab deployment and survey design will largely depend on the expected extent and distribution of sediment habitats within the survey area, together with the degree of biological importance attributed to them. This information should be initially supplied by the acoustic mapping and supporting drop-down video data.

Where the development site is dominated by sedimentary habitats, sampling either using a grid arrangement, or by adopting a random sampling design provides the most comprehensive and systematic cover of the area. Equally spaced sample stations within a grid arrangement, assuming an adequate interval, would provide information on the continuous distribution of faunal communities, sediment granulometry and, if required, baseline contaminant levels. While this approach is attractive for a single pre-installation survey, it does not support the statistical assumptions that would be required if the sample data were to be subsequently used for an examination of post-installation change. A more statistically robust approach is to generate replicated random sample stations. Over a large area, however, this approach is likely to experience problems with the sheer range of sediment types, rendering comparisons meaningless and so some form of sample stratification will almost always be necessary.



An alternative to the broad cover approach is to concentrate all or some of the sample stations within a confined area that corresponds to one or a series of defined zones that extend from the installation site in an orientation that follows the most likely direction of an impact gradient. This would effectively form a stratified randomly sampled “belt transect” of between 100m to 1000m width, which would include sample stations beyond the expected zone of impact.  This area range is intended to capture the spatial extent of habits and species of concern, while reflecting the footprint of the devices specified for this contract. Also, these are the size ranges that have been successfully used and reported in various UK monitoring projects.

When sediment habitats are sparsely or discontinuously distributed, a more simplified survey approach is likely to be more appropriate, either using a simple transect design or directed sampling to simply determine the nature of the sediment and community type.

The use of dredges to sample the seabed is inappropriate in the context of renewable devices because they are unnecessarily destructive, and this guidance is particularly concerned about vulnerable habitats and species. Therefore dredges have not been considered within this document.

## 9.3 Drop-down video/photography

Drop-down video or photography is suitable for quickly characterising a large area and the method of choice for ground-truthing acoustic mapping data. The recent advances in digital video image quality, ease of manipulation and convenient electronic storage/retrieval options, together with substantial reduction in equipment costs, all serve to make this a particularly cost-effective preliminary survey method for all substrate types. Drop-down video or photography can provide valuable documentation on the presence, abundance and distribution of epibenthic species and presence and extent of habitats, while also supporting other survey tasks such as identifying how sediment and other substrata are distributed, thus contributing to the design and probable effectiveness of, for example, a subsequent grab sampling strategy.

The size, weight and level of sophistication of drop-down imaging systems can vary considerably and these must be established and matched with an appropriately equipped supporting vessel. Some video frame systems are comparatively light-weight and can be operated from a small craft such as a rigid-hulled inflatable. While useful for shallow water and relatively benign sea conditions, these devices are unlikely to be able to operate in the deeper water high energy environments that will be present around some of the development sites. Even with the more robust devices, deployed off larger and more stable platforms, the quality of visual data reduces substantially with increasing current speed and high swell. This may therefore cause under-reporting of habitats present in very exposed locations or in areas where there is little or no slack water. Similarly, the positioning and static nature of the camera prevents satisfactory viewing of steeply-sloping or vertical rock faces and these will again tend to be under-reported.

While video cameras produce a continuous record of the seabed it is passing over, the speed and image resolution may create a blurred image, making the identification of some species difficult. Recent experience (C. Moore, pers. comm.) has indicated that where species identification is a key task the incorporation of a high quality housed stills camera and flash system provides a substantially improved ability to recognise species and dense community aggregations.

### 9.3.1 Survey design

The use of remote imaging would probably be expected to satisfy a number of purposes and may be employed at several stages of a survey plan, the most likely scenario being as an initial broad habitat or biotope mapping tool followed by a more directed task to refine the position and extent of priority or otherwise vulnerable habitats and species.

The simplest initial survey approach would be to establish a regularly-spaced sample pattern, such as a grid, across the area of interest, thus providing a map of the continuous distribution of habitats and species with the degree of resolution dependent on the density of the sample drops. While this will directly satisfy the requirements of a pre-installation survey it will limit any subsequent use of the data for comparative monitoring purposes if a statistically valid design is considered necessary. Where future statistical comparisons are planned the use of a randomised design is recommended. This may span the entire area if it is considered to be sufficiently small, or would more likely be stratified according to pre-existing information such as charted features and bathymetry, or through an assessment of the relative impact vulnerability of particular zones.

Where distinctive epibenthic features (habitats or species) are present with probable discrete distributions, such as bed- or reef-forming entities, the geographical extent can be determined using a series of regularly spaced drops along a single transect or an array of transects. The specific arrangement and number of the transects will be determined by the shape of the probable distribution pattern, the total area of cover and the level of significance attributed to the feature under investigation. In the case of vulnerable biogenic beds and reefs with distinctive boundaries it may be wise to concentrate proportionately more drops across the margins of the bed or reef as this will provide a valuable baseline for later assessments of change of extent. Extent is, however, only one parameter that is available to be measured by drop-down imaging and should be used in conjunction with some form of density estimation of the target species. Note also that bed- and reef-forming species usually incorporate a hard shell, or outer calcareous structure, that may survive the organism itself for a considerable length of time after death and there may be relict biogenic debris fields with no appreciable densities of living specimens in the area at all. These may in themselves constitute valuable habitats for other species but it is important in all cases to establish that live examples of the original biogenic structure builders are present before committing resources to an extensive survey and monitoring programme.

Beyond the more structured survey designs drop-down video can also be very usefully employed to quickly confirm the presence and status of a biological feature using single directed drops. Depending on the conditions and the extent of the feature under investigation, this may require a combination of favourable sea conditions and very precise deployment to achieve the level of positional accuracy that will guarantee a good visual confirmation of presence.

Further information on the use of remote video, including suggestions for survey design, logistic and analysis can be found in Moore and Bunker (2005)

## 9.4 Remotely Operated Vehicle (ROV)

A remotely operated vehicle (ROV) can essentially be considered as a technically complex drop-down system, but with the added ability to navigate to, and examine, specific targets on the seabed. Unlike the drop-video system it does have the ability to be more accurately orientated for increased precision when collecting visual data and can therefore inspect vertical or steeply sloping rock habitats in detail. When suitably equipped, ROVs can also perform some limited remotely-operated manipulative functions, such as collecting voucher specimens.

As with drop-down imaging systems ROVs can be used to determine species, habitat, biotope and substrata distribution, but, apart from their navigability, rarely offer an advantage over less sophisticated video equipment. Their value for surveys of the type under consideration here is probably limited, being restricted to the deeper water surveys and for situations where the presence of particular species or discrete biological structures is required to be confirmed. ROVs equipped with a built-in means of seabed area definition, such as an attached quadrat or laser projection device are theoretically capable of providing quantitative epifaunal data, but the degree of effort and time required to set up, calibrate and successfully deploy such systems is perhaps more appropriate for academic study, rather than a pre-installation survey.

An ROV's ability to cope with water movement and swell will be related to the size and thruster power of the vehicle. The larger, more powerful devices, designed predominantly for deep-water maintenance and inspection work for offshore industries, although able to operate in the more difficult conditions, require large support vessels and maintenance teams, making them logistically unsuitable for environmental surveys. Smaller ROVs would be more practical, but still require a suitably equipped vessel and are difficult and dangerous to deploy in conditions of moderate swell. Most models will also struggle to cope with current speeds greater than 2-3 knots and would effectively become a drop-down video device anyway.

All ROVs are mechanically complex and, as with the majority of instrumentation exposed to the marine environment, require considerable maintenance, operational attention and adherence to set-up routines. Not surprisingly, therefore, substantial time can be lost to technical failure, while the vehicles themselves are expensive to buy or hire. Moreover, the turnaround times between deployment, recovery and relocation is longer than that of drop-down video systems, potentially resulting in a significant reduction in the number of survey stations achieved.

### 9.4.1 Survey design

Because of the inherent similarity with the more basic drop-down imaging systems ROVs can be used in much the same way and incorporating the same survey designs. Because of the additional technical difficulties there are very few situations where ROVs offer major advantages over a non-powered system, except, as previously indicated where steep or vertical substrates need to be examined, or where periods of positional stability are required to identify the presence and possibly the broad abundance of particular species.

## 9.5 Diver sampling

Diver sampling is largely restricted to depths shallower than 30m below sea level. The rapidly increasing physiological risk beyond this depth, with an associated requirement for more complex breathing gases, together with a statutory obligation to maintain a recompression chamber on-site, makes the use of a dive team logistically and financially difficult to justify in many cases. In addition, the broadly turbulent or fast flowing conditions that make a particular location attractive for renewable devices present considerable dangers to a diving surveyor attempting to complete a survey task, regardless of the depth.

Diver surveys do, however, provide the greatest level of taxonomic detail and have consistently proved to be the best means of obtaining quantitative epifaunal data and good quality video or photographic documentation. The restriction in operating depth aside, the manual dexterity and freedom of controlled movement afforded to a diver surveyor allows a considerable range of tasks to be undertaken. Observations on species, habitat, biotope and substratum presence, abundance and distribution can be completed with a greater degree of confidence than with the use of remote systems, particularly where there is a high occurrence of cryptic biota which usually requires manual manipulation to reveal obscured individuals. Similarly, some reef or bed-forming species (such as *Limaria hians* 'nests'), are not immediately obvious and require a divers viewpoint, intuition and ability to physically handle the substrata and associated biota before confirmation of presence can be made.

Where the recovery of epifaunal specimens for taxonomic identification is required, diver collection is by far the most efficient method of doing so. Attempts using an ROV manipulator arm are cumbersome, time-consuming and restricted to larger and easily grasped fauna and flora, while dredges may collect large amounts of material, but are overly destructive and fundamentally random in their collecting ability.

Divers are also particularly good for obtaining quantitative soft sediment samples by means of hand-deployed cores, which can be accurately replicated and would therefore provide a reliable basis for statistical analyses. Similarly, individual epibenthic species density counts using replicated quadrats can be achieved *in situ*, or, where time constraints are an issue, quadrats can be carefully recorded using video or photography and quantitatively analysed later.

The use of diver surveyors does carry significant intrinsic restrictions, with safety considerations, time limitations dictated by air supply and a strict inability to operate in currents or rough seas, all conspiring to make the use of divers the method most restricted by the local conditions. In addition, divers are under substantial deployment time restrictions for physiological reasons and require lengthy intervals between dives, which increase with greater operating depths. Because of these restrictions, diver surveys are only suitable for investigations of discrete locations or very small areas that can be adequately surveyed within a short time period.

### 9.5.1 Survey design

The most common method of conducting a diver survey is to establish a series of short transects along which the diver swims, while recording the occurrence and semi-quantitative abundance of conspicuous epibenthic species using the JNCC 'Phase 2' reporting protocol (Hiscock, 1996). The transect, typically between 20m and 100m in length can either be delineated by a buoyed line (deployed by a boat or the divers themselves), or can be simply followed on a compass bearing. Longer transects can be achieved by deploying divers in a sequence of ‘spot dives’ along a bearing intended to incorporate important or characterising elements of the development site. It is important that the diver undertaking the survey is an experienced diving taxonomist, familiar with Scottish flora and fauna. It is also often useful to deploy a second diver to simultaneously obtain a video record of the transect and collect biological material for later identification, if required.

Using the transect method (perhaps combined with remote imaging data) locations supporting densities of species that can be quantitatively examined may be identified and quadrat counts undertaken. These quantitative data can then be adopted as a baseline and incorporated into the subsequent monitoring programme.

## 9.6 Intertidal survey

An intertidal survey may be considered appropriate where the positioning of a device may have an effect on a nearby shore. This is most likely to be necessary for inshore wave devices where the sheltering effect may change the exposure regime shoreward of the device and subsequently modify the natural seashore community.

The evidence from modelling studies suggests that the risk of an observable change occurring in intertidal communities is low but could nevertheless result in reduced vertical zonation on rocky shores (APB Marine Environmental Research Ltd., 2009). To establish a baseline against which any future community migration can be measured, one, or more, permanent relocatable vertical shore transects should be established at conveniently accessible locations along the shoreline identified as within the possible zone of impact.

### 9.6.1 Survey design

The methodology is unlikely to require any deviation from well-documented standard rocky shore survey protocols.

The vertical zonation pattern of the numerically or spatially dominant flora and fauna is recorded as delineated zones along the transect and referenced to height above chart datum using a surveyor’s level. Semi-quantitative abundance of other species is also usually recorded from which the identification of a biotope for each identified zone can be made.

In instances of specific concern for individual species, such as *Fucus distichus,* a broader search may be considered necessary and their location established using accurate position fixing followed by the initiation of a simple surveillance programme to establish the continued presence of the species.

Intertidal surveys would also be required for the footprint of cable landfall, on-shore supply and maintenance infrastructure, however landfall and onshore infrastructure are not considered within this guidance document. Where appropriate, these surveys could be combined with those conducted to provide pre- and post-installation data on changes to the intertidal habitat caused by the operation of devices.

# 10 MONITORING METHODS TO ESTABLISH IMPACTS OF CONSTRUCTION AND OPERATION OF WAVE DEVICES

In broad terms, the wave device types selected as the main targets for this guidance have a high degree of similarity in the components of their potential impacts and therefore retain major synergies in the core methodologies that can be used to monitor such impacts. The overall monitoring objectives will almost always be relatively simple in their aims and will essentially revolve around two key questions, namely:

- Has the human activity associated with the installation and/or operation of the device(s) caused any broad community changes beyond natural fluctuations?
- If vulnerable or priority marine features have been found within the potential impact zone, has the installation and/or operation of the device(s) caused either a loss or degradation of such habitats and species?

To answer these questions through an achievable and appropriately designed monitoring programme it is advisable to begin with three planning prerequisites:

*Baseline data (prior to installation)* – The most desirable situation for any monitoring programme is to be in possession of good pre-impact survey data that are compatible with a planned post-impact monitoring design. The early establishment of baseline data is consistently referred to in the section on pre-installation survey because the most robust monitoring programme will need to be planned at this stage. A monitoring strategy can still be implemented without pre-installation data, but the powerful ability to compare the pre- and post-installation condition will be lost and the programme is left with the more difficult task of assessing the relative differences between communities from the 'impact' zone and the (usually) more distant reference stations.

*Establishing a good understanding of the prevailing conditions of the area* – The physical characteristics and operating conditions of the site will strongly dictate the methods and equipment used in any monitoring programme and will certainly be instrumental in ruling out particular methods. The wave devices being considered here are designed to operate in a wide range of depths and so, for example, the use of divers may be an option for one design but not for others. All devices will obviously be placed in exposed locations and so issues of accessibility, underwater visibility and robustness of equipment need to be considered.

*Identification of the site- and device-specific impact concerns* – given unlimited time, logistical resources and funding a highly detailed assessment of change throughout the area would, of course, be possible, but the reality is that any project of this complexity will be under a wide range of constraints. Compromises will inevitably need to be made in which the priority consideration is the selection of a method, or a suite of methods, that is/are most likely to yield a measurable change if it has indeed occurred. Clearly, the best way to achieve this is to directly target a proportionally greater share of the monitoring effort to the locations that will be expected to receive the major part of the impact and would therefore provide the best chance of detecting that change.

For the three types of wave devices under consideration here, the major impact possibilities are primarily related to the mooring of installation platforms, direct loss of habitat during the placing of seabed structures, and, in the case of the floating attenuator device only, the abrasive effect of the permanent mooring assembly.

The direct loss of habitat is an issue that is effectively resolved at the pre-installation survey phase, since that is where the seabed installation location is examined for priority marine features and a confirmation of their absence will have been obtained prior to the commencement of the installation phase. Both the Point Absorber and the Oscillating Wave Surge Converter devices will require solid structures to be placed on the seabed and these may have a range of benthic impacts relating to the size of the structure(s) and the process by which they are secured to the seabed. If the structure(s) are simply gravity supported under their own weight, then there is unlikely to be any major impacts from the device itself other than possible localised disturbance and scouring effects. If the device(s) is/are secured by piling and/or grouting then the likelihood exists for some degree of smothering of biota during the installation phase. Further installation phase impacts may also be caused by the vessels and platforms employed to lower the devices into place. These will require secure and substantial mooring or anchor points which will, together with the associated mooring chain or cable, impart some physical damage to seabed habitats. All of these effects are localised and confined to defined areas, are easily evaluated by visual methods and would thus be most effectively monitored by directed video documentation, either by drop-down video, ROV or diver operated cameras.

The Floating Attenuator device will have no operating structure on the seabed but will require a substantial permanent mooring array. The mooring options essentially fall into two types, each with slightly different impact concerns and monitoring focus. Where the use of a buoy and a weighted sinker is selected, secure anchor points will be required, which may involve large anchor blocks or drilled pin-piling. The majority of the mooring chain or cable would, however, be expected to remain above the seabed and would therefore be limited in its abrasive impact. An alternative mooring configuration might be the use of a catenery system, where a longer and heavier chain forms an integral part of the movement damping system for the device and a large section would be expected to be in permanent or intermittent contact with the seabed. With the catenery arrangement, the zone of direct physical damage is likely to be larger and will be directly related to the length of mooring chain and the potential for lateral movement across the seabed.

## 10.1 Acoustic mapping

In order to monitor and document any effects that wave and tidal installations may have on the marine environment, it is necessary to monitor the environment at regular intervals through the life of the installations. The survey tools used will be similar to those used for baseline survey but the survey strategies will be altered to incorporate a monitoring procedure.

### 10.1.1 Survey Design

Several protocols and guidelines pre-exist for monitoring marine installations and these should be referenced when considering survey design (CEFAS, 2004; Davies et al, 2001), CEFAS, 2002 or CEFAS, In prep). The same suite of tools used for baseline survey are available for monitoring survey and again, the use of a suite of tools is likely to provide the most comprehensive data sets and therefore be of most use in assessing any changes the marine environment.

Monitoring using acoustic systems can be used where there is likely to be a change in the shape or nature of the seabed due to increased erosion, accretion or scouring, due to changes in currents caused by wave or tidal installations. If these issues are identified as a priority for an area, then it would be important to measure changes in bathymetry and boundary conditions between sediment types (e.g., sand/cobble).

For monitoring purposes, a nested survey strategy may be appropriate to enable efficient survey resources to be directed at areas in which change is likely or is detected. A general bathymetric and seabed habitat survey could then be carried out over the whole baseline area which would provide information on the distribution of habitats around and adjacent to the installation sites and would also enable any large scale sediment or bathymetric changes to be detected. This would then ensure that detailed, high resolution data collection would be targeted over areas which show change or over areas of ecological importance identified from baseline or previous results.

Acoustic systems alone can be used to detect changes in bathymetry or sediment types and boundaries, but for specific ecology measures, such as species composition or priority species detection, it is vital that a suitable direct sampling ground truthing programme is incorporated to verify the presence of the habitats identified from the acoustic data.

## 10.2 Drop-down video & grab sampling

For all devices, a continuation of dropdown video and/or grab sample strategies (depending on dominating substrate types) as proposed in the section on pre-installation survey would be suitable to determine the broader benthic effects of both the construction and operation phases. These approaches constitute the most practical methods for monitoring over a wide area and at all depth ranges, where there are no particular species or habitat concerns. Using a randomised video drop or grab design, incorporating sample plots that include reference locations outside the influence of the development would allow simple, but effective, temporal comparisons of species occurrence, diversity and habitat/biotope stability. In mixed substrate locations, where there is sufficient epifaunal abundance, a drop-down video programme alone would probably be adequate without the requirement of the more resource intensive grab sampling. If, however, the site is rich in sedimentary habitats and there are concerns of significant chemical contamination during either the construction or operational phases then grab sampling will be an important tool in establishing whether undesirable change has occurred.

Results from two preliminary drop-down video surveys of potential renewable device sites off Orkney and the Pentland Firth (Moore 2009, 2010) provide strong support for the effectiveness of drop-down imaging systems in wave exposed or strongly tidal locations. The data collected in these surveys were certainly sufficient for the identification of characterising species and community type or biotope, indicating that, should a modification or major change in species composition occur, a simple drop-down camera survey of a sufficient sample size should be able to provide a reasonably early alert. In addition, the vast majority of sites sampled were observed to be of consistently low diversity and dominated by widely distributed scour-tolerant species. It seems likely that this is the typical state in locations suitable for wave devices, suggesting that the use of more intensive quantitative sampling designs over smaller spatial scales would be considerably hampered by very low sample abundance.

Overall, randomised “broad scale” drop-down video monitoring may be analysed for change in a number of ways. These could be temporal comparisons of:

- the frequency of biotopes
- total or stratified species richness or diversity
- proportional occurrence of selected species

It cannot, of course, be assumed that all sites will be entirely composed of low diversity communities. Where important biological features, such as maerl or *Modiolus* beds have been identified and their spatial extent established in the pre-installation survey, there may be a requirement to demonstrate that the extent and integrity of such features are being maintained as part of a consent condition, or if they are a feature of a designated site. This will be best achieved using a transect method as described in the pre-installation survey section. Similarly, the direct effects of mooring lines, particularly if the catenery system is used across hard substrata, may be evaluated using a simple parallel visual transect approach, arranged such that they pass across the lines at, or near to, 90$^{o}$ to the mooring direction. Depending on the prevailing wind and currents this may require several sampling stations along a series of linear transects, or the wind direction may be used to allow the camera to passively drift across the mooring line without repeated recovery and redeployment.

## 10.3 Diver Observation and Sampling

As previously indicated the use of divers is restricted to operating depths of less than 30m and would therefore only be suitable for monitoring of the shallower deployments of seabed-mounted Oscillating Wave Surge Converters. Because of the shallower depths, wave-induced water movement will, however, be a considerable problem for diving operations, the effects of which, depending on the level of wave energy present, may be expected to penetrate even to 30m.

Given the expected challenging conditions, it will be advantageous to keep diver tasks relatively uncomplicated and to avoid the use of bulky or delicate survey equipment wherever possible.

The simplest approach is to employ a straightforward visual assessment of change, by recording the extent and degree of severity of physical damage to substrate and habitats at locations selected for severity of impact, or as representative of a particular impact or receptor. This is most effectively undertaken in the form of a surveillance programme using periodic diver video records targeting the immediate vicinity of seabed structures, pilings, mooring and associated chains and cables. For the most part, this would be documenting the recovery of impacted areas, hopefully providing confirmation of the re-establishment of natural communities or the maintenance of a limited zone of impact. The inclusion of a structured method in the use of video, such that the diver sequentially obtains both detailed and wide-angle contextual footage of the same area at each visit, will ensure that a valid comparison can be made and that significant biological changes are captured.

Divers may also be used in the same type of sampling designs previously suggested for drop-down video and grab sampling. A ‘broad-scale’ randomised diver observation, hand-held video or sediment coring programme can be undertaken (assuming the entire area is within diving depth) through simple effort-limited ‘spot dives’ of a predetermined bottom time duration (typically between 5-20 minutes). A variation on this method is the use of short diver-deployed transects at each randomly generated position, usually between 10-20m in length, rather than the time limitation. The fauna and flora falling within one or two metres either side of the transect, depending on visibility and/or natural species abundance, are documented using semi-quantitative abundance scales to give a dataset from which a biotope may be derived for each sample station.

The ‘spot dive’ approach can also be used along an impact gradient, or as a means of directing or reducing effort by placing sample stations at regular intervals along a transect.

An alternative method to a randomised design is the use of permanent or fixed quadrats. These can be used to determine the impact of a development on specific species or communities within small defined areas and is best suited to situations where highly localised and vulnerable biological features have been identified. The quadrat or frame that defines the area under investigation can either be fixed into position as a permanent structure, or some form of marker or locating pins may be fixed into the substrate such that a frame structure can be positioned at the same location and orientation at each monitoring visit. Given the degree of expected exposure at these locations the long-term durability of a solid quadrat assembly will always be suspect and a minimum of permanent structure should always be considered. In addition, the presence of the frame itself may potentially have modifying effects on the species which are covered or enclosed by it.

Moreover, it is important to note that this method performs a census over the same area at each visit and is therefore restricted to only detecting change *within that area* and cannot be used to extrapolate effects with any degree of confidence to other locations within the development site.

# 11 MONITORING METHODS TO ESTABLISH IMPACTS OF CONSTRUCTION AND OPERATION OF TIDAL DEVICES

In general, all of the approaches suggested for wave devices remain valid for the monitoring of the effects of the construction and operation of tidal devices and there is therefore no reason to revisit them in this section.

There are, however, some important differences in the physical conditions in which a tidal device operates which will influence the selection of particular methods and equipment. The principal difference is obviously the presence of strong tidal currents and these may produce environments that are distinct from wave exposed locations. Tide-swept areas, particularly inshore locations such as around headlands, in tidal narrows between islands, or at the entrance to sea lochs and shallow inlets, often support high diversity and biomass, probably due to the reliable supply of food entrained in the water column. Because of this, there may be a requirement for greater taxonomic expertise and monitoring designs operating over a smaller spatial scale than in the less abundant wave exposed habitats.

The strong water movement may also produce more pronounced directional impact effects from a device, either arising from scouring, changes in turbulence, travel of contaminants, or the direct removal of downstream energy. In addition, fast flowing water makes the undertaking of any monitoring task difficult, with some methods such as grab sampling or the use of divers extremely challenging. For all tasks, the optimisation for successful sampling will revolve around the often short, but predictable tidal direction changes and monthly neap tides.

The overall effects of a single or multiple tidal devices would, as for wave devices, be most effectively monitored by a combination of broad-scale acoustic mapping and random drop-down image sampling. To ensure images of a suitable quality to identify community types or biotopes, the use of drop-down video equipment will be restricted to slack or slow water movement periods which may either limit the spatial resolution of a survey or require a compromise in the area of coverage. In most cases, a suite of confined or stratified locations which are well-characterised will be preferable to a wider but more sparsely distributed sampling strategy if time and resources are an issue.

Because of the expected strong directional component of any impact, which will be sharply orientated along the direction of current flow, the greater part of the post-installation and operational monitoring can be concentrated in a relatively narrow area directly downstream (for half a tidal cycle) of the axis of an individual device. With a relatively homogeneous seabed, a transect-based approach covering one downstream/upstream side of the device is likely to be sufficient for impact monitoring, providing that a reference station of similar faunal composition can be located outside the identified impact zone. The reference station need not be particularly distant and could simply be located laterally to the device at a sufficient distance to be confidently beyond any influence from the tidal turbine. In practice this is likely to be no more than 50 – 100m, unless extensive sea bed excavation or contamination has taken place. Where there is a range of relatively diverse habitats present within the predicted impact zone, more than one transect may be necessary to ensure that the full range of possible impacts are being investigated.

At present, there is very little information on the effects of tidal turbine operation on the benthos and it is difficult to predict whether observable habitat or species effects will be present and over what distance. It is conceivable that combination or amplified effects may result when the number of devices is increased, consequently when multiple turbine arrays are being considered it may be prudent to ensure that at least one monitoring transect is placed along the axis of a single device that is central, or near central, to the array.

The SeaGen tidal turbine, currently installed in Strangford Lough, Northern Ireland, provides the only example of a successful ongoing benthic monitoring programme for an operating tidal device.  This case study is outlined below:

***Example: SeaGen, Northern Ireland***

SeaGen is a single structure supporting two horizontal axis turbines on a cross-beam arrangement. It is installed at around 25m depth with the surrounding predominantly rocky sea bed achieving a maximum depth of 30m. The location is within a Special Area of Conservation and the rocky reef is a qualifying feature of the site. A pre-installation survey of the area was carried out using broad scale acoustic mapping with dropdown video and diver observation ground-truthing. The benthic communities were found to be relatively uniformly distributed and dominated by an often dense hydroid turf with a high incidence of sponge cover.

The depth range, in this case, is within the reach of diver surveyors and the density of biota is appropriate for a quantitative monitoring design that operates over a small spatial scale. This was considered important since the tidal regime allows a very limited time window in which a sample station can be visited and species abundance data collected.

The monitoring design for the SeaGen device consists of two elements:

1. A rapid general video sweep concentrating on (a) one of four anchor points established for the installation platform during the construction process; (b) one of four pin-pile legs supporting the turbine structure; and (c) directly beneath the supporting structure. These were selected as representative of the initial physical impact of the installation procedure, although each location for a and b was also further distinguished from the four choices as containing the greatest density of longer-lived and fragile circalittoral fauna, such as the soft coral *Alcyonium digitatum* and various erect sponge species.

2. A transect aligned along the downstream axis of one of the turbines with fixed sample stations established at distances of 20m, 150m and 300m from the turbine plane of rotation. A reference station was also identified at a distance of 50m to one side of the device. The sample stations are permanently marked with acoustic beacons which can be quickly relocated by the diving support vessel. At each station five 0.25m$^2$ quadrats, divided into twenty-five 10cm x 10cm squares, are deployed by a diver. Each square is sequentially captured by video using a slow panning motion.

The sampling stations were established and sampled prior to the installation of the device, which required close collaboration with the installation engineers to achieve an accurately positioned transect that would subsequently be precisely in alignment with the chosen turbine. The monitoring schedule incorporates two irregularly spaced sampling periods in a year, one in early spring and the other in mid- to late summer. These were selected to correspond with the pre-installation sample timing and to reflect optimal faunal growth, while avoiding the winter months, where seasonal dormancy or die-back of some characterising species might obscure the more subtle impact effects of the device.

The diver-deployed video image quality has provided quantitative abundance estimates of the communities at each sampling station, with a total of over sixty species recorded, although the samples from all stations are always heavily dominated by around four species of hydroid or sponge. Multivariate statistical analysis of the communities (ANOSIM) has revealed statistical differences between stations and sample times, but the community changes across all stations within the downstream influence of the SeaGen turbine are broadly similar over time and are largely mirrored in the reference station. It has therefore been concluded that the observed changes over four sample times are relatively minor and are a result of a combination of normal seasonal variation and a natural process of species competition and succession.

The results from the SeaGen monitoring strongly imply that the overall effects of this tidal turbine, assuming negligible seabed disruption or damage during the installation phase, are likely to be minor and probably difficult to detect. The SeaGen monitoring programme has strongly benefited from the manipulative dexterity that comes with the use of divers.  The next phase of tidal device deployment is, however, expected to be beyond the reach of unspecialised diving techniques and will inevitably be dependant on remote sampling techniques, of which drop-down video as previously suggested is likely to be the most practical.

# 12 SUMMARY OF SURVEY AND MONITORING METHODS

**Table 12.1** Summary of methods available for the monitoring of renewable device impacts on the benthos. 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 of change | Comments |
|---|---|---|---|---|---|---|
| Acoustic survey | Substrate distribution<br><br>Habitat/ community distribution | AGDS, sidescan sonar Multibeam | Overlapping parallel tracks | One pre-installation then every 2-5 years. | Visual comparison of seabed maps, GIS spatial analysis | May not be necessary if more frequent monitoring methods indicate no direct substrate or bathymetric modifications |
| Drop-down video/ photography | Distribution of habitats/ communities/ biotopes | Drop-down imaging system | Grid arrangement, Random sampling, stratified random sampling, transect sampling | One pre-installation then annually | Chi-square or Wilcoxon signed rank test comparison of biotope composition of site<br><br>Simple visual comparison of biotope frequency data | Fastest flowing or most turbulent and vertical rock habitats may be under-recorded |
| | Presence of specified species | Drop-down imaging system | Random sampling, stratified random sampling, transect sampling | One pre-installation then annually | Comparison of proportional occurrence | |

| Method | Metric | Equipment required | Survey design | Suggested monitoring interval | Analyses of change | Comments |
|---|---|---|---|---|---|---|
| | Maintained presence of priority species at specific locations | Drop-down imaging system | Directed visual sampling | One pre-installation then annually | Simple confirmation of presence | Note that the failure to detect a species in the sampling programme does not mean that the species is absent. |
| ROV video/ photography | As for drop-down video | ROV | As for drop-down video | As for drop-down video | As for drop-down video | As for drop-down video |
| Grab sampling | Species abundance per unit area<br><br>Species richness<br><br>Diversity indices | Van Veen grab<br>Day grab<br>Hamon grab | Grid arrangement, Random sampling, stratified random sampling, transect sampling | Annually, but at least two at pre-installation to establish natural variability | ANOVA | Note that the Hamon grab is the least reliable for quantitative recovery, but is most reliable for recovery of recover coarse sediments |
| | Community composition | Van Veen grab<br>Day grab<br>Hamon grab | Grid arrangement, Random sampling, stratified random sampling, transect sampling | Annually, but at least two at pre-installation to establish natural variability | Ordination (MDS, PCA)<br><br>ANOSIM | Note that the Hamon grab is the least reliable for quantitative recovery, but is most reliable for recovery of coarse sediments |
| Diver core sampling | Species abundance per unit area<br><br>Species richness<br><br>Diversity indices | SCUBA, diver-deployed cores | Random sampling, stratified random sampling, transect sampling | Annually, but at least two at pre-installation to establish natural variability | ANOVA | |
| | Community composition | SCUBA, diver-deployed cores | Grid arrangement, Random sampling, stratified random sampling, transect sampling | Annually, but at least two at pre-installation to establish natural variability | Ordination (MDS, PCA)<br><br>ANOSIM | |
| Diver video/ photography | Broad community character and substrate condition | SCUBA, underwater video or stills camera | Location directed | One pre-installation, then every 3-6 months (or synchronise with other diving tasks) | Simple visual comparisons | Should target locations where physical damage is expected |

| Method | Metric | Equipment required | Survey design | Suggested monitoring interval | Analyses of change | Comments |
|---|---|---|---|---|---|---|
| Diver transects (visual survey) | Semi-quantitative species abundance (MNCR Phase 2 surveys)<br><br>Biotope presence and distribution | SCUBA (underwater video or stills camera optional) | Transects, stratified random sampling, directed 'spot dives' | One pre-installation, then a minimum of two per year | Direct comparison of community attributes (semi-quantitative abundance, biotope presence | Can be combined with video or photographic documentation.<br><br>Sample times should be selected to correspond to periods of maximum species presence i.e. avoid times when some species may be inactive, dormant or undergoing die-back |
| Diver quadrats | Species abundance (individual abundance or % cover) | SCUBA, quadrat | Replicated samples from plots arranged along transects | At least one pre-installation, then a minimum of two per year | Ordination (MDS)<br><br>ANOSIM, SIMPER | Size of quadrat dependant largest species present (see section 15.4) |
| | Species richness/ diversity | SCUBA, quadrat | Replicated samples from plots arranged along transects | At least one pre-installation, then a minimum of two per year | ANOVA | Size of quadrat dependant largest species present (see section 15.4) |
| | Abundance of selected conspicuous species | SCUBA, quadrat | Replicated samples from plots arranged along transects | At least one pre-installation, then a minimum of two per year | ANOVA | Size of quadrat dependant on species being quantified (see section 15.4) |
| Intertidal survey | Presence and spatial distribution of intertidal communities/ biotopes<br>Beach profiles | Tape measure/ transect line | Vertical shore transect | One pre-installation survey then annually | Simple comparison of spatial arrangement of biological zonation relative to tidal height | |
| | Selected species abundance | Tape measure/ transect line and, quadrats | Replicate quadrats within selected zones | One pre-installation survey then annually | ANOVA | |
| | Maintained presence of priority species at specific locations | GPS | Visual location and repeated observation | One pre-installation survey then annually | Simple confirmation of maintained presence (may require additional information on condition. | |

# 13 DATA GAPS AND MITIGATION

## 13.1 Data gaps

The wave and tidal industry is still at an early stage in development, and therefore several uncertainties exist as to the impacts of deployment of such devices.

In particular, there is limited current knowledge on the effects associated with wave shadowing associated with surface deployed wave devices, and the potential impacts on the intertidal environment. As discussed in the protocols, intertidal surveys should therefore form part of the monitoring strategy for wave devices situated within 2km of the coastline, to enable a better understanding as to the modifications, if any, caused to coastline habitats.

In addition, there is limited data currently available regarding the natural change of benthic sediments and associated shifts in community structure. It would be of benefit to the industry for further research to be conducted into community succession in wave and tidal environments, to develop a greater understanding on the pattern of natural community change in sublittoral infaunal communities.

## 13.2 Mitigation

An understanding of the benthic habitats and communities, and the potential impacts caused during deployment and operation of devices, enables mitigation to be fed into design from an early phase in the development, for example with regards to micro-siting of devices to avoid more sensitive or vulnerable areas. Monitoring data designed to assess impacts will also feed into a mitigation plan and an adaptive management programme.

# 14 SHARING BENTHIC DATA

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

The creation of a joint database would also be beneficial to allow scientists to access each others' data sets easily. There is potential for benthic 'control' sites to be shared between development sites, however close collaboration between developers is essential for this to be successful.

# 15 SURVEY AND MONITORING PROTOCOLS FOR BENTHIC HABITATS AND SPECIES

## 15.1 Drop-down video/photography

### 15.1.1 Survey design

#### *15.1.1.1 Grid sampling design*

The simplest initial survey approach is the establishment of a regularly-spaced sample pattern, such as a grid, across the area of interest, thus providing a map of the continuous distribution of habitats and species with the degree of resolution dependent on the density of the sample drops. While this will directly satisfy the requirements of a pre-installation survey it will limit any subsequent use of the data for comparative monitoring purposes if a statistically valid design is considered necessary.

#### *15.1.1.2 Wider scale random sample monitoring*

If the seabed is largely homogeneous, drop-down video can be deployed using a more statistically robust randomised sampling design over the entire area. There is, however, no generic rule for determining sample density and distribution. The number of video samples will depend on the area to be surveyed and the density of the identifiable biota as determined from the pre-installation survey. Each sample should consist of a standardised video segment – either by deployment time (5-20 minutes) or distance (50 -100 m straight line distance). The choice of an appropriate sample unit may be location specific and will depend on either current velocity or prevailing wind speed and direction; or a combination of the two.

Where the area contains different substrates or habitats a more refined approach may be considered necessary and stratified random sampling should be employed to concentrate more of the effort onto areas that may yield more detail (e.g. rock vs. sediment).

An alternative stratified sample design might be to establish sampling blocks or ‘belt transects’ that cross a good range of habitats and effectively allow a greater sampling intensity in a smaller area but provide a proxy for the whole site.

#### *15.1.1.3 Feature extent monitoring*

Where an important biogenic feature is found to be confined a discrete area with well-defined boundaries, drop-down video can be used to monitor for any change in extent of that feature. The sample design would depend on the shape or pattern of the feature distribution, but would commonly comprise sample points along transects that span the feature boundaries. Repeat sampling would establish whether the boundaries were moving, indicating an expansion or contraction. An example of the use of this method would be in the determination of undesirable impacts on maerl or *Modiolus* beds.

Note that bed- and reef-forming species usually incorporate a hard shell, or outer calcareous structure that may survive the organism itself for a considerable length of time after death and there may be relict biogenic debris fields with no appreciable densities of living specimens in the area at all. These may in themselves constitute valuable habitats for other species but it is important in all cases to establish that live examples of the original biogenic structure builders are present before committing resources to an extensive survey and monitoring programme.

### 15.1.2 Equipment and other resources

#### *15.1.2.1 Video camera*

The video camera should be a professional high definition model, capable of producing clear images when paused. The mounting orientation of the camera differs in some systems, with the viewpoint either looking directly downwards at the seabed or at an angle (~45$^{o}$ to the horizontal is common). The use of oblique angle of view improves the ability to identify species.

In low visibility, during plankton blooms, or on easily disturbed soft sediments, the camera may have a tendency to mis-focus if set to autofocus. In these situations, the camera should be set to a manual and a fixed focus distance appropriate for the intended operational parameters selected.

Additional technical information on video equipment can be found in Eleftheriou and McIntyre (2005).

#### *15.1.2.2 Lighting*

The use of the correct video lighting system vastly improves the definition and overall visual quality of underwater footage and thus the ability to identify species and habitats. Lighting can either be from high intensity discharge (HID), halogen or light-emitting diode (LED) sources, but must provide sufficiently bright and even illumination with no ‘hot spots’ and should approximate to daylight colour temperature (3200K or greater). There should be a light source either side of the camera, positioned to provide optimum light distribution at the correct camera-to-subject distance.

#### *15.1.2.3 Scale measurement*

When reviewing video footage, species identification can greatly benefit from an indication of scale, either having some idea how far an object is away or what its dimensions are. Vertically orientated systems often have a plum-line (a line with a weight at the end) that indicates both the orientation of the camera and a specific distance from the seabed when the weight rests on the bottom. Other systems use specifically aligned laser beams to indicate size of a seabed feature or the distance from a target object.

#### *15.1.2.4 Position fixing*

An accurate position, using differential GPS, must be established at the start and end of a video tow or drift. The actual position is usually taken from the vessel when seabed contact is made at the start and when recovery commences at the end, taking care to manoeuvre the deployment vessel such that the umbilical or tether line is vertical and is therefore a true representation of the seabed position of the camera. If this is not possible and the operating depths are large, an estimation of ‘layback’ may be necessary, involving a trigonometric calculation based on camera depth and observed angle of umbilical (usually established with the use of a hull-mounted protractor system. Some systems may be fitted with a locator beacon that can be directly referenced to a vessel mounted dGPS. A direct display of dGPS position of vessel on to a projected GIS display with the added ability to record the exact positions of the TV tow and still photograph positions is also useful feature of a video recording system.

The selected positioning coordinate system must be compatible with all of the other survey and monitoring tasks and would normally be relative to the World Geodetic System (WGS84) datum

#### *15.1.2.5 Digital stills camera*

The analysis of video footage requires constant pausing and replaying to derive a full census of species present. The almost constant movement during the deployment of a drop-down video system means that there is an inevitable blurring of most, or all, of the images when paused, often rendering confident identification a difficult task. Many experienced surveyors strongly recommend the use of a supplementary digital stills camera and flash system which can be configured to continuously take images at short intervals or can be triggered manually. The quality of these images is usually substantially better than a paused video frame.

Analysis of the recent drop-frame video survey data from the Pentland Firth and other Orkney sites strongly suggests that a supplemental attachment of a high quality photographic stills camera, either manually or automatically triggered to fire at short intervals provides the best quality images for determining species composition of benthic communities (Moore, 2009, 2010).

Additional technical information on photographic equipment can be found in Eleftheriou and McIntyre (2005).

#### *15.1.2.6 Vessel*

Holt and Sanderson (2001) list the following as important considerations in the selection of a drop-down imaging system deployment vessel:

- Is it capable of manoeuvring in shallow restricted waters or wherever the equipment is to be deployed?
- Does the boat have a power supply for running the drop-down equipment? If not, can batteries or a generator be adequately housed on board?
- Is there suitable dry cabin space or is the boat open to the elements?
- Is there a position on board where the sled and video can be easily deployed without long drops to
- The sea surface or danger from entangling the umbilical with other equipment/propellers etc?
- Can the helmsman and video operator both see the video image in real-time?
- Does the vessel carry sufficient safety equipment and comply with current workboat codes of practice?

Further detail on equipment options and the field use of remote video, including suggestions for survey design, logistic and analysis can be found in the guidance notes of Moore and Bunker (2005) and Holt and Sanderson (2001).

### 15.1.3 Personnel

The number of field staff and degree of specialist expertise required of each will be dependent on the task and type of equipment. Smaller, more portable devices can be operated from small vessels or even rigid-hulled inflatables and will require a minimum of three survey team members; one surveyor viewing the real-time video and directing operations, another laying and recovering umbilical cable and a boat skipper with an optional additional crew member. Larger devices will require a powered winch necessitating an additional suitably qualified crew member dedicated to this task. If there is an element of work that is dependent on recognising and locating particular species or habitats in the field, then one of the team must be an experienced marine biologist.

Because of the presence of an umbilical cable, the boat skipper must be suitably experienced and comfortable with manoeuvring the vessel around potential fouling hazards in sometimes difficult sea conditions.

The review and analysis of the video footage must be carried out by an experienced marine biologist, preferably with some experience of video analysis and knowledge of Scottish marine benthos. Moore and Bunker (2005) also recommend that a system of quality assurance should be initiated, incorporating the use of a second marine biologist.

A standardised system of QA and specialist accreditation specifically for establishing consistency in benthic video analyses is presently under development through the NMBAQC scheme, although at the time of writing this guidance no formal UK-wide QA procedures or requirements have been produced. The results of a programme currently at the trial stage, including some useful observations and recommendations can be found in Envision (2010), AFBI (2010) and Addison (2010)

### 15.1.4 Procedures

#### *15.1.4.1 Pre-survey planning*

Using existing information, such as charts or existing survey information, the survey area should be examined for opportunities to divide the site into defined zones or stratifications based on bathymetry, existing human use or community and species affinities. In the case of a pre-installation survey, with little or no previous information, the initial survey design may be planned for broad coverage, partly or wholly as ground-truthing in support of a broad-scale acoustic mapping survey.

### 15.1.4.2 Method selection

As with all monitoring, the aims and objectives of the sampling strategy, together with methods of analyses must be established prior to committing to a full field survey, since this will ensure that the correct types of data are collected. In reality, a stratified random approach will satisfy a range of metrics and may be adapted for effort appropriate to the spatial scale over which the survey is expected to operate. Table 15.1 provides a summary of the methods suggested in this guidance.

**Table 15.1 Summary of methods and target options for drop-down imaging devices**

| Metric | Method | Assessment target |
|---|---|---|
| Range of biotopes present | Random sampling or stratified random sampling | Establish that each biotope originally present is still extant in the impact area |
| Number of biotopes present (habitat diversity) | Random sampling or stratified random sampling | The number of individual biotopes has remained the same in the impact area |
| Species richness (species diversity) | Random sampling or stratified random sampling | The total number of species and the mean number per sample are maintained in the impact area. |
| Species presence/community structure | Random sampling or stratified random sampling | Benthic community structure is maintained - measured as the frequency of occurrence of selected conspicuous species in the impact area (i.e. % of samples in which a species occurs) |
| Extent of biogenic feature | Transect sampling | The spatial extent of the biogenic feature has not changed. |

### 15.1.4.3 Field deployment

The information obtained from drop-down video reduces with increasing speed of travel over the seabed, so deployment in fast moving water should be avoided. Because powered towing of a drop-down video system causes the device to lift away from the bottom, the usual method of use is to allow the support vessel to passively drift with the tide. If working from a small vessel in strong winds the resulting wind-induced drift may also significantly reduce the quality of the image.

In low visibility situations, a moderate sea, with significant swell may cause it to be intermittently raised from the seabed beyond the distance at with the bottom can be seen, rendering the images difficult to interpret.

Remote video systems usually consist of a frame-mounted camera and lighting system with an umbilical running to the surface where a monitor and video recorder allows real time viewing and storage of the video data. When travelling over the seabed the frame system is raised and lowered following the contours of the bottom to prevent collision. Because of the risk of entanglement, the use of drop-down systems around moorings, cables and buoys requires considerable care and in strong water movement deployment should be avoided. Entanglement may also be a problem when surveying infralittoral habitats dominated by kelp, where the ability to see the biota below the kelp canopy is likely to be severely restricted anyway.

Between 10 and 40 video drops can be achieved in a single day although this number is very dependant on time/distance of run, operating depth, sea conditions and the interval or distance between each drop. For most surveys a working estimate of 25 drops per day is a sensible number to assume for planning purposes.

See Holt and Sanderson (2001) and Moore and Bunker (2005) for additional detailed discussion of field deployment methods.

#### *15.1.4.4 Device time codes*

Holt and Sanderson (2001) point out the importance of equipment set-up prior to use, in particular the correct synchronisation of internal clocks in all of the field equipment that has such a facility. These will include dGPS, data loggers, digital video recorders and computers. Failure to do so may lead to confusion when attributing video records to particular locations, creating confusion, additional analyses and a lack of confidence in the collected data.

#### *15.1.4.5 Sampling frequency*

The frequency of sampling will be strongly dependent on the target habitats or species. Some communities in both wave exposed and tideswept locations may be subject to seasonal variability caused by physical (e.g. winter storms, light levels) or biological (e.g. annual algal growth, benthic recruitment, predation) factors. For this reason at least one sampling events should be carried out at the same time of the year, preferably between the months of May to September, which will also correspond to the period where the most favourable sea conditions would be expected. In general, unless there are particularly delicate or vulnerable species or habitats present, a drop-down video monitoring programme incorporating annual sampling should be sufficient to establish whether change due to anthropogenic influence has occurred.

#### 15.1.4.6 *Biotope assignment*

During the video analysis the assignment of community types as biotopes will form the basic unit from which ecological change will be measured. The unambiguous determination of biotopes is, however, not always straightforward from visual data and a means of applying consistency across all monitoring events will need to be established to maintain confidence in the ability to recognise community change. Moore and Bunker (2005) proposed a protocol for assisting in the biotope recording process (Table 15.2). This protocol should be viewed as a starting point for developing a set of site-specific rules that are appropriate to the equipment and sampling methods used in a drop-down video monitoring programme.

**Table 15.2 Protocol for assigning biotopes to video samples according to the heterogeneity of seabed (Moore and Bunker, 2005)**

| Heterogeneity of the video | Protocol for assigning biotopes |
|---|---|
| 1. Recording is of one single, unambiguous biotope representing 100% of the record. | One biotope tag. |
| 2. Record is of two or more biotopes along a tow, but the biotopes are separated from each other by distance (heterogeneity at the video tow scale). | Tow is divided into two or more records and the position of each record estimated from time that elapsed between the start of the tow, the total time of the tow and the total distance of the tow. Each record given one biotope tag. |
| 3. The viewer is uncertain as to which biotope tag to use because of poor correspondence with biotope classes in Manual. | The most favoured option used is to tag the record provisionally, but with other possible classes noted. Examples of records should be referred to a biologist with knowledge of the biotopes in the region. |
| 4. Key features or species can not be recognised from the video. | The record is tagged with higher class, life form or sediment type as appropriate. |
| 5. The record shows a mixture of two or more biotopes arranged patchily* within a single video frame (heterogeneity at a video frame scale). | The record is tagged with the predominant biotope but an estimate given as a percentage of the constituent biotopes. The record is also tagged as containing a boundary between biotopes (to distinguish from 6). |
| 6. The record has features which indicate that it could be regarded as lying between two or more biotope classes**. For example, very small quantities of *Laminaria saccharina* on sand could be considered as partially belonging to both a kelp and a sandy biotope. | The record is tagged with the most likely biotope, but an estimate of the degree of membership to each biotope given as a percentage value. If the record is patchy, these percentages are estimates of cover. The record is also tagged as containing a transitional biotope (to distinguish from 5). |
| Note that both patchy biotopes* and biotopes laying along a continuum** can be expressed as percentages which are estimates of the degree of membership to the component biotope classes. | |

Moore and Bunker (2005) also point out that recording consistency can be greatly improved if ‘crib notes’ are taken to help the surveyors recognise biotope characteristics and make decisions in borderline cases. This can be further aided by supplementing notes with clear examples obtained using digital video frame capture techniques and maintaining a well-documented library of representative images throughout the duration of the monitoring programme.

### 15.1.5 Data recording

During field operations it is advisable to keep a handwritten field log of times and positions of actual deployment alongside the intended positions. Even if GPS positions and depths are being logged automatically, basic details of the start and finish of each particular run and how these data correspond to the videotape time-coded sequence must be recorded to avoid the unusual, but nevertheless always possible eventuality of electronic instrument failure in salt-water environments. To aid efficiency, a standardised pro-forma containing all important information should be designed and printed before the commencement of field activities.

The reviewing or post-processing of video footage is usually undertaken in a comfortable office or laboratory environment equipped with facilities to view the footage directly with a high-resolution monitor and to slow or freeze the images when identifying the fullest possible range of species. Estimates of abundance are made by eye using the relative sizes of known features/species to gauge the size of the field of view. Notes should be made on standardised recording sheets. Once a complete run has been scored, the data are organised into biotopes (or habitat types if the characterising epifauna/flora could not be identified). Effort-limited drop-down survey methodology will require the minimum area over which a biotope can be assigned. Holt and Sanderson (2001) suggest an area of $5m^2$, below which the community cannot be distinguished from the surrounding biotope. Sparse or scattered features, such as boulders on sediment plains, should only be counted as separate biotopes if their total cumulative area exceeds $5m^2$ although their presence should be noted.



### 15.1.6 Data analysis

If distribution information, such as biotope maps, is to be produced then a GIS application will be necessary.

Change is assessed by a simple temporal comparison of the biotope composition and biotope richness of the entire site. This can also, however, be undertaken as a comparison for individual transects or depth zones, but the associated reduction in samples will inevitably reduce the overall power of any statistical test.

Change in biotope frequency can be statistically analysed in a number of ways, although a reduction or increase in particular biotopes will be almost certainly be easy to determine by simply visually comparing the frequency data.

Moore and Bunker (2005) suggest the use of the non-parametric Wilcoxon signed rank test, treating the individual biotope frequencies from the baseline and survey years as matched pairs.

An alternative method is a chi-square, or goodness of fit, test (also non-parametric) in which the biotope frequency distribution is assumed to be identical for both the baseline and post-installation sampling. A comparison is thus made between the observed (post-installation) biotope frequency and the expected (baseline) frequency. This method is sensitive to sample size, however, and biotopes with an expected frequency of less than 5 should either be omitted from the analysis, or included within the group of a higher classification level.

Since this analysis is carried out on frequency values there is no requirement for a balanced number of samples, so the number of drops could be increased if more resources are available, or reduced if, for example, deteriorating sea conditions prevent the completion of a full compliment of video drops.

## 15.2 ROV Survey

### 15.2.1 Survey design

From a benthic survey perspective ROVs provide remote visual sampling opportunities comparable to that of drop-down video/photography devices and can therefore be deployed in a similar way (see Section 15.1). Unlike the drop-video system, ROVs do have the ability to be more accurately orientated for increased precision when collecting visual data and can therefore inspect vertical or steeply sloping rock habitats in detail. When suitably equipped, ROVs can also perform some limited remotely-operated manipulative functions, such as collecting voucher specimens.

ROVs can be used to determine species, habitat, biotope and substrata distribution, but for simple visual documentation tasks they rarely offer an advantage over less sophisticated video equipment. Their value for benthic survey and monitoring is limited, being restricted to the deeper water surveys and for situations where the presence of particular species or discrete biological structures have to be confirmed. ROVs equipped with a built-in means of seabed area definition, such as an attached quadrat or laser projection device are theoretically capable of providing quantitative epifaunal data, but the degree of effort and time required to set up, calibrate and successfully deploy such systems is perhaps more appropriate for academic study, rather than a pre-installation survey.

### 15.2.2 Equipment and other resources

ROVs come in many shapes and sizes, but in general the size is related to the propulsion power and maximum depth they are designed to operate at. A ROV's ability to cope with water movement and swell will be related to the size and thruster power of the vehicle. The larger, more powerful devices, designed predominantly for deep-water maintenance and inspection work for offshore industries, although able to operate in the more difficult conditions, require large support vessels and maintenance teams, making them logistically unsuitable for environmental surveys. Smaller ROVs would be more practical, but still require a suitably equipped vessel and are difficult and dangerous to deploy in conditions of moderate swell. Most models will also struggle to cope with current speeds greater than 2-3 knots and would effectively become a drop-down video device anyway.

Most ROVs are fitted with one and sometime two high quality video cameras together with integrated lighting systems. Many have built-in locator beacons that can be directly referenced to the support vessel's dGPS to provide an accurate indication of the ROV geographical positions on the seabed.

### 15.2.3 Personnel

ROV operators need to be experienced in the particular ROV model to be deployed and be sufficiently competent to maintain fine control over the vehicle's position above the seabed while maintaining a steady position during imaging features of interest. Loss of control of such a device carries the potential for substantial damage to delicate habitats and species, while sustaining damage to the vehicle itself.

Apart from the operator the number of additional staff required for ROV operations will be dependant on the size and complexity of the vehicle itself. The smaller type of ROV that is likely to be used for biological surveys can usually be deployed and recovered with a winch operator with the assistance of one or two deck hands to steady the vehicle. While the ROV is submerged the operator will normally require the assistance of a field biologist to maintain an operational log and notes on observations.

Because of the presence of an umbilical cable, the boat skipper must be suitably experienced and comfortable with manoeuvring the vessel around potential fouling hazards in sometimes difficult sea conditions.

The review and analysis of the video footage must be carried out by an experienced marine biologist, preferably with some experience of video analysis and knowledge of Scottish marine benthos.

### 15.2.4 Procedures

Because of the inherent similarity with the more basic drop-down imaging systems, ROVs can be used in much the same way, incorporating the same survey designs and procedures. Because of the additional technical difficulties there are very few situations where ROVs offer major advantages over a non-powered system, except, as previously indicated where steep or vertical substrates need to be examined, or where periods of positional stability are required to identify the presence and possibly the broad abundance of particular species.

### 15.2.5 Data recording

As for drop-down video/photography.

### 15.2.6 Data analysis

As for drop-down video/photography.

## 15.3 Grab Sampling

### 15.3.1 Survey design

A range of sampling designs may be applied to the field deployment of grab samples, the intensity and extent of which will be dictated by the overall purpose, most significantly in the context of this guidance, whether sampling is to fulfil the needs of pre-installation survey, post-installation monitoring or a combination of the two.

Sampling may be arranged in a simple regularly-spaced grid which will give a representation of the continuous distribution of communities and habitats over the site, the resolution of which is dependent on the interval between the samples (and thus the number of samples). This approach is, however, not recommended for tasks involving comparative metrics because it violates statistical assumptions of sample independence. A grid arrangement may still be used, though, if a larger number of grid cells are created and sampled by random selection.

A more rigorous sampling design may be achieved by generating entirely random positions throughout the development site (and selected unimpacted zone if appropriate). The production of random positions can be accomplished through the use of a simple random number table for each of the x and y axes of a charting positional system. A more sophisticated alternative is to use the random position generator available in most GIS applications. This method provides a statistically valid sampling strategy and can be scaled to accommodate available resources and appropriate spatial intensity, but it can result in inconsistent or grossly uneven coverage, with some areas being greatly under-sampled over one or multiple sample intervals. In addition an 'entire area' random sampling approach may encounter particular difficulties in locations where there is a significant occurrence of hard substrata, since many of the generated positions will have to be sequentially discarded as effort is expended on the repeatedly unsuccessful deployment of the grab.

With greater information on the substrate occurrence and distribution (or other significant parameters) perhaps gained through a pre-installation or preliminary survey, a more focused strategy may be used where randomised sampling is partitioned and weighted to areas of greater or lesser importance. The stratification may be based on discrete areas of suitable soft substratum, presence of communities or habitats of particular interest, or to simply concentrate sampling effort to a representative area to increase statistical power.

Statistical analyses will usually require replicated samples. In general, a minimum of five replicates is considered adequate for most sampling programmes, although the larger samples obtained by the Hamon grab may be reduced to four (Thomas 2001).

More information on sampling design is provided in Thomas (2001).

### 15.3.2 Equipment and other resources

A detailed inventory of the equipment required for the grab sampling process, from collection through to enumeration, is beyond the scope of this guidance. A short outline with an example equipment list is provided in Thomas (2001), while a more detailed examination, through a review of several organisations' standard operating procedures, is provided in Cooper and Rees (2002).

In broad terms a grab sampling programme cannot be completed without the use of the following:

#### *15.3.2.1 Maps and charts*

These are essential for the design of the sampling strategy and every effort should be made to obtain the most detailed and up-to–date available. Digital versions on a GIS application platform will allow easy generation of randomised sampling positions.

#### *15.3.2.2 Grabs*

The devices most frequently used for UK marine survey work are the van Veen grab, the Day grab and the Hamon grab. The van Veen grab is acknowledged as a good all-round option and has been adopted as the standard by some organisations, notably for benthic surveys in the Baltic Sea. It is simple and quick to deploy and its long lever arms provide a substantial jaw closing force, but they also make it cumbersome to manoeuvre on a ship's deck and will sometimes cause it to be pulled onto its side before closing if the vessel is drifting. The Day grab is also a popular choice because it is also simple to use and is known to sample efficiently due to its greater weight which improves sediment penetration. In addition, the grab mechanism is incorporated into a metal frame which keeps the grab level on the seabed and prevents it from toppling over. The Hamon grab utilises a rectangular scooping action and is considered to be particularly effective in coarse, loose sediments, although is reported to be the least successful of the three at maintaining consistency where comparative quantitative sampling is required (Eleftheriou and McIntyre, 2005). Both the van Veen and the Day grab commonly collect a sample of around $0.1m^2$ of sea bed, while the Hamon grab usually recovers a larger sample of around $0.29m^2$.

#### *15.3.2.3 Vessel*

Grabs are necessarily heavy and bulky pieces of equipment and therefore require vessels equipped with adequate lifting gear and of a suitable size from which they can be safely deployed. In addition, samples are usually wet-sieved on board the vessel to separate the biota from the sediment to reduce the inconvenience of handling and transporting unwanted bulk, while also preventing unnecessary physical damage to the biological material before reaching the laboratory. Sufficient deck space will have to be available to allow this activity alongside the grab deployment and recovery.

#### *15.3.2.4 Positioning equipment*

A differential Geographical Positioning System with greater than 5m accuracy is considered essential (Thomas, 2001).

### *15.3.2.5 Sampling and preservation*

Sieve - The sieve mesh size will influence the time and cost of sample processing. The most commonly used mesh sizes are 0.5mm and 1.0mm, with the latter most frequently used for general habitat characterisation and the former if much more detailed analyses are required. The differences in retention abundance and species richness can be significant and may vary between sediment types. In general, though, a 1.0mm mesh size is adequate for the pre-installation survey and a subsequent assessment of community change.

Sample storage and preservation – A calculation of the correct number of sample containers is essential before departing for field sampling. The ability to be able to retain all of the samples collected, with suitable provision for possible *ad hoc* additions and a consideration for the further volume required for preservative reagents is an important part of the survey planning process. Similarly, an accurate estimation of the amount of preservative (commonly formalin) with the addition of a generous contingency must be undertaken to ensure that all samples are preserved at the earliest opportunity and are treated in a consistent manner.

Formalin must be buffered either by using sea water to dilute the concentrated formalin or by adding chemical buffers, such as borax, to the diluted solution.

Note that sample containers for non-biological material, particularly where sediments are to be submitted for chemical analyses, may be of a different design or capacity and may require specialist cleaning or treatment to avoid erroneous results due to prior contamination.

## 15.3.3 Personnel

The different types of grabs and their variations may require slightly differing methods of deployment, entailing a knowledge of optimum rigging and setting up procedures that are specific to the grab itself. It is anticipated that in most cases this work will be carried out by contractors who will supply both the equipment and sufficient numbers of knowledgeable operators, fully experienced in the deployment and recovery of the particular grab model in the range of conditions expected for the site and from a variety of vessel types.

Deployment of the most common types of grabs can be successfully achieved using two survey staff with the addition of a winch operator and boat skipper.

Field operators must also be experienced in the techniques of standardised ship-board sample treatment, processing and storage as it is likely that, given adequate deck space, the samples will be sub-sampled and sieved between or during grab deployment and dispensed to appropriate storage containers. For this reason the optimum number of sampling-dedicated survey staff is three; two for grab deployment and recovery and a third for recording and sample processing (Thomas, 2001). In addition, once calm waters have been reached they will usually be responsible for adding the correct concentration and amount of fixing/preservative solution prior to transportation to the laboratory for sorting and identification.

Benthic sample identification in the laboratory must only be undertaken by skilled taxonomists with a proven knowledge of Northern European benthic infauna. Individual taxonomists or contracting organisations may demonstrate their professional suitability through the (currently voluntary) participation in the UK National Marine Biological Analytical Quality Control Scheme (NMBAQC), in which samples from participants are submitted for examination by other members to evaluate identification accuracy and consistency. Similarly, granulometric and chemical samples must be processed and examined by appropriately trained personnel and may involve the selection of suitably accredited individuals, organisations or institutions.

### 15.3.4 Procedures

A description of field and laboratory methods, including a detailed procedural guide for grab deployment, together with general rules for working from boats is provided in the text and Appendices of Thomas (2001). In addition, a comparative review of standard operating procedures of twenty-three other participating NMBAQC members is reported in Cooper and Rees (2002).

The sieve mesh size selected for the retention of biological material is a choice that is often debated and will substantially affect the effort and cost of laboratory analysis. For most surveys the choice will be between a 0.5mm and 1.0mm square mesh. In general, although a 0.5mm mesh is likely to provide a greater number of individuals, a 1.0mm mesh has proved adequate for most survey and monitoring programmes and some operators suggest that the smaller size is more suited to estuarine studies Cooper and Rees (2002).

Standard PSA sampling, processing and analyses methods are widely available and guidance for achieving constant results is published and followed by most survey practitioners. Standardised procedures should be requested and contracted laboratories should be part of a recognised QA scheme such as the European Biological Effects Quality Assurance in Monitoring Programmes (BEQUALM) or the NMBAQC scheme.

### 15.3.5 Data recording

A range of data may be generated during the ship-board and laboratory phases of the sampling process. These are briefly listed below.

On-board data:

- GPS position of grab deployments
- Surface colour and texture of sediment (optional)
- Redox potential (optional)
- Photographic record of each sample (mandatory)
- Sieve mesh size(s) used
- Confirmation of collection of (sub)sample for PSA
- Confirmation of collection of sample for chemical analyses

Laboratory data:

- Species abundance per sample
- Particle size fraction weights
- Assayed chemical content

Note that it is important that the format of all positional data together with the correct datum must be established and agreed before the start of the fieldwork as this will have to be communicated to the vessel skipper to allow the appropriate adjustment of navigational equipment as necessary.

In general, for vessel-based work it is recommended that all data recording tasks are the responsibility of a single member of the survey team to ensure consistency of approach and to avoid some elements being missed during grab recovery and sample processing. For all sample data the association with positional information and sample numbering scheme must be accurately and rigidly maintained from the point of recovery. This is usually achieved through a previously prepared master pro-forma.

The laboratory-derived species abundance data should be entered into a Microsoft Excel or equivalent spreadsheet, with species names as rows and sample numbers as columns. This format allows easy import into PRIMER or other analytical software. Some applications may also require a zero entered where a species was not encountered.

There will inevitably be a number of species that cannot be identified to species level, either because the taxonomic literature is insufficient or, as is often the case, the specimen is only present as a juvenile, lacking the complete morphological characteristics necessary for definitive identification. Incompletely identified juveniles may constitute a substantial proportion of the sample and may even dominate the community. Where adults cannot be assigned a full species name it is sufficient to follow the Genera or Family name with "sp. A", "sp. B"…etc., since this can be legitimately used in diversity calculations and community analyses. Juvenile recording must be treated with care, because the assignment of a separate line on a spreadsheet will be incorrectly interpreted by analytical software as a separate species. Where large numbers of juveniles are present this will considerably modify the diversity and community characteristics, compromising temporal comparisons, particularly if one set of samples was taken during a seasonal, but transitory, peak in larval production. The options are to assume that the juveniles are representative of the abundance of the adult taxa and proportionately reassign abundance on the basis of adult occurrence, or to remove all juveniles not identified to species level. Both options are regularly used in benthic studies, but each may give different results when used in a statistical comparison. It is therefore recommended that the raw data be accompanied with spreadsheets accommodating both levels of alternative analysis.

### 15.3.6 Data analysis

#### *15.3.6.1 Biological community*

Grab samples provide a relatively complete representation of the benthic infaunal communities present at the sample station and can therefore be examined for change at both the population and community level using univariate and multivariate analytical methods.

The simplest statistical approach is to compare the mean abundance of a selection of species, usually the most numerically abundant or of particular conservation concern, across areas that are identified as within 'impact' and 'non-impact' zones. Data can be quickly and easily examined for statistically significant spatial and temporal change using analysis of variance (ANOVA) or the non-parametric equivalent, Kruskal-Wallis test, if there are suspicions of a non-normal distribution or unequal variance.

The same analysis can be applied to an assessment of mean biological diversity, either represented as a simple species richness (i.e. number of species or taxa present per unit area) or as an index, such as the Shannon-Wiener or Simpson Index.

These analyses, however, do not fully exploit the broad scope of community detail present in grab sample data. Multivariate analytical methods provide a means of examining change within the entire community beyond the constraints of a single species or index value.

Similarities and differences in community character across the site can be determined using cluster analysis, which will also indicate the presence of any major variation in replicate samples, either caused by micro-spatial variation or erroneous sample labelling.

Temporal change in community character in repeat sampled plots or stratified areas can be visually assessed by examining MDS ordination plots and statistically significant differences verified by applying the ANOSIM routine to replicate grab samples. Where differences are demonstrated, or are suspected but are perhaps not statistically supported, the use of the SIMPER application in PRIMER will provide a useful indication of the species that are contributing most to any sample differences.

#### *15.3.6.2 Sediment character*

Change in sediment granulometry can be assessed in terms of the variation in the proportion (percentage) of each of silt/clay, fine sand, medium sand, coarse sand and gravel (Udden/Wentworth scale).

More robust temporal statistical analyses (discussed in Eleftheriou and McIntyre, 2005) can be performed on derived descriptive parameters for each sample, such as:

- measures of central tendency (mean, median and mode)
- measures of scatter around a central value (dispersion, deviation, sorting)
- measures of the degree of asymmetry (skewness)
- measures of the degree of peakedness (kurtosis)

#### *15.3.6.3 Chemical contamination*

Where chemical contamination is considered an issue, a simple comparative assessment of the sediment concentration trend over time is likely to be sufficient to determine whether there is cause of concern.

## 15.4 Diving surveys

### 15.4.1 Survey design

Diver surveys, when compared to other sampling options, provide the greatest level of taxonomic detail and have consistently proved to be the best means of obtaining quantitative data and good quality video or photographic documentation. The manual dexterity and freedom of controlled movement afforded to a diver surveyor allows a considerable range of tasks to be undertaken. Observations on species, habitat, biotope and substratum presence, abundance and distribution can be completed with a greater degree of confidence than with the use of remote systems, particularly where there is a high occurrence of cryptic biota which usually requires manual manipulation to reveal obscured individuals. Similarly, some reef or bed-forming species (such as *Limaria hians* 'nests'), are not immediately obvious and require a diver's viewpoint, intuition and ability to physically handle the substrata and associated biota before confirmation of presence can be made.

The incorporation of diver survey methods into a monitoring programme examining the impacts of marine renewable devices does, however, require careful planning with full initial consideration given to whether the objectives may be more easily and safely achieved through other methods. Preliminary attention should be directed to:

- *Operating depth* – Increasing physiological risk, a requirement for more complex breathing gases and a major escalation in statutory on-site safety equipment requirements all become issues beyond a 30m depth threshold. For these reasons, and unless there are overriding grounds for considering otherwise, diver surveys should only be planned if there are clear opportunities to collect useful benthic data shallower than 30m.

- *Presence of spatially distinct features* – Unlike remote methods, diving activities will be constrained by the necessarily short periods on the seabed dictated by air supply and decompression issues, together with the need for extensive surface intervals. This substantially restricts the spatial area over which a practical diving study can provide useful data. In general, the greater detail and increased taxonomic precision afforded by a human presence on the seabed is best concentrated over smaller, more compact survey areas with a comparatively high density of benthic biota. Specific targets may include areas supporting delicate or vulnerable habitats, or discrete biogenic reefs or beds.

- *Presence of safe operating periods* – By their nature, sites selected for wave and tidal devices will present significant challenges for diver surveyors, being either prone to high wave-induced turbulence or strong tidal races. It is expected, therefore, that diver operations will be restricted to short periods when conditions become manageable. At some sites this may be prohibitively short, immediately indicating that diver sampling methods are not feasible. Sites identified for wave devices may be prone to periods of very low visibility and the times at which diving is possible will not be predictable. In this case an examination of records of seasonal calm water for the area may be necessary to predict if diving surveys are a practical option. In contrast, tidal devices rely on predictable water movement and the periods of directional change and reduced velocity (i.e. 'slack water') should be easily determined from tide tables and the measurements taken for the development itself. In general, divers cannot comfortably maintain position on the seabed beyond a current speed of 0.5 knots and the interval over which this speed or greater is absent at neap tides will be the major determinant in the design of a diver sampling strategy.

Diver sampling can be used in a range of survey designs, involving different levels of technical skill and ancillary survey equipment.

#### *15.4.1.1 Continuous transect sampling.*

A method commonly used for conservation monitoring in the UK. A transect line is deployed either along a particular route corresponding to an area of interest, or randomly deployed in a non-specific direction. The transects can be of any length, but typically range between 20m and 100m, depending on the diversity, level of detail collected and spatial area intended to be covered. Fixed location transects tend to be longer and fewer, while randomly deployed transects need to be of a suitable number to adequately reflect the diversity of biotopes within the sample area. A single diver, or a diver pair swim along the transect noting all of the species and their estimated semi-quantitative abundance within a 2m band either side of the transect line. Changes in substrate and habitat type are also noted to allow the determination of zones in which individual biotopes can be assigned. This is often referred to as a 'MNCR Phase 2' survey. The divers undertaking the survey must be experienced diving taxonomists, familiar with Scottish flora and fauna. A video record of the transect is often taken to provide a permanent record and to capture any species that might have been missed by the in situ observations.

A detailed description of the use of diver transect methodology can be found in Holt and Sanderson (2001).

#### *15.4.1.2 Spot dive sampling*

Divers descend at a series of random positions usually marked with a shot line deployed from a boat and, in a manner similar to the above, all species together with associated habitats and substrates are noted within a defined area relative to the shot line and a biotope is subsequently assigned. The survey area will depend on the degree of diversity and underwater visibility among other things, but will usually be of the order of 5-10m radius from the shot line. Spot dives may also be arranged as a series of regularly placed plots along an extended transect.

#### *15.4.1.3 Directed dives*

This method can be a variation of spot dive sampling where the surveyors are examining a specific location of interest in detail, or it might be a simple and rapid assessment of the presence or absence of a species of interest. Similarly, directed video dives may be used to document the biological recovery (or lack of) at a sample station which has received physical damage during the installation process.

A description of the use of hand-held video for sublittoral monitoring can be found in Munro (2001) and further technical discussion of techniques and equipment in Eleftheriou and McIntyre (2005).

#### *15.4.1.4 Quadrat sampling*

The pattern of deployment of replicated randomly placed diver quadrats will vary according to the preferred survey strategy, but will usually be either within a grid array, as random (or stratified random) plots, or arranged at regular intervals along a transect. Quadrat size will be dependent on the size and distribution of the biota (see below). Similarly, the number of replicate quadrats will be determined by a range of factors, but will always be greater than four to satisfy the requirements of multivariate analytical techniques (see Section 8.5).

An alternative method to a randomised design is the use of permanent or fixed quadrats. These can be used to determine the impact of a development on specific species or communities within small defined areas and the method is best suited to situations where highly localised and vulnerable biological features have been identified. The quadrat or frame that defines the area under investigation can either be permanently placed into position as a permanent structure, or some form of marker or locating pins may be fixed into the substrate such that a frame structure can be positioned at the same location and orientation at each monitoring visit. Given the degree of expected exposure at these locations the long-term durability of a solid quadrat assembly will always be suspect and a minimum of permanent structure should always be considered. In addition, the presence of the frame itself may potentially have modifying effects on the species which are covered or enclosed by it.

A detailed description of the use of diver-deployed quadrats can be found in Murray (2001).

#### *15.4.1.5 Core sampling*

Macrofaunal core sampling will only be appropriate where there is an interest in discrete areas of sediments, perhaps bounded by hard substrata, which cannot be adequately or accurately sampled by grab sampling techniques.

A detailed description of the use of diver-operated corers can be found in Brazier (2001).

### 15.4.2 Equipment and other resources

#### *15.4.2.1 SCUBA*

Diving shallower then 30m will normally involve the use of self-contained underwater breathing apparatus (scuba), comprising a main air cylinder, a back-up or emergency cylinder and a regulator for each. Neutral buoyancy at depth is usually achieved by using a dry suit connected to the air supply, which also provides thermal insulation in combination with an undersuit, hood and gloves. Additional emergency buoyancy is provided by a buoyancy compensator (also attached to the air supply) which is usually integrated into the cylinder attachment harness. The excess buoyancy of the equipment at the surface is counteracted by lead weighting fitted to a belt or harness, or integrated into the buoyancy compensator. A simple half-mask, covering the eyes and the nose is commonly used for biological surveys, although in situations where contamination is an issue, and where voice communication devices are considered necessary a full-face positive-pressure system will be required.

An emergency diver to surface communication system is mandatory under HSE regulations and this can be achieved by a simple rope/lifeline, or by the use of more sophisticated through-water or hard-wired microphone devices. The latter option is preferred by the HSE and additional justification on the grounds of safety may be considered necessary if the use if a lifeline is selected as the preferred means of communication.

Diving computers, although not mandatory if a timer and depth gauge is carried, are almost always used in scientific diving projects. Most modern diving computers store a great deal of information and allow an individual's dive profile to be downloaded to a computer in the event of an incident or incorrectly recorded details. They are often programmable to accommodate different gas mixtures and usually provide audible or visual warnings when approaching no-decompression time limits. The setting of a safe depth and time limit for each dive (based on commercial dive tables) is the responsibility of the Dive Supervisor, but computers provide an important safety backup if time or depth limits are accidentally exceeded.

*15.4.2.2 Video/ photographic equipment*

Diver-deployed video or photography might form an integral part of the monitoring methodology or may simply be a tool for visually documenting seabed species and habitats.

Compact high definition digital video cameras are readily available and manufacturers are constantly improving the image quality and resolution of imaging devices. Recording formats and digital storage media are also changing rapidly, such that a discussion here would probably be out of date very shortly after publication.

The major limitation on the use of a specific video camera model for underwater survey work will always be the availability of a good quality underwater housing that can reliably withstand the rigours of constant use during the course of a diving survey. A suitable housing should be rated to 50m depth or greater, be either neutrally or slightly negatively buoyant and allow underwater access to the full range of camera functions. Professional systems with large viewing monitors are particularly beneficial if accurate close-up framing and focusing is required.

Lighting can either be from high intensity discharge (HID), halogen or light-emitting diode (LED) sources, but must provide sufficiently bright and even illumination with no 'hot spots' and should approximate to daylight colour temperature (3200K or greater). There should be a light source attached to either side of the camera, positioned to provide optimum light distribution at the correct camera-to-subject distance.

Housings for photographic cameras are similarly model-specific and again must be of a professionally robust construction with a depth rating of 50m+. Camera resolution should be of 6 mega-pixels[7] or greater and the camera itself should be capable of capturing images in a RAW format. The use of a proprietary RAW format, available on most quality digital SLR cameras, allows a considerable degree of exposure latitude after the photograph has been taken. This is particularly helpful when some areas of a photograph are indistinct or partially obscured by shading effects, resulting in underexposure on some parts of the image. Detail that is not immediately visible can be restored without loss of image quality through increasing the exposure by the equivalent of several f-stops. Similarly, areas of the image over-exposed or 'burnt out' can be darkened and significant detail reinstated if required.

The continued operation of housed video or photographic cameras is highly dependent on regular care and maintenance. Most systems rely on pressure-seated rubber or silicone seals for their watertight properties. Each housing will be opened on a daily basis to remove media and download image data, replace batteries or adjust settings. Regreasing and re-seating seals together with other maintenance tasks, although not necessarily complex tasks, should be assigned to an experienced team member for the duration of the survey to ensure that the chances of equipment flooding is minimised.

#### *15.4.2.3 Vessel*

Diving operations will require a suitable platform from which the divers can safely be deployed and recovered. This can be either a suitably licensed and coded rigid-hulled inflatable or a standard work vessel equipped with a ladder or platform for diver retrieval. Survey locations greater than 3 miles from land are likely to require the additional flexibility and support afforded by the more substantial vessel. In more exposed conditions, however, a combination incorporating both types of vessels, taking advantage of the speed and manoeuvrability of the inflatable for rapid diver recovery may be advisable.

As a minimum all vessels must be equipped with dGPS, a marine VHF radio and pure oxygen in the event of a diving emergency.

#### *15.4.2.4 Compressor*

Extended diving operations in remote locations will require the use of one or more compressors to keep the divers supplied with compressed air (or nitrox). Some larger diving support vessels will be equipped with an on-board compressor, but where this is not

[7] Note that increased resolution in terms of megapixels does not equate to improved image quality. A consumer camera with a high megapixel rating may produce a significantly inferior image to a professional camera with half the megapixel density or less. This is because professional grade digital

available cylinder recharging will be a necessary daily task for one or more survey team members.

*15.4.2.5 Quadrats & cores*

The size of quadrats suitable for sublittoral surveys is discussed in Section 8.4. In general, replicated 0.5m x 0.5m (0.25m$^2$) is suitable for substrates supporting relatively dense individuals or turf forming species. If further subdivided into 10cm x 10cm squares, a full quadrat can be recorded in detail using video or photography and quantitative counts suitable for statistical analyses can be derived.

Larger quadrats may be necessary for sparser faunal distributions and larger species, such as echinoderms and sponges.

Quadrats frames can be constructed of metal or plastic, although if plastic tubing is used, lead weighting will have to be incorporated to counteract the natural buoyancy.

Diver-deployed macrofaunal cores should be of the dimensions 10cm diameter x 30cm length with two caps or rubber bungs for each end of the tube. The length permits a penetration depth of 20cm with a short protrusion to allow the end to be capped and to provide purchase when extracting the core from sediment. The construction material can be either metal or the thick plastic tubing commonly used in the plumbing trade.

15.4.3 Personnel

All diving personnel must be qualified to the minimum standards as set out in the HSE diving regulations and the Scientific and Archaeological Approved Code of Practice (ACoP). Contracting organisations vary in the specific qualifications accepted. Some will allow divers with advanced recreational certificates (CMAS 3-star equivalent and higher) to undertake surveys on their behalf, while others will only accept commercially orientated qualifications (HSE part IV, HSE SCUBA, European Scientific Diver). Even with these qualifications it is the responsibility of the Diving Contractor, through the Diving Supervisor, to ensure that each diving team member is adequately trained and experienced for the tasks undertaken and is proficient in the use of any specialised equipment.

All diving personnel must be in possession of a current medical (issued annually) and be physically fit and well before entering the water.

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SLRs incorporate better quality components and contain larger sensors with enhanced data handling capability, resulting in less noise and a cleaner, more accurate image.

Diving supervisors are appointed in writing by the Diving Contractor before the project begins. They require no specific additional diving qualifications, but must have a valid First Aid certificate and are expected to be well-experienced and familiar with all of the techniques and equipment that will be used in the survey. Diving Supervisors can be non-diving members of the team, but it is more usual for some or all of the diving team to rotate supervising duties.

Diving surveyors must have adequate taxonomic skills for the particular survey task. Where biological communities in their entirety are being recorded a high level of familiarity with benthic species will be needed. Tasks that require the quantification of a small group of selected species can usually be completed by surveyors with a less comprehensive level of knowledge.

### 15.4.4 Procedures

#### *15.4.4.1 Pre-survey planning and preparation*

Diving operations are labour-intensive and almost always carry considerable logistical challenges, involving important decisions in terms of equipment, personnel and vessel support. Sufficient time must be factored into the planning stage to critically examine the proposed methodology, establish competencies with prospective diver-surveyors and to confirm that equipment suitable for the planned tasks is available and functioning correctly.

All working diving activities require a Diving Contractor to be registered as the individual legally responsible for all aspects of the diving project. The Diving Contractor (usually the Managing Director or Chief Executive of a company or organisation) may then nominate a Diving Project Manager in writing to carry out the duties of the Diving Contractor. Diving Supervisors will also be appointed in writing by the Diving Contractor. Organisations and companies that regularly carry out diving operations will usually maintain a set of 'in-house' diving rules[8] that transpose the HSE Diving Regulations and relevant ACoPs into policy. Where diver surveyors from several organisations are involved it is advisable to arrange a meeting to identify and discuss differences in diving rules so that a unified system can be adopted.

Biological monitoring work will almost always be carried out under the Scientific and Archaeological diving ACoP, but if additional tasks are expected to be undertaken, such as

[8] For illustrative purposes a set of diving rules prepared for the University of Wales, but based on those currently adopted by the JNCC can be found at: http://nshss.bangor.ac.uk/documents/divingdoc2rules_000.pdf

the installation and maintenance of moorings, then the Commercial inland/inshore ACoP will apply, with an associated change in specific competencies and qualifications.

Prior to departure the Diving Project Manager will prepare a written risk assessment and project plan which will be issued to all members of the diving team and passed to the Diving Contractor for approval.

#### *15.4.4.2 Method selection*

The selection of a particular method incorporating diver surveys (Table 15.3) will initially revolve around the question of whether enough meaningful data can be gathered by diving given the restrictions of time and adverse conditions. In general, where conditions allow, diver sampling of the epibenthos using quadrats, either visually or by video/photographic recording, will offer the best opportunity for obtaining detailed data that will provide a statistically robust indication of change. This level of effort may, however, be unnecessary, unless there is a justified concern for the habitat being sampled.

Diver transect surveys will provide a greater level of taxonomic precision than if undertaken using remote imaging techniques, but the value of the additional data should again be considered against the potential reduction in area coverage and survey resolution.

Overall, the use of divers should be considered when positional accuracy is a priority (e.g. the use of fixed quadrats), where in-water obstructions exclude the use of tethered remote imaging devices and where particularly detailed taxonomic records are important.



**Table 15.3 Summary of methods and target options for diver observation and sampling**

| Metric | Method | Assessment target |
|---|---|---|
| Range of biotopes present | Continuous transect using MNCR Phase 2 methodology | Establish that each biotope originally present is still extant in the impact area |
| Number of biotopes present (habitat diversity) | Continuous transect using MNCR Phase 2 methodology | The range and number of individual biotopes has remained the same in the impact area |
| Priority or vulnerable species presence | Directed spot dives | The presence of the identified species is maintained in the impact area. |
| Epibenthic community structure | Random quadrat sampling or stratified random quadrat sampling | Benthic community character and structure is maintained |
| Infaunal community structure | Core sampling | Benthic community character and structure is maintained |

Methods that depend on repeat sampling at a specific location, such as fixed quadrats, will require a method for accurately relocating the site. While dGPS may allow sub-10m accuracy the underwater conditions may still make visual relocation difficult and valuable time will be lost in the search. Depending on the value placed on pin-point accuracy, the use of electronic relocation beacons may be considered a cost effective option.

#### *15.4.4.3 Standardisation and consistency*

Underwater operations are often complex and physically demanding, with divers constantly adjusting equipment to compensate for changes in their environment, while monitoring their depth and time. The addition of yet more complicated equipment and tasks inevitably increases the risk of confusion and inconsistency which cannot easily be rectified in situ. To avoid lost dives through confusion or incompatible data due to surveyor variability, each task should be described in detail, assuming no prior knowledge of the method so that all divers are operating to the same established set of procedures. Video capture, for example, should follow a standardised directional sequence, and should include both contextual slow panning and close-up habitat and species footage. Similarly, quadrat video or photographic documentation should always begin at a particular corner and follow a consistent sweep pattern.

#### *15.4.4.4 Sampling frequency*

Sampling frequency and the duration of sampling intervals will be entirely dependent on the sampling methodology and the target species, habitat or feature. A major limitation, however, will be the regularity of favourable sea conditions and neap tides. For most sampling tasks a single survey visit in the summer months will be adequate to determine coarse changes after one year post-installation. More sensitive species and habitats may require a more intensive sampling strategy, with perhaps two or three visits between March and October.

### 15.4.5 Data recording

Field data will be recorded predominantly in one of two forms; either as direct observations (species abundance, habitat type, substrate type etc.) made by the diver surveyor onto a slate or waterproof notepaper, or as image data (video or photographic) onto a digital storage medium.

In situ written records made by divers must be transcribed daily so that the underwater slates can be immediately returned to service and to avoid accidental removal due to abrasion during transport and storage. Transcription into a complete survey document is usually a task undertaken by the diver who originated the record to avoid misinterpretations and other errors.

Digital video footage and photographic images should be downloaded, logged and stored at the end of each day. It is advisable to maintain a second backup of this and other digital data on an external hard drive, since physical corruption is an ever-present danger with all digital media, particularly where there is regular exposure to abrupt temperature changes and the presence of moisture through condensation.

If using video tapes (MiniDV etc) it is essential to label and log them accurately. All media should be changed frequently so that there will be no chance of dives having to be terminated early due to reaching its capacity. To aid efficiency, a standardised pro-forma containing all important information should be designed and printed before the commencement of field activities. As a minimum this must include: date, location, videographer/photographer, time code start & end.



### 15.4.6 Data analysis

#### *15.4.6.1 Continuous transect sampling*

The observational data obtained from the MNCR Phase 2 methodology will comprise semi-quantitative species abundance, habitat and substratum records allowing the assignment of single or multiple biotopes along a transect. In the case of fixed repeat-survey transects, change will be determined by a simple direct comparison to determine if community modifications due to the development have occurred along the length of the transects. The evaluation of change using data from randomly placed transects requires a different approach. Here, the maintenance of the number and range of biotopes is under investigation, in particular the persistence of dominating community assemblages.

#### *15.4.6.2 Spot dive sampling*

As for continuous transect sampling.

### 15.4.7 Directed dives

Directed dives are primarily location-specific visual assessments and therefore only require a simple direct comparison, either confirming the maintained presence of a particular species or biogenic feature, or the general recovery status of a previously damaged area of seabed.

#### 15.4.7.1 Quadrat sampling

The treatment and analysis of quadrat sample data will vary depending on the type of data collected. Species abundance counts for large macrobenthic species may be analysed directly using univariate methods such as ANOVA (assuming homogeneity of variance), comparing mean abundance over each sample event.

Where communities are dominated by turf-forming and colonial species the abundance data should be quantified as a percentage cover rather than number of individuals. Prior to statistical analysis each sample will then be converted to decimal proportions and arcsine-square root transformed to reduce the skewness that often results from proportional values and to make the samples more comparable. The replicate samples can then be subjected to multivariate analysis to determine community similarity or dissimilarity across both sample location and sample time.

Cluster analysis (e.g. Bray-Curtis similarity) calculates a rank similarity matrix that will group each sample according to similarity in a dendrogram, simultaneously confirming the common spatial origin of replicate samples and indicating where major community divergences occur. Similarly, multidimensional scaling (MDS) using the same similarity matrix will display sample similarities and differences in the form of a two- or three-dimensional ordination plot. The presence of a statistical difference between replicate quadrat groups can be further determined by the use of the analysis of similarities (ANOSIM) routine, while the contribution of particular species to these differences can be established by applying the similarity percentages (SIMPER) application.

#### 15.4.7.2 Core sampling

Replicate core samples should be treated and analysed as indicated for grab samples (Section 15.3.6)

## 15.5 Littoral Survey

### 15.5.1 Survey design

A littoral survey is only likely to be necessary when an inshore wave device with a significant area of floating structure is placed sufficiently close to a shore to modify wave action or present a significant risk of contamination from chemicals or debris.[9] A reduction in wave energy, in particular, has the potential to change the community composition of the shore through a number of processes (Murray *et al*., 2006):

- Change in food delivery regime and loss of other nutrient sources;
- Modification of gas composition of water;
- Reduction in the arrival of propagules;
- Reduction in the wetting of surfaces and total duration of submergence; and
- Limitation in the foraging capabilities of selected predators.

The most likely suspected outcome would be a change in species abundance, the visible manifestation of which may be an increase in algal cover, together with a possible downward shift in assemblage zonation pattern. Any survey will therefore need to be able to detect these types of changes.

The littoral survey design will depend on the type, extent and severity of the suspected impacts and whether priority species may be affected, but will almost always be based on the standard intertidal rocky shore methodology commonly employed for biological characterisation and conservation assessment (see Murray *et al*., 2006; Wyn and Brazier, 2001; Hiscock, 2001, Glanville, 2001). Sedimentary shores are not considered here since an exposed shore aspect suitable for a wave power generator or an adjacent seabed depth suitable for a tidal device will almost always result in the intertidal presence of hard substrata.

One or several locations will be selected on the parts of the shore corresponding to the 'lee side' of the device as defined by the seasonally predominating incident wave direction. At each survey location a re-locatable vertical transect (at 90$^{o}$ to the waters edge) will be established and the zonation pattern of biotopes and characterising species relative to tidal height will be determined along the length of the transect.

[9] Note that onshore activities associated with the development as part of infrastructure, construction support or grid connection may also require a littoral survey, but are outwith the scope of this guidance. It is important to recognise, however, that there will be significant advantages in co-ordinating and integrating all littorals survey efforts.

The presence of other important features, not captured within the transect area should also be recorded and subsequently monitored though a directed surveillance programme using GPS re-location or fixed quadrat methods. These may include distinctive biogenic structures, such as mussel aggregations, or locally significant species that are known to be sensitive to a change in exposure regime, such as the priority seaweed species *Fucus distichus*.

### 15.5.2 Equipment and other resources

Equipment required for an intertidal survey programme will include:

#### *15.5.2.1 Hand-held GPS*

This instrument is required for the repeated accurate positioning of re-locatable transects (although a marking system may be used to assist relocation). A dGPS can also be used to establish zonation patterns where the vertical extent of a shore is particularly long and tape measure delineation is impractical. A further use is the documentation and re-location of vulnerable or priority marine features outside of the transect area.

#### *15.5.2.2 Surveyors level*

For establishing the tidal height of community/biotope zone boundaries.

#### *15.5.2.3 Water-resistant tape measure*

For establishing the planar distance (relative to the transect origin) of the biological zones along the shore. The combination of the distance and tidal height measurements allows the production of an accurate graphical depiction of the shore profile.

#### *15.5.2.4 Quadrat*

The use of quadrats may be considered if quantitative estimates of particular species are incorporated into the survey programme. The quantification of larger species is usually achieved using a 0.5m x 0.5m (0.25m$^2$) quadrat size, while smaller species that are often found in high densities, such as gastropods and barnacles will require a quadrat of a substantially smaller area (Marclim (2008) recommend the use of 2cm x 2cm, 5cm x 5cm or 10cm x 10cm quadrat sizes depending on the expected density).

#### *15.5.2.5 Digital camera or video*

A video and/or photographic record of each of the survey elements will provide an invaluable reference for subsequent surveys. In addition, digitally imaged quadrats can be analysed in more detail without the time limitations caused by an incoming tide.

#### *15.5.2.6 Boat*

Small vessel support may be required where the identified shores are inaccessible by road vehicle.

### 15.5.3 Personnel

Littoral survey personnel should be adequately experienced in shore survey methods, including the use of semi-quantitative abundance assessments and be able to identify littoral species and biotopes in situ. The number of surveyors will depend on type and the level of detail of the survey methodology adopted. The use of the transect and levelling method will require at least three people to achieve the documentation of a transect over a single tidal cycle. Establishing the presence and extent of vulnerable or priority marine features on a particular shore can, however, be undertaken by a surveyor pair (essential for safety reasons).

### 15.5.4 Procedures

#### *15.5.4.1 Pre-survey planning*

Littoral survey work should be undertaken during periods where low spring tides occur and correspond to the optimum number of daylight hours either side of low tide. For this reason all surveys are likely to be scheduled during the summer months. Note also that the exposed nature of the shores under investigation may result in significantly reduced access to the lower shore zones during or following storm conditions and a full transect may not therefore be possible.

Initial consideration will in the first instance be directed towards whether a littoral survey will be necessary at all. The degree of wave attenuation and therefore scale of possible biological effects (assuming impacts from contamination are negligible) may be predictable from modelling studies, hydrological calculations and the examination of GIS data and nautical charts. At present, there are very few studies on the shoreward impacts of wave devices, but modelling studies reported by APB Marine Environmental Research Ltd. (2009)

suggest that a 20% reduction in wave energy may be present at a distance of around 1.3km from the device. In the absence of reliable field data we suggest that a pre-installation littoral survey should at least be carried out if a device is placed at a distance of 2km or less from a coastline.

In addition, knowledge of the locally prevailing wind and wave direction, relative to the final position of the device will provide a good indication of which shores will sustain the greatest impact should any change occur.

#### *15.5.4.2 Field Methods*

Shore surveys will comprise three distinct elements, two potentially achievable though a transect approach, while the other simply targets specific features or species beyond the confines of a transect. These survey elements are summarised in Table 15.4.

**Table 15.4** Summary of methods and target options for littoral surveys.

| Metric | Method | Assessment target |
|---|---|---|
| Range and spatial position of littoral communities/ biotopes (vertical zonation) | Vertical transect | Establish that each biotope originally recorded is still present at the same height on the shore |
| Selected species abundance | Vertical transect with quadrats (deployed in selected zones) | The abundance of selected species is maintained |
| Priority or vulnerable species presence | Directed repeated searches on the shore | The presence and abundance of the identified species is maintained in the impact area. |

One or a series of re-locatable transects should be established at locations where there is a relatively simple sloping rocky shore (if possible). Areas of extensive rockpool should be avoided or, if the pools are particularly species-rich, these may be incorporated as a separate survey element. The upper limit of the transect, usually placed in the supralittoral, may be marked with a peg, stake or paint mark or photographed and the dGPS position recorded. The tidal height of the marker point should also be established using the surveyor's level.

A tape measure is extended down the shore to the waters edge, following the slope contours. The community zonation pattern as identified by characterising species and the tape distance and tidal height for the boundary of each is recorded. A tidal height at an accurately recorded time, preferably at the time of low tide, must also be taken so that all tidal heights can subsequently be related to Chart Datum. Within each identified zone the semi-quantitative abundance of all identifiable species is recorded with an area 2m either side of the deployed transect line to allow the assignment of a biotope.

Quantitative counts of suitably abundant and conspicuous species can be taken using quadrats, but these must be stratified to a particular zone or community if statistical analyses are to be applied. The number of quadrats suitable for statistical tests will vary with local species densities, but would probably be greater than twenty.

If vulnerable or priority marine features have been identified, where possible transects should be positioned to incorporate these elements. A broader search should, however, be initiated to establish the abundance and extent of these within a defined area. The boundaries of larger biogenic structures can be defined by simply walking round them while repeatedly pressing the ‘record position’ button on a hand-held dGPS.

The location of small colonies or isolated patches of priority species such as *Fucus distichus* should be recorded with an estimate of abundance or density.

#### *15.5.4.3 Sampling frequency*

Transect sampling should be undertaken annually and at the same time of year because of the considerable seasonal variability in littoral biota, while directed searches for the continued presence of vulnerable species may be carried out at intervals throughout the year depending on the level of concern.

### 15.5.5 Data recording

All data are recorded on waterproof paper or slates when in the field. The efficiency of this process can be improved by preparing a pro-forma prior to field surveys. Note that the accurate recording of the dates and times at which tidal height measurements, in particular, are taken is critical since these data have to be resolved against daily tide tables to allow a calculation of the standardised height above Chart Datum.

When recording positions using a dGPS the selected positioning coordinate system must be compatible with all of the other survey and monitoring tasks and would normally be relative to the World Geodetic System (WGS84) datum.

### 15.5.6 Data analysis

The results of the transect surveys will provide data on the spatial extent and tidal height of the boundaries of the characterising biological zones found at those particular points along the shore. Repeat surveys should be examined for:

- Loss of previously identified communities/biotopes or presence of previously unrecorded communities/biotopes
- Changes in tidal height of biological zone boundaries
- Absence of species previously recorded as frequent or common or presence of species not previously recorded

Where comparative quantitative species counts have been taken using quadrats the data should first be examined to establish that the counts were made within the same zone (i.e. biological community type) at each survey visit. If the communities are comparable and confirmed to be from the same tidal height, then the mean abundance of the characterising species can be compared statistically using univariate techniques, such as ANOVA.

The directed searches or re-location of selected biogenic features or species are simply compared by location for evidence of species loss or a reduction in abundance or density.

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## 16.2 Personal Communications

C. Moore, pers. comm.

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