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The benthic environment of the North and West of Scotland and the Northern and Western Isles: sources of information and overview

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1. EXECUTIVE SUMMARY

The temperate west coast of Scotland, from Burrow Head, Galloway to Unst, Shetland, hosts several areas that may be suited for the placement of devices designed to extract the energy contained in wind-induced waves or tidally induced currents. These areas are, by their very nature, exposed to waves or strong tidal currents and support quite different biological communities.

Within the region under review, the wave-exposed shorelines are characteristically steep, rocky and backed by cliffs. Such exposed shorelines are typically poor in terms of species diversity, a trend that continues subtidally where sediments are coarse and mobile. Conversely rocky areas that are exposed to rapid tidal currents, without the extreme rigour of an open oceanic aspect, typically host high biodiversity, unique biological assemblages and are relatively scarce. As a consequence tidal rapids are a priority habitat under the UK Biodiversity Action Plan.

Wave-and tide-powered devices will be located in quite different receiving environments and therefore have quite different impacts on the local benthos. Wave generators are likely to have minimal impact as they are not likely to significantly reduce the wave energy reaching the shoreline behind them. The moorings of such structures may have very localized impacts that will be commensurate with the degree of change in the nature of the sediment caused. With careful siting it is doubtful if associated changes in the benthos would be considered deleterious. Tide-powered devices are more likely to be located in areas with high benthic conservation value. Structures that reduce the mean velocity of water moving through a restricted tidal channel are likely to cause a shift in community structure commensurate to the decrease in current speed. Where a significant reduction occurs the resultant re-structuring of the community, to one associated with a decreased current flow, might be considered deleterious.

Within the reviewed area there are several sites considered of particular conservation value. These include the Firth of Lorn, Sound of Barra, and Kyle Rhea area.

In order to make a proper assessment of the likely benthic impact of power-generation devices, and advise regarding the siting of various components, the receiving environment needs to be extensively mapped using a suite of acoustic and visual methods. Of the areas reviewed here only the Firth of Lorn and Sound of Barra have been adequately covered in this way.

2. INTRODUCTION

The Scottish Executive commissioned a major study to examine the environmental impacts of harnessing energy from Scotland's marine environment

in 2005 following the decision to increase the target amount of electricity generated from renewable sources, in Scotland, to 40% by 2020. As part of that study, the environmental consultancy Metoc were employed to oversee the commissioning of a Strategic Environmental Assessment (SEA) to inform the future development of marine renewable energy in Scotland. The SEA will cover all relevant marine, coastal and land based environmental issues ranging from marine ecology, to fisheries, archaeology and the coastal landscape.

This document forms part of that review and summarises the data pertaining to the benthos of the west coast of Scotland, from Shetland to Burrow Head in the Solway Firth. In addition, a brief commentary on the likely impacts of tide/wave powered electricity generation devices, on the benthos, is given.

3. SOURCES OF INFORMATION

This report constitutes a preliminary review of the relevant literature and is based, primarily, on the major benthic reviews undertaken around Scotland commissioned by the Joint Nature Conservation Committee and published under the auspices of the Marine Nature Conservation Review (MNCR). A review of Strategic Environmental Assessment, Area 4 (SEA4) has also recently been conducted, and relevant parts of that review are reproduced here for convenience. In addition, excellent summaries of the UK seas, region by region, are available in the 'Coasts and Seas of the United Kingdom' series.

The MNCR reviews collated information from a variety of published and unpublished sources. Unpublished sources include the findings from amateur surveys such as those undertaken by the Marine Conservation Society, university societies and interested individuals. In addition, extensive field work was commissioned for the MNCR and survey teams employed.

A majority of the species data reported here, and in the MNCR documents, are based on visual surveys. Visual surveys are subject to bias, particularly where the surveyor is of limited experience or expertise. This problem is particularly pertinent in those surveys conducted underwater using divers, which, in addition, are expensive to conduct and logistically difficult. The logistical problems are exacerbated in areas that are remote particularly where exposed to waves and/or tidally driven currents. In addition, such environments are often characterized by rather impoverished fauna and flora, particularly on mobile, coarse sediments which offer little to the observer in terms of recordable megafauna. This makes them 'unattractive' to amateur surveyors and, consequently, they are often undersampled.

4. BASELINE DESCRIPTION OF SPECIES AND HABITATS

The following sections summarise the current state of knowledge of the benthic ecology of the areas identified as having potential for wave or tidal stream energy extraction, in approximate geographic sequence from north to south.

Where possible, a brief physical description of each region is given, followed by a generic overview of the benthic environment then a more detailed synopsis of the species present in the EMEC designated locations (Figure 1).

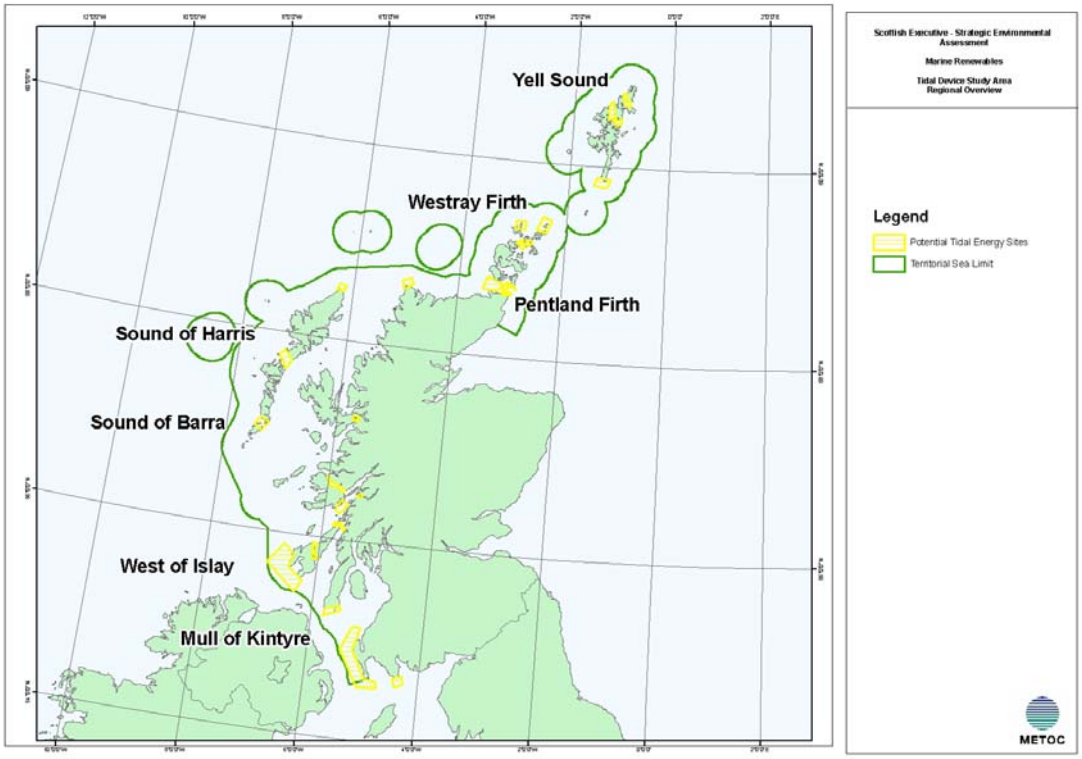

Figure 1 – Designated sites for tidal power extraction.

Particular reference is made to any statutory site designations and to the known presence of rare or sensitive species or biotopes.

Within the reviewed area minor changes in species composition can be expected as a consequence of the latitudinal gradient covered. Such regional differences are much less important compared with the local hydrodynamic /sedimentary conditions in determining community structure.

4.1 Shetland

The Shetland Isles form the most northerly part of the British Isles and consist of an archipelago stretching some 130 km from Sumburgh Head in the south to

Muckle Flugga in the north. The main island in the group (The Mainland) is separated by a narrow sound from the second and third islands of Yell and, further north, the island of Unst.

The coastline is heavily indented consisting of narrow channels and numerous small islands. The western coast is very exposed to the Atlantic but the voes and channels between the islands offer significant protection from the strength of the Atlantic swell and a full range of exposure regimes is found (Eleftheriou 2003). The benthic environment is almost entirely determined by the degree of exposure to water currents that are either tidally or wave driven. Exposed parts of the shoreline are mainly rocky, consisting of high cliffs, caves, arches and geos grading in increasingly sheltered environments through shingle to fine muds in sheltered voes (Howson 1999). The nearshore sedimentary environment shows similar gradients correlated with exposure and depth. Rocks and boulders in exposed locations are replaced by shingle, shelly sand and mud in more sheltered environments (Howson 1999). In very sheltered areas there are patches of submerged peat.

The seabed around Shetland is steeply shelving such that at a distance of 1km from the shore the depth is commonly >50 m.

4.1.1 General overview of the benthos

The following general description of the littoral and nearshore sublittoral is taken from Eleftheriou (2003).

> On exposed littoral rock in the outermost locations are barnacles such as *Semibalanus balanoides,* the limpet *Patella spp., Fucus distichus subsp.anceps* and *F. spiralis f. nana*, *Blidingia* spp. *Mytilus edulis*, *Corallina officinalis, Himanthalia elongata* and accompanying species were characteristic. In moderately sheltered conditions, barnacles and fucoids such as *Fucus vesiculosus* and *F. serratus,* red seaweeds such as *Palmaria palmata, Gelidium pusillum*, *Chondrus crispus, Porphyra purpurea* and several others were typical of this biotope. The sheltered littoral rock was dominated by the alga *Ascophyllum nodosum* and had a low diversity of fucoids. On mixed sediments and boulders, *Littorina littorea*, barnacles and mussels were present (Howson 1999). It appears that in conditions of intermediate exposure the species diversity is greatest. The sides of geos on exposed rocky shores had a rich fauna of encrusting forms (sponges, ascidians and hydrozoans) in the inner part, and barnacles, the mussel *Mytilus edulis* and hydroids in the outer reaches. In the sheltered parts of the voes and in many inlets, the littoral is almost exclusively rocky with boulders, cobble, shingle and mixed sediments being present in the inner parts. *Ascophyllum nodosum* was characteristic of such biota accompanied by *Pelvetia canaliculata* and *Fucus vesiculosus,* while in gravelly and stony beaches there were amphipods, littorinids such as *Littorina saxatilis*, *L. littorea* and *Mytilus edulis*. At the outer and moderately exposed parts of the voes, rocky outcrops are animal-dominated, with the barnacles *Semibalanus balanoides*, limpets *Patella vulgata*, mussels *Mytilus edulis* and the

dogwhelk *Nucella lapillus* with red algae such as *Laurencia pinnatifida, Porphyra umbilicalis, Mastocarpus stellatus, Corallina officinalis* and accompanying species. Fucoids were generally absent but brown algae such as *Laminaria digitata* was found lower down on the shore. The oil-related development in Sullom Voe sparked large and long-term studies of the benthic fauna and flora as a reference for possible future changes. The ecology of rocky shores was studied by Hiscock (1981) and subsequently by Moore & Little (1995), and the MNCR data conforms to these findings (Howson 1998, 1999). In the extensively surveyed Sullom Voe, the gastropod *Gibbula umbilicalis* was found, thus extending its northernmost distribution, a fact not recorded by Doody *et al*. (1993). On the other hand, many species of *Cystoseira* spp., and *Anemone sulcata*, *Chthamalus stellatus, Chthamalus montagui, Monodonta lineata, Littorina neritoides, Patella depressa* and *P. ulyssiponensis* are southern species which are nonetheless present in Shetland. Furthermore, the non-native Australasian barnacle *Elminius modestus* (Howson 1988, 1999) is present in small numbers in Sullom Voe (Hiscock 1981) as well as in other voes. Hiscock (1981) who compiled several years' data, produced lists about the common rocky shore littoral animals and plants in Shetland in connection with such organisms in the British Isles. He found that certain species such as *Lichina pygmaea, Margarites helicinus, Lacuna pallidula, Acmaea tessulata* are present in Shetland but were either absent or rarely recorded from areas further to the south in the British Isles. In the same way the fucoid *Fucus distichus*, represented by two subspecies *distichus* and *anceps* (*sensu* (Chapman 1985) is found in Shetland in the southern limits of its distribution.

In terms of the sites identified by EMEC for potential tidal energy generation the following site specific details are taken from Howson (1999).

4.1.2 Northern Unst

This forms the northern limit of the Shetlands and the UK and is characterised by cliffs and steep rocky shores that are extremely exposed.

The littoral zone demonstrates typical species zonation consisting of, from the top of the shore downwards, yellow and grey lichens, the black lichen *Verrucaria maura,* mussels *Mytilus edulis*, barnacles *Chthamalus stellatus* and *Semibalanus balanoides*, the limpet *Patella vulgata,* the algae *Corrallina officinalis, Mastocarpus stellatus* and *Alaria esculenta.* The kelp *Laminaria digitata* is present in the sublittoral fringe. More sheltered areas, such as cave entrances, are typified by shade tolerant red algae and sponges.

The sublittoral zone consists of steep or vertical bedrock breaking at approximately 20 – 30 m depth to coarse clean sediments which are frequently duned. The community shows typical zonation with *Laminaria hyperborea* and *Laminaria saccharina* dominated to a depth of ca. 30 m with the red alga *Delesseria sanguinea* extending the algal range to ca. 35m. Also present are beds of the jewel anemone *Corynactis viridis,* dead-man's fingers *Alcyonium digitatum* and colonial ascidians (unspecified). The urchin *Echinus esculentus* and the keel-worm *Pomatoceros triqueter* are also found.

4.1.3 Bluemull Sound and the eastern approaches.

Bluemull Sound separates the islands of Unst from Yell. It lies on a north-south axis and reaches a maximum depth of ca 40 m. Whilst it is predominantly sheltered from wave action it is exposed to strong tidal currents (up to 5 knots).

Bluemull sound is fringed by bedrock and boulder shores many of which are steep. Sandy bays are also present in the more open bays where shingle and muddy sediments are found. The littoral zone is characterised, from the top to the bottom, by the lichen *Verrucaria maura*, the algae *Pelvetia canaliculata* and *Fucus spiralis, F. serratus, Ascophyllum nodosum* under which are commonly found barnacles.The sublittoral fringe is dominated by the kelp *Laminaria digitata.* The green alga *Enteromorpha sp.* has also been recorded.

Sublittorally the steep rocky shores break to boulder and cobble plains. In the central channel rocky outcrops dominate – there is little sediment in the sound. In the eastern approaches the benthic environment consists of mixed sediments and the largest bed of maerl described from Shetland.

In areas such as the northern entrance to Bluemull Sound, which are subject to rapid tidal currents and surges, characteristic benthic organisms include the sponges *Halichondria panicea* and *Pachymatisma johnstonia,* the ascidian *Diplosoma spongiforme* and the anemones *Metridium senile* and *Sagartia elegens.* Bedrock in areas subject to rapid tidal streams hosts dense canopies of the kelp *Laminaria hyperborea* to a depth of ca. 20 m. Associated with dense *L. hyperborea* forests are additional kelp species such as *L. saccharina* and *Saccorhiza polyschides* and the epiphytic sponge *H. panicea* together with the anemones *Urticina felina* and *Cereus pedunculatus.*

Maerl is recognized as a habitat supporting a particularly high diversity and is associated with several scarce or rare species that are of conservation interest. Any development that is likely to disturb or displace maerl beds is likely to meet opposition from conservation agencies.

4.1.4 Yell Sound

The Yell Sound separates Yell from the mainland. It can be divided into two sections, the northernmost runs north-south, is relatively exposed and approximately 4 – 6 km wide. The southern section runs in a northwest-southeast orientation, is ca. 2km wide and relatively sheltered from wave action. The entire sound is subject to rapid tidal currents, of up to 7 knots, the degree of exposure to which dictates biological community structure. The following synopsis, taken from Howson (1999), indicates that large areas of the subtidal environment in Yell Sound remains uncharacterised.

Yell Sound is fringed by bedrock and boulder shores, many of which are steep or vertical. However, there are sandy beaches in several of the more open bays

and shingle overlying muddy sediment in more enclosed areas. Sublittorally, the near vertical bedrock gives way to boulder, cobble and pebble and sandy plains at ca. 20 – 25 m. In the northern part of Yell Sound, which runs approximately north–south, the exposed shores are dominated by littoral rock supporting, from the top downwards, the lichen *Verrucaria maura*, mussels *Mytilus edulis* and barnacles such as *Semibalanus balanoides*. Also present are limpets *Patella vulgata*. The distribution of organisms is highly influenced by the degree of exposure with more sheltered shores hosting, in addition, brown algae such as *Fucus vesiculosis, F. serratus, Laminaria saccharina* and *Laminaria digitata* and a range of red and green algae including *Cladophora rupestris* and *Mastocarpus stellatus*. More sheltered shores host the algae *Ascophyllum nodosum* and *Fucus serratus* together with high densities of the gastropods *Littorina sp*., limpets *Patella vulgata* and barnacles.

The sublittoral environment is dominated by nearshore steep bedrock and boulder slopes which drop to seabeds consisting of cobble, gravel or coarse sand. Towards the south of the northern section the sediment becomes increasingly fine, where sands support a diverse molluscan fauna including species such as *Ensis arcuatus*, *Lutraria lutraria, Mya truncata, Venerupis rhomboides* and *Dosina exoleta*. Also present in these finer sediments are lugworms *Arenicola marina*, sand-mason worms *Lanice conchilega* and burrowing echinoderms such as *Amphiura brachiata* and *Echinocardium cordatum.* Crabs and starfish are also found.

In the shelter of voes and behind the islands of Lamba and Little Roe muddier sediments are located hosting seapens and mud-burrowing crustacea and a diverse range of polychaetes.

4.1.5 Sumburgh Head

This is a very exposed area consisting of spectacular cliffs, numerous skerries, stacks, caves and geos. Most of the shores consist of steep or vertical bedrock, boulders and platforms. The bedrock extends to ca. 25 m depth where it breaks to sand.

The area has one main bay, the Bay of Quendale, which is backed by a large, clean, sand beach and Shetland's largest dune system. Quendale Bay was the scene of the Braer Oil Spill in 1993 which initiated considerable benthic recovery research in the area.

The littoral zone consists of steep or vertical bedrock and cliffs except around the Bay of Quendale where the foreshore consists of mobile, clean sands. The biotopes of the rocky shores are typical of extremely exposed conditions consisting of yellow and grey lichens, the lichen *Verrucaria maura,* the red algae *Porphyra umbilicalis and P. linearis.* Local shelter, in the form of crevices, support littorinids whilst further down the shore are the barnacles *Semibalanus balanoides* and *Chthamalus stellatus*, the limpet *Patella vulgata* and the mussel

Mytilus edulis. The lower eulittoral hosts the thongweed *Himanthalia elongate,* the red algae *Mastocarpus stellatus*, *Callithamnion sp, Porphyra umbilicalis* and *Corallina officinalis* in addition to mussels, barnacles and limpets (species listed above). Rockpools are common and host kelps such as *Laminaria digitata, L. saccharina* and *A. esculenta* with an understory of corraline crusts consisting mainly of *Corallina officinalis.*

The sublittoral consists of steep or vertical bedrock occasionally with boulders at the base. This is heavily colonized by the kelp *Laminaria hyperborea* to a depth of 15 – 18 m and the kelp park continues to a depth of 22 m. Growing on the kelp stipes and on exposed rock are foliose algae such as *Odonthalia dentata* and *Delesseria sanguinea.* In the shallower infralittoral there is a rich surge-tolerant fauna on the rock, including sponges such as *Halichondria panicea, Oscarella lobularis* and *Clathrina coriacea* and ascidians such as *Lissoclinum perforatum* and *Polyclinum aurantium.* Sumburgh Head itself is considered too exposed for grazing animals such as urchins and starfish although these are common in neighbouring areas.

The hard substratum generally extends to at least 25 m and gives way to coarse, mobile, clean sands that are often formed into dunes or waves. Despite the proximity of the Braer oil spill Howson (1999) does not allude to any studies of the benthos associated with the deeper habitats, which probably consist of mobile sands, in the area.

4.1.6 Fair Isle

Fair Isle lies about 40 km south of Sumburgh Head and is considered a part of the Shetland archipelago.

The island consists almost entirely of bedrock and boulders, much of which is vertical or steeply sloping. The island is very exposed, particularly the northern and western facing coasts which are bounded by cliffs. The coastline is indented with numerous geos, stacks and caves and more sheltered conditions can be found locally leading to a patchy distribution of biotopes.

The tidal range around Fair Isle is only about 2 m but the strength of the wind and waves extends this littoral zone 8 m above sea level.

The upper littoral zone of exposed shores (which includes most of the island) is dominated by the lichen *Verrucaria maura* then the red alga *Porphyra umbilicalis* followed by a zone of the barnacles of various species including *Semibalanus balanoides* which extends into the mid eulittoral. The brown alga *Fucus distichus* is present in some locations together with small mussels *Mytilus edulis*. In the lower shore a turf of the red alga *Mastocarpus stellatus* and the kelp *Alaria esculenta* dominates together with the mussels. This zone extends to 12 m.

In less exposed conditions the brown algae are more common and include *Fucus spiralis* f. *nana, F. vesiculosus* f. *linearis,* and *F. serratus* together with *Pelvetia*

canaliculata and *Himanthalia elongata.* The sublittoral fringe tends to be dominated by *Laminaria digitata* or *Alaria esculenta*.

As the degree of shelter increases species such as the brown alga *Ascophyllum nodosum, F. vesiculosus* occur together with the rare *F. evanescens* in association with *F. serratus.*

In the sublittoral the steep rocky shore extends to ca. 40 and 30 m on the west and east sides respectively. It then breaks to a rippled shell-gravel. The sublittoral hard substrata dominate the nearshore environment and are heavily colonised by kelps, either *Laminaria hyperborea, L. digitata* or *L. saccharina* dependent on depth and degree of exposure. Living under and attached to the kelp are species such as the red algae *Odonthalia dentate, Plocamium cartilagineum* and *Phycodrys rubens* together with cnidarians such as *Alcyonium digitatum* and the anemone *Corynactis viridis.*

The caves and geos around Fair Isle form an important habitat for various surge resilient biotopes characterised by sponges, cnidarians, barnacles and algae. These are listed in Howson (1999).

There is relatively little in the way of subtidal sediments, other than rather deep and coarse shell-gravels. Areas of shelter, such as that found around North Haven, host finer sediments which are characterised by species such as the lugworm *Arenicola marina* and the sand-mason *Lanice conchilega*.

In terms of conservation the Fair Isle Marine Partnership was established in 1999 to ensure sustainable management of local marine resources including crustacean and sand-eel fisheries (http://www.fairisle.org.uk/FIMETI/Reports/Safeguarding_Our_Heritage/future.htm).

4.2 Orkney

The Orkney Islands lie off the northern coast of Scotland, separated from the mainland by the Pentland Firth. The waters around Orkney, unlike Shetland, are relatively shallow and host a greater variety of sedimentary substrata. The west facing coast of Orkney is highly exposed to wave action and consists of cliffs, such as those on Hoy, caves and geos and the occasional storm beach. However, the archipelago offers areas of sheltered water, particularly Scapa Flow, where fine sedimentary biotopes are found.

The benthic flora and fauna around the Orkney Islands are dependent on the physical conditions which vary considerably on a very local scale. Given the likely location of tidal/wave energy generators in exposed locations the following summary only details the fauna for exposed locations.

4.2.1 General overview

The Orkney Islands are included within Strategic Environment Assessment Area 4 and the benthos of this region has been extensively reviewed as part of the strategic assessment process. The relevant section from that report (Eleftheriou 2003) is reproduced here for convenience.

Exposed littoral rock is inhabited by typical encrusting species found in exposed conditions, such as *Mytilus edulis* and barnacles with the limpet *Patella* spp., the barnacles *Chthamalus, Semibalanus balanoides*, and some lichens and brown algae such *as Fucus distichus* sub sp.*anceps* and *F. spiralis f. nana*, *Corallina officinalis, F. serratus* and a few red seaweeds (*Chondrus crispus, Mastocarpus stellatus, Rhodothamniella floridula*). In the sheltered parts of the rocky coast and on mixed sediments there were dense fucoids such *as Pelvetia canaliculata, Fucus spiralis, F.vesiculosus*, barnacles and in the very sheltered areas *Ascophyllum modosum* was present (Murray *et al*. 1999). It should be mentioned that the fucoids *Fucus distichus and F. spiralis f. nana* found on exposed shores on Orkney generally have a northern distribution, although the latter is absent from the whole North Sea. Elements of the southern fauna, species such as the barnacles *Chthamalus stellatus*, and *C. montagui*, as well as the gastropods *Littorina (Melaraphe) neritoides* and *Gibbula umbicalis* are also present on the Orkney shores. However the limpet *Patella ulyssiponensis* reported from the northern isles (Doody *et al*. 1993) does not appear in the faunal list of the detailed studies of Murray *et al.* (1999) of the Orkney area.

The shallow rocky sublittoral and other exposed hard substrata were dominated by the alga *Laminaria hyperborea* along with several brown algae such as *Alaria esculenta, Mytilus edulis* and several species of red algae, while in some wave-surged south coast sites dense growths of encrusting sponges (*Dendrodea/Clathrina*), ascidians, bryozoans and hydroids were present. In the less exposed areas, *Laminaria hyperborea* was replaced by *L. saccharina* with the presence of coralline crusts and other seaweed communities.

In the deeper and exposed sublittoral, faunal crusts with the polychaete *Pomatoceros triqueter*, the barnacle *Balanus crenatus* and bryozoans were present while dead man's fingers *Alcyonium digitatum*-dominated communities were found on moderately exposed rock. Bryozoans, mussel beds (both *Mytilus* and *Modiolus*) brittle stars and faunal and algal encrusting species with the presence of the sea urchin *Echinus esculentus* form the characteristic species of these communities.

4.2.2 Papa Westray

Papa Westray lies of the north-east of Westray, separated by the Papa Sound and the Pierowall Road to the south. The whole of the island is relatively exposed to the wind and tidal streams, around the north of the island (Mull Head), reach 5 knots. Little information is available regarding the littoral communities here (Murray et al. 1999) but 56 sublittoral sites around the island have been surveyed. Towards the north (Mull Head) the sublittoral is dominated by bedrock with steeply shelving rock walls and gullies. Dense stands of the kelp *Laminaria hyperborea* together with an understory of red algae including *Odonthalia dentata* and *Delesseria sanguinea* with the anemone *Sagartia elegans*, the sponge *Halichondria panicea*, hydroids such as *Sertularia argentea* and bryozoans including *Alcyonidium diaphanum* (Murray et al. 1999). Also present around the Mull Head are patches of the mussel *Musculus discors* and

associated fauna such as dead-man's fingers *Alcyonium digitatum.* There are no benthic marine-related conservation designations around Papa Westray.

4.2.3 Sanday

The benthic environment around Sanday is mostly shallow and sandy with several large intertidal embayments. The coast is only moderately exposed, protected by offshore shallows and the complicated coastline. Tidal streams are negligible on the open coasts but strong in the Sound of Sanday and at the east of the North Ronaldsay Firth. The coast consists of a mixture of machair in the north and rocky promontories in the south. Littoral communities are typically dominated by fucoid biotopes (*Fucus spiralis, Pelvetia canaliculata, F. vesiculosis)* and barnacle mosaics. Rockpools are common and host a diverse range of algae the nature of which depends on the degree of sand-scour; fucoids and kelps are recorded including *Laminaria saccharina, Chorda filum* and *Halidrys siliquosa*.

Subtidally, the kelp *Laminaria hyperborea* is very common and dense stands occur in association with epiphytic red algae including *Ptilota gunneri* and *Callophyllis laciniata* and the ascidian *Aplidium punctum.* Gullies throughout the kelp forest provide habitats for encrusting sponges and mobile megafauna such as starfish and crabs. At the entrance to Sanday Sound the tide swept sediment is coarse and consists of dead maerl and shell debris with sparse infauna which includes the bivalve *Ensis arcuatus* among others. To the east of the North Ronaldsay Firth the seabed consists of infralittoral gravels and sand again associated with sparse infauna while, to the west, exposed bedrock with the kelp *Laminaria hyperborea* and encrusting turf has been recorded.

There are no benthic marine-related conservation designations around Sanday.

4.3 The Pentland Firth and Cape Wrath

The Pentland Firth is the body of water lying between the north coast of mainland Scotland (Caithness) and the Orkney Islands. It is very exposed to both tidally driven currents and wave action. The local shoreline is predominantly rocky with small bays containing clean sand beaches.

The exposed rocky shore communities of Caithness host a diverse range of brown algae and common encrusting forms with the addition of blue-green algae and many Lusitanian species such as the red alga *Porphyra umbilicalis*, the limpet *Patella ulyssiponensis siculosus* alongside brown algae such as *Fucus vesiculosus, F. linearis* and *Himanthalia elongata* (Eleftheriou 2003). The barnacle *Chthamalus montagui*, the gastropod *Littorina neritoides* and the top-shell *Gibbula umbilicalis* are also characteristic of the area (Eleftheriou 2003).

The Pentland Firth forms the northern boundary of some southern species which do not extend into the colder waters of the North Sea.

Cape Wrath is the most north-westerly point of mainland UK and is very exposed to waves and tidally-driven currents. There are few survey data available for the cape itself.

The following is taken from Bennett (1991) citing the Glasgow University Exploration Societies 1975 Durness Expedition. The area is characterised by bedrock with crevices, gullies, overhangs and caves together with large boulders giving way to pebbles, clean sand or mud at depth. The bedrock extends deeper with increasing exposure and, in most sites, was colonised by kelp to the limit of the hard substratum with the deepest occurring at 23 m. The brown alga *Alaria esculenta* was also recorded down to about 3 m at the more exposed sites. Fauna was apparently scarce and dominated by dead-man's fingers *Alcyonium digitatum.* Also recorded were the feather star *Antedon bifida*, the anemone *Urticina felina* and the scallop *Pecten maximus* on clean sand.

Exposed parts of Cape Wrath were included in the MNCR survey (MNCR Survey 63, Site 5 http://www.jncc.gov.uk/mermaid) which states that the area is exposed to considerable wave action and the predominant substratum is vertical and steep bedrock with fauna typical of 'surge-gullies'.

Considerable survey work has been conducted in the vicinity of Cape Wrath, particularly in nearby Loch Eriboll (Bennett 1991). Loch Eriboll hosts a wide range of biotopes, from the highly exposed loch entrance, to highly sheltered conditions at the head. For a detailed species list of this region see Moss (1986), Bennett (1991) and references therein.

4.4 The Outer Hebrides

The Outer Hebrides or Western Isles form the most westerly large offshore group of islands in the UK. They consist of two main island groups, Harris and Lewis in the north and the Uists, Benbecula and Barra in the south. These two main island groups are separated by the Sound of Harris.

The islands are exposed, on west facing coasts, to the full force of the Atlantic, while the east facing coasts are more sheltered. The east facing coasts are characterized by fjards which consist of a very complex series of interconnected sea- and freshwater lochs that are variously exposed to gradients of salinity, current and wave action. This complex habitat provides steep environmental gradients and is associated with high biological diversity. West facing coasts are characterized by wave exposed beaches consisting of mobile, clean sands.

A majority of benthic surveys have concentrated on the sealoch systems described above while mid-channel areas exposed to strong currents and/or wave action have been surveyed less frequently. Benthic biotope maps are in production for the Sound of Barra, on the basis of habitats of high value present there (see below).

4.4.1 Butt of Lewis

The Butt of Lewis is a rocky headland that forms the most northerly point of Lewis and the Western Isles. It is very exposed and characterized by cliffs of up to 40 m height. Relatively little survey work appears to have been conducted off the Butt itself although intertidal data are available for exposed beaches in the vicinity. Typical of exposed locations, sandy beaches consist of relatively coarse size fractions. Angus (1979) describes two beaches, one either side of the headland: Traigh Sands, on the west side, and a small cove at Port Sto on the east side. Overall there was a paucity of fauna as expected with mobile coarse sands. *Nephtys sp, Eurydice pulchra* and *Talitrus saltator* were found on the Traigh Sands whilst the dominant species for Port Sto included *Nerine cirratulus* and capitellids, the latter exploiting seaweed detritus that accumulated there. George (1979) describes the polychaete communities from shores at the Butt of Lewis and Port Sto including, in addition to sediment-associated species, those associated with the coralline alga *Corallina officinalis* and *Laminaria sp* holdfasts. A species list is given but, in general, there were few polychaetes reported.

4.4.2 Sound of Harris

The Sound of Harris lies between North Uist and South Harris, within the South Lewis, Harris and North Uist National Scenic Area, and is a Marine Consultation Area. There are major conservation interests within this area namely Loch an Duin which is the largest UK example of a fjardic system. This complex system of tidal channels, shallow rapids and islands forms the north-east end of North Uist, and is considered of high conservation value. Loch an Duin is also a RAMSAR site on the basis of the large population of North Scottish Greylag geese hosted there (see http://www.jncc.gov.uk/_pdf/RIS/_7UK044._pdf). In addition, the area contains lagoons, a priority habitat under the EU Habitats Directive, particularly at Loch Roag while Loch Maddy is a candidate Special Area of Conservation and a Marine Consultation Area, partly as a consequence of the presence of lagoons, maerl, tidal rapids and reefs. Any type of development within this region is likely to cause concern to conservationists.

Away from the complex fjardic system, the seabed in the Sound of Harris main channel consists mostly of 'foul ground' and rock (Admiralty Charts) indicating a current-swept environment. Areas of sediments within, and at the periphery of the sound, consist of coarse, mobile, clean pebbles and gravels that are associated with low species diversity but may host species considered scarce or rare (see Table 1).

The biotope diverse fjardic systems host a broad spectrum of biota, from low-salinity-sheltered to full salinity, exposed biotopes. Each biotope is associated with a unique biological assemblage (Thorpe et al. 1998).

4.4.3 Sound of Barra

Barra lies at the southern end of the Outer Hebrides. It is separated from South Uist by the Sound of Barra. The Sound of Barra has been selected as a possible Special Area of Conservation (pSAC) on the basis of the nationally important colony of common seals (*Phoca vitulina*) and also for the wide variety of habitats associated with shallow 'sandbanks which are slightly covered by seawater all the time'. A number of the sandbank habitats are of considerable conservation value, most notably the extensive beds of the eelgrass *Zostera marina* and tide-swept maerl beds composed of the coralline red alga *Phymatolithon calcareum*.

The estimation of the geographic distribution and extent of the major habitats in the sound of Barra was undertaken in August 2001, by a collaborative research group comprising staff from the University of St Andrews, Heriot-Watt University, Edinburgh University and Scottish Natural Heritage (SNH). This information supplemented the existing knowledge on the distribution of marine communities within the Sound of Barra pSAC and all this information was synthesised into a record of habitat information depicted in a series of biotope classification maps. These data should be comprehensive and are available from the SNH (not forthcoming in time for this review).

5. THE INNER HEBRIDES AND MAINLAND

5.1 Kyle Rhea

Kyle Rhea forms part of the narrow strait separating the Scottish mainland from the easternmost point of the Isle of Skye. The area is wave-sheltered but experiences tidal streams exceeding 8 knots on spring tides. Hiscock & Covey (1991) carried out diving surveys at two sites in Kyle Rhea. The area was also surveyed by Scottish Natural Heritage in January 1997 using an ROV (http://www.jncc.gov.uk/mermaid/). At the north end of the kyle small cobbles and pebbles overlaid a bed of gravel and shell at 15-16 m depth. At the southern end, broken bedrock extended from 9-22 m depth, with drifts of coarse shell gravel at 12-13 m. In this tidally-swept area *Alaria esculenta* was the dominant kelp species. Common animals among the kelp included barnacles, the anemone *Urticina felina* and the bryozoan *Alcyonidium diaphanum.* In deeper water, bedrock and boulders supported a rich and diverse sessile animal community including hydroids (*Tubularia indivisa* and *Sertularia argentea*), the plumose anemone *Metridium senile* and the sponges *Myxilla incrustans* and *Pachymatisma johnstonia.* The nationally-scarce sea anemone *Phellia gausapata* has been recorded from Kyle Rhea (Plaza & Sanderson, 1997b). Owing to the high richness of hard substratum biotopes in the area, Kyle Rhea is included within the Lochs Duich, Alsh and Long Reefs Marine Special Area of Conservation (SAC).

5.2 Sound of Mull

The Sound of Mull is very sheltered from wind and wave action but experiences strong tidal streams. Along much of the sound, a narrow intertidal zone of bedrock or large boulders gives way to a steep boulder slope extending to 20-25 m depth (Bishop, 1984). At greater depths the substratum is mostly muddy, shell-rich sand with occasional cobbles and boulders. Spectacular underwater cliffs exist in some parts of the Sound of Mull, particularly off Calve Island near Tobermory.

There is very little published information on biological communities of the Sound of Mull. Steeply-sloping or vertical rock faces support a rich growth of sessile animals such as sponges, soft corals, hydroids and bryozoans (Bishop, 1984, and personal observations). Several of the nationally-rare or scarce species of sponge, hydroid and anemone listed by Plaza & Sanderson (1997a) from the west coast of Scotland have been recorded in the Sound of Mull.

5.3 Falls of Lora

At the entrance to Loch Etive a combination of shallow sill depth and constricted topography gives rise to the most spectacular tidal rapid system of any Scottish sea loch, with flow rates exceeding 8 knots in places. Benthic biotopes in the Falls were described by Holt (1991). Kelp (*Laminaria hyperborea*) forest covers shallow bedrock to 5 m depth, with an understorey community of flow-resistant hydroid, bryozoan and barnacle species. The understorey faunal turf extends down onto the bedrock ridges and gullies that make up the sill at the loch entrance, the predominant species being the hydroid *Sertularia argentea* and the barnacle *Balanus crenatus.* Bowl-shaped depressions at the bottom of the bedrock gullies are filled with deep drifts of dogwhelk (*Nucella lapillus*) shells.

In the narrows above and below the Falls of Lora tidal speeds are slightly less extreme and the flow less turbulent. The more moderate conditions allow development of a more diverse sessile community including turfs of the sponge *Halichondria bowerbanki*, the bryozoans *Alcyonidium diaphanum* and *Flustra foliacea* and a variety of solitary ascidian species (Holt, 1991). The nationally-rare nudibranch *Aldisa zetlandica* has been recorded here. Among other mobile animals, the most abundant species are typically the shore crab *Carcinus maenas* and the common starfish *Asterias rubens.*

5.4 Firth of Lorn, Gulf of Corryvreckan and surrounding area

This region of dissected coastline, extended peninsulas and numerous islands has a complex bathymetry and hydrography and a high diversity of benthic habitats. In consequence, the area supports some of the richest and most diverse marine communities in Scottish waters (Irving, 1997a). The biological

richness of the Firth of Lorn has led to the designation of the area as a Marine Consultation Area and more recently as a Marine Special Area of Conservation (SAC) under the terms of the EU Habitats Directive.

Davies (1999) summarised the results of biotope mapping surveys carried out using RoxAnn^{TM}, side-scan sonar and drop-down underwater video. The survey area extended roughly from Oban to the isle of Colonsay, taking in the Gulf of Corryvreckan, Garvellachs and Slate Isles. As expected, a wide range of benthic habitats and communities was identified, with the highest diversity recorded in the central Firth around the Garvellachs. Forty-nine biotopes and ten biotope complexes were identified, including several that had not been recorded in previous surveys. Notable finds in the area between Mull and the Garvellachs included dense fields of crinoids (*Leptometra celtica*) on sediments in deep troughs (> 100 m), and sediment-covered stony seabeds supporting large numbers of northern sea-fans (*Swiftia pallida*).

The Gulf of Corryvreckan, a narrow sound between the islands of Scarba and Jura, experiences the strongest tidal currents of any site on the open British coast, with speeds exceeding 4 m sec^{-1}. Benthic communities in current-swept parts of the Gulf are dominated by a small number of highly resistant species able to flourish in conditions of extreme tidal energy. A steep pinnacle rising to within 27 m of the surface in the middle of the Gulf supports dense turfs of the hydroids *Tubularia indivisa* and *Sertularia cupressina* and the bushy bryozoan *Securiflustra securifrons*, with the most exposed areas covered by the barnacles *Balanus crenatus* and *B. hameri* (Picton et al., 1982; Hiscock, 1983). Slightly less current-tolerant species such as the soft coral *Alcyonium digitatum* are confined to hollows and other microhabitats sheltered from the full force of the tidal streams.

Tidal streams are also strong to the east of Corryvreckan at the entrances to Lochs Crinan and Craignish, but the more moderately-energetic conditions are reflected in richer benthic communities than are found in the Gulf itself. At Ardnoe Point to the south of Loch Crinan steep rock communities are characterised by large numbers of the northern sea-fan *Swiftia pallida*, the colonial ascidian *Diazona violacea*, and the sponges *Axinella infundibuliformis* and *Mycale lingua.* The cup-coral *Caryophyllia inornata* reaches its northern limit in British waters in this area (Howson, 1990).

A rich and diverse range of benthic communities is found in Clachan Sound, where strong tidal currents flow between Seil Island and the mainland. A notable feature here is the unusually large size attained by fronds of several common coastal brown algal species, including *Laminaria saccharina* and *Himanthalia elongata* (Powell et al., 1977). Sublittoral communities are also highly diverse in the waters surrounding the Garvellachs and Slate Isles in the central and southern Firth of Lorn (Picton et al., 1982). Rocky habitats are very rich in red algae and sessile animals such as hydroids, bryozoans and sponges, the diversity of biotopes reflecting the range of hydrodynamic conditions from wave-exposed and tidally-swept to highly sheltered.

The high diversity of sublittoral habitats and biotopes in the Firth of Lorn area is reflected in the occurrence of several nationally-rare and scarce benthic species (listed in Plaza & Sanderson, 1997a). In the high-energy habitats considered here most of these are either algae or sessile animals such as sponges, hydroids or anemones. The latter group includes the nationally-rare sea-fan anemone *Amphianthus dohrnii*, which lives as a commensal of the northern sea-fan *Swiftia pallida. Amphianthus dohrnii* is a UK Biodiversity Action Plan target species (http://www.ukbap.org.uk/UKPlans.aspx?ID=91).

5.5 Sound of Islay

The Sound of Islay is a narrow, deep channel separating the islands of Islay and Jura. The sound is mostly sheltered from wave action but experiences strong tidal streams. Biological information is very limited and largely confined to descriptions of seven sublittoral sites in the central and northern parts of the sound (Hiscock, 1983). On the Islay shore kelp forest extends to 15 m depth, with the biota of the underlying rock dominated by encrusting coralline algae as a result of heavy grazing by urchins (*Echinus esculentus*). Rich communities of algae and sessile animals were noted on the kelp stipes. Small boulders and pebbles at depths > 12 m were observed to support a diverse hydroid and bryozoan fauna.

On the Jura side of the sound a plain of maerl (mostly dead) with tide-swept boulders was recorded from 4-14 m depth. Foliose algae and sabellid polychaetes were noted among the associated flora and fauna (Hiscock, 1983).

A few of the nationally-rare or scarce benthic species listed by Plaza & Sanderson (1997a) are believed to be confined to maerl habitats and may occur in the Sound of Islay.

5.6 West of Islay

The large area to the west of Islay under consideration as a potential tidal energy site overlies a sea bed grading from gravel to gravelly sand (British Geological Survey, 1991). There is practically no published information on benthic biotopes and communities in this area, apart from a small number of coastal sites in west Islay surveyed by Hiscock (1983). From the nature of the bottom sediments a community characterised by burrowing echinoderms (such as irregular urchins) and bivalves would be expected.

5.7 Mull of Kintyre

Around the exposed headland of the Mull of Kintyre the sea bed is mainly sandy gravel with a higher proportion of sand further to the southeast (British Geological Survey, 1991). There is very little in the literature on the benthic fauna of the area with just a few historical records of the results of dredge sampling (Hyndman 1842). Deegan (1973) described a large bed of the gaping file shell *Limaria hians* off the south east Kintyre coast. The continued existence of this bed is uncertain given the known vulnerability of *Limaria* to damage from bottom-trawling and dredging (Hall-Spencer & Moore, 2000).

5.8 Rhinns of Galloway

The long, open coast of the Rhinns of Galloway peninsula consists mostly of rocky shores backed by cliffs. Sandy gravel sediments are found immediately offshore along the Rhinns, grading into finer sands and gravelly sands further offshore and north towards Ballantrae. Extensive bedrock outcrops occur on the sea bed between the Mull of Galloway and the Isle of Man but are not known from the area considered here (British Geological Survey, 1991).

Little biological information is available for this area (Irving et al., 1996). The sandy gravel sediments off the Rhinns of Galloway are occupied by a 'Deep *Venus*' community, an assemblage characteristic of relatively coarse sand, gravel or shell sediments at depth of 40-100 m (Mackie, 1990). Typical species include the burrowing urchin *Spatangus purpureus* and bivalves of the genera *Glycymeris, Astarte* and *Venus.* A number of sites in the shallow sublittoral off the Mull of Galloway were described by Covey (1992). Red algal turfs in the infralittoral (7-10 m depth) gave way to sessile animal-dominated biotopes at 10-21 m, characterised by a rich assemblage of anemones, sponges, hydroids and ascidians.

No nationally-rare or scarce benthic species are known to occur in this area (Sanderson, 1996).

5.9 Burrow Head

Burrow Head is a wave-exposed headland on the northern shore of the Solway Firth. The littoral zone supports a typical barnacle and mussel-dominated exposed shore community (Covey, 1990). Rocky substrata also extend offshore from the headland. Communities on these rocky ridges and tide-swept boulders are strongly influenced by water turbidity and strength of tidal streams, with a faunal discontinuity apparent at the Isle of Whithorn (Covey, 1992). To the west communities are dominated by the reef-building polychaete worm *Sabellaria spinulosa* and a rich associated biota of sponges, ascidians and other sessile

invertebrates. Communities to the east of Whithorn are less diverse and consist mainly of hydroid and bryozoan turfs.

Further offshore from Burrow Head the rocky sea bed gives way to muddy sand characterised by burrowing species such as the urchin *Echinocardium cordatum*, the brittlestar *Amphiura filiformis* and the bivalve *Ensis* sp. (Covey, 1992).

No nationally-rare or scarce benthic species are known to occur in this area (Sanderson, 1996), but the polychaete *Sabellaria spinulosa* is considered to be of conservation importance owing to its reef-building habit. *Sabellaria spinulosa* aggregations are regarded as biogenic reefs under the terms of Annex I of the EU Habitats Directive and are also the subject of a UK Biodiversity Action Plan (http://www.ukbap.org.uk/UKPlans.aspx?ID=38).

6. IMPACTS OF OFFSHORE MARINE RENEWABLE ENERGY GENERATION

6.1 General comments

The nature of the receiving environment is a major factor in determining the likely impacts of any offshore device, both during its construction and lifetime.

Very exposed habitats, particularly those facing the full force of the Atlantic swell, and those consisting of mobile sediments, generally show reduced species diversity. These environments are likely to be resilient to the types of changes that could occur during and following the construction of power-extraction devices.

However, habitats that experience rapid tidal flows, but not extremes of wave action, often host particularly diverse communities of sessile suspension-feeders such as sponges, bryozoans and hydroids. As a consequence of the diversity of such tidally-swept habitats, and their relative scarcity, they have been designated under the UK Biodiversity Action Plan (UK BAP) as deserving of particular protection. This legislation has obliged local authorities to draw up local BAPs in order to protect these important habitats and particular consideration has been given to the potential effects of siting power-extraction devices in them. The UK BAP for tidal rapids (http://www.ukbap.org.uk/_UKPlans.aspx?ID=39#2) states that:

The richness and variety of marine life in tidal rapids relies primarily on the strong water currents to carry food in, and waste materials and fine sediments away. ***Any obstruction to the water flow can be expected to have adverse effects on the fauna and flora****. Various impacts which potentially affect water flow are listed below.*

Tidal power generation has been suggested in conjunction with bridge construction in areas with strong tidal flow as a means of generating electricity. Depending on scale and local circumstances, these could have

a devastating effect on communities in rapids and within enclosed bodies of water.

Tidal barriers have been built for various reasons in the past, usually for fishing activities. These have generally been across small, shallow rapids connecting brackish lochs with the sea, and may well have changed the ecology of the lochs considerably through restriction of seawater influence and consequent changes in salinity. ***The effects on the connecting rapids can also be expected to be drastic***

Interruptions of tidal flows are likely to induce localised changes in sedimentation patterns with implications for fauna and flora. Whether significant changes in community structure would occur and whether they would be considered deleterious would depend on the degree of change and the nature of the receiving environment. For example, proposed developments resulting in significant reductions in water exchange within a sea-loch system supporting mussel farmers, or in fjardic systems, are likely to find opposition from mussel growers and conservationists respectively.

Within the UK's territorial waters Government agencies have identified species that are considered rare or scarce although they have no formal designation or protection under the EU Habitats Directive or UK BAP. Some of these species (Table 1) inhabit high energy environments such as those proposed as sites for wave, and particularly tide, electricity generation schemes.

Table 1 Species considered rare or scarce and which live in high-energy environments (Plaza and Sanderson 1997).

Species	Type	Habitat
Tethyspira spinosa	Sponge	Wave exposed sub-tidal rock
Plocamilla coriacea	Sponge	Vertical, subtidal rock or on other sponges
Arachnanthus sarsi	Anemone	Shell-sand
Phellia gausapata	Anemone	Rocks in kelp zone
Austrocsyrrhoe fimbriatus	Amphipod	Possibly associated with maerl
Synoicum incrustatum	Ascidian	Horizontal surfaces subject to sand-scour
Ophiopsila annulosa	Brittlestar	Subtidal, coarse gravel
Gelidiella calcicola	Red alga	Maerl beds
Scmitzia hiscockiana	Red alga	Sublitttoral on tide-swept cobbles
Carpomitra costata	Brown alga	Epilithic on small stones and shells in strong currents

In addition to the physical disturbance or alteration of current flows caused by the presence of wave/tidal stream powered electricity generation there is potential for other impacts. This includes the leaching of toxic components from the immersed structure. The UK BAP for tidal rapids (http://www.ukbap.org.uk/UKPlans. aspx?ID=39#2) states the following in relation to pollution from

electricity generating plant: '*Rapids may contain species sensitive to water pollution. Although the currents in rapids may quickly disperse one-off sources of pollution, chronic continuing pollution could affect sensitive marine life'.* Careful consideration of the likely fate and behaviour of chemicals derived from the generators must be made. The chemicals of most concern include those derived from antifoulants, electrical insulation and possibly oil-based lubricants

6.2 Site-specific comments

Reduction of downstream water flow, if it occurs, will be more significant in straits, tidal rapids and other constricted areas (among the sites considered here these could include Kyle Rhea and the Falls of Lora) than along broad areas of open coastline such as the Rhinns of Galloway.

Of the sites considered here the Sounds of Harris and Barra are likely to be considered extremely sensitive sites on the basis of their high amenity and conservation value. In addition, the Firth of Lorn is a Marine SAC, and Kyle Rhea is included within the Lochs Duich, Alsh and Long Reefs SAC. Designation as SACs has been made on the basis of the diversity of subtidal hard substratum biotopes (generically termed 'reefs') present in each area, rather than because of the presence of individual protected or sensitive species (such as reef-building serpulid polychaetes or cold-water corals). The statutory designations of the Firth of Lorn and Kyle Rhea areas would necessitate detailed local studies of potential impacts before siting of wave or tidal energy generators.

In addition to these two areas designated as Marine SACs, Burrow Head supports a biotope regarded as being of conservation importance, namely an extensive area of reefs built by the polychaete *Sabellaria spinulosa.* This Annex I and UK BAP habitat is physically fragile and highly sensitive to physical disturbance of the seabed. Any proposed siting of tidal or wave energy generators off Burrow Head would therefore need to take into account the local distribution of *Sabellaria* reefs in relation to the positioning of moorings or other seabed structures.

None of the other sites discussed here have any statutory designation on the basis of subtidal benthos or are known to support individual species or biotopes of particular sensitivity. However, hard-substratum biotopes that would probably fall within the 'reef' category of Habitats Directive Annex I are present in all of them, and it would be necessary to consider potential impacts of seabed disturbance or water flow modification at a local scale before installation of tidal or wave energy devices.

7. GAPS IN INFORMATION AND RECOMMENDATIONS FOR FURTHER SURVEY WORK

Of the sites discussed here, only the Firth of Lorn Marine SAC and the Sound of Barra has been mapped and biologically surveyed using up-to-date acoustic methods supplemented by video ground-truthing (Davies, 1999). Because of their very limited spatial extent the Falls of Lora have also been well-described by the MNCR diving survey (Holt, 1991).

Information is much more limited for the remaining sites, and in most cases inadequate to give more than a general account of the benthic biotopes likely to occur in the area unless it coincided with a surveyed site. It is recommended that in the event of a particular area being futher considered as a location for tidal or wave energy generation, the broad-scale distribution of benthic biotopes should be surveyed using modern acoustic methods (RoxAnn^{TM} , side-scan sonar) and ground-truthed by underwater video, using the Firth of Lorn mapping project (Davies, 1999) as a model. If water depth permits, diving surveys by trained observers should be used to supplement the video survey, providing information at a smaller spatial scale at sites likely to be disturbed by sea bed moorings.

We recommend that as the main data gaps are related to the specific interaction of wave and tidal-stream power generators with the benthic environment, that future efforts be targeted to better understanding the specific process involved that may cause impact. In our view this would be much more useful in terms of the SEA than detailed survey work on very large areas of the Scottish seaboard.

We believe that trial-EIAs of hypothetical but well specified developments located in a areas thought to be representative for wave and tidal power extraction would provide best insight into the most important and probable environmental risks.

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