High Level Environmental Screening Study for Offshore Wind Farm Developments – Marine Habitats and Species Project

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EXECUTIVE SUMMARY

High level environmental screening study for offshore wind farm developments – marine habitats and species

This report provides an awareness of the environmental issues related to marine habitats and species for developers and regulators of offshore wind farms. The information is also relevant to other offshore renewable energy developments.

The marine habitats and species considered are those associated with the seabed, seabirds, and sea mammals.

The report concludes that the following key ecological issues should be considered in the environmental assessment of offshore wind farms developments:

- likely changes in benthic communities within the affected area and resultant indirect impacts on fish, populations and their predators such as seabirds and sea mammals;
- potential changes to the hydrography and wave climate over a wide area, and potential changes to coastal processes and the ecology of the region;
- likely effects on spawning or nursery areas of commercially important fish and shellfish species;
- likely effects on mating and social behaviour in sea mammals, including migration routes;
- likely effects on feeding water birds, seal pupping sites and damage of sensitive or important intertidal sites where cables come onshore;
- potential displacement of fish, seabird and sea mammals from preferred habitats;
- potential effects on species and habitats of marine natural heritage importance;
- potential cumulative effects on seabirds, due to displacement of flight paths, and any mortality from bird strike, especially in sensitive rare or scarce species;
- possible effects of electromagnetic fields on feeding behaviour and migration, especially in sharks and rays, and
- potential marine conservation and biodiversity benefits of offshore wind farm developments as artificial reefs and 'no-take' zones.

The report provides an especially detailed assessment of likely sensitivity of seabed species and habitats in the proposed development areas. Although sensitive to some of the factors created by wind farm developments, they mainly have a high recovery potential.

The way in which survey data can be linked to Marine Life Information Network (*MarLIN*) sensitivity assessments to produce maps of sensitivity to factors is demonstrated.

Assessing change to marine habitats and species as a result of wind farm developments has to take account of the natural variability of marine habitats, which might be high especially in shallow sediment biotopes. There are several reasons for such changes but physical disturbance of habitats and short-term climatic variability are likely to be especially important.

Wind farm structures themselves will attract marine species including those that are attached to the towers and scour protection, fish that associate with offshore structures, and sea birds (especially sea duck) that may find food and shelter there.

Nature conservation designations especially relevant to areas where wind farm might be developed are described and the larger areas are mapped. There are few designated sites that extend offshore to where wind farms are likely to be developed. However, cable routes and landfalls may especially impinge on designated sites.

The criteria that have been developed to assess the likely marine natural heritage importance of a location or of the habitats and species that occur there can be applied to survey information to assess whether or not there is anything of particular marine natural heritage importance in a development area.

A decision tree is presented that can be used to apply ‘duty of care’ principles to any proposed development.

The potential ‘gains’ for the local environment are explored. Wind farms will enhance the biodiversity of areas, could act as refugia for fish, and could be developed in a way that encourages enhancement of fish stocks including shellfish.

REPORT

High level environmental screening study for offshore wind farm developments – marine habitats and species

1. Introduction

Available information has been brought together in this report to identify:

1. the species and habitats (as biotopes) likely to occur in areas being developed or that might be developed for offshore wind farms;
2. the additional biotopes that are likely to develop in an area as a result of the construction of offshore wind farms;
3. the likely sensitivity to and possible adverse effect on marine species and biotopes as a result of offshore wind farm developments;
4. the locations currently designated for protection and for which measures should be taken to ensure they are not adversely affected by offshore wind farm developments;
5. methods that might be used to identify where existing habitats and species may be sensitive to wind farm developments and incorporation of those methods into decision-making.

The report provides an awareness of the environmental issues related to marine habitats and species for developers and regulators. The information is particularly for wind farm developments but many of the conclusions are relevant to other offshore renewable energy developments.

2. Biological characterisation of areas that may be developed for wind farms

2.1 Species and habitats (biotopes) present

The species present in and on the seabed together with the physical habitat in which they occur is known as a 'biotope'. For practical purposes, 'biotope' is considered synonymous with 'habitat' in the sense that 'habitat' is used in work being undertaken under OSPAR (the Convention on the Protection of the Marine Environment of the North-East Atlantic). Biotopes are identified and named according to the classification developed by the Marine Nature Conservation Review and published in Connor *et al.* (1997a&b). That classification includes about 370 distinct entities and is the basis of the marine section of the classification being developed in the European Union Nature Information System (EUNIS). The Britain and Ireland classification is currently being revised.

In the case of offshore wind farm developments, the most likely biotopes to be present are sediment biotopes. Figure 1 shows a cross sectional impression of a sediment community that illustrates the sorts of species that occur in subtidal sediments and how the majority are burrowing species hidden beneath the surface. Plates 1 to 8 (at the end of the report) are photographs of the seabed taken in areas and of biotopes that might be typical of the bottom types where offshore wind farms may be developed.

Information describing the seabed species present has been obtained for the areas shown in Figure 2. Where that information is held on the MNCR database (accessed from www.jncc.gov.uk/mermaid) the data points have been interrogated to see if biotopes have been identified. Additionally, the MNCR Area Summaries have been inspected to identify biotopes where offshore areas have been included. Where information has not been included on the MNCR database or where biotopes have not been identified, relevant published survey data has been inspected to identify the likely biotopes that survey data represents. Survey data has been identified from the MNCR review of benthic marine ecosystems (Hiscock, 1998) and through correspondence with marine biologists and consultants. Appendix 1 lists the information sources used.

Significant data sets are known from some locations (Liverpool Bay, North Morecambe gas field) but are not readily obtained. However, knowledge from these areas has been obtained through consultation. Further information may be expected soon from surveys being undertaken in areas to be developed.

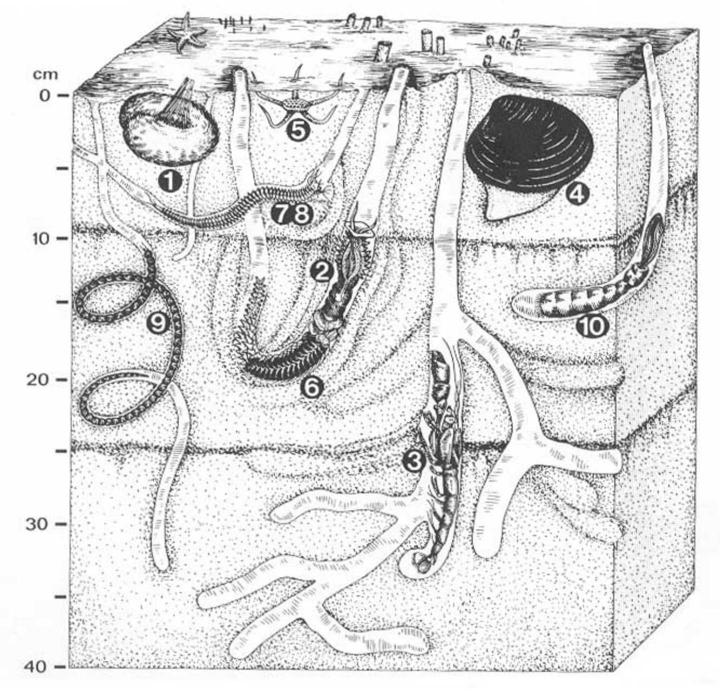

Figure 1. Communities living in sediments are predominantly of burrowing species. The community illustrated is a stable rich community from an offshore area of the Netherlands. 1. Spatangid sea urchins (includes *Echinocardium cordatum*, *Echinocardium flavescens*, *Brissopsis lyrifera*). 2. Parchement worm *Chaetopterus variopedatus.* 3. Callianassid crustaceans (includes *Callianassa subterranea*, *Upogebia deltaura*). 4. Icelandic cypine *Arctica islandica.* 5. Brittle stars (includes *Amphiura filiformis*, *Amphiura chiajei*). Worms: 6. *Gattyana cirrosa*; 7. *Glycera rouxi*; *Glycera alba*; 8. *Nereis* (now *Hediste*) and *Nephtys* spp.; 9. *Notomastus latericeus*; 10. *Echiurus echiurus.* From de Wilde, Berghuis & Kok (1984).

Box 1 lists the biotopes most likely to occur in the vicinity of the wind farms and in which of the areas currently being developed or likely to be developed they occur. A more detailed description of the biotopes and their geographical occurrence is given in Appendix 2. The approach used to produce Box 1 and Appendix 2 could be transferred to any location where existing data sources describe the benthic species present. However, survey data for exact locations may be lacking.

Where a biotope is known to have been discontinued, it is not named or researched here. However, the category "Shallow muddy sand faunal communities (IMS.FaMS)", which it is proposed to delete in the next revision of the biotopes classification, is widely mapped and has been included in Table 1 and Appendix 2. Sensitivity information is taken from one of the biotopes that it is planned will replace it, "*Fabulina fabula* and venerid bivalves in infralittoral compacted fine sand (IGS.FabMag)". Four proposed new biotopes have been included. Cable routes inshore are likely to cross a wide variety of other inshore biotopes including hard substratum communities on cobbles and pebbles. Biotopes such as "*Haliclona oculata* and *Flustra foliacea* with a rich faunal turf on tide-swept sheltered circalittoral mixed substrata (MCR.Flu.Hocu)" occur in the Lune Deep off Morecambe Bay but are too localized and unlikely to be included in developments (except possibly cable routes) to be included.

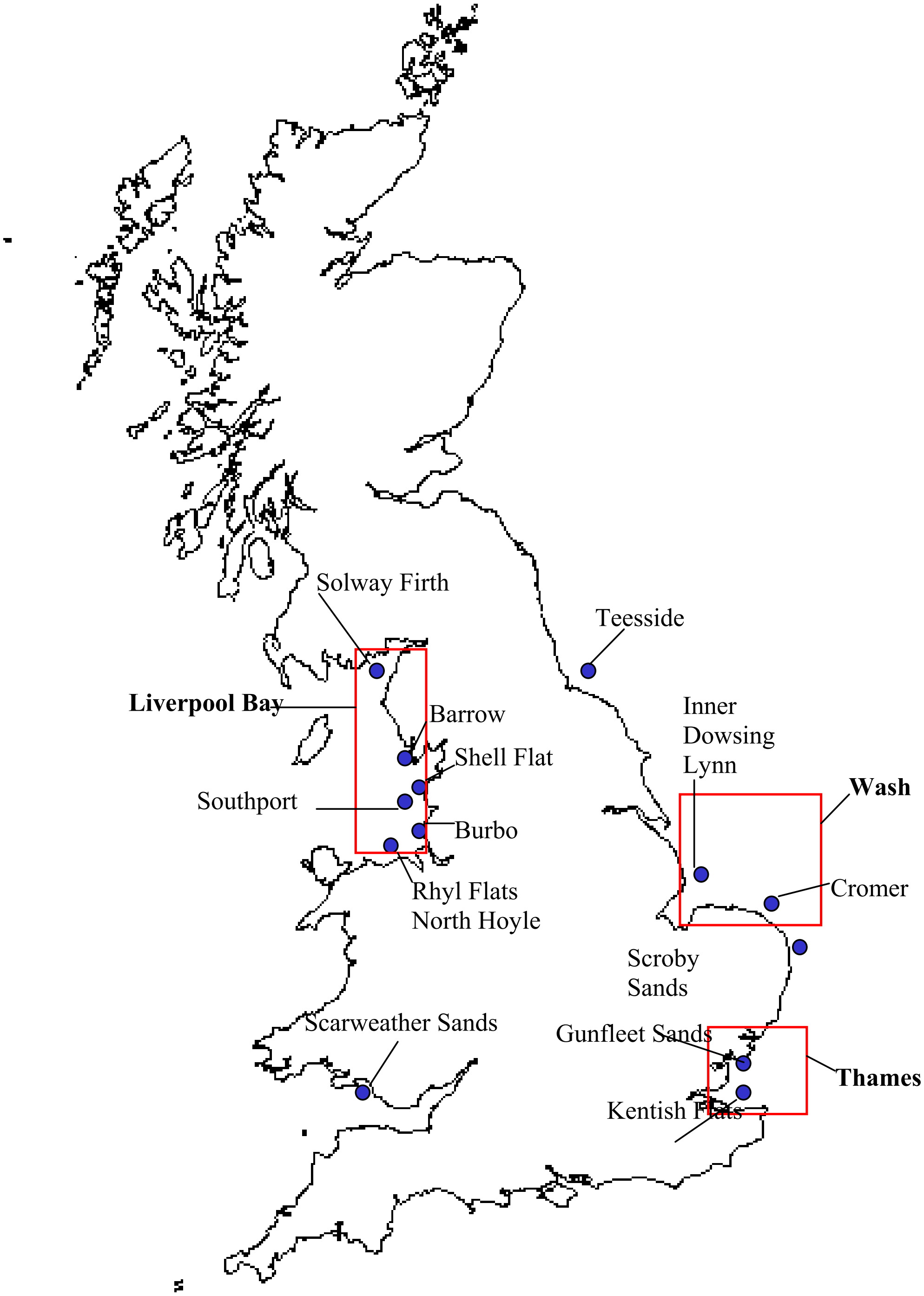

Figure 2. Location of possible major offshore wind farm development areas. This map shows existing proposed wind farm locations. Boxes indicate boundaries of proposed areas identified as potentially suitable for offshore wind farm developments.

Box 1. Biotopes (species and their habitats) present or likely to be present in areas identified for the development of offshore wind farms

WIDELY DISTRIBUTED

Infralittoral gravel and sands
Shallow sand faunal communities
- *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand. (IGS.NcirBat.)
- *Sertularia cupressina* and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand. (IGS.ScupHyd.)

Circalittoral muddy sands
- Venerid bivalves in circalittoral coarse sand or gravel. (CGS.Ven.)

Infralittoral muddy sands
- Shallow muddy sand faunal communities (IMS.FaMS / IGS.FabMag.)
- *Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud. (FaMsMacAbr.)

Circalittoral muddy sands
- *Abra alba, Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment. (CMS.AbrNucCor.)
- *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sands. (CMS.AfilEcor.)

Infralittoral mixed sediments
- Shallow mixed sediment faunal communities. (IMX.FaMx.)

Circalittoral mixed sediments
- *Modiolus modiolus* beds on circalittoral mixed sediment. (CMX.ModMx.)

EAST COAST AREAS

Infralittoral gravel and sands
Shallow sand faunal communities
- Dense *Lanice conchilega* and *Magelona mirabilis* with venerid bivalves in infralittoral mobile sand. (IGS.Lcon.)

Infralittoral muds
Estuarine sublittoral muds
- *Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral soft mud. (IMU.EstMuAphTub.)
- *Nephtys hombergii* and *Tubificoides* spp. in reduced salinity infralittoral muddy sediment. (IMU.EstMuNhomTub.)

Circalittoral mixed sediments
- *Sabellaria spinulosa* and *Polydora* spp. on stable circalittoral mixed sediment. (Cmx.SspiMx.)
- *Lumbrineris* spp. in circalittoral mixed sediments (novo.LumbMX).
- *Protodorvillea kefersteinea* in impoverished heterogenous sediment (novo.PkerMX).

WEST COAST AREAS

Circalittoral muddy sands
- *Virgularia mirabilis* and *Ophuira* spp. on circalittoral sandy or shelly mud. (CMS.VirOph.)

2.2 Variability and change in benthic communities

2.2.1 Extent and type of change

Information described in Section 2.1 is mainly from single surveys. It is particularly important, in relation to assessing potential impacts of human activities or to establishing ‘baselines’, to understand the degree of change that occurs naturally in marine communities.

Seabed communities may show significant change with time in the occurrence of dominant species, in biomass and in the occurrence of species of commercial or other importance. Closely related biotopes are identified in the MNCR biotopes classifications and, in some cases, it is noted that a change in the abundance of one or a few species can result in the biotope changing to a different one. Where change to a different biotope is or may be brought about by changes in an environmental factor caused by human activities, that change is identified in Marine Life Information Network (*MarLIN*: www.marlin.ac.uk) sensitivity reviews.

Significant studies have been undertaken of long term changes in muddy sand biotopes from eastern Anglesey (E.I.S. Rees, pers. comms), the German Bight (Rachor, 1990) and bays on the north coast of France. Some of the results of those surveys relevant to understanding temporal variation in likely wind farm locations are summarized below (substantially from text supplied by E.I.S. Rees).

Red Wharf Bay on the east coast of Anglesey has a 35+ year history of sampling. Many of the species there, for instance the worm *Lagis koreni* and the small bivalve mollusc *Abra alba*, are short lived species prone to great temporal variations in abundance (Rees *et al*. 1977; Rees & Walker, 1983). On the other hand, species such as the bivalve *Nucula* spp. are longer-lived and less prone to wild swings in their abundance.

Two sorts of trends have been apparent in Red Wharf Bay over the 20 and 35 years to 1997. Firstly, there have been long-term changes which were reflected most clearly in increases of about an order of magnitude in the abundances of both *Nucula nitidosa* and the brittle star *Amphiura brachiata.* Though less abundant overall, the bivalve mollusc *Pharus legumen* and burrowing sea urchin *Echinocardium cordatum* also became somewhat more abundant over the mid 1960s to mid 1990s period. It appeared therefore that there was a tendency towards increased stability over time in the composition of the fauna in this part of Red Wharf Bay. In addition to periodic outbursts of *Lagis koreni* and *Abra alba* there were other less expected and short lived events in the relative abundance of particular benthic species. This included two separate occasions when there were abnormally large numbers of the sand mason worm *Lanice conchilega* present. The sediment remained as the familiar muddy sand, but with very large numbers of the sandy tubes of *Lanice* protruding from it. Eagle (1973; 1975) found similar periodic increases of *Lanice conchilega* in a generally muddy sand location off the North Wirral coast, between the Dee and Mersey Estuaries. The MNCR classification has an IGS.Lcon biotope in the current swept shallow sublittoral, but an IMS.Lcon version was not listed for muddy sand. Occasional mass colonization by *Lanice conchilega* originating from nearby extensive subtidal sands seems the most likely explanation for such occurrences.

The other, even less familiar, short lived outburst event was of the tube dwelling amphipods *Ampelisca brevicornis* and *Ampelisca tenuicornis*. For just two years in the early 1980s these two species, accompanied by abnormally high numbers of another amphipod, *Photis longicaudata*, were found in quantities.

The bivalve mollusc *Spisula subtruncata* has nearly always been present in samples from the Red Wharf Bay and Conwy Bay muddy sands. However, in most years those in the counts from grab samples were very small spat sized individuals, no bigger than the other very common small bivalve, *Mysella bidentata*. This would suggest that predation intensity on them was usually such that few survived to their second or third years. Small mesh beam trawl samples and photographs frequently show substantial numbers of *Ophiura ophiura* as well as various other potential predators of bivalve spat. In Red Wharf Bay in 1973 a substantial number of *Spisula subtruncata* from a single cohort survived to the second and third winters, reaching shell lengths of about 10-15mm. Temporarily *Spisula subtruncata* became the biomass dominant in the middle of Red Wharf Bay. Indeed when samples were spread out in trays of about the same dimensions as the $0.1m^2$ area sampled by the grab, *Spisula subtruncata* covered about 80% of the bottom of the trays. At this particular time, there were abnormally large numbers (>2000) of common scoters *Melanitta nigra* in Red Wharf Bay. The birds were seen to concentrate their diving in just the part of the bay where the 1+ to 2 year old *Spisula subtruncata* had been found in abundance in grabs. A similar short-lived event, with a single cohort of *Spisula subtruncata* surviving for 2 years and being a significant part of the total biomass, was also observed in Conwy Bay in 1994. *Spisula subtruncata* is well known for its intermittent occurrence in single age cohort patches and fluctuations in abundance may be linked to fluctuations in the occurrence of common scoters at specific locations.

It appears, that using the MNCR (1997) codes, the same place in the southeast corner of Red Wharf Bay, might have been allocated to at least four different biotopes at various times if there had been no appreciation of the temporal variability. Moreover, there are anomalies in fitting the muddy sand assemblage here to any one of the MNCR biotopes.

2.2.2 Reasons for change

Identifying the reasons for change is essential if impacts from construction and development are to be separated from those brought about by natural fluctuations or fluctuations brought about by external influences unconnected with wind farm development and operation. Wherever information is available, *MarLIN* sensitivity reviews will identify the degree of change known to occur in a biotope or in species. However, information on variability is rarely available and it is more often that interpretation of reasons for change relies on advice from experienced benthic ecologists. Monitoring studies should ensure that similar habitats are sampled in reference locations away from developments.

Severe cold conditions may initiate substantial and possibly long-term changes in benthic communities. In Red Wharf Bay, it is notable that, when quantitative samples were first taken, in 1969 it was only 6 years after the very severe winter of 1962/63. That winter was reported to have caused mass mortalities of *Pharus* *legumen* and other southern bivalves as well as the heart urchin *Echinocardium cordatum* both locally in Red Wharf Bay and in bays on the south coast of England (Crisp 1964). As another inshore species with a southerly distribution, *Amphiura brachiata* may also have suffered a decline at this time, but it would have been a less obvious component of stranded debris on which the reports of soft bottom benthos effects were largely based. Further east in Liverpool Bay, both *Echinocardium* and *Amphiura brachiata* were virtually absent in the early 1970s from suitable locations that were sampled regularly during sewage sludge disposal effects monitoring. They became quite common at the same stations by the mid 1990s though sludge disposal was still going on. It is possible that what was seen was a gradual return to greater stability in benthic populations after the exceptional and widespread disturbance event of the 1962/63 winter.

Strong winds and associated wave action are a further cause of change in benthic communities. The shallow water in both Red Wharf and Conwy Bay is intermittently exposed to disturbance by severe northwesterly gales. Rees *et al*. (1977) document one such event that caused mass stranding of the benthic fauna in Red Wharf Bay. Several other storm-induced events are known to have occurred in recent decades. Similar mass strandings of infaunal benthos have occurred from time to time at Llanfairfechan on the shore of Conwy Bay.

Smothering by sediment movements will occur naturally. For instance, storms were reported to deposit 4-10cm of sand at 28m near Helgoland in the German Bight and up to 11cm of sand off the Schleswig-Holstein coast (Hall, 1994). Deposited spoil may directly clog the feeding or respiratory apparatus of suspension feeders. For example, Maurer *et al.,* (1986) reported that epifaunal or deep-burrowing siphonate suspension feeders were unable to escape burial by more than 1cm of sediment. However, many burrowing species will be capable of returning to their preferred depth in the sediment. Seabed communities may therefore be greatly altered by smothering events and may take some years to recover.

Plankton blooms and subsequent de-oxygenation events may also result in significant changes. Most commonly, when intense blooms of the dinoflagellate planktonic alga *Phaeocystis pouchetii* collapse, the decaying bladders sink to the bottom carrying with them other organic particles from the water column. Sometimes the near-bed advective and sorting process, through cyclic deposition and re-suspension, results in patchy concentrations of the organic matter to such an extent that near bed hypoxia occurs. In response to oxygen shortage several of the macrofaunal species commonly emerge onto the sediment surface (Diaz and Rosenberg, 1995). The results of oxygen deficiency in the German Bight and Danish waters of the North Sea in 1981-1983 caused wide-scale mortality of benthic species (Dyer *et al.* 1983; Niermann *et al.* 1990). However, recovery was rapid and, by 1986, biomass as well as species and individual numbers rose to values similar to those determined in earlier surveys (Niermann *et al.* 1990).

Climate change may have an increasing effect. The British Isles lies in the transition between warm temperate and cold temperate or boreal-arctic biogeographical regions. Southern species are likely to show increased recruitment and northern species decreased recruitment as seawater temperatures rise.

Eutrophication (increased nutrients) is the suggested reason for the long-term changes observed in the benthos of the German Bight (Rachor, 1990) and the Kattegat at the entrance to the Baltic Sea (Pearson, *et al.*, 1985). Changes that might be expected as a result of eutrophication include greatly increased biomass, increased abundance of short-lived adaptive species and decreased abundance and possible disappearance of long-lived species.

Fishing, especially fishing using mobile bottom gear, may significantly change the nature of benthos. Physical removal of the substratum will result in loss of the associated community, depending on depth, as well as physical damage or displacement of seabed habitats and biota. Damaged and dying macrofauna in turn may attract scavenging organisms (e.g. fish, common whelk and starfish) (Kaiser & Spencer, 1995; Ramsay *et al.*, 1998, 2000). Thus, the biotopes may be substantially changed although the presence of scavenging species and perhaps absence of long-lived emergent species may give an indication that fisheries have been implicated in any change. Where wind farm developments prevent the use of mobile bottom gear where it had previously been used, it seems likely that the seabed away from the immediate proximity of towers will develop communities that can be considered close to undisturbed natural communities.

3. Potential ecological effects of offshore wind farm developments

3.1 Effects on existing habitats and species

3.1.1 Introduction

Maritime activities affect the ecology of habitats by changing environment factors. The magnitude, extent, duration or frequency of physical and chemical (abiotic) and biological (biotic) environmental factors influences the physical and chemical structure of the habitat, and hence the composition and dynamics of the marine community present. This section outlines the environmental factors likely to be affected by offshore wind farm development, followed by a discussion of the likely sensitivities of ecological components (i.e. sea mammals, sea birds, fish and benthos) to changes in the environmental factors identified. The magnitude, extent, duration and frequency of effects are site-specific, dependant on the location of the site, baseline environmental conditions and the nature and extent of the proposed development.

Potential ecological effects and the likely affected environmental factors are summarized in Table 2 and explained in detail, with definitions of terms, in Appendix 3. The information summarizes more detailed environmental assessments and targeted studies on the effects of wind farm development, to which the reader should refer for further detail (e.g. Metoc, 2000, Percival, 2001; Vella *et al*., 2001 Parkinson, 2002).

The review has benefited from information resources already available. In particular:

- Marine Life Information Network (*MarLIN*) Biology and Sensitivity Key Information Reviews for seabed species and biotopes (www.marlin.ac.uk);
- UK Marine SACs Project reviews of dynamic and sensitivity characteristics for conservation management of marine SACs (www.ukmarinesac.org.uk), especially Elliot *et al.* (1998), Holt *et al*. (1998), Hartnoll (1998), Hughes (1998), Cole *et al.* (1999) and Jones *et al.* (2000);
- sensitivity and vulnerability of commercial and other fish and shellfish published by Mitson (1995), Coull *et al*. (1998) and available on the UKOOA Web site (www.ukooa.co.uk) and Percival (2001);
- sensitivity and vulnerability of seabird populations published by Webb *et al.* (1995), Vella *et al.* (2001) and Percival (2001);
- vulnerability of sea mammal populations published in Richardson *et al.* (1995) and Vella *et al.* (2001), and
- background information on wind farm development published by Metoc (2000), DWIA (2002) (www.windpower.org), the BWEA (2002) (www.offshorewindfarms.co.uk) and Parkinson (2002).

Identifying sources and types of man-made noise and vibration required access to basic information and targeted studies by Evans *et al.* (1992), Mitson (1995), Richardson *et al.* (1995), Vella *et al.* (2001) and Percival (2001).

The development of offshore wind farms involves the following phases:

- pre-installation exploration;
- construction;
- operation, and
- decommissioning.

3.1.2 Pre-installation and exploration

Prior to construction and installation of wind turbines, potential sites (identified on the basis of wind energy and hydrographic information) require further survey to ascertain the depth contours, sediment type and suitability for the proposed foundation techniques. In addition, the sediment type and depth contours need to be described in order to choose the most efficient route for laying electrical cables connecting the wind farm onshore to the national grid.

Pre-installation surveys are likely to involve sediment coring, and geophysical surveys using variety of techniques, potentially including seismic survey. Survey vessels themselves are localized noise sources, while geophysical scanning techniques, such as sonar and air guns are powerful sound emitters. Preliminary core-sampling of the sediment will remove sediment, and its associated benthic infauna and/or displace organisms in the vicinity but be very localized in effect.

The likely effects of pre-installation activities are summarized in Figure 3.

3.1.3 Construction

Construction activities can be summarized as follows (Metoc, 2000; Parkinson, 2002):

- transport of foundations and turbines to site;
- construction vessels on site, including transport barges, jack-up barges and drilling barges;
- site preparation and foundation installation;
- disposal of associated spoil,
- installation of tower, turbine housing or nacelle, generators, hub and blades,
- cable installation between turbines and to shore;

The likely effects of construction activities are summarized in Figure 4.

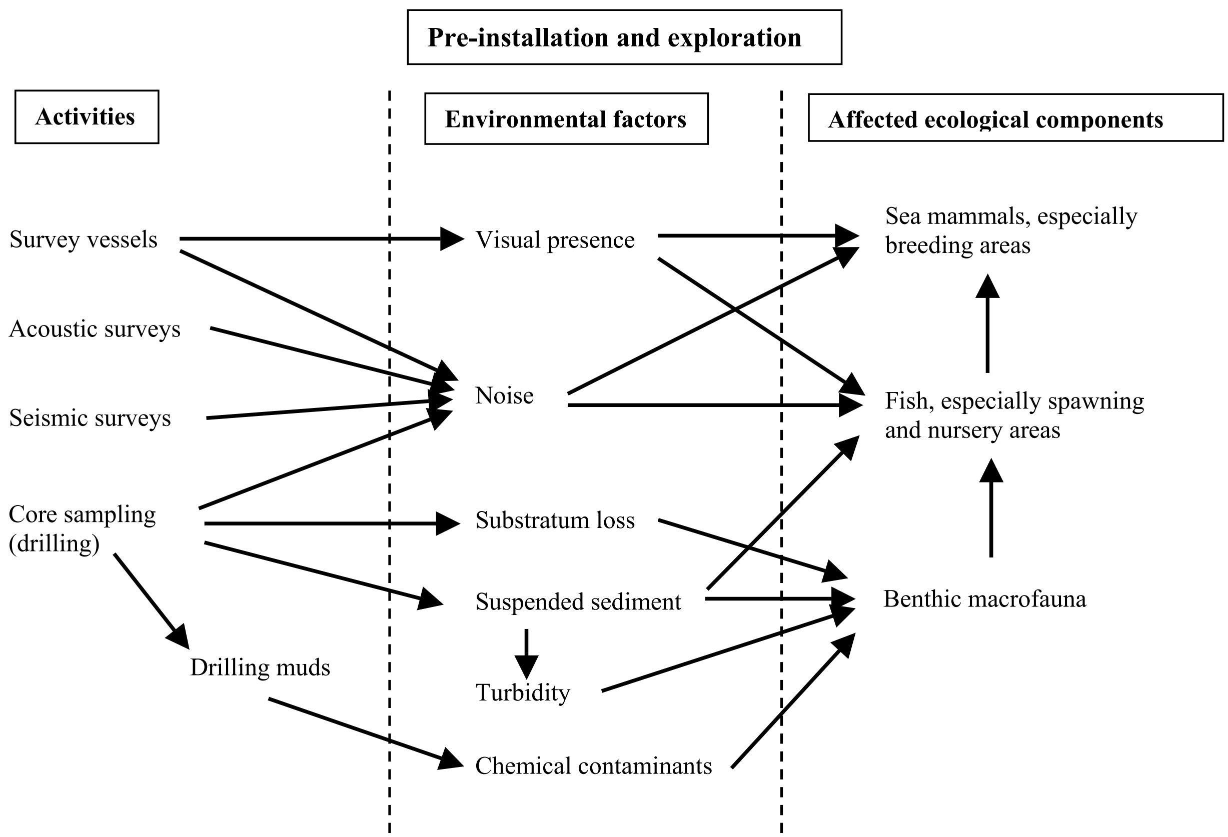

Figure 3. Conceptual diagram of effects of pre-installation and exploration (adapted from Elliot 2002; Parkinson, 2002).

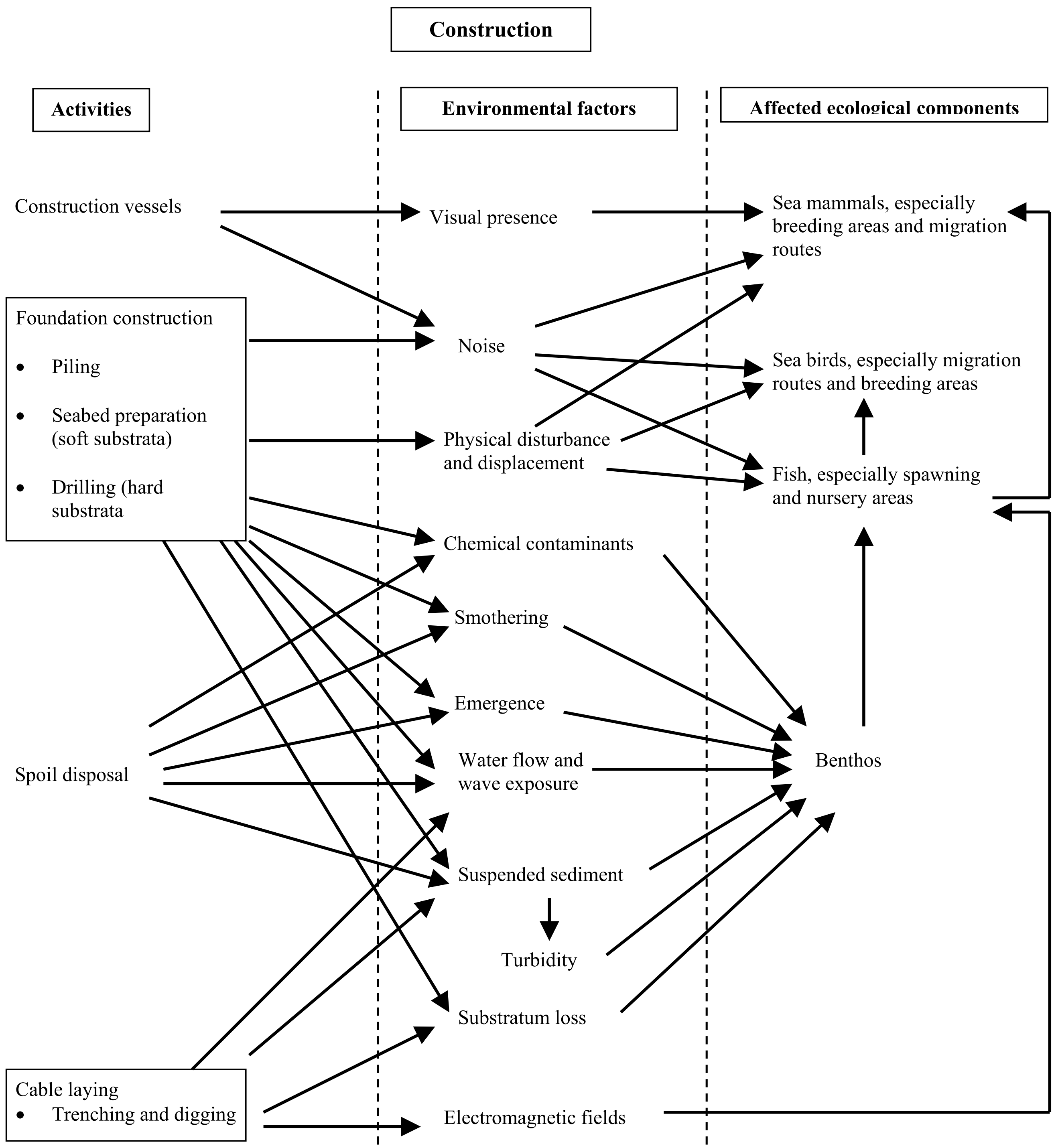

Figure 4. Conceptual diagram of the effects of construction (adapted from Elliot 2002; Parkinson, 2002).

Vessels associated with construction works.

The presence of construction vessels, barges, tugs, and support vessels is likely to result in surface and underwater noise and visual presence with associated possible effects on sea mammals, seabirds and fish. The increased large boat traffic from the local harbour or port chosen to service the wind farm development will probably result in additional disturbance of the bird (e.g. waders and over-wintering water fowl) or seal populations of intertidal or shallow subtidal sedimentary habitats, e.g. intertidal mudflats. The legs of jack-up barges and anchorage of construction vessels is likely to result in physical disturbance and abrasion and/or displacement of the benthic macrofauna.

Standard operating procedures for the handling of ship wastes (garbage and sewage), ballast and bilge waters should ensure that potential pollution effects are minimal. However, accidental collision between vessels or vessels and foundations may result in release of chemical contaminants such as oils.

Foundation construction

Construction activities such as drilling noise, pile driving and dredging of sediment will undoubtedly result in a variety of underwater noise (see noise below) of which pile driving will probably produce acute short term disruption. Explosives may be used to remove boulders that impede the insertion of the monopile into the sediment (DWIA, 2002), resulting in short pulses of intense sound.

The presence of artificial structures in the marine environment provides additional substrata for colonization by epifaunal communities, potentially increasing the biodiversity, productivity, and nutrient cycling of the locality, although the benthic community may be modified as a result.

The ecological effects of foundation construction depend on the type of foundation chosen (see Box 2).

Gravity foundations

Seabed preparation includes removal of surface layer of 'silt' and laying of a horizontal bed of shingle. Drilling and dredging activities result in removal of the substratum and re-suspension of sediment, resulting in plumes of sediment that increase light attenuation (turbidity) and may smother organisms when the material settles again. The distance traveled by the plume depends on the particle size: finer particles remaining in suspension longer and potentially being dispersed over several kilometres depending on prevailing currents. Physical removal of the substratum will result in loss of the associated community,

Box 2. Foundation types (Metoc, 2000; DWIA, 2002, Parkinson, 2002).

Concrete gravity based foundation - consisting of a single concrete support structure with a wide a flat base. Usually requires seabed preparation, depending on the particle size of the substratum, including removal of silt and laying of a smooth, horizontal bed of shingle by divers, followed by scour protection material. Concrete caissons are usually ca 15m in diameter, weigh ca 1050 tonnes and are used at water depths of 4-10m.

Steel gravity foundations - lighter and easier to transport than concrete version, the foundations are weighted on site with dense materials, e.g. olivine. Usually requires seabed preparation as above.

Monopile foundations - comprise a single steel pile between 2.5 and 4.5m in diameter that is driven ca 10-20m into the seabed. No seabed preparation is required but the presence of boulders may prevent its use. On rock substrata, a suitable hole is drilled for each monopile, into which the monopile is placed and secured by grout/cement materials.

Tripod foundations - small diameter tubular frames with 3-4 legged steel jackets. Each leg is fixed to the seabed by a steel pile (ca 0.9m diameter), driven 10-20m into the seabed. Tripod foundations are suitable for deeper waters but not for waters shallower than 6-7m.

depending on depth, as well as physical damage or displacement of macrofauna. Damaged and dying macrofauna in turn may attract scavenging organisms (e.g. fish, common whelk and starfish) (Kaiser & Spencer, 1995; Ramsay *et al.*, 1998, 2000). Re-suspension of sediment may also re-suspend adsorbed chemical contaminants (e.g. heavy metals, and radionucleides if present), and disturb the anoxic layer resulting in temporary, very localized reduction in nutrient and oxygen concentrations and exposure to hydrogen sulphide (H_2S). Accidental release of cements or grouting material may contaminate the sediment with e.g. organic polymers or heavy metals (Metoc, 2000; Parkinson, 2002; DWIA, 2002).

The addition of material to reduce or prevent localized scour around the foundation may provide additional habitats for colonization by other macrofauna.

Monopile foundations

A single steel pile is driven into the seabed, with resultant underwater and aerial noise production. Noise and visual presence are addressed as above. The action of driving a monopile into sediment is likely to severely damage any organisms unable to avoid the monopile, while any resident organisms trapped inside the pile will die.

In rocky habitats, a suitable hole may be drilled into which the pile is lowered. Drilling will remove affected habitats and their communities, create suspended sediment and may require drilling muds, which could potentially release chemical contaminants into the surrounding benthos.

Tripod foundations

The likely effects are similar to those resultant from monopile foundations above.

Disposal of spoil

Disposal of excavated spoil at sea is likely to result in a plume of material as it is released onto the seabed, potentially smothering some seabed: the area affected depending on amount dumped, depth to seabed and dispersal in the water column. Finer particulate remain in suspension longer than larger particulate and can potentially disperse over a wide area. If the spoil collects on the seabed, smothering is likely to significantly affect suspension feeding organisms and some epifauna. If the sediment type of the spoil deviates from the sediment type in the disposal site, then benthic infauna may also be significantly affected, resulting in changes in community present.

However, for the types of excavation associated with the establishment of wind farm structures, it is not expected that sufficient material will be deposited to affect seabed morphology and therefore cause changes in the local water depths, and resultant changes in water flow locally and wave action on the coast. However, any contamination of the spoil by drilling lubricants may introduce contaminants to the disposal site, affecting benthic communities and their recolonization rates.

Spoil disposal is well studied and it should be possible to minimize impact by adopting standard operating procedures. However, if a large number of wind farm developments are given the go-ahead, the overall potential spoil production should be investigated to ensure that present disposal sites could accommodate the predicted spoil volume generated. At some sites, on-site disposal may be possible or favoured.

Installation of tower, nacelle, generators, hub and blades

No additional effects and likely to occur as a result of the installation of the remaining wind tower components.

Cable installation between turbines and to shore

Metoc (2000) suggested that, in most marine areas, cables would be buried in order to:

- protect the cable itself, and
- prevent the cable from presenting a physical obstacle to fishing or shellfishing gear or anchors.

Cables may be jetted or ploughed into sedimentary substrata or lowered into trenches prior to cable laying (Metoc, 2000). Cable laying will potentially disturb a large area of the seabed in the development area and along the chosen cable route to shore. Digging and trenching will result in substratum loss together with its associated community, re-suspension of the sediment, and physical disturbance, damage and displacement of benthos. Subsequent subsidence of filled trenches may also result in changes in the hydrography, water flow and wave action, resulting in indirect changes in sediment and hence its benthos. The noise and visual presence generated by cable laying vessels are covered above.

If rocky substrata occurred (most likely at landfall locations) cables may need to be laid on the surface but may also need protection that would introduce unnatural hard substrata.

The cable connecting the wind farm to the local grid will pass through intertidal habitats and their communities. The effects on intertidal sedimentary communities will be similar to those mentioned above. In more detail, observations from the Lavan Sands near Bangor (North Wales) suggest how pipe laying operations may disturb communities and for how long (Rees, 1978). The pipe was laid in a trench dug by excavators. The spoil from the trenching was then used to bury the pipe. The trenching severely disturbed a narrow zone, but a zone some 50 m wide on each side of the pipeline was also disturbed by the passage of vehicles. The tracked vehicles damaged and exposed shallow-burrowing species such as the bivalves *Cerastoderma edule* and *Macoma balthica*, which were then preyed upon by birds. Deeper-dwelling species were apparently less affected; casts of the lugworm *Arenicola marina* and feeding-marks made by the bivalve *Scrobicularia plana* were both observed in the vehicle tracks. During the construction period, the disturbed zone was continually re-populated by mobile organisms, such as the gastropod *Hydrobia ulvae*. Post-disturbance recolonisation was rapid. Several species, including the polychaetes *Arenicola marina*, *Eteone longa* and *Scolplos armiger* were recruited preferentially to the disturbed area. However, the numbers of the relatively long-lived *Scrobicularia plana* were markedly depressed, without signs of obvious recruitment several years after the pipeline operations had been completed.

Visual presence and noise may be of increasing significance inshore in the proximity of feeding birds populations (including over-wintering migrants), breeding areas of birds and sea-mammals (e.g. seal haul-outs) and human habitation. Sensitive intertidal areas should be avoided.

In addition, the electromagnetic field generated by current within the cable may interfere with feeding behaviour of sharks and rays and migration of routes of sharks, some fish and cetaceans.

3.1.4 Operation

The ecological effects of an offshore wind farm are predominantly from the physical presence of the turbine towers both in the sediment and the water column and above the water surface, together with the noise and vibration generated by operating machinery. An overview of the potential ecological effects is shown in Figure 5 and summarized in Table 2. Additional impacts may result from routine maintenance and potential accidental collisions of shipping.

Physical presence of the turbine towers

Effects on hydrography

The base of the tower and foundations will alter the local water flow across the sediment, resulting in localized sediment scour in the lee of the tower and deposition to the front the tower. Metoc (2000) suggested that the need to space wind turbines far apart to prevent wind shadow should minimize impact. A gap of >300m between monopiles should be adequate to ensure that the 'wake' effects around the base of the monopile are minimized (Metoc, 2000).

Sedimentary habitats are primarily controlled by the hydrographic regime and the availability of sediment. The type of sediment present in any location, its stability, grain size, dynamics and bed-form are dependant on the current strength and direction, seasonal changes in currents, storms, wave action (especially in the intertidal), and the resultant equilibrium between accretion and erosion. Any structure that affects water flow or wave action is likely to change the sediment dynamics locally and potentially over a wide area within any given sediment cell. Sedimentary communities are themselves dependant on the stability of the sediment, its grain size and hence porosity, organic content and nutrient cycling, oxygen content and redox potential (see Elliot *et al*., 1998; Parkinson 2002). Therefore, an activity or structure that changes the hydrography is likely to affect the benthic communities present.

The presence of multiple turbines and foundations could potentially affect water flow around and through the development area. In addition, diffraction or interference of wave energy through or around the development area could potentially affect the amount of wave energy impinging on the adjacent coastal habitats, affecting wave action. Wave action is an important factor determining the structure and function of both rocky and sedimentary intertidal communities, as well as influencing coastal accretion or erosion.

Effects on birds

Metoc (2002) suggested that the presence of wind turbines may cause:

- disturbance to bird feeding areas in the proximity of the turbines;
- direct collision of birds with turbine and rotor blades;
- effects on the bird flight patterns in the vicinity of the wind farm;
- potentially attract birds to the turbines, either in search of food, or due to night-time illumination by navigational lights, and
- indirect effects due to changes in prey species.

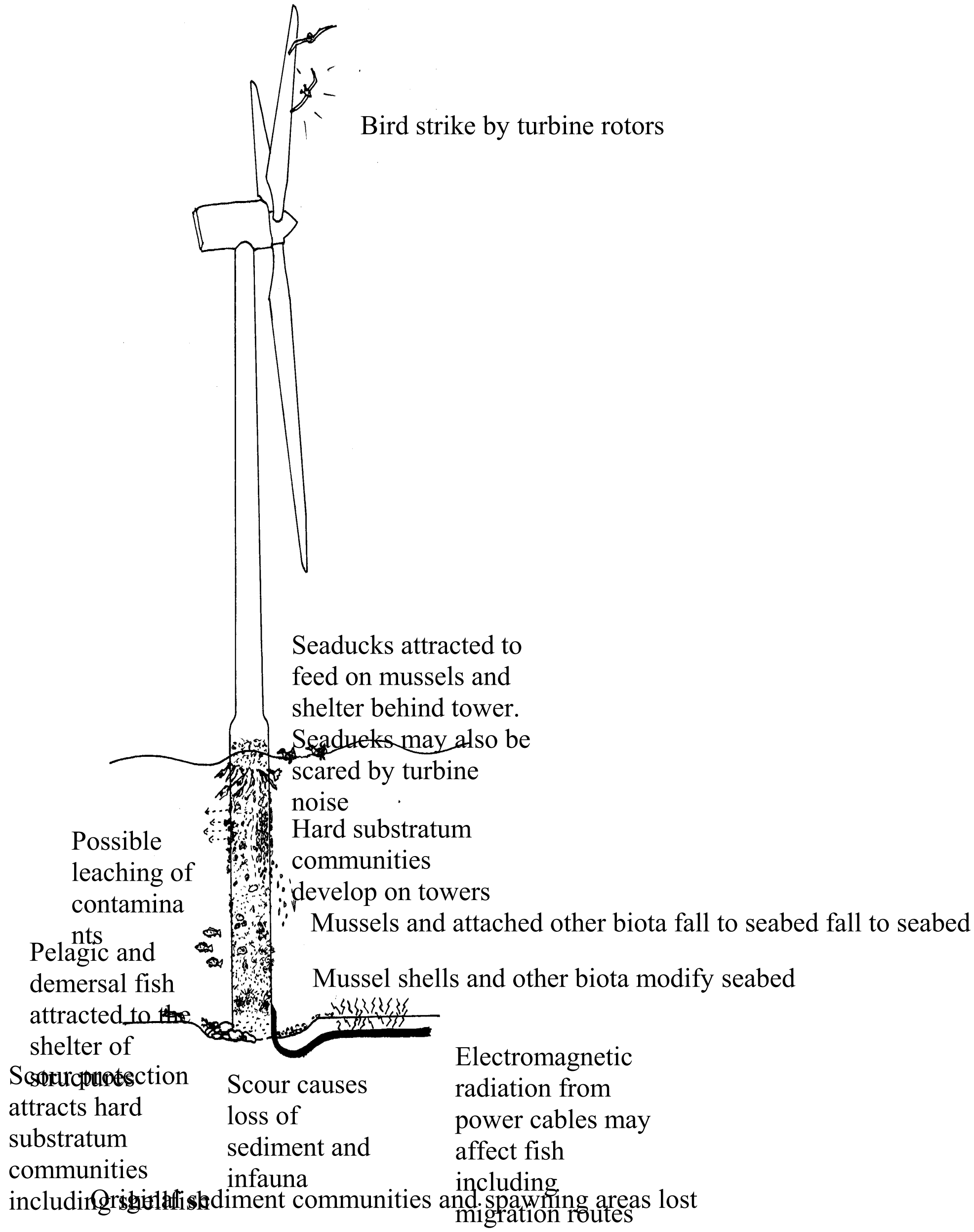

Figure 5. Effects and probable impacts of a monopile offshore wind turbine on the marine environment and its associated flora and fauna.

Turbine towers and their rotors potentially present a physical barrier to bird flight feeding and migration (see sensitivity to physical disturbance for further detail). In poor visibility conditions (e.g. fog) and/or at night the navigational lights may attract birds to the wind farm, increasing the potential risk of bird strike and resultant mortality.

Noise and vibration

Turbines generate mechanical noise due to movement of the gearbox and generators, and aerodynamic noise due to movement of the blades through the air (Metoc, 2000; Vella *et al.*, 2001). Noise and vibration from the turbines will be transmitted down the tower into the foundations and transmitted as vibration into the water column and through the sediment (Vella *et al.*, 2001).

Turbine noise may disturb feeding seabirds and seals, however under water noise could potentially disturb or displace populations of sea mammals and fish (Metoc, 2000) depending on intensity. The proposed lifetime for wind farms is 20 years, so that any effects caused by operational noise and vibration are likely to be long term (see section 3.2).

The likely effects of operational activities are summarized in Figure 6.

Maintenance

Routine maintenance activities involving movement of servicing equipment to the wind farm from the supporting port or harbour is unlikely to have any significant ecological effects as long as standard operating procedures for vessels are adhered to.

Accidental collision with shipping

Wind farms provide a potential hazard to navigation and shipping. Accidental collision could result in environmental contamination with shipboard wastes, oils and cargo depending on the vessel. Metoc (2000) suggested that an emergency response plan should be put into operation for any wind farm development.

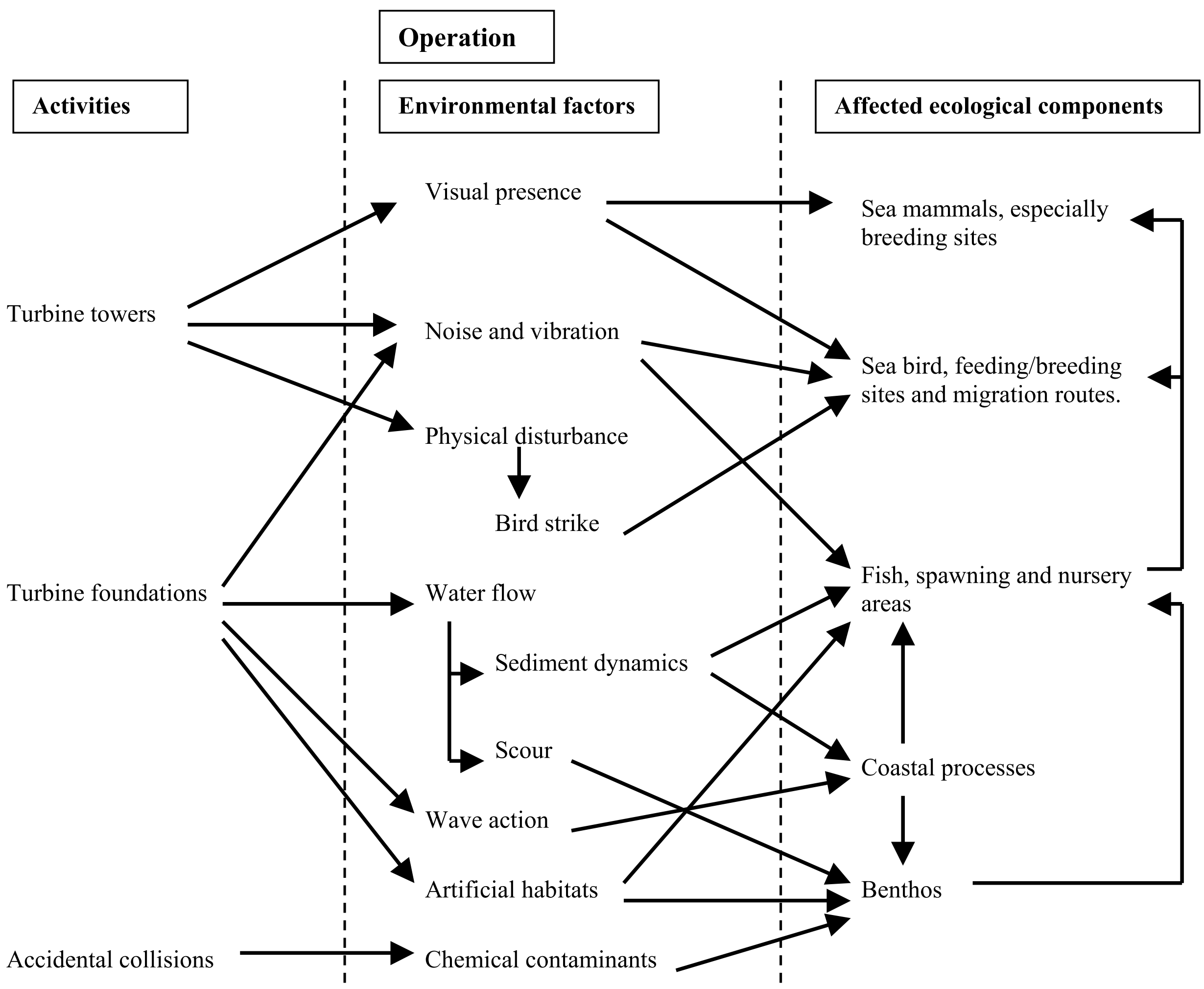

Figure 6. Conceptual diagram of the operational effects of offshore wind farm development (adapted from Elliot 2002; Parkinson, 2002).

Table 2. Summary of the potential ecological effects of offshore wind farm development. **Local =** local, immediate vicinity of development; **Area** = immediate area surrounding the development; **Region** = regional, sea area or sediment cell; **Short term** = short-term, days to weeks; **Long term** = long-term, years.

	Environmental factors likely to be affected													**Potential effects and comments. (Estimate of extent and duration in bold)**
Developmental stage / activity	Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	
PRE-INSTALLATION EXPLORATION														
Geophysical surveys • survey vessels • acoustic surveys								■	■		■			**Local, short term** • Potential physical damage of internal tissues (e.g. swim bladders), fish larvae or embryos and auditory sensors at short range due to underwater explosions or seismic survey arrays. • Stress and disruption of mating and social behaviour in cetaceans. • Disruption of fish shoals and feeding behaviour, startle response and potential reduction in catch rate (within 10m-10km) • Sonar induced flight responses in cetaceans, potentially resulting in increased incidence of live strandings • Interference with fish spawning areas **Area, short term** • Displacement of fish (within 10-1km) and sea mammals from the affected area, • Indirect effects on predatory seabirds
Core sampling of sea bed	■		■	■						■	■	■		Direct removal of samples of benthos and substratum, resulting in very localized increases in suspended sediment and turbidity and extraction of the benthic macrofauna. The use of drilling muds may expose organisms to chemical contaminants. Very localized and probably of low significance.

	Environmental factors likely to be affected													Potential effects and comments. (Estimate of extent and duration in bold)
Developmental stage / activity	Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	
CONSTRUCTION														
Transportation of foundations and turbines to site • Transport barges • Jack-up barges • Drilling barges								■	■	■				**Local, short term** • Disruption of fish shoals and feeding behaviour, startle response and potential reduction in catch rates (within 10m-10km) • Stress and disruption of mating and social behaviour in cetaceans • Sonar induced flight responses in cetaceans, potentially resulting in increased incidence of live strandings • Direct disturbance of feeding seabirds and waterfowl due to increased visual presence and noise; • Physical disturbance of benthic macrofauna due to anchoring and legs of jack-up barges on seabed **Area, short term** • Displacement of fish (within 10-1km) and sea mammals from the affected area • Indirect effects on predatory seabirds
Foundation construction (General effects)	■	■	■	■	■	■	■	■	■	■	■			**Local, short term** • Disruption of fish shoals and feeding behaviour, startle response and potential reduction in catch rates • Stress and disruption of mating and social behaviour in cetaceans • Physical disturbance, abrasion, displacement and damage of macrofauna, especially epifauna and biogenic reefs, due to anchoring and legs of jack-up barges on seabed • Removal of substratum and loss of benthic macrofauna **Area, long term** • Displacement of fish and sea mammals from the affected area • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators • Provision of new substrata and habitats for colonization

Developmental stage / activity	Environmental factors likely to be affected: Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	Potential effects and comments. (Estimate of extent and duration in bold)
A) Gravity foundations • seabed preparation • positioning of foundation on seabed • addition of scour 'prevention' material	■	■	■	■	■	■	■	■	■	■	■	■		**Local, short term** • Removal of sediment and associated macrofauna • Physical disturbance, abrasion, displacement and damage of macrofauna • Attraction of scavenging species • Plumes of suspended sediment, increased turbidity and potential for smothering of surrounding habitats • Re-suspension of sediment bound contaminants if present • Very localized deoxygenation and release of H_2S and nutrients form anoxic layer. **Local, short - long term** • Release of chemical contaminants (e.g. synthetic polymers and hydrocarbons) from cements and grouting chemicals **Area - region, long term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast (see below) • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators
B) Monopile foundations	■	■	■	■		■	■	■	■	■	■	■		**Sedimentary habitats (pile driving)** **Local, short term** • Noise and visual presence (see foundation construction above) • Physical disturbance, abrasion, displacement and damage of macrofauna, especially epifauna and biogenic reefs • Attraction of scavenging species **Rocky habitats (drilling)** **Local, short term** • Noise and visual presence (see foundation construction above) • Destruction of species attached to affected rock surface and removal of substratum. • Suspended sediment and smothering • Physical disturbance, abrasion, displacement and damage of macrofauna, especially epifauna and biogenic reefs • Attraction of scavenging species • Release of chemical contaminants from drilling muds
C) Tripod foundations	■	■	■	■		■	■	■	■	■	■	■		Effects similar to monopile foundations above
Disposal of excavated spoil		■	■	■	■	■	■							**Local-area, short term** • Plumes of suspended material and increased turbidity • Smothering of benthic organisms on site and the wider area • Potential modification of seabed sediment types and resultant changes in benthic community **Region, long term** • Changes to the seabed height and hence wave action on the coast • Changes to sediment dynamics in the wider area

	Environmental factors likely to be affected													**Potential effects and comments. (Estimate of extent and duration in bold)**
Developmental stage / activity	Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	
Installation of the turbine														Installation of the turbine and its support structure is unlikely to have additional direct effects on marine organisms at the construction stage.
Cable installation • cable laying vessels • trench digging, • plowing • electromagnetic fields	■	■	■	■				■	■	■	■	■	■	**Local, short term** • Noise and visual presence effects as above • Removal of sediment and associated macrofauna • Physical disturbance, abrasion, displacement and damage of macrofauna, especially epifauna and biogenic reefs • Attraction of scavenging species • Plumes of suspended sediment, increased turbidity and potential for smothering of surrounding habitats • Re-suspension of sediment bound contaminants if present • Very localized deoxygenation and release of H_2S and nutrients form anoxic layer. • Release of chemical contaminants (e.g. synthetic polymers and hydrocarbons) from cements and grouting chemicals • Disturbance of feeding water birds, seal pupping sites and damage to sensitive or important intertidal sites where cables come onshore **Area-region, long-term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Potential changes in macrofaunal communities with indirect effects on fish and their predators • Potential electromagnetic disruption of feeding behaviour in sharks and rays and migration is sharks and bony fish.

	Environmental factors likely to be affected													Potential effects and comments. (Estimate of extent and duration in bold)
Developmental stage / activity	Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	
OPERATION														
Physical presence of the turbine towers	■					■	■	■	■	■	■	■	■	**Local, long term** • Resultant changes in the benthic communities in the vicinity of the turbines • Disturbance of feeding birds in the vicinity • Displacement of bird flight paths, a potential barrier to flight paths or migration routes and mortality due to bird strike • Loss of preferred feeding habitat in bird due to displacement • Provision of new substrata and habitats for colonization and formation of an artificial reef • Attraction of fish species to the artificial reef and their predators (seabirds and sea mammals) • Potential collision hazard with shipping **Area-region, long-term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators • Potential disturbance of baleen whale communication and migration routes • Potential effect on electromagnetic fields on fish migration and feeding behaviour, especially in elasmobranchs (sharks and rays) • Provision of 'non-fishing' or 'no-take' zones
DECOMMISSIONING														
	■	■	■	■		■	■	■	■	■	■	■	■	**Local, short term** • Noise and visual presence as above • Removal of foundations and cabling resulting in considerable sediment disturbance, substratum loss, re-suspension of sediment and turbidity, potential smothering of surrounding habitats and physical disturbance • Loss of the artificial reef and associated species and habitats **Area-region, long-term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators

	Environmental factors likely to be affected													**Potential effects and comments. (Estimate of extent and duration in bold)**
Developmental stage / activity	Substratum loss	Smothering	Suspended sediment	Turbidity	Emergence	Water flow	Wave action (climate)	Noise	Visual presence	Physical disturbance	Displacement	Chemical contaminants	Other	
CUMULATIVE IMPACTS														
	■					■	■			■	■		■	Potential cumulative effects of multiple developments within a region may include: • Potential changes in bed-form and height and hence hydrography, water flow and wave energy impinging on the coast • Potential changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators • Potential effects on spawning and nursery areas for fish due to habitat loss or changes in hydrography • Potential changes to preferred feeding habitats for seabirds • Potential disturbance of baleen whale communication and migration routes due to emission of low frequency sound • Potential effect on electromagnetic fields on fish migration and feeding behaviour, especially in elasmobranchs (sharks and rays) • Provision of new substrata and habitats for colonization and formation of an artificial reef • Provision of 'non-fishing' or 'no-take' zones.

3.1.5 Decommissioning

Existing offshore wind farms have a design life of about 20 years (Metoc, 2000). Decommissioning will require removal of the foundation, tower, turbines and blades together with the associated cables between the turbines and the shore.

Removal of the foundations and cabling will result in considerable disturbance of the seabed with resultant removal or physical disruption of benthic communities and re-suspension of sediment, the effects of which have already been discussed above. In addition, removal of the foundations will remove the epifaunal communities and associated fish communities that they support resulting in a reduction of the local biodiversity.

At present the Crown Estate and DEFRA favour the return of the seabed to its original state and complete removal of seabed structures (Metoc, 2000). Furthermore, as a result of OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations, there is a presumption that all offshore installations will be removed for re-use, recycling or final disposal to land. However, Lindeboom (2000) suggested the use of fishing 'no go' or 'no-take' zones for marine conservation of fishery resources. If the wind farm foundations support productive artificial reef communities, especially if they form a nursery for commercial species, then leaving the foundations in place may be a more environmentally beneficial and cost-effective alternative than complete removal.

3.2 New habitats and likely communities and species

3.2.1 Introduction.

Whilst there is likely to be both localized modification to the character of sediments in the region of wind farm towers, it is the wind farm structures themselves and any scour protection that is introduced that will be likely to create the largest changes to the communities and species present in the area.

A great deal of work has been undertaken to survey and describe fouling growths on offshore structures. However, for commercial reasons, very little has been published. Published information includes the work of Forteath *et al*. (1982) for steel platforms in the central and northern North Sea and Picken (1986) on fouling communities in the Moray Firth. Other published work, with similar information, includes Forteath *et al* (1982) and Terry & Picken (1986). Colonization on jetty piles, although usually in wave sheltered areas, also provides information on the communities likely to develop on offshore structures. Much of the description below is based on a limited range of observations of jetty piles by one of the report authors (K. Hiscock). Information sources that have been consulted include Hiscock & Cartlidge (1980-1983), observations on the communities that develop on wrecks are also relevant and the MNCR biotopes classification (Connor *et al*. 1997) has been consulted.

The locations where offshore wind farms are planned and expected are in sedimentary wave exposed areas of open sea. Where those locations are in shallow depths (seabed less than about 5 m below chart datum) scour conditions are likely and will most likely prevent the establishment of stable communities. Instead, rapid-settling, fast growing species typical of scoured situations will establish on the structure above the seabed. Any structures that are in areas where sediment scour is unlikely (because of depth to the seabed, stable substratum type or local shelter) or where the structure extends higher in the water column than the area of significant scour, will develop hard substratum communities typical of artificial structures such as jetty piles and wrecks.

Figure 7 is an illustration of the types of colonization likely to occur in the region of wind turbine towers.

3.2.2 Towers

Marine growth on new surfaces typically commences with colonization by species that produce large numbers of planktonic larvae for extended periods and are fast growing once settled. Intertidal areas are likely to be dominated initially by green algae and by laver, *Porphyra* spp., later joined by barnacles (*Semibalanus balanoides*) and mussels (*Mytilus edulis*). In subtidal areas, fast growing colonizing species include the keeled tubeworm *Pomatoceros triqueter*, barnacles especially *Balanus crenatus*, encrusting seamats and, in shallow depths, algae such as gutweed *Enteromorpha* sp and sea lettuce *Ulva lactuca*. Where sand is in suspension, the ross worm *Sabellaria spinulosa* may dominate especially near to the seabed. The same species will continue to characterize the communities of areas of the structure subject to frequent sand scour. In the year following establishment overgrowth of initial colonizing species will occur. Solitary sea squirts, *Ascidiella* spp. are likely to colonize deeper parts of the structure, barnacles (*Balanus crenatus* and *Balanus balanus*) and mussels (*Mytilus edulis*)are likely to become established especially in shallow regions and kelps might grow on the shallowest part of the structure. A more diverse algal community on the upper few metres of the structure and a rich community of ‘soft’ fouling organisms will develop over the three years subsequent to establishment, possibly displacing many initial colonizing species including mussels. The species that will occur include, in shallow depths, a variety of red algae including *Polysiphonia* spp. and *Palmaria palmata*, kelps including *Alaria esculenta* and species of *Laminaria* and some filamentous brown algae especially *Ectocarpus* sp. Deeper areas are likely to become dominated by hydroid sea firs such as *Tubularia* spp., *Obelia* spp. and *Kirchenpauria pinnata*, plumose anemones *Metridium senile*, sagartia anemones *Sagartia elegans* and *Actinothoe sphyrodeta*, soft coral *Alcyonium digitatum*, erect bryozoan sea mats such as species of *Bugula*, feather stars, *Antedon bifida*, various solitary or clumped sea squirts such as *Ascidiella* spp., *Ciona intestinalis* and *Clavelina lepadiformis* together with fleshy sea squirts such as the star ascidian *Botryllus schlosseri* and polyclinid sea squirts such as *Morchellium argus*, and sponges such as the orange tassel sponge *Esperiopsis fucorum*. Shallow areas dominated by algae and sometimes deeper areas, may become covered in the tubes of jassid amphipod crustaceans (*Parajassa pelagica* in very shallow depths, *Jassa falcata* deeper. However, such occurrences were found to be transitory by Hiscock & Cartlidge 1980-1983). Attached fouling growths will attract predators including starfish *Asterias rubens* and various crab species and will be colonized by a wide range of inconspicuous molluscs, worms and crustaceans. Fouling growths were found to be up to about 15 cm thick in the Moray Firth (Picken, 1986).

Species that colonize structures will depend mainly on depth to the seabed, degree of scour and geographical location. The description above is for structures to be built closer than 10 km from the coast; further offshore, larval supply from inshore hard substratum species may be reduced and elements of deep-water communities may occur.

Figure 7. Stylized drawing of zonal communities likely on structures placed in waters deeper than 15 m where scour is limited to the lowest part of the column. Sketches of species are not to scale.

3.2.3 Water column.

Offshore structures and wrecks attract fish that live in the water column but appear to benefit from the shelter afforded by those structures. Species of wreck fish, *Trisopterus* spp., seem to be especially attracted to deeper areas together with pollack, *Pollachius pollachius*, and in northern waters, saithe, *Pollachius virens*, in areas where there is kelp.

3.2.4 Adjacent seabed

Tidal currents and wave action will be accelerated around the obstruction caused by wind turbine towers and winnowing of sediment will occur. Typically around wrecks, this winnowing leads to a scour pit about 50 cm to 1 m deeper than the surrounding seabed extending away from the structure several metres. The fine sediments are removed leaving large shells and coarse sediment often colonized by fast-growing species such as tube-worms and barnacles, sometimes with the peacock work *Sabella pavonina* present. Such scour pits appear to be attractive to some mobile seabed species and crabs and lobster will often be found in them together with fish such as ling. The scour pits may have similarities in the fauna present to those recorded from the Lune Deep off Morecambe. Where mussel beds develop on columns, these scour pits could be expected to become filled with mussels shells which would be distributed by storms around the surrounding seabed. Live mussels detached from the structure would attract scavengers such as starfish *Asterias rubens* and flat fish such as plaice *Pleuronectes platessa* and flounder *Pleuronectes flesus*.

3.2.3 Colonization on anti-scour structures.

Where the base of columns is protected by rock deposited to protect against the winnowing of sediment, the rock will become colonized by marine growth and could also provide a significant habitat for mobile species including commercial species. Because of winter storms and consequent scouring, the community attached to this 'rock armour' is likely to be ephemeral and of fast growing species such as barnacles and tube-worms. Solitary sea squirts may also settle, grow rapidly and may survive winters if conditions are not severe. Well-planned scour protection may provide a significant habitat for crustacean shellfish especially lobsters, *Homarus gammarus*, but also brown crabs, *Cancer pagurus*, velvet swimming crabs, *Necora puber*, and various species of squat lobster. Significant work has been undertaken at the University of Southampton to investigate the optimum size of stone that might create additional habitat for shellfish (See Jensen & Collins, 1997 and Halcrow Maritime *et al*. 2001). Fish, especially wrasse, are also attracted to the fissures and caves created by boulder heaps.

4. Nature conservation

4.1 Introduction

Box 3. Summary of guidance relevant to offshore wind farm development and given in 'Wind farm developments and nature conservation' (English Nature *et al.*, 2001).

- Where wind farms are proposed, their development should not adversely affect the conservation objectives and/or reasons for identification and notification or designation of sites of national wildlife importance.
- Where a proposed wind farm development is likely to have a significant adverse effect on a site of regional or local nature conservation importance, it should only be permitted if it can be clearly demonstrated that there are reasons for the proposal which outweigh the need to safeguard the nature conservation value of the site.
- To minimize the potential for adverse effects on birds, including the risk of collisions, wind farm developers should be made aware of known bird migration routes ……
- Where wind farms are proposed, their development should not cause significant disturbance to, or deterioration or destruction of, key habitats of species listed in Annex IV of the Habitats Directive.
- Where wind farms are proposed, their development should not contravene the protective measures that apply to Schedule 1 birds, Schedule 5 animals and Schedule 8 plants [of the Wildlife and Countryside Act 1981].
- Where wind farms are proposed, their development should respect, and where possible further, the objectives and targets for priority habitats and species listed in the UK Biodiversity Action Plan.
- Consideration must be given to the potential impacts of offshore wind farm developments on coastal processes.
- Consideration must be given to any significant adverse impacts of increased demand for coastal defenses.
- Consideration must be given to the potential impacts of wind farm development on … rare and scarce species found in the marine environment.

'Wind farm developments and nature conservation' (English Nature *et al.*, 2001) provides guidance to nature conservation organisations in England to wind farm proposals. The guidance is summarized in Box 3. The report includes a checklist of possible impacts of relevance to nature conservation.

Whilst provisions exist to identify and protect marine sites of natural heritage importance (for Marine Nature Reserves and intertidal Sites of Special Scientific Interest under the Wildlife and Countryside Act 1981; for specified habitats under the EU Habitats Directive), the series of protected areas is acknowledged as incomplete (see, for instance Laffoley *et al*. 2000). The lack of consideration of offshore areas for designation/protection and the approach required to identifying sites under the Habitats Directive, means that statutory designations cannot be relied upon to give an indication of whether rare, scarce, keystone or sensitive features are present in an area or, indeed, which parts of a large designated area might be especially important or sensitive. This section therefore gives major consideration to assessing whether or not there are features of marine natural heritage importance present wherever there are proposals for development.

4.2 Existing areas designated for protection

Developers will need to be aware of the location of areas designated for protection. From the point-of-view of marine natural heritage, the types of designation are listed in Box 4. Some areas, especially Special Areas of Conservation and Special Protection Areas, may be very large and it may be that their interest features will not be adversely affected by wind farm developments or that only a part of their area may be adversely affected.

Measures have recently been proposed (the *Marine Wildlife Conservation Bill*) to create Marine Sites of Special Interest. The measures proposed would enable the designation of protected sites at locations that are not already Marine Nature Reserves or Special Areas of Conservation.

European Marine Sites. The European Union Habitats and Birds Directives are international agreements which set out a number of actions to be taken for nature conservation. The Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements, and set out measures to maintain or restore, natural habitats and species of European Union interest at favourable conservation status. The Birds Directive protects all wild birds and their habitats within the European Union, especially migratory birds and those that are considered rare and vulnerable.

The Habitats and Birds Directives include requirements for the designation of conservation areas. In the case of the Habitats Directive these are Special Areas of Conservation (SACs) which support certain natural habitats or species, and in the Birds Directive, Special Protection Areas (SPAs) which support wild birds of European Union interest. These sites will form a network of conservation areas to be known as "Natura 2000". Where SACs or SPAs consist of areas continuously or intermittently covered by tidal waters or any part of the sea in or adjacent to Great Britain up to the limit of territorial waters, they are referred to as European Marine Sites

Further guidance on European marine sites is contained in the Department of the Environment, Transport and Regions/Welsh Office document: *European marine sites in England and Wales: A guide to the Conservation (Natural Habitats &c.) Regulations 1994 and to the preparation and application of management schemes.*

Selection procedures for SACs are described on www.jncc.gov.uk/SACselection (McLeod *et al*. 2002) which also provides maps showing extent and boundaries of candidate SACs. Selection procedures for SPAs in the marine environment are not yet agreed.

The location of candidate marine SACs is shown in Figure 8. Information on their interest features and sub-features is given in Appendix 4. The conservation objectives and the 'favourable condition' requirements (features that should be accounted for in any assessment of environmental impacts from a development) can be found in the advice given under Regulation 33(2) of the Conservation (Natural Habitats &c) Regulations 1994. The advice is included in reports issued by the statutory nature conservation agencies for each site. At the time of this report, Regulation 33 documents are available for English sites.

Sites of Special Scientific Interest. The objectives of the SSSI series (Nature Conservancy Council, 1989) are:

> "to form a national network of areas representing in total those parts of Great Britain in which the features of nature, and especially those of greatest value to wildlife conservation, are most highly concentrated or of highest quality."

Until recent years, few SSSI had been established specifically for their marine biological interest. At the end of 1994, there were 744 coastal and intertidal SSSI in Great Britain of which 84 included marine biology in their citations (Hiscock & Connor, 1996). Guidelines specifically relevant to the identification of intertidal and lagoon SSSI were developed in the mid 1990's (JNCC, 1996). A significant number of SSSI have subsequently been added to the series, mainly because any area that qualifies under the guidelines within a proposed SAC has also to be scheduled as a SSSI. Locations and reasons for establishment of SSSI are difficult to obtain and summarize for all SSSI in Great Britain. For England, there were, at July 2002, 275 SSSI that included intertidal habitats (figures supplied by EN Designated Sites Unit). English SSSI boundaries can be seen on www.english-nature.org.uk/pubs/gis/gis_register.asp. For Wales, the total number of intertidal, saltmarsh, sand dune, shingle ridges and coastal lagoon SSSI totaled 175 (figures supplied by Paul Brazier, CCW). For Scotland, it has not been possible to obtain numbers of coastal and intertidal SSSI but the location of all SSSI in Scotland can be seen on www.avian.co.uk/snh/report.asp. Details of precise locations and boundaries of SSSI usually require a specific enquiry to local offices of the relevant nature conservation agency.

Box 4. Natural heritage designations relevant to marine areas.

STATUTORY DESIGNATIONS

Marine Nature Reserve. Established in Great Britain under the Wildlife & Countryside Act 1981. Can be established within the 3 mile limit of territorial seas or, by Order in Council, the 12 mile limit.

Special Protection Area. A site of European Community importance designated under the Wild Birds Directive (Commission of the European Communities Council Directive 79/409/EEC of 2 April 1979 on the Conservation of Wild Birds). Criteria for designation of at sea areas yet to be determined.

Special Area of Conservation. A site of European Community importance designated under Council Directive 92/43/EEC on the conservation of natural habitats of wild fauna and flora.

Where SACs or SPAs consist of areas continuously or intermittently covered by tidal waters or any part of the sea in or adjacent to Great Britain up to the limit of territorial waters, they are referred to as 'European Marine Sites'. (A full list including interest features and sub-features is given in Appendix 2.)

Site of Special Scientific Interest Established in Great Britain under the Wildlife & Countryside Act 1981. (Areas of Special Scientific Interest are the equivalent designation in Northern Ireland).

Ramsar Site. Statutory areas designated by the UK government on the advice of the conservation agencies under the Ramsar Convention (the Convention on wetlands of international importance especially as waterfowl habitat). Contracting parties are required to designate wetlands of international importance and to promote their conservation and 'wise use'.

INDICATIVE DESIGNATIONS

Voluntary Marine Conservation Area Identified by English Nature in 1994 the aim of a VMCA is to raise the awareness of the value of marine wildlife, encourage enjoyment and understanding, and inform people of the potential of the wider marine environment. The designation does not restrict present activities in the area, but encourages harmonious use between all activities while respecting the local sea and sea wildlife.(There are similar other titles applied with the same broad objective.)

Marine Consultation Area Identified by Scottish Natural Heritage as deserving particular distinction in respect of the quality and sensitivity of the marine environment within them (especially sea lochs). Their selection encourages coastal communities and management bodies to be aware of marine conservation issues in the area

Sensitive Marine Area. Important areas for marine wildlife which were identified by English Nature as nationally important and notable for their marine animal and plant communities or which provide ecological support to adjacent statutory sites. They have a further aim of raising awareness and disseminating information to be taken into account in estuarine and coastal management planning.

Marine Environmental High Risk Area (MEHRA). Established in December 1999 to identify comparatively limited areas of high environmental sensitivity, which are also at risk from shipping. Once identified the locations are brought to the attention of ship owners and insurers to encourage ships to avoid these sites.

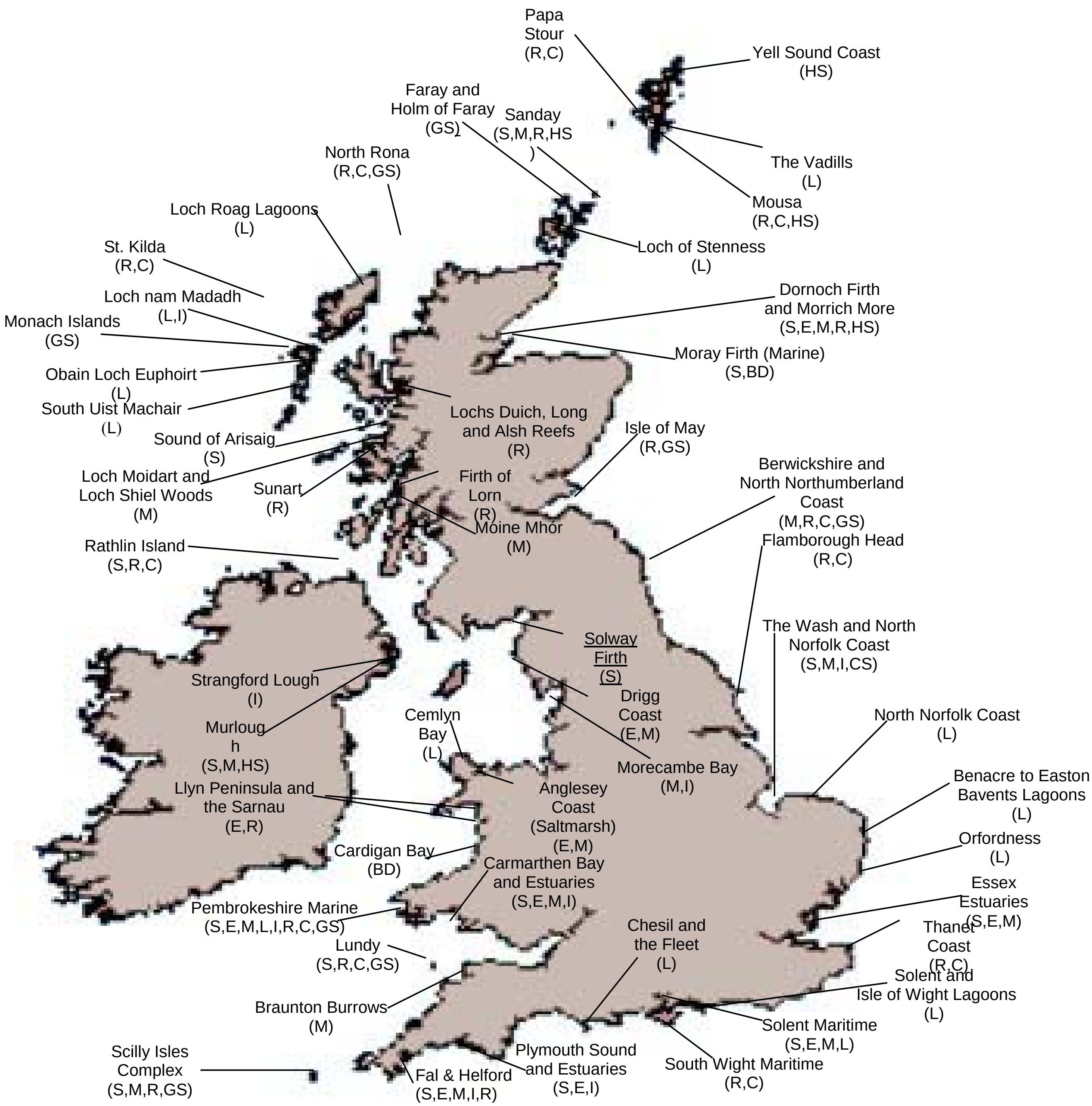

Figure 8. The location of U.K. candidate sites for marine Special Areas of Conservation. Key to special features*:* S - Sandbanks which are slightly covered by sea water at all times; E – Estuaries; M - Mud and sand flats not covered by sea water at low tide; I - Large shallow inlets and bays; L – Lagoons; R – Reefs; C - Submerged or partly submerged sea caves; HS – Harbour seal; GS - Grey seal; CS - Common seal; BD - Bottlenose dolphin.

Box 5. UK Biodiversity Action Plan marine habitats and species

Habitat Action Plans (HAPs)

Priority Habitats:

- Coastal saltmarsh
- Littoral and sublittoral chalk
- *Lophelia pertusa* [deep water coral] reefs
- Maerl [calcified detached seaweed] beds
- *Modiolus modiolus* [horse mussel] beds
- Mud habitats in deep water
- Mudflats
- *Sabellaria alveolata* [honeycomb worm] reefs
- *Sabellaria spinulosa* [ross worm] reefs
- Saline lagoons
- Seagrass beds
- Serpulid reefs
- Sheltered muddy gravels
- Sublittoral sands and gravels
- Tidal rapids

Broad Habitats:

- **Inshore sublittoral rock**
- Inshore sublittoral sediment
- Littoral rock
- Littoral sediment
- Oceanic seas
- Offshore shelf rock
- Supralittoral rock
- Supralittoral sediment

Species Action Plans (SAPs)

Algae

- *Anotrichium barbatum* Red Algae
- *Ascophyllum nodosum* Knotted wrack

Anemones and corals

- *Amphianthus dohrnii* Sea-fan Anemone
- *Eunicella verrucosa* Pink sea fan
- *Edwardsia ivelli* Ivell's sea anemone
- *Funiculina quadrangularis* Tall sea pen
- *Leptopsammia pruvoti* Sunset cup coral
- *Nematostella vectensis* Starlet sea anemone

Worms

- *Armandia cirrrhosa* Lagoon sandworm

Molluscs

- *Atrina fragilis* Fan mussel
- *Ostrea edulis* Native oyster
- *Thyasira gouldi* Northern hatchett snail
- *Tenella adspersa* Lagoon sea slug

Reptiles

- Grouped plan for marine turtles

Sea squirts

- *Styela gelatinosa* Sea Squirt

Fish

- *Alosa alosa* Allis Shad
- *Alosa fallax* Twaite Shad
- *Cetorhinus maximus* Basking shark
- *Coregonus oxynrhynchus* Houting
- Grouped plan for UK commercial fish

Mammals

- *Phocoena phocoena* Harbour porpoise
- Grouped plan for baleen whales
- Grouped plan for toothed whales
- Grouped plan for small dolphins

(Compiled from: www.ukbap.org.uk)

5. Criteria to identify species, habitats and areas of marine natural heritage importance

5.1 Introduction

Existing designated areas give a very 'coarse sift' of where features of marine natural heritage importance might be. Indeed, some are so large that the question "but where within these areas is really 'important' or 'sensitive' to the activity that I plan?" needs to be asked. Furthermore, the process of identifying marine sites of special interest using scientifically sound criteria has hardly started – especially offshore. The criteria that determine if a location has 'special' features should be applied to all proposed developments as a part of a 'duty of care' or 'good stewardship' approach that will assist in taking measures to avoid sensitive locations or at least to minimize damage.

Much sound thinking has gone into identifying criteria and structures to identify species and habitats and locations of marine natural heritage importance in recent years. In particular, the process of identifying species and habitats for Biodiversity Action Plans has developed practical criteria relevant to the information resources that we have for marine species and habitats (Box 6). Also, the development of a 'Marine Natural Heritage Assessment Protocol' by the nature conservation agencies has taken advantage of the structure offered by the biotopes classification (Connor *et al*. 1997a&b) to produce a systematic approach to assessment reflected in the approach recommended to DEFRA in their Review of Marine Nature Conservation (Laffoley *et al*. 2000). This section therefore outlines the criteria that can be used to screen environmental information from an area to establish whether or not there are features (habitats or species) present there that it will 'matter' (from the point-of-view of marine natural heritage) if they are damaged or lost as a result of a development.

Box 6. Selection criteria being used in the UK to identify marine habitats and species for Biodiversity Action Plans to be prepared to fulfil obligations under the Biodiversity Convention.

Habitats

- Habitats for which the UK has international obligations.
- Habitats at risk, such as those with a high rate of decline especially over the past 20 years.
- Habitats which are rare.
- Areas, particularly marine areas, which may be functionally critical for organisms inhabiting wider ecosystems.
- Marine habitats if 40% or more of the north-east Atlantic's occurrence of the habitat is located in the UK.
- Habitats which may be formed from a keystone species – one which hosts a characteristic community of other species.
- Areas important for rare species.

Species

- Threatened endemic and globally threatened species.
- Species where the UK has more than 25% of the world or appropriate biogeographical population.
- Species where number or range have declined by more than 25% in the last 25 years.
- Species found in fewer than 15 10x10 km squares in the UK.
- Species for which the UK has international obligations or which are protected under UK legislation.

5.2 Species

Application of the criteria from the recommendations to the RMNC (see Box 7) requires some guidance. If a species or biotope is 'rare' or 'scarce', it immediately identifies itself as worthy of protection and 'rarity' is an internationally recognized and used criterion. Interpreting IUCN guidelines (IUCN, 1994) in a Great Britain context, nationally 'rare' and 'scarce' species have been identified on the basis of their percentage occurrence in 10x10 km map squares. For inshore areas within the three nautical mile (ca 5.5 km) limit of territorial seas (which approximates to the zone under the influence of coastal processes), a 'nationally rare' species would occur in 8 or fewer squares, and a 'nationally scarce' species in 9 to 55 squares (Sanderson, 1996). There are significant problems in identifying 'rarity' especially in relation to availability of data. However, the value of this criterion demands pragmatic approaches.

Box 7. Criteria to identify seascapes, habitats and species that may require special conservation measures. From the recommendations to the DEFRA Working Group on the Review of Marine Nature Conservation (Laffoley *et al*. 2000).

Criteria to identify best examples:

- **Representivity**. The area contains examples of habitats/biotope types, habitat complexes, species, ecological processes or other natural characteristics that are typical and representative;
- **High natural biological diversity**. The area has a naturally high variety of habitats or species, or includes highly varied habitats or communities (compared to other similar areas) ;
- **Naturalness**. The area has a high degree of naturalness and ecosystems, habitats and species are still in a very natural state as a result of the lack of human-induced disturbance or degradation. Those that are more natural would be chosen in preference to other equally good examples but which subject to higher degrees of human impacts.

Criteria to identify those locations requiring special measures:

- **Rarity**. Habitat restricted to a limited number of locations or to small, few and scattered locations in UK waters. A species that is sessile or of restricted mobility at any time of its life cycle is assessed as being rare if it occurs in a limited number of locations in UK waters, and in relatively low numbers.
- **Sensitivity**. A very sensitive habitat or species is one that is very easily adversely affected by external factors arising from human activities, and is expected to recover only over a very long period, or not at all. A 'sensitive' habitat or species is one that is easily adversely affected by a human activity, and is expected to only recover over a long period.
- **Ecological significance**. An ecologically significant habitat is very important for the wider significance of the ecological processes, functions and species it supports. A species is of high ecological significance if it has a controlling influence on a community (i.e. a keystone species).
- **Decline**. Significant decline in numbers, extent or quality of a species of habitat
- **Proportional importance of the UK**. A high proportion of the habitat, or population of a species (at any time of its life cycle) occurs within the UK.
- **Potential value** for rehabilitation or re-creation of habitats.

Applying such quantitative measures offshore requires further discussion and the development of international standards. In practice, identifying species that are 'important' because of rarity or scarcity requires a considered approach as many species are naturally rare, may have been under-recorded and so on. Also, mapping species distributions with any confidence that they reflect the real distribution of a species relies on having extensive survey data to hand, usually in electronic format. Whilst the MNCR database includes records from approximately 31,500 locations, most are inshore and surveyed by diving. Much work remains to be done to add datasets from sediment habitats and especially offshore but is underway as apart of populating the UK National Biodiversity Network (NBN) Gateway (www.searchnbn.net). A provisional list of nationally rare and scarce species is given in Appendix 5. However the list is unlikely to include species from offshore sediment environments because: 1. it is derived from MNCR data from inshore areas mainly surveyed by diving, and 2. most offshore species are most likely widely distributed in what are very extensive areas of similar habitats.

6. Deciding acceptability, managing risks

From the point-of-view of environmental protection, the "will it matter if …?" question is of central importance. If we are to be good stewards of the natural environment, we need to understand what 'matters' from the point-of-view of conservation of biodiversity, welfare of species and sustainable use of resources.

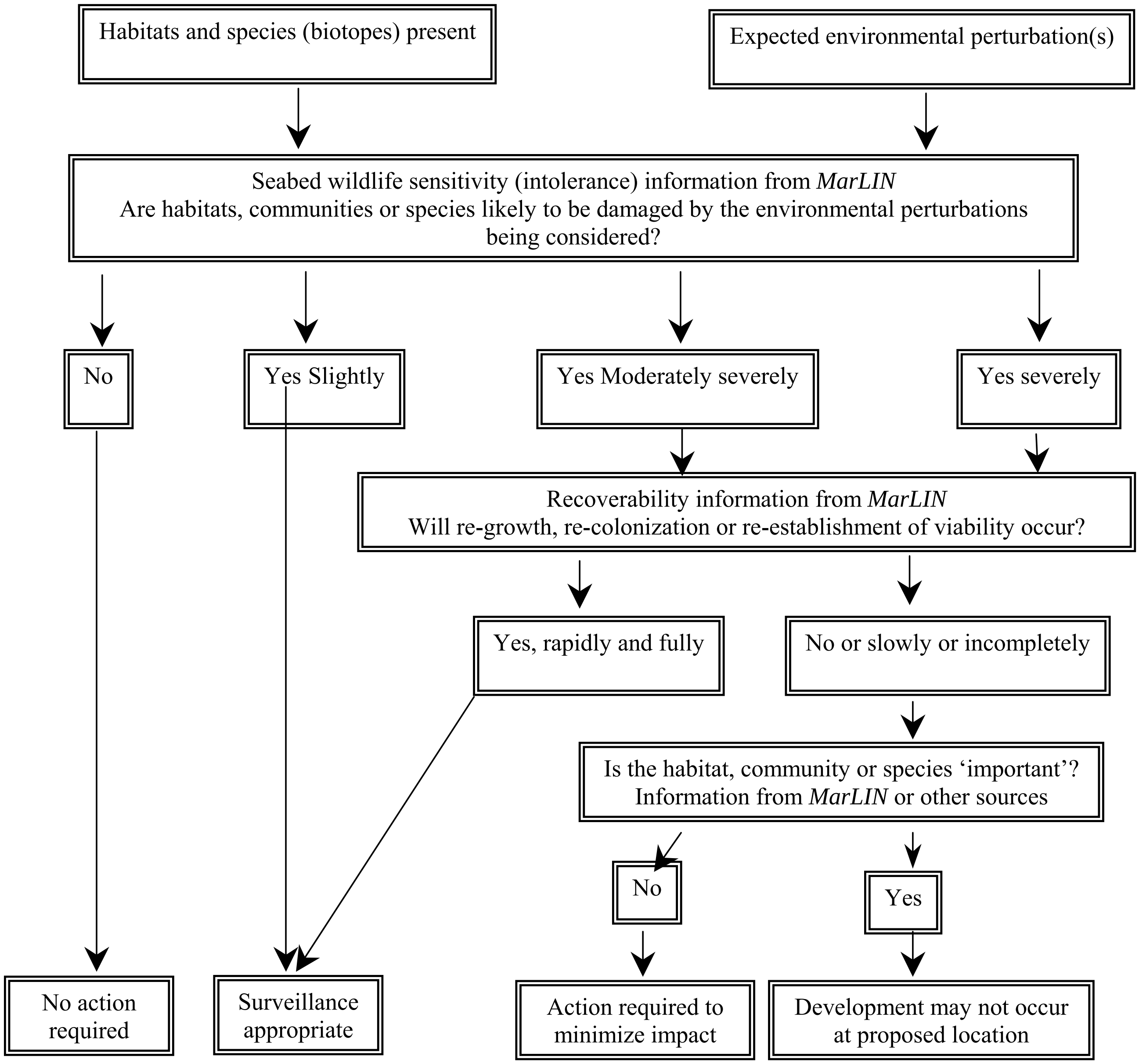

Figure 9. A 'decision tree' for environmental management incorporating concepts of sensitivity and importance (based on Hiscock, 1999).

Figure 9 draws on the information resources described earlier in this report to produce a decision tool for a wide range of uses of the marine environment. Box 8 suggests what effects from any development or activity might be considered adverse or damaging.

7. Making local environmental gains from offshore wind farm development

Judging whether an effect of wind farms is 'favourable' to marine life will inevitably depend on the viewpoint of the person making the judgement. Wind farms are not favourable to the maintenance of 'naturalness' (see Section 5, Nature conservation) and may disturb or displace some species. However, wind farms may also increase biodiversity in an area, possibly support some species that are a new source of food for some predators, provide refugia from mobile fishing gear and may enhance populations of some fish and shellfish by providing shelter. Table 3 summarizes what might be considered environmental gains from wind from developments.

Box 8. From the point-of view of protection of marine natural heritage importance and marine wildlife resources, it will 'matter' if offshore wind farm developments cause:

- rare or scarce species or habitats to be lost from an area;
- protected or rare or scarce migratory species to be adversely affected;
- charismatic or 'public-interest' species to be lost or damaged;
- keystone species to be lost from an area;
- spawning areas to be lost;
- aggressive non-native species to be introduced or encouraged;

Apart from the global intention of contributing to use of renewable resources and reducing polluting substances, wind farms have the potential to make local environmental gains. Those gains can be achieved with minimal effort although many will require agreement or at least acquiescence from some existing users.

Table 3. Exploring the potential for local environmental gains from wind farm developments.

Perceived 'gain'	Arguments for	Arguments against	Notes
Increased biodiversity (introduction of hard substratum)	Species richness in the area will increase as a result of substrata being available for sessile epibenthic species.	So what? Will there be any 'benefit' from that extra biodiversity – no. 'Naturalness' is an important consideration in nature conservation and wind farm constructions are not 'natural'. Artificial hard substrata may be 'stepping stones' for non-native species	No decline in species richness would be expected as a result of the establishment of wind farms. Increase in biodiversity of hard substratum species would increase species richness in an area.
Prevention of damage to the seabed from mobile fishing gear.	The use of mobile fishing gear that disturbs the seabed results in changed communities that are 'unnatural'. Where fishing does not occur, natural communities might develop so that the degree of change brought about by fishing can be assessed (i.e. research potential).	In existing fished areas, effective banning of fishing may mean significant income loss.	
Possibility of 'refugia' for fish resulting in stock conservation.	Fisheries pressure is intense and areas where at least mobile fishing gear might be prohibited may help in stock recovery and even local enhancement.	In existing fished areas, effective banning of fishing may mean significant income loss.	
New habitats for sea duck food established.	Sea duck will feed on the mussels that will settle on structures.	Mussels will fall off structures and significantly modify seabed biotopes.	

New habitats for fish species.	Fish species that are attracted to structures such as pollack and saithe (shallow kelp), wreck fish, conger, ling and wrasse (deeper pilings and rock shields) may be fished by angling or possibly set nets. Commercial fish species that find refuge immediately adjacent to structures but then venture away may enhance fishable stocks nearby.	The fish are not really 'available' and angling and set netting might be prohibited within wind farms anyway.	A considerable amount of work has been carried out on types of structures and their likely colonization (see Seaman & Sprague, 1991) and Jensen (1997).
New habitats for commercial shellfish species established.	Fisheries are enhanced. A new source of income for the area will be established.	In the case of mussels growing on structures, increased drag may create an engineering problem. Scour prevention by boulders or other hard substrata will obstruct and damage mobile fishing gear.	Careful planning is needed if the habitats created, especially by anti-scour structures, are to support shellfish (lobster and crab) stocks. Work to identify optimum reef design is underway at Southampton University (see Jensen & Collins, 1997)

8. Acknowledgements

We have consulted with a range of individuals during the course of our study. We are particularly grateful to Ivor Rees for advice on Liverpool Bay and offshore Morecambe Bay and more generally on likely impacts of wind farm developments, to Antony Jensen (Southampton University) and David Sell and Gordon Picken (Cordah) for information on colonization on artificial structures and to Stuart Rogers (Centre for Ecology, Fisheries and Aquaculture Science) for advice on fisheries sensitive areas. Ivor Rees (consultant, ex. University of Wales at Bangor) and Jim Allen (Institute of Estuarine & Coastal Studies, University of Hull) contributed as sub-contractors to the identification of biotopes likely to occur in the region of wind farm development. We have also maintained contact with and benefited from discussions with BMT-Cordah who have undertaken the Strategic Environmental Assessment Policy and Implementation Project.

9. Plates

High Level Environmental Screening Study for Offshore Wind Farm Developments – Marine Habitats and Species.

Plates 1 to 8 Photographs of typical and probable seabed types in the areas of proposed wind farm developments.

Plate 1. Compact rippled muddy sand. Surface detritus of tubes and hydroid material. Brittle star *Ophuira ophiura* present. Depth 18m. Image width c. 50 cm.

Plate 2. Bioturbated muddy, gravely sand with broken shell. A seastar *Asterias rubens* and queen scallop *Aequipecten opercularis* are present. Liverpool Bay. Depth 20m. Image width c. 50 cm.

Plate 3. Brittle star, *Amphiura filiformis,* arms visible in circalittoral muddy sand. Representative of biotope CMS. AfilEcor. Image width c. 15 cm.

Plate 4. Sandy mud/muddy sand showing signs of bioturbation.. Epifauna include the sea pen *Virgularia mirabilis* and brittle star *Ophiura* sp. Arm tips present indicate a large *Amphiura* spp. brittle star population. Image width c. 50 cm.

Plate 5. Muddy gravelly sand with shell fragments and large cobbles. The latter provide habitat for hydroids and the anemone *Metridium senile.* Liverpool Bay. Depth 20m. Image width c. 50 cm.

Plate 6. A horse mussel (*Modiolus modiolus*) bed with associated epifauna. Deposits of grey fine sediment, representing accumulated faecal material, on the shells. A representative image of biotope MCR. ModT. Image width c. 50 cm.

Plate 7. Current swept seabed comprising embedded cobbles, lag gravel, and some interstitial coarse sand and a little shell material. Cobbles covered in a hydroid mat with a large dahlia anemone present. The ground is populated by something similar to the 'Deep *Venus*' community. Image width c. 50 cm.

Plate 8. *Glycymeris* shell accumulation. Epifauna comprise the fan worm *Sabella pavonina* and hydroid sea firs. A similar habitat may develop in scour areas at the base of wind turbine structures. Image width c. 50 cm.

Plates 9-18 Photographs of likely and probable communities and species associated with offshore wind farm developments.

Plate 9. Intertidal communities dominated by barnacles with green foliose algae. Similar to the community likely to develop on offshore wind farm structures. Jetty pile diameter approx 1.5m.

Plate 10. Shallow kelp dominated communities similar to those likely to be found on offshore wind farm structures. Jetty pile diameter approx 1.5m.

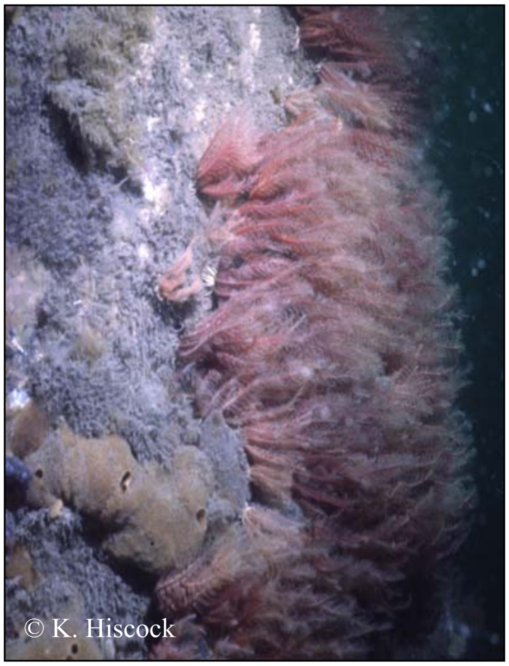

Plate 11. Feather stars, cushion sponges and branching bryozoans on a mature jetty pile. Similar communities are likely to develop at moderate depths on offshore wind farm towers. Image width ca 50cm.

Plate 12. Plumose anemones likely to dominate wind farm structures where strong water movement occurs. Image width ca 40cm.

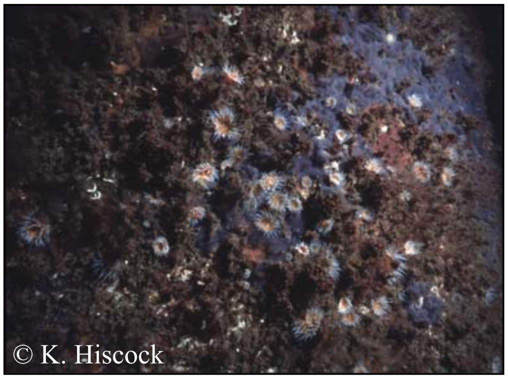

Plate 13. Sea anemones, encrusting sea squirts, sponges, and encrusting and filamentous algae likely to characterise the middle depths of offshore structures. Image width ca 40cm.

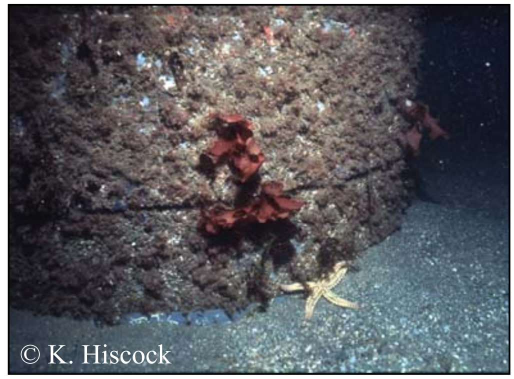

Plate 14. Inshore jetty pile community on an occasionally wave exposed coast showing low encrusting fauna and areas occasionally covered by sand, with keeled tubeworms characteristic of scoured areas. Image width ca 90cm.

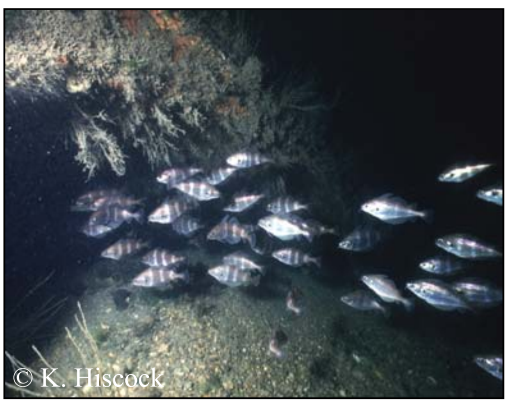

Plate 15. Pouting are commonly associated with artificial reef structures, such as wrecks, jetties, and are likely to become resident at the offshore wind farms structures. Image width ca 2m.

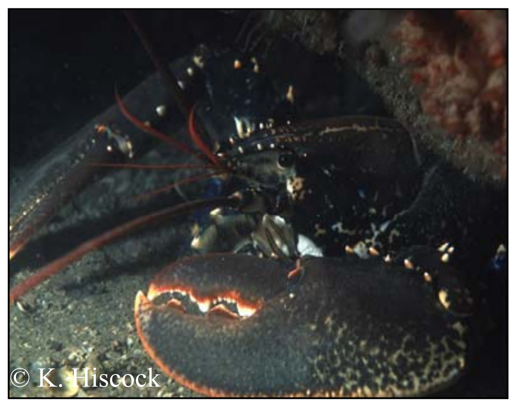

Plate 16. Scour protection measures of appropriate size and construction may provide significant habitat for shellfish such as lobsters. Image width ca 15cm.

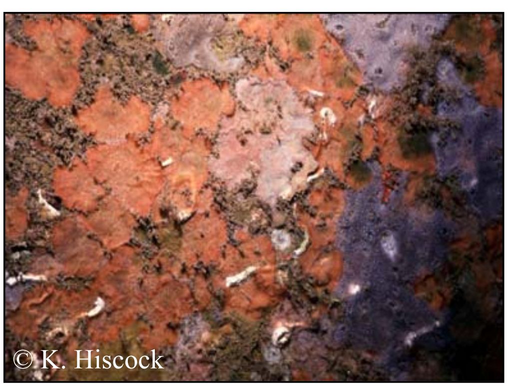

Plate 17. Community dominated by encrusting sea mats (bryozoans) between heavily scoured and non-scoured areas on offshore structures. Image width ca 20cm.

Plate 18. Mussels colonising structures may drop to the seabed where they modify the substratum and are scavenged. Image width ca 40 cm.

REFERENCES (REPORT AND APPENDICES) AND BIBLIOGRAPHY

Aberkali, H.B. & Trueman, E.R., 1985. Effects of environmental stress on marine bivalve molluscs. *Advances in Marine Biology*, **22**, 101-198.

Aronson, R.B., 1990. Onshore-offshore patterns of human fishing activity. *Palaios*, **5**, 88-93.

Attrill, M.J., Ramsay, P.M., Thomas, R.M. & Trett, M.W., 1996. An estuarine biodiversity hot-spot. *Journal of the Marine Biological Association of the United Kingdom.* **76,** 161-175.

Axiak, V., George, J.J. & Moore, M.N., 1988. Petroleum hydrocarbons in the marine bivalve *Venus verrucosa*: accumulation and cellular responses. *Marine Biology*, **97**, 225-230.

Bamber, R.N., 1984. The benthos of a marine fly-ash dumping ground. *Journal of the Marine Biological Association of the United Kingdom.* **64,** 211-226.

Beaumont, A.R., Newman, P.B., Mills, D.K., Waldock, M.J., Miller, D. & Waite, M.E., 1989. Sandy-substrate microcosm studies on tributyl tin (TBT) toxicity to marine organisms. *Scientia Marina*, **53**, 737-743.

Bergman, M.J.N. & Hup, M., 1992. Direct effects of beam trawling on macro-fauna in a sandy sediment in the southern North Sea. *ICES Journal of Marine Science*, **49**, 5-11.

Besten, P.J. den, Donselaar, E.G. van, Herwig, H.J., Zandee, D.I. & Voogt, P.A., 1991. Effects of cadmium on gametogenesis in the seastar *Asterias rubens* L. *Aquatic Toxicology*, **20**, 83-94

Besten, P.J. den, Herwig, H.J., Zandee, D.I. & Voogt, P.A., 1989. Effects of Cd and PCBs on reproduction in the starfish *Asterias rubens*: abberations in early development. *Ecotoxicology and Environmental Safety*, **18**, 173-180.

Boero, F., 1984. The ecology of marine hydroids and effects of environmental factors: a review. *Marine Ecology*, **5**, 93-118.

Boisson, F., Hartl, M.G.J., Fowler, S.W. & Amiard-triquet, C., 1998. Influence of chronic exposure to silver and mercury in the field on the bioaccumulation potential of the bivalve *Macoma balthica*. *Marine Environmental Research*, **45**, 325-340.

Booman, C., Dalen, J., Leivestad, H., Levsen, A., van de Meeren, T. & Toklum, K., 1996. The eefects of airguns on eggs larvae and fry. *Fiskens og Havet*, **3**, 83.

Boon, J.P., Zantvoort, M.B., Govaert, M.J.M.A. & Duinker, J.C ., 1985. Organochlorines in benthic polychaetes (*Nephtys* spp.) and sediments from the southern North Sea. Identification of individual PCB components. *Netherlands Journal of Sea Research*, **19**, 93-109.

Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2000. The effects of scallop dredging on gravelly seabed communities. In *Effects of fishing on non-target species and habitiats* (ed. M.J.Kaiser & S.J. deGroot), pp.83-104. Oxford: Blackwell Science.

Bryan, G.W., 1984. Pollution due to heavy metals and their compounds. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters,* vol. 5. *Ocean Management*, part 3, (ed. O. Kinne), pp.1289-1431. New York: John Wiley & Sons.

Bryan, G.W. & Gibbs, P.E., 1991. Impact of low concentrations of tributyltin (TBT) on marine organisms: a review. In: *Metal ecotoxicology: concepts and applications*, (ed. M.C. Newman & A.W. McIntosh), pp. 323-361. Boston: Lewis Publishers Inc.

Bryan, G.W. & Hummerstone, L.G., 1971. Adaptation of the polychaete *Nereis diversicolor* to estuarine sediments containing high concentrations of heavy metals. I. General observations and adaption to copper. *Journal of the Marine Biological Association of the United Kingdom*, **51**, 845-863.

Bryan, G.W. & Langston, W.J., 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to UK estuaries: a review. *Environmental Pollution*, **76**, 89-131.

Buchanan, J.B., 1964. A comparative study of some of the features of the biology of *Amphiura filiformis* and *Amphiura chiajei* (Ophiuroidea) considered in relation to their distribution. *Journal of the Marine Biological Association of the United Kingdom*, **44**, 565-576.

Buchanan, J.B., 1966. The biology of *Echinocardium cordatum* (Echinodermata: Spatangoidea) from different habitats. *Journal of Marine Biological Association of the United Kingdom*, **46**, 97-114.

Buchanan, J.B., 1967. Dispersion and demography of some infaunal echinoderm populations. *Symposia of the Zoological Society of London*, **20**, 1-11.

Buchanan, J.B. & Moore, J.J., 1986. Long-term studies at a benthic station off the coast of Northumberland. In: *Long-term changes in coastal benthic communities. COST 647 project on coastal benthic ecology*, (eds. Heip, B.F., Keegan, B.F. & Lewis, J.R.), pp 121-127: *Hydrobiologia*, **142**.

Buchanan, J.B., Sheader, M. & Kingston, P.F., 1978. Sources of variability in the benthic macrofauna off the south Northumberland coast, 1971-1976. *Journal of the Marine Biological Association of the United Kingdom,* **58**, 191-209.

Bullimore, B., 1985. An investigation into the effects of scallop dredging within the Skomer Marine Reserve. *Report to the Nature Conservancy Council by the Skomer Marine Reserve Subtidal Monitoring Project, S.M.R.S.M.P. Report,* no 3.

BWEA (British Wind Energy Association), 2002. [On-line] *Guided tour on wind energy.* Copenhagen: Danish Wind Energy Association. [Cited on 02/08/02] Available from <http://www.windpower.org>.

Cabioch, L., Dauvin, J.C. & Gentil, F., 1978. Preliminary observations on pollution of the sea bed and disturbance of sub-littoral communities in northern Brittany by oil from the *Amoco Cadiz*. *Marine Pollution Bulletin*, **9**, 303-307.

Carter, I.C., Williams, J.M., Webb, A. & Tasker, M.L., 1993. Seabird concentrations in the North Sea. An atlas of vulnerability to surface pollutants. *Joint Nature Conservation Committee, Offshore Animals Branch* pp.39. Aberdeen: Joint Nature Conservation Committee.

Clark, R.B., 1997. *Marine Pollution*, 4th ed. Oxford: Carendon Press.

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites.
Natura 2000 report prepared for the UK Marine SACs Project. 441 pp.

Collier, L.M. & Pinn, E.H., 1998. An assessment of the acute impact of the sea lice treatment Ivermectin on a benthic community. *Journal of Experimental Marine Biology and Ecology*, **230**, 131-147.

Comely, C.A., 1978. *Modiolus modiolus* (L.) from the Scottish West coast. I. Biology. *Ophelia*, **17**, 167-193.

Comely, C.A. & Ansell, A.D., 1988. Invertebrate associates of the sea urchin *Echinus esculentus* L. from the Scottish west coast. *Ophelia*, **28**, 111-137.

Conan, G., 1982. The long-term effects of the *Amoco Cadiz* oil spill. *Philosophical Transactions of the Royal Society of London B*, **297**, 323-333.

Connor, D.W., Brazier, D.P., Hill, T.O. & Northen, K.O., 1997a. Marine Nature Conservation Review. Marine biotope classification for Britain and Ireland. Volume 1. Littoral Biotopes. Peterborough: Joint Nature Conservation Committee.

Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. & Sanderson, W.G., 1997b. Marine Nature Conservation Review. Marine biotope classification for Britain and Ireland. Volume 2. Sublittoral Biotopes. Peterborough: Joint Nature Conservation Committee.

Cooke, A., & McMath, M., 2000. SENSMAP: Development of a protocol for assessing and ampping the sensitivity of marine species and benthos to maritime activities. *Countryside Council for Wales, Bangor, CCW Marine Report:* 98/6/1, (2000, Working draft).

Cotter, A.J.R., Walker, P., Coates, P., Cook, W. & Dare, P.J., 1997. Trial of a tractor dredger for cockles in Burry Inlet, South Wales. *ICES Journal of Marine Science*, **54**, 72-83.

Coull, K.A., Johnstone, R., & S.I. Rogers., 1998. *Fisheries Sensitivity Maps in British Waters.* [On-line] United Kingdom Offshore Operators Association (UKOOA) Ltd. [Cited 21/08/02]. Available from <http://www.ukooa.co.uk/issues/>.

Covey, R., 1992. Sublittoral survey of the north coast of the outer Solway (Mull of Galloway to Auchencairn). Nature Conservancy Council, CSD Report, No. 1193. (Marine Nature Conservation Review Report, No. MNCR/SR/15.).

Crisp, D.J., (ed.) 1964. The effects of the severe winter of 1962-63 on marine life in Britain. *Journal of Animal Ecology*, **33**, 165-210.

Crompton, T.R., 1997. *Toxicants in the aqueous ecosystem.* New York: John Wiley & Sons.

Daan, R. & Mulder, M., 1996. On the short-term and long-term impact of drilling activities in the Dutch sector of the North Sea *ICES Journal of Marine Science*, **53**, 1036-1044.

Dahllöf, I., Blanck, H., Hall, P.O.J. & Molander, S., 1999. Long term effects of tri-n-butyl-tin on the function of a marine sediment system. *Marine Ecology Progress Series*, **188**, 1-11.

Dauvin, J.C., 1982. Impact of *Amoco Cadiz* oil spill on the muddy fine sand *Abra alba - Melinna palmata* community from the Bay of Morlaix. *Estuarine and Coastal Shelf Science*, **14**, 517-531.

Dauvin, J.C., 2000. The muddy fine sand *Abra alba - Melinna palmata* community of the Bay of Morlaix twenty years after the *Amoco Cadiz* oil spill. *Marine Pollution Bulletin*, **40**, 528-536.

Dauwe, B., Herman, P.M.J. & Heip, C.H.R., 1998. Community structure and bioturbation potential of macrofauna at four North Sea stations with contrasting food supply. *Marine Ecology Progress Series*, **173**, 67-83.

Davoult, D., Gounin, F. & Richard, A., 1990. Dynamique et reproduction de la population d'*Ophiothrix fragilis* (Abildgaard) du détroit du Pas de Calais (Manche orientale). *Journal of Experimental Marine Biology and Ecology*, **138**, 201-216.

De Groot, S.J. & Apeldoorn, J., 1971. Some experiments on the influence of the beam trawl on the bottom fauna. *International Council for the Exploration of the Sea (CM Papers and Reports)* CM 1971/B: pp 2-5.

Diaz, R.J. & Rosenberg, R., 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: an Annual Review*, **33**, 245-303.

Diaz-Castaneda, V., Richard, A. & Frontier, S., 1989. Preliminary results on colonization, recovery and succession in a polluted areas of the southern North Sea (Dunkerque's Harbour, France). *Scientia Marina*, **53**, 705-716.

Dinnel, P.A., Pagano, G.G., & Oshido, P.S., 1988. A sea urchin test system for marine environmental monitoring. In *Echinoderm Biology. Proceedings of the Sixth International Echinoderm Conference, Victoria, 23-28 August 1987*, (ed. R.D. Burke, P.V. Mladenov, P. Lambert, Parsley, R.L.), pp 611-619. Rotterdam: A.A.Balkema.

Dipper, F.A., Irving, R.A. & Fowler, S.L., 1989. Sublittoral survey of the Wash by diving and dredging. (1985 and 1986). Nature Coservancy Council.

Dirksen, S., Spanns, A.L., van der Winden, J., 1998. Studies on nocturnal flight paths and alttitudes of waterbirds in relation to wind turbines: A review of current research in The Netherlands. In *Proceedings of National Avian – Wind Power Planning Meeting,Denver, CO, July 1994,* National Wind Coordination Committee.

Dow, R.C., 1978. Size-selective mortalities of clams in an oil spill site. *Marine Pollution Bulletin*, **9**, 45-48.

Dow, R.L. & Wallace, D.E., 1961. The soft-shell clam industry of Maine. *U.S. Fish and Wildlife Service, Department of the Interior, Circular* no. 110.

DWIA (Danish Wind Industry Association), 2002. [On-line] *Guided tour on wind energy.* Copenhagen: Danish Wind Energy Association. [Cited on 02/08/02] Available from <http://www.windpower.org>.

Dyer, M.F., Pope, J.G., Fry, P.D., Law, P.J., & Portmann, J.E., 1983. Changes in fish and benthos catches off the Danish coast in September 1981. *Journal of the Marine Biological Association of the United Kingdom,* **63,** 767-775.

Dyfed Wildlife Trust, 1995. *Grey seals and you – the grey seal code of conduct.* Dyfed:Dyfed Wildlife Trust.

Eagle, R.A., 1973. Benthic studies in the south east of Liverpool Bay. *Estuarine and Coastal Marine Science*, **1**, 285-299.

Eagle, R.A., 1975. Natural fluctuations in a soft bottom benthic community. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 865-878.

Eggleston, D., 1972b. Factors influencing the distribution of sub-littoral ectoprocts off the south of the Isle of Man (Irish Sea). *Journal of Natural History*, **6**, 247-260.

Eisler, R., 1977. Toxicity evaluation of a complex meta mixture to the softshell clam *Mya arenaria*. *Marine Biology*, **43**, 265-276.

Eleftheriou, A. & Robertson, M.R., 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. *Netherlands Journal of Sea Research*, **30**, 289-299.

Elliott, M., 1994. The analysis of macrobenthic community data. *Marine Pollution Bulletin*, **28**, 62-64.

Elliott, M., 2002. The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. *Marine Pollution Bulletin*, **44**.

Elliot, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. & Hemingway, K.L., 1998. Intertidal sand and mudflats & subtidal mobile sandbanks (Vol. II). An overview of dynamic and sensitivity for conservation management of marine SACs. *Prepared by the Scottish Association for Marine Science for the UK Marine SACs Project*.

Emerson, C.M., Grant, J. & Rowell, T.W., 1990. Indirect effects of clam digging on the viability of soft-shell clams, *Mya arenaria* L. *Netherlands Journal of Sea Research*, **27**, 109-118.

English Nature, 2001. Wind farm development and nature conservation. *Publication by English Nature, Royal Society for the Protection of Birds, World Wildlife Fund UK & British Wind Energy Association.* Godalming:WWF-UK

Erbe, C., & Farmer, D.M., 2000. A software model to estimate zones of impact on marine mammals around anthropogenic noise. *Journal of the Acoustical Society of America*, **108,** 1327-1331.

Evans, P.G.H., 1991. The Cetaceans. In *Handbook of British Mammals.* (eds. G. Corbet, & S.Harris), Oxford:Blackwell Publications.

Evans, P.G.H., 1994. *Dolphins*. London: Whittet Books.

Evans, P.G.H., Canwell, P.J. & Lewis, E.J., 1992. An experimental study of the effects of pleasure craft noise upon bottle-nosed dolphins in Cardigan Bay, West Wales. In. *European Research on Cetaceans* **6**, (ed. P.G.H.Evans), Cambridge:European Cetacean Society.

Evans, P.L., Kaiser, M.J. & Hughes, R.N., 1996. Behaviour and energetics of whelks, *Buccinum undatum* (L.), feeding on animals killed by beam trawling. *Journal of Experimental Marine Biology and Ecology*, **197**, 51-62.

Evans, S.M., Arnott, S. & Wahju, R.I., 1994. Evidence of change in the macrofauna of tidal flats subject to anthropomorphic impacts in north-east England. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **4,** 333-344.

Feldman, K.L., Armstrong, D.A., Dumbauld, B.R., DeWitt, T.H. & Doty, D.C., 2000. Oysters, crabs, and burrowing shrimp: review of an environmental conflict over aquatic resources and pesticide use in Washington State's (USA) coastal estuaries. *Estuaries*, **23**, 141-176.

Ferns, P.N., Rostron, D.M. & Siman, H.Y., 2000. Effects of mechanical cockle harvesting on intertidal communities. *Journal of Applied Ecology*, **37**, 464-474.

Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore.* Cambridge: Cambridge University Press.

Forteath, G.N.R., Picken, G.B., Ralph, R. & Williams, J., 1982. Marine Growth Studies on the North Sea Oil Platform Montrose Alpha. *Marine Ecology Progress Series*, **8**, 61-68.

Gales, R.S., 1982. Effects of noise of offshore oil and gas operations on marine mammals-An introductory assessment, vol. 2, San Diego, California: U.S. Naval Ocean Systems Centre, pp. 79-300. NOSC TR 844.

Gentry, R.L., Gentry, E.C., Gilman, J.F., 1990 Response of Northern fur seals to quarrying operations. *Marine Mammal Science*,**6**, 151-155.

George, J.D., Chimonides, P.J., Evans, N.J. & Muir, A.I., 1995. *Fluctuations in the macrobenthos of a shallow-water cobble habitat off north Norfolk, England*. Fredensborg (Denmark): Olsen & Olsen.

Gili, J-M., & Hughes, R.G., 1995. The ecology of marine benthic hydroids. *Oceanography and Marine Biology: An Annual Review*, **33**, 351-426.

Gill, A.B. & Taylor, H., 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. *Report to the Countryside Council for Wales. CCW Contract Report* no. 488.

Gilmour, T.H.J., 1967. The defensive adaptations of *Lima hians* (Mollusca, Bivalvia). *Journal of the Marine Biological Association of the United Kingdom*, **47**, 209-221.

Gommez, J.L.C. & Miguez-Rodriguez, L.J., 1999. Effects of oil pollution on skeleton and tissues of *Echinus esculentus* L. 1758 (Echinodermata, Echinoidea) in a population of A Coruna Bay, Galicia, Spain. In *Echinoderm Research 1998. Proceedings of the Fifth European Conference on Echinoderms, Milan, 7-12 September 1998*, (ed. M.D.C. Carnevali & F. Bonasoro) pp. 439-447. Rotterdam: A.A. Balkema.

Gordon, J., & Moscrop, M., 1996. Underwater noise pollution and its significance for whales and dolphins. In *The Conservation of Whales and Dolphins: Science and Practice,* (eds. M.P. Simmonds, & J.D. Hutchinson), pp 281-320. Chicester:John Wiley & Sons Ltd.

Goss-Custard, J.D. & Verboven, N., 1993. Disturbance and feeding shorebirds on the Exe estuary. *Wader Study Group Bulletin*, **68** (special issue).

Grant, J. & Thorpe, B., 1991. Effects of suspended sediment on growth, respiration, and excretion of the soft shelled clam (*Mya arenaria*). Canadian Journal of Fisheries and Aquatic Science, 48, 1285-1292.

Grellier, K., Arnold, H., Wilson, B. & Curran, S., 1995. Management recommendations for the Cardigan Bay Bottlenosed Dolphin population. *Countryside Council for Wales, Bangor*, CCW Contract Science Report no. 134.

Gubbay, S., & Knapman, P.A., 1999. A review of the effects of fishing within UK European marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 134 pp. English Nature. (UK Marine SACs Project, vol .12).

Guillemette, M., 1998. The effect of time and digestion constraints in Common Eiders while feeding and diving over Blue Mussel beds. *Functional Ecology,* **12**, 123-131.

Guillemette, M., Larsen, J.K., Clausager, I., 1999. Assessing the impact of the Tunø Knob wind park on sea ducks: the influence of food resources. *National Environmental Research Institute,Denmark.* pp 21, NERI Technical Report no. 263.

Guillou, J., 1985. Population dynamics of *Echinocardium cordatum* (Pennant) in the bay of Douarnenez (Brittany). In *Proceedings of the Fifth International Echinocardium Conference / Galway / 24-29 September 1984* (ed. B.F. Keegan & B.D.S. O'Conner), 275-280. Rotterdam: Balkema.

Halcrow Maritime, 2001. Design criteria for enhancing marine habitats within coastal structures: A feasibility study. Department for Environment, Food and Rural Affairs. [Cited 02/08/02]. Available from <http://www.defra.gov.uk/research/Publications>.

Hall, J.A. & Frid, C.L.J., 1995. Response of estuarine benthic macrofauna in copper-contaminated sediments to remediation of sediment quality. *Marine Pollution Bulletin*, **30**, 694-700.

Hall, S.J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology: An Annual Review*, **32**, 179-239.

Hall-Spencer, J.M., & Moore, P.G., 2000. *Limaria hians* (Mollusca: Limacea): A neglected reef-forming keystone species. *Aquatic Conservation*, **10**, 267-278.

Hartley, J.P., & Bishop, J.D.D., 1986. The Macrobenthos of the Beatrice Oilfield, Moray Firth, Scotland. In: *The Marine Environment of the Moray Firth*, (ed. Ralph, R.), pp 221-245. Edinburgh: Proceedings of the Royal Society of Edinburgh, Series B: Biological Sciences.

Hartnoll, R.G., 1983. Substratum. In *Sublittoral ecology. The ecology of the shallow sublittoral benthos* (ed. R. Earll & D.G. Erwin), pp. 97-124. Oxford: Clarendon Press.

Hartnoll, R.G., 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Scottish Association of Marine Sciences, Oban, Scotland.* [UK Marine SAC Project. Natura 2000 reports.]

Hartnoll, R.G., 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Scottish Association of Marine Sciences, Oban, Scotland.* [UK Marine SAC Project. Natura 2000 reports.]

Harvey, M. & Bourget, E., 1995. Experimental evidence of passive accumulation of marine bivalve larvae on filamentous epibenthic structures. *Limnology and Oceanography*, **40**, 94-104.

Hayward, P.J. & Ryland, J.S. (ed.), 1995. *Handbook of the marine fauna of North-West Europe.* Oxford: Oxford University Press.

Herrando-Perez, S. & Frid, C.L.J., 1998. The cessation of long-term fly-ash dumping: Effects on macrobenthos and sediments. *Marine Pollution Bulletin,* **36**, 780-790.

Hill, A.S., Brand, A.R., Veale, L.O. & Hawkins, S.J., 1997. *Assessment of the effects of scallop dredging on benthic communities. Final Report to MAFF*, Contract CSA 2332

Hiscock, K. & Connor, D., 1996. The rationale and setting for the Review. In: *Marine Nature Conservation Review: Rationale & Methods,* (ed. by K. Hiscock.), pp. 17-21. Peterborough; Joint Nature Conservation Committee.

Hiscock, K., 1983. Water movement. In *Sublittoral ecology. The ecology of shallow sublittoral benthos* (ed. R.Earll & D.G. Erwin), pp. 58-96. Oxford: Clarendon Press.

Hiscock, K., 1985. Littoral and sublittoral monitoring in the Isles of Scilly. September 22nd to 29th, 1984. *Nature Conservancy Council, Peterborough*, CSD Report, no. 562.

Hiscock, K., 1999. Identifying marine 'sensitive areas' - the importance of understanding life-cycles. In: *Aquatic Life Cycle strategies - Survival in a variable environment*, (eds. Whitfield, M., Matthews, J. & Reynolds, C.), pp 139-149. Plymouth: Marine Biological Association of the United Kingdom.

Hiscock, K., Connor, D.W. & Hill, T.O., 1998. Recovery of seabed wildlife from natural change and human activity - assessing 'sensitivity' and 'importance'. *Recovery and Protection of Marine Habitats and Ecosystems from Natural and Anthropogenic Impacts.*Plymouth: Marine Biological Association of the United Kingdom.

Hiscock, K., Rostron, D.M. & Little, A.E., 1980-1983. Effects of Refinery Effluents on the Sublittoral Fauna and Flora of Jetty Piles at the Amoco Refinery, Milford Haven. Field Studies Council Oil Pollution Research Unit, Pembroke. Amoco (U.K) Ltd, London and Welsh Water Authority, Cardiff.

Hoare, R. & Hiscock, K., 1974. An ecological survey of the rocky coast adjacent to the effluent of a bromine extraction plant. *Estuarine and Coastal Marine Science*, **2**, 329-348.

Hoare, R. & Wilson, E.H., 1977. Observations on the behaviour and distribution of *Virgularia mirabilis* O.F. Muller (Coelenterata: Pennatulacea) in Holyhead harbour. In *Proceedings of the Eleventh European Symposium on Marine Biology, University College, Galway, 5-11 October 1976. Biology of Benthic Organisms*, (ed. B.F. Keegan, P.O. Ceidigh & P.J.S. Boaden, pp. 329-337. Oxford: Pergamon Press.

Holme, N.A. & Wilson, J.B., 1985. Faunas associated with longitudinal furrows and sand ribbons in a tide-swept area in the English Channel. *Journal of the Marine Biological Association of the United Kingdom*, **65**, 1051-1072.

Holt, T.J., Hartnoll, R.G. & Hawkins, S.J., 1997. The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, *Zostera* beds and *Sabellaria spinulosa* reefs. *English Nature, Peterborough, English Nature Research Report* No. 234.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G., 1995. The sensitivity of marine communities to man induced change - a scoping report. *Countryside Council for Wales, Bangor, Contract Science Report*, no. 65.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G., 1995. The sensitivity of marine communities to man induced change - a scoping report. *Countryside Council for Wales, Bangor, Contract Science Report*, no. 65.

Holt, T.J., Rees, E.I., Hawkins, S.J. & Seed, R., 1998. Biogenic reefs (Volume IX). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. *Scottish Association for Marine Science (UK Marine SACs Project)*, pp. 174.

Hong, J. & Reish, D.J., 1987. Acute toxicity of cadmium to eight species of marine amphipod and isopod crustaceans from southern California. *Bulletin of Environmental Contamination and Toxicology*, **39**, 884-888.

Houghton, J.P., Lees, D.C., Driskell, W.B., Lindstrom & Mearns, A.J., 1996. Recovery of Prince William Sound Intertidal Epibiota from *Exxon Valdez* Oiling and Shoreline Treatments, 1989 through 1992. In *Proceedings of the* Exxon Valdez *Oil Spill Symposium. American Fisheries Society Symposium,* no. 18*, Anchorage, Alaska, USA, 2-5 February 1993,* (ed. S.D. Rice, R.B. Spies, D.A., Wolfe & B.A. Wright), pp.379-411.

Howson, C.M., Connor, D.W. & Holt, R.H.F., 1994. The Scottish sealochs - an account of surveys undertaken for the Marine Nature Conservation Review.

Hughes, D.J., 1998. Sea pens and burrowing megafauna An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Natura 2000 report prepared for Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project.*

Hunt, J.D., 1925. The food of the bottom fauna of the Plymouth fishing grounds. *Journal of the Marine Biological Association of the United Kingdom*, **13**, 560-599.

IUCN., 1994. IUCN Red List Categories. Gland, Switzerland: IUCN (International Union for the Conservation of Nature and Natural Resources.).

Jennings, S. & Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology*, **34**, 201-352.

Jensen, A., & Collins, K., 1997. The use of artificial reefs in crustacean fisheries enhancement. *Proceedings of the 1st EARRN conference.* pp 115-123. Southampton: Southampton Oceanography Centre.

Jensen, A.C.(ed.), 1997. European Artificial Reef Research. *Proceedings of the 1st EARRN conference. March 1996,* Southampton: Southampton Oceanography Centre.

JNCC (Joint Nature Conservation Committee), 1996. Guidelines for selection of biological SSSIs: Intertidal habitats and saline lagoons. Peterborough: Joint Nature Conservation Committee.

JNCC (Joint Nature Conservation Committee), 1996. *Guidelines for selection of biological SSSIs: intertidal habitats and saline lagoons*. Peterborough: Joint Nature Conservation Committee.

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database: Marine Nature Conservation Review Survey Database*. Peterborough: Joint Nature Conservation Committee. [Cited Tuesday, February 08, 2000]. Available from: <http://www.jncc.gov.uk/mermaid/default.htm>

Johnston, R., 1984. Oil Pollution and its management. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters* vol. 5. *Ocean Management*, part 3 (ed. O. Kinne), pp.1433-1582. New York: John Wiley & Sons Ltd.

Joint Nature Conservation Committee., 1996. *Guidelines for selection of biological SSSIs: intertidal habitats and saline lagoons*. Peterborough.

Jones, L.A., Hiscock, K., & Connor, D.W., 2000. Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. *Joint Nature Conservation Committee, Peterborough. (UK Marine SACs Project report.).*

Julshamn, K. & Andersen, K-J., 1983. Subcellular distribution of major and minor elements in unexposed molluscs in western Norway-III.The distribution and binding of…...(abridged).......in the kidney and the digestive system of the horse mussel *Modiolus modiolus*. *Comparative Biochemistry and Physiology*, **75A**, 17-20.

Kaiser, M.J. & de Groot, S.J., (eds.), 2000. *The effects of trawling on non-target species and habitats: biological, conservation and socio-economic issues*. Oxford:Blackwell Science.

Kaiser, M.J. & Spencer, B.E., 1995. Survival of by-catch from a beam trawl. *Marine Ecology Progress Series*, **126**, 31-38.

Kalmijn, A.J., 1966. Electro-perception in sharks and rays. *Natur*e, **212**, 1232-1233.

Kalmijn, A.J., 1982. Electric and magnetic field detection in elasmobranch fishes. *Science,* **218**, 916-918.

Kaschl, A. & Carballeira, A., 1999. Behavioural responses of *Venerupis decussata* (Linnaeus, 1758) and *Venerupis pullastra* (Montagu, 1803) to copper spiked marine sediments. *Boletin. Instituto Espanol de Oceanografia*, **15**, 383-394.

Kenny, A.J. & Rees, H.L., 1994. The effects of marine gravel extraction on the macrobenthos: early post dredging recolonisation. *Marine Pollution Bulletin*, **28**, 442-447.

Kenny, A.J., & Rees, H.L., 1996. The effects of marine gravel extraction on the macrobenthos: Results 2 years post-dredging. *Marine Pollution Bulletin*, **32,** 615-622.

Khayrallah, N.H., 1977. *Studies on the ecology of* Bathyporeia pilosa *in the Tay Estuary.* PhD Thesis, University of Dundee.

Kinne, O. (ed.), 1970. *Marine Ecology: A Comprehensive Treatise on Life in Oceans and Coastal Waters. Vol 1 Environmental Factors Part 1.*Chicester: John Wiley & Sons

Kinne, O. (ed.), 1984. *Marine Ecology: A Comprehensive, Integrated Treatise on Life in Oceans and Coastal Waters.*Vol. V. *Ocean Management Part 3: Pollution and Protection of the Seas - Radiactive Materials, Heavy Metals and Oil*. Chicester: John Wiley & Sons.

Knight-Jones, E.W. & Nelson-Smith, A., 1977. Sublittoral transects in the Menai Straits and Milford Haven. In *Biology of benthic organisms* (ed. B.F. Keegan, P. O Ceidigh & P.J.S. Broaden), pp. 379-390. Oxford: Pergamon Press.

Knudsen, F.R., Enger, P.S. & Sand, O., 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, Salmo salar. *Journal of Fish Biology*, **45,** 227-233.

Knudsen, F.R., Schreck, C.B., Knapp, S.M., Enger, P.S. & Sand, O., 1995. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. *Journal of Fish Biology*, **51,** 824-829.

Laffoley, D.d.A., Connor, D.W., Tasker, M.L. & Bines, T., 2000. Nationally important seascapes, habitats and species. A recommended approach to their identification, conservation and protection. pp. 17. Peterborough: English Nature.

Levell, D., 1976. The effect of Kuwait Crude Oil and the Dispersant BP 1100X on the Lugworm, *Arenicola marina* L. In *Proceedings of an Institute of Petroleum / Field Studies Council meeting, Aviemore, Scotland, 21-23 April 1975. Marine Ecology and Oil Pollution* (ed. J.M. Baker), pp. 131-185. Barking, England: Applied Science Publishers Ltd.

Lin, J. & Hines, A.H., 1994. Effects of suspended food availability on the feeding mode and burial depth of the Baltic clam, *Macoma balthica*. *Oikos*, **69**, 28-36.

Lindeboom, H.J., 2000. The need for closed areas as conservation tools. In *The effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & S.J. de Groot), pp. 290-301. Oxford: Blackwell Science Ltd.

Lindley, J.A., Gamble, J.C. & Hunt, H.G., 1995. A change in the zooplankton of the central North Sea (55° to 58° N): a possible consequence of changes in the benthos. *Marine Ecology Progress Series*, **119**, 299-303.

Livingstone, D.R. & Pipe, R.K., 1992. Mussels and environmental contaminants: molecular and cellular aspects. In *The mussel* Mytilus*: ecology, physiology, genetics and culture,* (ed. E.M. Gosling), pp. 425-464. Amsterdam: Elsevier Science Publ. [Developments in Aquaculture and Fisheries Science, no. 25]

Luoma, S.N., Cain, D.J., Ho, K. & Hutchinson, A., 1983. Variable tolerance to copper in two species from San Francisco Bay. *Marine Environmental Research*, **10**, 209-222.

Mackie, A.S.Y., 1990. The effects of marine gravel extraction on the macrobenthos: results 2 years post dredging. *Marine Pollution Bulletin*, **32**, 615-622.

Magorrian, B.H. & Service, M., 1998. Analysis of underwater visual data to identify the impact of physical disturbance on horse mussel (*Modiolus modiolus*) beds. *Marine Pollution Bulletin*, **36**, 354-359.

Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., Wethe, C., Lord, C. & Church, T.M., 1986. Vertical migration and mortality of marine benthos in dredged material: a synthesis. *Internationale Revue der Gesamten Hydrobiologie*, **71**, 49-63.

May, S.J. & Pearson, T.H., 1995. Effects of oil-industry operations on the macrobenthos of Sullom Voe. *Proceedings of the Royal Society of Edinburgh*, **103B**, 69-97.

McCauley, R.D., 1994. Seismic surveys. In *Environmental Implications of offshore oil and gas development in Australia- The findings of an Independent Scientific Review*, (eds. J.M. Swan, J.M. Neff, & P.C. Young), Sydney:APEA.

McGreer, E.R., 1979. Sublethal effects of heavy metal contaminated sediments on the bivalve *Macoma balthica*(L.). *Marine Pollution Bulletin*, **10**, 259-262.

Mcleod, C.R., 1996. Glossary of Marine ecological terms, acronyms and abbreviations used in MNCR work. In *Marine Nature Conservation Review: rationale and methods, Appendix 1,* (ed. K. Hiscock), pp. 93-110. Peterborough: Joint Nature Conservation Committee. [Coasts and seas of the United Kingdom, MNCR Series.]

Mcleod, C.R., Yeo, M., Brown, A.E., Burn, A.J., Hopkins, J.J. & Way, S.F., 2002. The Habitats Directive: Selection of Special Areas of Conservation in the UK. Peterborough: Joint Nature Conservation Committee.

McLusky, D.S., Bryant, V. & Campbell, R., 1986. The effects of temperature and salinity on the toxicity of heavy metals to marine and estuarine invertebrates. *Oceanography and Marine Biology: an Annual Review*, **24**, 481-520.

McMath, A., Cooke, A., Jones. M., Emblow, C.S., Wyn, G., Roberts, S., Costello, M.J., Cook, B. & Sides, E.M., 2000. Sensitivity and mapping of inshore marine biotopes in the southern Irish Sea (SensMap): Final Report. *Countryside Council for Wales, Bangor.*

Meador, J.P., Varanasi, U. & Krone, C.A., 1993. Differential sensitivity of marine infaunal amphipods to tributyltin. *Marine Biology*, **116**, 231-239.

Merrill, A.S. & Turner, R.D., 1963. Nest building in the bivalve genera *Musculus* and *Lima*. *Veliger*, **6**, 55-59.

Metcalfe, J.D., Holford, B.H. & Arnold, G.P., 1993. Orientation of plaice (*Pleuronectes platessa*) in the open sea: evidence for use of extended directional cues. *Marine Biology*, **117**, 559-566.

Metoc Plc., 2000. An assessment of the environmental effects of offshore wind farms. *Report prepared for the Department of Trade and Industry/ETSU by Metoc Plc.* [ETSU W/35/00543/REP].

Michel, W.C. & Case, J.F., 1984. Effects of a water-soluble petroleum fraction on the behaviour of the hydroid Coelenterate *Tubularia crocea*. *Marine Environmental Research*, **13**, 161-176.

Michel, W.C., Sanfilippo, K. & Case, J.F., 1986. Drilling mud evoked hydranth shedding in the hydroid *Tubularia crocea*. *Marine Pollution Bulletin*, **17**, 415-419.

Miles, P.R., Malme, C.I. & Richardson, W.J., 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. *Report from BBN Labs Inc , Cambridge, MA, and LGL Ltd.,King City, Ont.,*for US Minerals Management Service., Anchorage, Alaska. BBN Report 6509, OCS Study MMS 87-0084.

Minchin, D., 1995. Recovery of a population of the flame shell, *Lima hians*, in an Irish bay previously contaminated with TBT. *Environmental Pollution*, **90**, 259-262.

Minchin, D., Duggan, C.B. & King, W., 1987. Possible effects of organotins on scallop recruitment. *Marine Pollution Bulletin*, **18**, 604-608.

Mitson, R.B., (ed.) 1995. Underwater noise of Research vessels reviews and recommendations. *ICES Cooperative research report*, **209.**

Mohammad, M-B.M., 1974. Effect of chronic oil pollution on a polychaete. *Marine Pollution Bulletin*, **5**, 21-24.

Möhlenberg, F. & Kiørboe, T., 1983. Burrowing and avoidance behaviour in marine organisms exposed to pesticide-contaminated sediment. *Marine Pollution Bulletin,* **14**, 57-60.

Moore, P.G., 1977. Inorganic particulate suspensions in the sea and their effects on marine animals. *Oceanography and Marine Biology: an Annual Review*, **15**, 225-363.

Moran, P.J. & Grant, T.R., 1993. Larval settlement of marine fouling organisms in polluted water from Port Kembla Harbour, Australia. *Marine Pollution Bulletin*, **26**, 512-514.

Morris, R.J., 1995. Underwater Noise. The forgotten marine pollutant. *North Sea Monitor***,** 4-8.

Muschenheim, D.K. & Milligan, T.G., 1998. Benthic boundary level processes and seston modification in the Bay of Fundy (Canada). *Vie et Milieu, Paris*, **48**, 285-294.

Nature Conservancy Council., 1989. *Guidelines for selection of biological SSSIs.* Peterborough: Nature Conservancy Council.

Navarro, J.M. & Widdows, J., 1997. Feeding physiology of *Cerastoderma edule* in response to a wide range of seston concentrations. *Marine Ecology Progress Series*, **152,** 175-186.

Newell, R.C., Seiderer, L.J. & Hichcock, D.R., 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent biological recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review*, **36**, 127-178.

Newton, L.C. & McKenzie, J.D., 1995. Echinoderms and oil pollution: a potential stress assay using bacterial symbionts. *Marine Pollution Bulletin*, **31**, 453-456.

Niermann, U., Bauerfeind, E., Hickel, W., & Westernhagen, H.V., 1990. The recovery of benthos following the impact of low oxygen content in the German Bight. *Netherlands Journal of Sea Research*, ***25***, 215-226.

O'Brien, P.J. & Dixon, P.S., 1976. Effects of oils and oil components on algae: a review. *British Phycological Journal*, **11**, 115-142.

O'Connor, B., Bowmer, T. & Grehan, A., 1983. Long-term assessment of the population dyanamics of *Amphiura filiformis* (Echinodermata: Ophiuroidea) in Galway Bay (west coast of Ireland). *Marine Biology*, **75**, 279-286.

Olafsson, E.B., Peterson, C.H. & Ambrose, W.G. Jr., 1994. Does recruitment limitation structure populations and communites of macro-invertebrates in marine soft sediments: the relative significance of pre- and post-settlement processes. *Oceanography and Marine Biology: An Annual Review*, **32**, 65-109

Olsgard, F. & Gray, J.S., 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. *Marine Ecology Progress Series*, **122**, 277-306.

Painter, S., Little, B. & Lawrence, S., 1999. Continuation of bird studies at Blyth Harbour Wind Farm and the implications for offshore windfarms. *DTI contract ETSU W/13/00495/REP,* Border Wind Ltd.

Pals, N., Valentijn, P. & Verwey, D., 1982. Orientation reactions of the dogfish *Scyliorhinus canicula* to local electric fields. *Netherlands Journal of Zoology*, **32**, 495-512.

Parkinson, K., 2002, Environmental consequences of offshore wind power generation. *M.Sc. Dissertation in Estuarine and Coastal Science and Management.* The University of Hull.

Pearson, T.H., Josefson, A.B., & Rosenberg, R., 1985. Petersen's benthic stations revisited. I. Is the Kattegatt becoming eutrophic? *Journal of Experimental Marine Biology and Ecology*, **92**, 157-206.

Pearson, W.H., Skalski, J.R. & Malme, C.I., 1992. Effects of sounds from a geophysical survey device on behaviour of captive Rockfish (*Sebastes* spp.). *Canadian Journal of Fisheries & Aquatic Sciences,* **49**, 1343-1356.

Percival, S. & Percival, T., 2001. Otterham Proposed Wind Farm: Breeding bird and habitat survey 2001. Powergen Renewables Developments Ltd. [Cited 02/08/02] Available from <http://www.powergenrenewables.com/pdf/otterham/Appendices/BirdBreedingandHabitatSurvey.pdf.>

Percival, S.M., 2001. Assessment of the effects of offshore wind farms on birds. *Report to the Department of Trade and Industry from Ecology Consulting.* [DTI/Pub URN 01/1434].

Picken, G.B., 1986. Moray Firth fouling communities. *Proceedings of the Royal Society of Edinburgh B*, **91**, 213-220.

Poggiale, J.C. & Dauvin, J.C., 2001. Long term dynamics of three benthic *Ampelisca* (Crustacea - Amphipoda) populations from the Bay of Morlaix (western English Channel) related to their disappearance after the *Amoco Cadiz* oil spill. *Marine Ecology Progress Series*, **214**, 201-209.

Prouse, N.J. & Gordon, D.C., 1976. Interactions between the deposit feeding polychaete *Arenicola marina* and oiled sediment. In *Proceedings of a Symposium of the American Institute of Biological Sciences, Arlington, Virginia, 1976. Sources, effects and sinks of hydrocarbons in the aquatic environment*, pp. 408-422. USA: American Institute of Biological Sciences.

Rachor, E., 1990. Changes in sublittoral zoobenthos in the German Bight with regard to eutrophication. *Netherlands Journal of Sea Research*, **25**, 209-214.

Ramsay, K., Kaiser, M.J. & Hughes, R.N., 1998. The responses of benthic scavengers to fishing disturbance by towed gears in different habitats. *Journal of Experimental Marine Biology and Ecology*, **224**, 73-89.

Ramsay, K., Kaiser, M.J., Richardson, C.A., Veale, L.O. & Brand, A.R., 2000. Can shell scars on dog cockles (*Glycymeris glycymeris* L.) be used as an indicator of fishing disturbance? *Journal of Sea Research*, **43**, 167-176.

Ramsay, K., Kaiser, M.J., Rijnsdorp, A.D., Craeymeersch, J.A. & Ellis, J., 2000b. Impact of trawling on populations of the invertebrate scavenger *Asterias rubens*. In *Effects of fishing on non-target species and habitats*, (ed. M.J. Kaiser & S.J. de Groot), pp151-162. Tonbridge Wells: Blackwell Science Ltd.

Rauck, G., 1988. What influence have bottom trawls on the seafloor and bottom fauna? *Informationen fur die Fischwirtschaft, Hamberg*, **35**, 104-106.

Read, P.A., Anderson, K.J., Matthews, J.E., Watson, P.G., Halliday, M.C. & Shiells, G.M., 1982. Water quality in the Firth of Forth. *Marine Pollution Bulletin*, **13**, 421-425.

Read, P.A., Anderson, K.J., Matthews, J.E., Watson, P.G., Halliday, M.C. & Shiells, G.M., 1983. Effects of pollution on the benthos of the Firth of Forth. *Marine Pollution Bulletin,* **14**, 12-16.

Rees, E.I.S., 1978. Observations on the ecological effects of pipeline construction across the Lafan Sands. (Contractor: University College of North Wales, Marine Science Laboratories, Menai Bridge.) *Nature Conservancy Council*, *CSD Report*, No. 188. (Benthos Research Report, No. 78-1.)

Rees, E.I.S., & Walker, A.J.M., 1983. Annual and spatial variation in the Abra community in Liverpool Bay. *Proceedings of the 17th European Symposium on Marine Biology. 27 Sep 1982,* pp 165-169.

Rees, E.I.S., & Walker, A.J.M., 1991. Indications of temporal variability in the benthos of Liverpool Bay. *Proceedings of the 19th Symposium of the Estuarine and Coastal Sciences Association. 4-8 Sep 1989,* pp 217-220.

Rees, E.I.S., Nicolaidou, A., & Laskaridou, P., 1977. The effects of storms on the dynamics of shallow water benthic associations. *In*: *Biology of benthic organisms. 11th European Marine Biology Symposium, Galway, October 1976*, (ed. B.F. Keegan, P.O. Céidigh & P.J.S. Boaden), pp. 465-474. Oxford, Pergamon Press.

Rees, H.L. & Dare, P.J., 1993. Sources of mortality and associated life-cycle traits of selected benthic species: a review. *MAFF Fisheries Research Data Report, no. 33*.

Rees, H.L., Rowlatt, S.M., Lambert, M.A., Lees, R.G. & Limpenny, D.S., 1992. Spatial and temporal trends in the benthos and sediments in relation to sewage sludge disposal off the northeast coast of England. *ICES Journal of Marine Science*, **49,** 55-64.

Rees, H.L., Waldock, R., Matthiessen, P. & Pendle, M.A., 2001. Improvements in the epifauna of the Crouch estuary (United Kingdom) folowing a decline in TBT concentrations. *Marine Pollution Bulletin*, **42**, 137-144.

Rhoads, D.C. & Young, D.K., 1970. The influence of deposit-feeding organims on sediment stability and community trophic structure. *Journal of Marine Research*, **28**, 150-178.

Richardson, W.J., Finley, K.J., Miller, G.W., Davis, R.A. & Koski, W.R., 1995. Feeding, social and migration behaviour of bowhead whales, Balaena mysticetus, in Baffin Bay vs. the Beaufort Sea regions with different amounts of human activity. *Marine Mammal Science*, **11**, 1-45.

Ringelband, U., 2001. Salinity dependence of vanadium toxicity against the brackish water hydroid *Cordylophora caspia*. *Ecotoxicology and Environmental Safety*, **48**, 18-26.

Rostron, D.R., 1992. Sublittoral benthic sediment communities of Morecambe Bay. Pembroke: Subsea Surveys.

Round, F.E., Sloane, J.F., Ebling, F.J. & Kitching, J.A., 1961. The ecology of Lough Ine. X. The hydroid *Sertularia operculata* (L.) and its associated flora and fauna: effects of transference to sheltered water. *Journal of Ecology*, **49**, 617-629.

Rygg, B., 1985. Effect of sediment copper on benthic fauna. *Marine Ecology Progress Series*, **25**, 83-89.

Ryland, J.S., 1976. Physiology and ecology of marine bryozoans. *Advances in Marine Biology*, **14**, 285-443.

Salzwedel, H., 1979. Reproduction, growth, mortality and variations in abundance and biomass of *Tellina fabula* (Bivalvia) in the German Bight in 1975/1976. *Veroffentlichungen des Instituts fur Meeresforschung in Bremerhaven*, **18**, 111-202.

Sand, O., Enger, P.S., Karlsen, H.E., Knudsen, F. & Kvernstuen, T., 2000. Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. *Environmental Biology of Fishes*, **57,** 327-336.

Sanders, H.L., 1978. *Florida* oil spill impact on the Buzzards Bay benthic fauna: West Falmouth. *Journal of the Fisheries Board of Canada*, **35**, 717-730.

Sanderson, W.G., 1996. Rarity of marine benthic species in Great Britain: development and application of assessment criteria. *Aquatic Conservation*, **6**, 245-256.

Santulli, A., Modica, A., Messina, C., Ceffa, L., Curatolo, A., Rivas, G., Fabi, G. & Damelio, V., 1999. Biochemical responses of European Sea Bass (*Dicentrarchus labrax*) (L.) to the stress induced by offshore experimental seismic prospecting. *Marine Pollution Bulletin*, **38**, 1105-1114.

Schafer, H., 1972. *Ecology and palaeoecology of marine environments*, 568 pp. Chicago: University of Chicago Press.

Sea Empress Environmental Evaluation Committee (SEEEC), 1998. The environmental impact of the *Sea Empress* oil spill. *Final Report of the* Sea Empress *Environmental Evaluation Committee*, 135 pp.

Seaman Jr, W., Sprague, L.M. & (eds.), 1991. *Artificial Habitats for Marine and Freshwater Fisheries*. California: Academic Press Inc.

Sebens, K.P., 1985. Community ecology of vertical rock walls in the Gulf of Maine: small-scale processes and alternative community states. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc.,* (ed. P.G. Moore & R. Seed), pp. 346-371. London: Hodder & Stoughton.

Sebens, K.P., 1986. Spatial relationships among encrusting marine organisms in the New England subtidal zone. *Ecological Monographs*, **56**, 73-96.

Service, M. & Magorrian, B.H., 1997. The extent and temporal variation of disturbance to epibenthic communities in Strangford Lough, Northern Ireland. *Journal of the Marine Biological Association of the United Kingdom*, **77**, 1151-1164.

Service, M., 1998. Recovery of benthic communities in Strangford Lough following changes in fishing practice. *ICES Council Meeting Paper*, CM 1998/V.6, 13pp.

Shillabeer, N., 1991. Benthic population studies of a North Sea disposal area used for industrial liquid waste. *Environmental Pollution*, **69,** 181-191.

Simmonds, M.P., & Lopez-Jurado, L.F., 1991. Whales and the Military, *Nature,* **351**, 448.

Skalski, J.R., Pearson, W.H. & Malme, C.I., 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp.). *Canadian Journal of Fisheries and Aquatic Sciences*, **49,** 1357-1365.

Smit, C.J. & Visser, G.J.M., 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden Sea and Delta area. *Wader Study Group Bulletin*, **68** (special issue).

Smith, J.E. (ed.), 1968. *'Torrey Canyon'. Pollution and marine life.* A report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Cambridge: Cambridge University Press.

SOAFD, 1996. *Monitoring and assessment of the marine benthos at UK dredged material disposal sites.* Scottish Fisheries Information Pamphlate No. 21, Aberdeen, ISSN 0309 9105 (3rd report of the Biology Task-team, GCSDM/MPMMG/DOE).

Soule, D.F. & Soule, J.D., 1979. Bryozoa (Ectoprocta). In *Pollution ecology of estuarine invertebrates* (ed. C.W. Hart & S.L.H. Fuller), pp. 35-76. Washington: Academic Press Inc.

Southward, A.J., 1982. An ecologist's view of the implications of the observed physioloical and biochemical effects of petroleum compounds on marine organisms and ecosystems. *Philosophical Transactions of the Royal Society of London. B*, **297**, 241-255.

Stebbing, A.R.D., 1971. Growth of *Flustra foliacea* (Bryozoa). *Marine Biology*, **9**, 267-273.

Stebbing, A.R.D., 1981. Hormesis - stimulation of colony growth in *Campanularia flexuosa* (Hydrozoa) by copper, cadmium and other toxicants. *Aquatic Toxicology*, **1**, 227-238.

Stekoll, M.S., Clement, L.E. & Shaw, D.G., 1980. Sublethal effects of chronic oil exposure on the intertidal clam *Macoma balthica*. *Marine Biology*, **57**, 51-60.

Stenton-Dozey, J.M.E. & Brown, A.C., 1994. Short term changes in the energy balance of *Venerupis corrugatus* (Bivalvia) in relation to tidal availability of natural suspended particles. *Marine Ecology Progress Series*, **103**, 57-64.

Still, D., Little, B. & Lawrence, S., 1996. The effect of wind turbines on the bird population at Blyth Harbour. Report to Border Wind Ltd. pp. 34.

Stirling, E.A., 1975. Some effects of pollutants on the behaviour of the bivalve *Tellina tenuis*. *Marine Pollution Bulletin*, **6**, 122-124.

Strömgren, T., 1979. The effect of copper on the increase in length of *Ascophyllum nodosum*. *Journal of Experimental Marine Biology and Ecology*, **37**, 153-159.

Stronkhorst, J., Hattum van, B. & Bowmer, T., 1999. Bioaccumulation and toxicity of tributyltin to a burrowing heart urchin and an amphipod in spiked, silty marine sediments. *Environmental Toxicology and Chemistry*, **18**, 2343-2351.

Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.

Terry, L.A., & Picken, G.B., 1986. Algal Fouling in the North Sea. In: *Algal Biofouling*, (eds. Evans , L.V. & Hoagland, K.D.), pp 179-192. Amsterdam: Elservier Science Publishers B.V.

Tittley, I. & Price, J.H., 1977. The Marine algae of the Thames. *London Naturalist*, **56**, 10-17.

Trueman, E.R. & Ansell, A.D., 1969. The mechanisms of burrowing into soft substrata by marine animals. *Oceanography and Marine Biology An Annual Review*, **7**, 315-366.

Tulp, I., Sckekkerman, H., Larsen, J.K., van der Winden, J., van de Haterd, R.J.W., van Horssen, P., Dirksen, S. & Spaans, A.L., 1999. Noctural flight activity of sea ducks near the windfarm Tunø Knob in the Kattegat. *IBN-DLO Report* no. 99.30.

Tyler-Walters, H., Hiscock, K., Lear, D.B. & Jackson. A., 2001. Identifying species and ecosystems sensitivities. *Report to the Department for the Environment, Food and Rural Affairs form the Marine Life Information Network (MarLIN), Marine Biological Association of the United Kingdom, Plymouth.* Contract CW0826. [Final Report].

Veale, L.O., Hill, A.S., Hawkins, S.J. & Brand, A.R., 2000. Effects of long term physical disturbance by scallop fishing on subtidal epifaunal assemblages and habitats. *Marine Biology*, **137**, 325-337.

Vella, G., Rushforth, I., Mason, E., Hough, A., England, R., Styles, P., Holt, T. & Thorne, P., 2001. Assessment of the effects of noise and vibration from offshore windfarms on marine wildlife. *DTI contract, ETSU W/13/00566/REP*, Liverpool: University of Liverpool.

Waldock, R., Rees, H.L., Matthiessen, P. & Pendle, M.A., 1999. Surveys of the benthic infauna of the Crouch Estuary (UK) in relation to TBT contamination. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 225 - 232.

Warner, G.F. & Woodley, J.D., 1975. Suspension feeding in the brittle star *Ophiothrix fragilis*. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 199-210.

Warner, G.F., 1971. On the ecology of a dense bed of the brittle star *Ophiothrix fragilis*. *Journal of the Marine Biological Association of the United Kingdom*, **51**, 267-282.

Warwick, R.M. & Uncles, R.J., 1980. Distribution of benthic macrofauna associations in the Bristol Channel in relation to tidal stress. *Marine Biology Progress Series*, **3**, 97-103.

Webb, A., Stronach, A., Tasker, M.L. & Stone, C.J., 1995. Vulnerable concentrations of seabirds south and west of Britain. *Joint Nature Conservation Committee,* Peterborough:JNCC

Widdows, J., Donkin, P., Brinsley, M.D., Evans, S.V., Salkeld, P.N., Franklin, A., Law, R.J. & Waldock, M.J., 1995. Scope for growth and contaminant levels in North Sea mussels *Mytilus edulis*. *Marine Ecology Progress Series*, **127**, 131-148.

Wilde, P.A.W.J.de., Berghuis, E.M., & Kok, A., 1984. Structure and energy demand of the benthic community of the oyster ground, central North Sea. *Netherlands Journal of Sea Research*, *18*: 143-159.

Wildish, D.J. & Fader, G.B.J., 1998. Pelagic-benthic coupling in the Bay of Fundy. *Hydrobiologia*, **375**, 369-380.

Wildish, D.J. & Kristmanson, D.D., 1984. Importance of mussels of the benthic boundary layer. *Canadian Journal of Fisheries and Aquatic Science*, **41**, 1618-1625.

Wildish, D.J. & Kristmanson, D.D., 1985. Control of suspension feeding bivalve production by current speed. *Helgolander Meeresuntersuchungen*, **39**, 237-243.

Wildish, D.J., Akage, H.M. & Hamilton, N., 2000. Effects of velocity on horse mussel initial feeding behaviour. *Canadian Technical Report of Fisheries and Aquatic Science*, no. 2325, 34pp.

Williams, M., 1995. The European Habitats Directive. In *Rural Wales.* Campaign for the protection of Rural Wales.

Witman, J.D., 1984. *Ecology of rocky subtidal communities: the role of Modiolus modiolus (L.) and the influence of disturbance, competition and mutalism.* Ph.D. Thesis. University of New Hampshire, Durham, USA.

Witman, J.D., 1985. Refuges, biological disturbance and rocky subtidal community structure in New England. *Ecological Monographs*, **55**(4), 421-445.

Wolff, W.J., 1968. The Echinodermata of the estuarine region of the rivers Rhine, Meuse and Scheldt, with a list of species occurring in the coastal waters of the Netherlands. *The Netherlands Journal of Sea Research*, **4**, 59-85.

Yell, D. & Riddell, J., (1995). *Institution of Civil Engineers Design and Practice Guide. Dredging*. London:Thomas Telford Publ.

Yonow, N., 1989. Feeding observations on *Acteon tornatilis* (Linnaeus) (Opisthobranchia: Acteonidae). *Journal of Molluscan Studies*, **55**, 97-102.

Young, G.A., 1985. Byssus thread formation by the mussel *Mytilus edulis*: effects of environmental factors. *Marine Ecology Progress Series*, **24**, 261-271.

Ziegelmeier, E., 1952. Beobachtungen über den Röhrenbauvon *Lanice conchilega* (Pallas) im Experiment und am natürlichen Standort. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **4/2**, 107-129.

Appendix 1. Sources of published information used to identify biotopes likely to be present. References are cited in full in the bibliography to the report.

Location	References used in addition to MNCR database and the MNCR Area Summaries	Notes
Moray Firth	Hartley & Bishop (1986)	
Northumberland incl. Tynemouth	Buchanan *et al.* (1978)	Variability in benthic macrofauna 71-76.
	Bamber 1984	Fly-ash dumping off Blyth
	Buchanan & Moore (1986)	Long-term changes off Blyth. Latest of a series. Survey data in Buchanan & Warwick (1974). Deep water (60-80 m) and possibly not relevant.
	Evans *et al.* (1994)	Comparison of benthic communities in the Tyne 1931 and 1991. (Included as evidence of long-term stability)
	Rees *et al.* (1992a)	Sludge dumping site off the Tyne. Latest reports.
	Shillabeer (1991)	Liquid waste disposal site off the Tyne.
The Wash	Dipper *et al.* (1989)	Descriptions of communities based on *in situ* surveys and dredging.
	Kenny & Rees (1996)	Communities on offshore coarse substrata exploited for aggregates.
	George *et al.* (1995)	Communities on shallow tide-swept cobble habitats off West Runton.
Thames Estuary	Attrill *et al.* (1996)	Mixed hard and soft substrata off Canvey Island.
	Tittley & Price (1977)	Algae on artificial substrata.
Liverpool Bay	Rees & Walker (1991)	Summary of communities found during extensive long-term studies in the area of sewage sludge dumping.
Morecambe Bay	Rostron (1992)	Summarized sample results and compared with Cumbrian coast and Liverpool Bay. Most were similar to the *Abra* community described by Rees & Walker (1983) with large numbers of the polychaete *Pectinaria koreni*. Deeper than 15m, muddy areas were characterised by *Amphiura filiformis* similar to that recorded by Jones (1952) off Cumbria and elsewhere in the Irish Sea (Mackie 1990).
Solway	Covey (1992)	Describes communities in fine sand with small amounts of mud, shell-gravel and empty shells, supporting a generally rich infauna in Luce Bay, impoverished, duned sand off Burrow Head and, further east, muddy sand, often with a high shell-gravel content in Wigtown Bay, Kirkudbright Bay and off Balcarry Point.

Appendix 2. Likely distribution of seabed biotopes in areas proposed for offshore wind farms development, occurrence of nationally rare and scarce species and whether or not *MarLIN* sensitivity review undertaken.

Known to be present at the location or in the area.

Likely to be present in the area. No precise match but survey data suggests present at the location or in the area.

May be present in the area. No biological survey data for the location but recorded from nearby areas.

? Believed to be this biotope but poor match to survey data.

MNCR Biotopes	**Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.**	**Beatrice**	**Teeside**	**I. Dowsing**	**North of Norfolk**	**Cromer**	**Scroby S.**	**Gunfleet S.**	**Kentish F.**	**Thames other**	**Scar S.**	**Rhyl F.**	**Burbo**	**Southport**	**Shell F.**	**Barrow**	**Solway Firth**	**Likely frequency of occurrence.**	**Nationally rare/scarce/ uncommon.**	***MarLIN* sensitivity review.**
Shallow sand faunal communities**.** **(IGS.FaS)**	Clean sands which occur in shallow water, either on the open coast or in tide-swept channels of marine inlets. The habitat typically lacks a significant seaweed component and is characterised by robust fauna, particularly venerid bivalves, amphipods and robust polychaetes. Relationships between the sand, muddy-sand and sandy-mud habitats are currently under review and upper level habitat/biotope complex codes subject to change.											?	?	?				Scattered records of this biotope but probably widely distributed.	None known	Biotopes NcirBat, ScupHyd, Lcon, Fabmag researched in this complex.
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand**.** **(IGS.NcirBat).** (Similar to and representative of **IGS.Mob** and **IGS.Sel**)	Well-sorted medium and fine sands characterised by *Nephtys cirrosa* and *Bathyporeia* spp. (and sometimes *Pontocrates* spp.) which occur in the shallow sublittoral to at least 30 m depth. This biotope occurs in sediments subject to physical disturbance, as a result of strong tidal streams or wave action and may be intermediate in the degree of disturbance between the subtidal biotopes **IGS.Mob** and **IGS.Sell**. The faunal diversity of this biotope is considerably reduced compared to less disturbed biotopes and for the most part consists of the more actively-swimming amphipods. Sand eels *Ammodytes* spp. may occasionally be observed in association with this biotope. The range in wave exposure and tidal streams within which this biotope occurs is indicative of the fact that either wave exposure or tidal streams are responsible for the level of physical disturbance that yields this biotope.														?			Widely distributed. Notable presences off Northumberland and Morecambe Bay.	None known	No

MNCR Biotopes	Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.	Beatrice	Teeside	I. Dowsing	North of Norfolk	Cromer	Scroby S.	Gunfleet S.	Kentish F.	Thames other	Scar S.	Rhyl F.	Burbo	Southport	Shell F.	Barrow	Solway Firth	Likely frequency of occurrence.	Nationally rare/scarce/ uncommon.	*MarLIN* sensitivity review.
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand. **(IGS.ScupHyd)**	Shallow sands with cobbles and pebbles, exposed to strong tidal streams, with conspicuous colonies of hydroids, particularly *Sertularia cupressina* and *Hydrallmania falcata*. These hydroids are tolerant to periodic submergence and scour by sand. *Flustra foliacea* and *Alcyonidium diaphanum* may also occur on the more stable cobbles and pebbles, whereas *Lagis koreni* is often a common component of the infaunal sand community. The less scoured biotope Flu.SerHyd occurs where there is less sand. Infaunal elements of the 'Venus' associations may occur in this biotope.(Not a biotope by itself. Merely an epifaunal overlay where there is a shell and gravel surface veneer to part of the deep Venus community - being addressed in the revised biotope classification.)																	Very few records but probably under-recorded as difficult to sample remotely. Probably this community off North Norfolk.Widespread in the Current swept parts of the Irish Sea.	None known	Yes
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand. **(IGS.Lcon)**	Where strong tidal streams or wave action and coarse sand occur in the shallow sublittoral, dense beds of *Lanice conchilega* may occur. Several other species of polychaete also occur as infauna e.g. *Scoloplos armiger*, *Chaetozone setosa* and *Arenicola marina*.																	Widely distributed.	None known	Yes
Venerid bivalves in circalittoral coarse sand or gravel. **(CGS.Ven)**.	Circalittoral gravels, coarse sands and shell gravels, often in relatively deep water, may be characterised by the presence of conspicuous venerid bivalves such as *Circomphalus casina*, *Clausinella fasciata*, *Timoclea ovata* and other robust bivalve species such as *Glycymeris glycymeris* and *Astarte sulcata*. The sea urchin *Spatangus purpureus* may also be present. Such communities in gravely sediments may be relatively species-rich as they may also contain epifauna such as *Hydroides norvegicus* and *Pomatoceros lamarcki*. In sand wave areas this biotope may contain elements of the Sell and FabMag biotopes. This biotope has previously been described as the 'Deep Venus Community' and the 'Boreal Off-Shore Gravel Association' by other workers (Ford 1923; Jones 1950). Collectively, the 'Ven' biotope dominates the offshore Irish Sea benthos (Mackie, Oliver & Rees 1995).															?		Recorded from a few areas including off the coast of Northumberland and Yorkshire. Nevertheless, may be widely distributed by extrapolation from Ford (1923), Jones (1950, 1951) and Glemarec (1973).	None known	Yes

MNCR Biotopes	Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.	Beatrice	Teeside	I. Dowsing	North of Norfolk	Cromer	Scroby S.	Gunfleet S.	Kentish F.	Thames other	Scar S.	Rhyl F.	Burbo	Southport	Shell F.	Barrow	Solway Firth	Likely frequency of occurrence.	Nationally rare/scarce/ uncommon.	*MarLIN* sensitivity review.
Shallow muddy sand faunal communities **(IMS.FaMS)** and *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand **(IGS.FabMag)**	IMS.FaMS (Shallow muddy sand faunal communities supporting a variety of animal-dominated communities, particularly of polychaetes, bivalves and the sea urchin *Echinocardium cordatum*) has been mapped as a part of MNCR work but will be deleted from the biotopes classification in the next revision. Therefore, one of the existing other biotopes that will be included in the replacment biotopes has been included so that sensitivity information is available: IGS.FabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand). Relationships between the sand, muddy-sand and sandy-mud habitats are currently under review and upper level habitat/biotope complex codes subject to change.																	Widely distributed in western Britain especially notable in Cardigan Bay and off Cumbria. Widely distributed in shallow water round the margin of Liverpool Bay.	None known	Yes. For IGS. FabMag
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud (**IMS. FaMsMacAbr)**	Near-shore shallow muddy sands and muds, and sometimes mixed sediments, may be characterised by the presence of the bivalve *Macoma balthica*. *Abra alba*, *Lagis koreni* and *Donax vittatus* may also be significant components although they may not necessarily all occur simultaneously. *Fabulina fabula*, *Nephtys cirrosa*, *Echinocardium cordatum* and *Crangon crangon* may also be present. The community is has been argued to be especially stable (Dewarumez *et al*. 1992), however it may also be likely to be variable over time due to dominance of opportunists and vulnerability to erratic storm events (Rees pers. com. 2002)													?				Widely recorded. Inshore muddy sand with numerous *Macoma* is unusual in the Irish Sea and seems to be restricted to very shallow patches actually in the mouths of estuaries where there are significant populations of adults on the intertidal flats	None known	Yes.
Abra alba, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment **(CMS.AbrNucCor)**	Muddy sands or slightly mixed sediments in sheltered or slightly reduced salinity environments may be characterised by the presence of the bivalves Abra alba, Nucula nitidosa and *Corbula gibba* as well as *Nucula nucleus, Lagis koreni* and *Nephtys sp*. The echinoderms *Echinocardium cordatum*, *Ophiura albida* and *Ophiura ophiura* may also be present. Sandier habitats contain the **AfilEcor** biotope and increasing silt (and depth) gives rise to the **BriAchi** biotope. The relative density of the characterising species in this biotope is known to vary from year to year; *Nucula nitidosa* can, in some cases, be at least if not more prevalent than *Abra alba.* Primarily an inshore biotope often dominated by *Lagis koreni*. In some bays in SW Britain there are significant populations of *Amphiura brachiata*. This is a highly productive biotope which, because of the abundance of bivalve molluscs such as *Spisula subtruncata* and *Pharus legumen*, attracts concentrations of scoter ducks. It is also a prime feeding area for juvenile flatfish. This biotope is under review and links with existing biotopes (AfilEcor) and new biotopes (novo.LagMu: Lagis koreni in (slightly mixed) muddy sediment) examined.																	Recorded from several areas of coast notably off Northumberland and off Cumbria. Occurs in a series of inshore pockets around the southern margin of Liverpool Bay, and more extensively from the Ribble northwards.	None known	Yes

MNCR Biotopes	Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.	Beatrice	Teeside	I. Dowsing	North of Norfolk	Cromer	Scroby S.	Gunfleet S.	Kentish F.	Thames other	Scar S.	Rhyl F.	Burbo	Southport	Shell F.	Barrow	Solway Firth	Likely frequency of occurrence.	Nationally rare/scarce/ uncommon.	*MarLIN* sensitivity review.
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand **(CMS.AfilEcor).**	Medium to fine clean / muddy (clayey) sand off shallow wave- exposed coasts can be characterised by *Amphiura filiformis* and *Echinocardium cordatum*. This community occurs in muddy sands and deeper water and may be related to the 'off-shore muddy sand association' described by other workers. This community is also characterised by *Pholoe* sp., *Nephtys hombergii, Nucula nitidosa, Callianassa subterranea* and *Eudorella truncatula. Virgularia mirabilis, Cerianthus lloydii* and *Chaetopterus variopedatus* may be other conspicuous surface features but they do not occur in high numbers in this biotope. Deeper, more muddy sediments may give rise to **AbrNucCor**. In the Irish Sea this biotope is a cohesive muddy sand / sandy mud biotope mostly at depths >20m.																	Widely distributed in western and northeastern Britain	None known	Yes
Virgularia mirabilis and *Ophiura* spp. on circalittoral sandy or shelly mud **(CMS.VirOph)**.	Circalittoral fine sandy mud and shelly gravel may contain the sea pen *Virgularia mirabilis* and the brittle star *Ophiura* spp. Whilst recorded mainly from sea lochs, this species assemblage may be closest to undisturbed areas of sandy mud on the open coast. *Virgularia mirabilis* is usually accompanied by *Cerianthus lloydii*, *Chaetopterus variopedatus*, terebellids, including *Lanice conchilega* and, less commonly, *Arenicola marina* and *Myxicola infundibulum* in this biotope. *Amphiura chiajei* and *Amphiura filiformis* occur in high densities in the sandier examples of this biotope but are uncommon in the more gravely muds.														?	?		Recorded especially in sea lochs but may be present on the open coast where wave shelter occurs because of depth.	None known	Yes
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud **(IMU. EstMu AphTub)**	Variable salinity cohesive muddy sediment dominated by the polychaete *Aphelochaeta marioni* and the oligochaetes *Tubificoides* spp. The polychaetes *Polydora ciliata*, *Cossura longocirrata* and *Melinna palmata* may also occur in high numbers. The cirratulid polychaete *Caulleriella zetlandica* may also occur. This biotope is very common in stable muddy environments and may extend from reduced salinity to fully marine conditions.																	Recorded from several areas especially in eastern and south-western Britain. The biotope may be separated from similar biotopes such as NhomTub by the abundance of *Aphelochaeta marioni*, terebellids and an indication of the stability of the sediment.		Yes
Nephtys hombergii and *Tubificoides* spp. in variable salinity infralittoral soft mud **(IMU.EstMu NhomTub)**	Variable salinity soft infralittoral mud and sandy mud characterised by the polychaete *Nephtys cirrosa* and oligochaetes of the genus *Tubificoides*. Also present are low numbers of the bivalves *Macoma balthica*, *Abra alba* and the polychaete *Scoloplos armiger*. The biotope is found in areas of silt deposition in soft and sandy muds but may not form a stable habitat.																	Recorded from several areas especially in eastern and south-western Britain. It is closely similar to IMU.ThaTub which has a higher abundance of Tharyx marioni and occurs in more cohesive sediments. This biotope may occur in conjunction with IMS.MacAbr.	None known	No

MNCR Biotopes	Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.	Beatrice	Teeside	I. Dowsing	North of Norfolk	Cromer	Scroby S.	Gunfleet S.	Kentish F.	Thames other	Scar S.	Rhyl F.	Burbo	Southport	Shell F.	Barrow	Solway Firth	Likely frequency of occurrence.	Nationally rare/scarce/ uncommon.	*MarLIN* sensitivity review.
Shallow mixed sediment faunal communities **(IMX.FaMx)**.	A widely variable array of communities may be found due to the quite variable nature of the sediment type, including those characterised by bivalves (**VsenMtru**), anemones (**An**) and file shells (**Lim**) (Scotland). Brittle stars may also be common. A shallow water heterogeneous habitat.																	Sporadic distribution around England, Wales and Scotland. Often present in wave sheltered locations. Inshore Mixed Sediment occurs on several likely connector routes but probably not at the proposed sites in Liverpool Bay.	Component species of some sub-biotopes may be uncommon or scace. For instance, *Limaria hians* and some burrowing anemones.	Biotope Complex, see Biotopes IMX.An, IMX.Lim, IMX.Vsen Mtru
Sabellaria spinulosa and *Polydora* spp. on stable circalittoral mixed sediment. **(CMX.SspiMx)**	The tube-building polychaete *Sabellaria spinulosa* at high abundances on mixed sediment, with *Polydora* spp. tubes attached. Infauna comprise typical sublittoral polychaete species, together with the bivalves *Abra alba* and *Nucula nitidosa*. Epifauna comprise calcareous tubeworms, pycnogonids, hermit crabs and amphipods.															?		Crusts of *Sabellaria spinulosa* on coarse sediments may produce a 'concreted' surface to which a large number of epifauna species attach. With both infauna and epifauna occuring in the biotope, species richness may be high. Biotope recorded from off Yorkshire and may be present in development areas.	None known	Not researched
Modiolus modiolus beds on circalittoral mixed sediment **(CMX.ModMx)**	Muddy gravels and coarse sands in deeper water of continental seas may contain venerid bivalves with beds of the horse mussel *Modiolus modiolus*. The clumping of the byssus threads of the *Modiolus modiolus* creates a stable habitat that attracts a very rich infaunal community. Brittlestars such as *Ophiothrix fragilis* may also occur with this community. This biotope is very similar to the 'boreal off-shore gravel association' and the 'deep Venus community' described by previous workers (Ford 1923; Jones 1951).															?		Whilst it seems unlikely that wind farms will be proposed for development at the depths this biotope occurs, elements of the biotope may occur in shallower waters where wind farms are constructed. Recorded off west Wales and in the northern Irish Sea.	[To do]	No, but see MCR.Mod T
Lumbrineris spp. in circalittoral mixed sediments **(novo.LumbMX)**	*Lumbrineris* spp. in circalittoral mixed gravelly-sandy sediments. This biotope is found in relatively stable quite coarse sediments with generally low but varying amounts of silt/clay. This biotope resembles a more stable version of GlycGS and PkerMx with Glycera spp. and *Protodorvillea kefersteini* common but with a much richer infaunal community including taxa such as *Mediomastus fragilis*, *Ampelisca spinipes* and numerous other polychates and amphipod taxa. Elements of CGS.Ven may also be apparent although bivalves are generally less dominant in this biotope.																	Proposed new biotope. Widespread. May be part of biotope complex.		No

MNCR Biotopes	**Biotope description (relevant information from the MNCR sublittoral biotopes classification: Connor *et al*. 1997) and additional notes.**	**Beatrice**	**Teeside**	**I. Dowsing**	**North of Norfolk**	**Cromer**	**Scroby S.**	**Gunfleet S.**	**Kentish F.**	**Thames other**	**Scar S.**	**Rhyl F.**	**Burbo**	**Southport**	**Shell F.**	**Barrow**	**Solway Firth**	**Likely frequency of occurrence.**	**Nationally rare/scarce/ uncommon.**	***MarLIN* sensitivity review.**
Protodorvillea kefersteinea in impoverished heterogenous sediment **(novo.PkerMX)**	Impoverished heterogenous slighlty muddy gravelly sands characterised by the hesionid polychaete *Protodorvillea kefersteini* at low abundances, nemerteans and other polychaetes in low numbers. This biotope is related to the impoverished coarse unstable gravelly sand biotope (MobGS) but the existing records show it to occur near *Sabellaria spinulosa* colonies and it may be a transitional biotope found where *Sabellaria spinulosa* colonies have been disturbed e.g. by dredging or storm events.																	Proposed new biotope. Information on distribution not currently available.	Potentially affected by dredging activity.	No
Mobile/unstable coarse sand and gravelly sand **(novo.MobGS)**	Impoversished mobile/unstable coarse sand and gravelly sand with relatively few taxa. Similar to the sandy IGS.Mob biotope but the increased level of coarse material means that it is characterised by hesionids such as *Hesionura* spp., and *Microphthalamus* spp. with deposit feeders such as *Travisia forbesii*, and *Protodrillus* sp. The meiofauna may be an important componant of this biotope.																	Potentially widespread.	None known	No
Dense *Sabella* in mixed sediment **(novo.SabMX)**	*Sabella pavonina* on rocks and stones in infralittoral mixed sediment. Large numbers of other epifaunal populations may also be found in this biotope e.g. the serpulid polychaete *Pomatoceros triqueter* and the hydroid *Hydrallmania falcata*.															?		Locally common off east & west coasts.	None known	No

Appendix 3. Sensitivity to potential environmental change

A3.1. Introduction

Sensitivity assessment is a strategic environmental management tool to appraise the likely effects of environmental change resulting from natural events or man-made impacts at the species or habitat and community level. The assessment of habitat, community or species 'sensitivity' includes the appraisal of the likely damage from an activity, the potential for recovery after damage and their importance from the point-of-view of maintaining marine natural heritage importance.

In definitive terms, 'sensitivity' is the intolerance of a habitat, community or species to damage, or death, from an external factor. A habitat, community or species becomes 'vulnerable' to adverse effect(s) when the external factor is likely to happen. For instance, a crab might have a high sensitivity to physical impact but is only vulnerable if activities such as scallop dredging are being undertaken where it is present. Key terms and definitions are shown in Box A3.1.

Box A3.1. Key definitions.

'Vulnerability' expresses the likelihood that a habitat, community or species will be exposed to an external factor to which it is sensitive. Degree of 'vulnerability' therefore indicates the likely severity of damage should the factor occur at a defined intensity and/or frequency.

'Sensitivity' is the intolerance of a habitat, community or species to damage, or death, from an external factor (based on McLeod, 1996). Sensitivity must be assessed relative to change in a specific environmental factor.

'Recoverability' is the ability of a habitat, community or species to return to a state close to that which existed before the development, activity or event. Recovery may occur through re-growth, re-colonization by migration or larval settlement from undamaged populations or re-establishment of viability where, for instance, reproductive organs or propagules have been damaged by the event. Recovery can be partial or complete.

'Importance' in the context of marine natural heritage: species or biotopes that are rare or very restricted in their distribution; species or biotopes that are in decline or have been; species or biotopes where a country has a high proportion of the regional or world population or extent; species that are keystone in a biotope by providing a habitat for other species; biotopes with a particularly high species richness; locations or biotopes that are particularly good or extensive representatives of their type. Species will also be 'important' if they are listed for protection on statutes, directives and conventions.

'Biotope' the physical 'habitat' with its biological 'community'; a term which refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. The Marine Nature Conservation Review (MNCR) used the biotope concept to enable description and comparison.

'Activity' (maritime) an anthropogenic operation or activity which occurs in the marine or coastal environment (Cooke & McMath, 2000).

'Environmental factor' a component of the physical, chemical, ecological or human environment that may be influenced by natural events or anthropogenic activity (Tyler-Walters & Jackson, 1999).

The term 'sensitive' is currently used to mean 'intolerance' (see Box A3.1) but can also combine intolerance and recoverability to mean (from the Review of Marine Nature Conservation report: Laffoley *et al*. 2001) "A very sensitive habitat or species is one that is very easily adversely affected by external factors arising from human activities, and is expected to recover only over a very long period, or not at all. A 'sensitive' habitat or species is one that is easily adversely affected by a human activity, and is expected to only recover over a long period." The definition from Laffoley *et al*. (2001) needs quantification to bring together *MarLIN* assessments of sensitivity (=intolerance) and recoverability and is currently under development.

All systems for assessing the sensitivity of wildlife to human activities or identifying locations that are sensitive have their advantages and disadvantages. Most are tailored to the sort of information that is available for an area, habitat, species or activity at the time the system was devised. Particular attention is drawn to the work of Holt *et al*. (1995, 1997), which thought through many of the concepts of sensitivity, vulnerability, recoverability and intolerance.

A3.2 Marine benthic species and habitats

The sensitivity assessment of marine benthic species and habitats has developed considerably in the last few years by the SensMap and *MarLIN* programmes. The application of sensitivity data in mapping marine inshore biotopes was described by McMath *et al.* (2000). The *MarLIN* approach to sensitivity assessment was recently described by Tyler-Walters *et al.* (2001).

Tyler-Walters *et al.* (2001) outlines a generic but systematic approach to the assessment of the sensitivity and recoverability of marine benthic species and habitats (biotopes) based on available scientific information. The report includes simple decision trees for sensitivity and recoverability assessment. All relevant information is available on the *MarLIN* Web site (www.marlin.ac.uk). The *MarLIN* team may be consulted for advice concerning sensitivity assessment of marine benthos and operates a general enquiries service.

A3.3 Commercially important fish and shellfish

Information for the assessment of the likely sensitivity of commercial fish and some shellfish species is reviewed by Coull *et al*., (1998) and is available on the UKOOA Web site (www.ukooa.co.uk). The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in England and Wales or Fisheries Research Services in Scotland should be consulted for further advice.

A3.4 Seabirds

Carter *et al.* (1993) and Williams *et al.* (1995) present methodologies for the assessment of the likely vulnerabilities of seabird populations to surface pollution. The distribution of vulnerable seabird concentrations was developed by Carter *et al.* (1993) for the North Sea and Webb *et al.* (1995) for south and west Britain. Important seabird sites in the UK were listed in Percival (2001). Percival (2001) outlined a sensitivity assessment protocol for the identification of areas inappropriate for wind farm development. The Seabird at Sea Team at the JNCC should be consulted for further advice.

A3.5 Sea mammals

Up to twenty six different species of cetacean frequent coastal waters of Britain and Ireland (Evans *et al.,* 1992; Evans, 1994) and are listed in Table A3.1.

No information on the sensitivity assessment of sea mammals was found in this study. Several recent reviews on the conservation of sea mammals and the likely effects of marine pollution were found (see below). The Sea Mammal Research Unit (SMRU) at St Andrews should be consulted for advice.

A3.6 Sensitivity of environmental components

Introduction

Offshore wind farm developments are likely to affect a number of environmental factors, depending on development phase (see Box A3.2).

Box A3.2. Environmental factors influenced by offshore wind farm developments:

- substratum loss;
- smothering;
- suspended sediment;
- turbidity;
- emergence;
- water flow;
- wave action;
- physical disturbance and abrasion;
- displacement;
- noise;
- visual presence;
- chemical contaminants, and
- electromagnetic fields.

Table A3.1. Distribution of cetaceans regularly recorded within the coastal and near shore waters of the UK.

Species name	Common Name	UK records (Evans *et al.,* 1992; Evans, 1994)
Baleen whales (Mysticeti)		
Balaenoptera physalus	Fin Whale	Mainly along Atlantic seaboard of Britain and Ireland. Scarce.
Balaenoptera acutorostrata	Minke Whale	Widely distributed along Atlantic seaboard. Regular in North Sea
Megaptera novaeangliae	Humpback Whale	Rare
Toothed whales (Odontoceti)		
Kogia breviceps	Pygmy sperm Whale	Regular
Mesoplodon densirostris	Blainville's beaked whale	Regular
Phocoena phocoena	Harbour porpoise	Commonest recorded. Regular around UK coastline except the South coast and Thames estuary where it becomes scarce.
Stenella coeruleoalba	Stripped dolphin	Rare
Lagenorhynchus acutus	Atlantic white-sided dolphin	Common in northern North Sea, NW Scotland and Ireland.
Lagenorhynchus albirostris	White-beaked dolphin	Common in northern North Sea and NW Scotland to SW Britain and Ireland.
Orcinus orca	Killer whale	Fairly common off the Atlantic seaboard.
Globicephala melas	Long-finned pilot whale	Commonest offshore cetacean. Mainly found along Atlantic seaboard and northern North Sea.
Delpinus delphis	Common dolphin	Common. Mainly around SW Britain and Ireland.
Tursiops truncatus	Bottlenose dolphin	Common on Atlantic seaboard, Cardigan Bay and Moray Firth. Locally abundant elsewhere.
Grampus grisen	Risso's dolphin	Fairly common. Mainly around Atlantic seaboard, northern North Sea and Irish Sea.

Sediment disturbance is also likely to release bound nutrients and disturb the anoxic layer releasing hydrogen sulphide and causing local, temporary de-oxygenation. However, these effects are likely to be short-lived and extremely localized.

The following components of the marine ecosystem are most likely to be affect by wind farm developments:

- marine benthos;
- fish species, including commercially important fish and shellfish;
- seabirds and inshore bird populations, and
- sea mammals.

In the following section the ecological effects of change in each environmental factor is discussed in turn, with respect to the likely changes associated with wind farm developments. The likely sensitivity and recoverability of the habitats (biotopes) identified as vulnerable to wind farm development are shown in Tables A3.2 to A3.12 (included at the end of the Appendix 3). Each table lists the assessed sensitivity and recoverability, provides a summary or explanation of the evidence used to make the assessment and an estimate of the confidence in that assessment. Detailed reviews of the ecology and sensitivity of the potentially vulnerable habitats (biotopes) are published on the *MarLIN* Web site (www.marlin.ac.uk).

In addition, the collation of existing survey data into databases, such as the National Biodiversity Network and the Marine Nature Conservation Review (MNCR), allows the distribution of sensitive species or biotopes to be mapped. Figure A3.1 shows the distribution of survey data in the MNCR database and Figure A3.2 shows the distribution of additional survey data hosted on the *MarLIN* Web site. Figures A3.3 and A3.4 demonstrate sensitivity maps for species and biotopes respectively, likely to be sensitive to physical disturbance. These demonstration maps only show sensitivity and not recoverability, and therefore probably exaggerate potential impact.

Substratum loss

The physical removal of the substratum inhabited or required by the species or community in question. For example, Newell *et al.* (1998) reported that trailer suction hopper dredging could result in dredged tracks 2-3m wide and 0.5m deep but up to 2m deep in some cases. In comparison, anchored dredging may result in pits of up to 75m in diameter and 20m deep. Hall (1994) reports pits 3.5m wide and 0.6m deep as a result of suction dredging for *Ensis* in a Scottish sea loch. The use of gravity foundations requires seabed preparation, including removal of the surface layer of silt. The installation of electrical cables between turbines and from the wind farm to shore involves trenching or ploughing of the substratum. Metoc (2000) concluded that cable laying would result in considerable sediment disturbance.

The significance of the effect would depend on the extent to the sediment removal compared to the area occupied by the habitat, or the presence of sensitive, keystone, important, declining, rare or scarce species.

Benthos. Physical removal of the substratum will remove or damage all the epifaunal and infaunal species and slow moving species. Only species capable of rapid movement are likely to avoid the factor. Surviving individuals may be damaged or displaced (see physical disturbance and displacement below).

For example, Newell *et al.* (1998) stated that removal of 0.5m of sediment was likely to eliminate benthos from the affected area. Epifauna, large infaunal species (e.g. the heart urchin *Echinocardium cordatum*) and large numbers of molluscs, echinoderms and crustaceans, were reported to be killed or damaged by dredging operations, while the abundance of sessile polychaetes decreased (Eleftheriou & Robertson, 1992; Service & Magorrian, 1997; Elliot *et al.*, 1998). Large numbers of the burrowing sand eel *Ammodytes* spp. (an important food source for seabirds) were reported to be destroyed by dredging (Eleftheriou & Robertson, 1992; Elliot *et al.*, 1998). Therefore, most sublittoral habitats and their species are likely to be highly sensitive to substratum loss (see Table A3.2).

Mobile sandbanks are subject to considerable natural physical disturbance due to hydrographic conditions, e.g. strong currents and storms. The resident communities tend to be dominated by relatively mobile species, e.g. mobile amphipods and mysids. Therefore, mobile sandbanks may be less sensitive to substratum loss in the short term.

Recoverability will depend on the time taken for the substratum to return to similar condition, pits or trenches to fill and recolonization to occur. For example, in the Baltic dredged tracks may still be detectable 12 months later. The time taken for pits to fill in the Dutch Wadden Sea was between 1 year in high currents, 5-10 years in lower currents and up to 15 years on tidal flats (Newell *et al.,* 1998).

Recolonization of benthic invertebrates is dependent on the availability of colonists, either by dispersal of adults or recruitment of larvae and juveniles (Hiscock, 1999). Adults may colonize new habitat by swimming in mobile species (e.g. large crustacea, copepods, and amphipods) or by juveniles due to passive bed load transport (a influx of sediment carrying juveniles and adults). The availability of larvae varies seasonally with species and depends on the distance from reproductive populations and hydrographic conditions. Recruitment between geographically or hydrographically isolated populations may be slow. Some species demonstrate sporadic and un-predictable recruitment, with potentially good annual recruitment but experiencing unpredictable pulses of good recruitment interspersed with periods of poor recruitment, e.g. bivalve molluscs and echinoderms (see Olafsson *et al.*, 1994; Elliot *et al.* 1998). However, communities of mobile sandbanks are tolerant of physical disturbance, mobile and likely to recover quickly (Elliot *et al.* 1998).

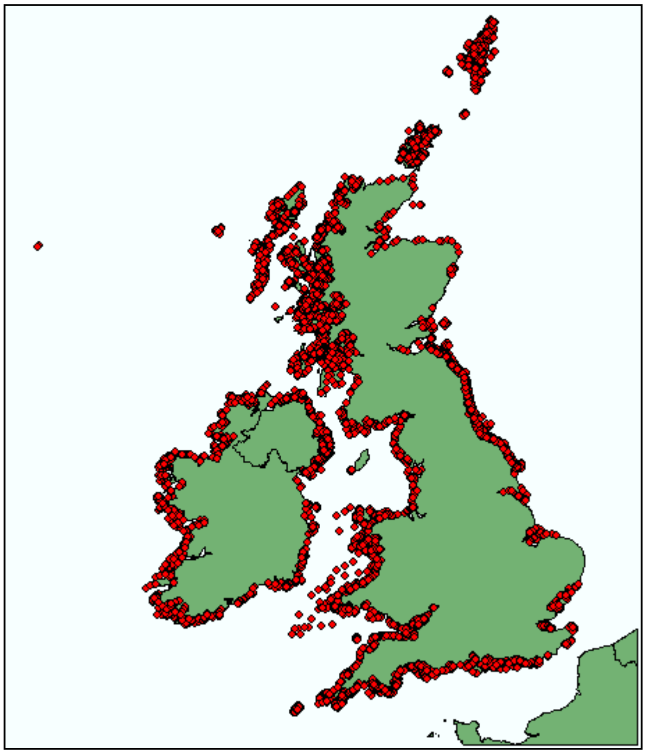

Figure A3.1. Survey data points available from the Marine Nature Conservation Review (MNCR) database.

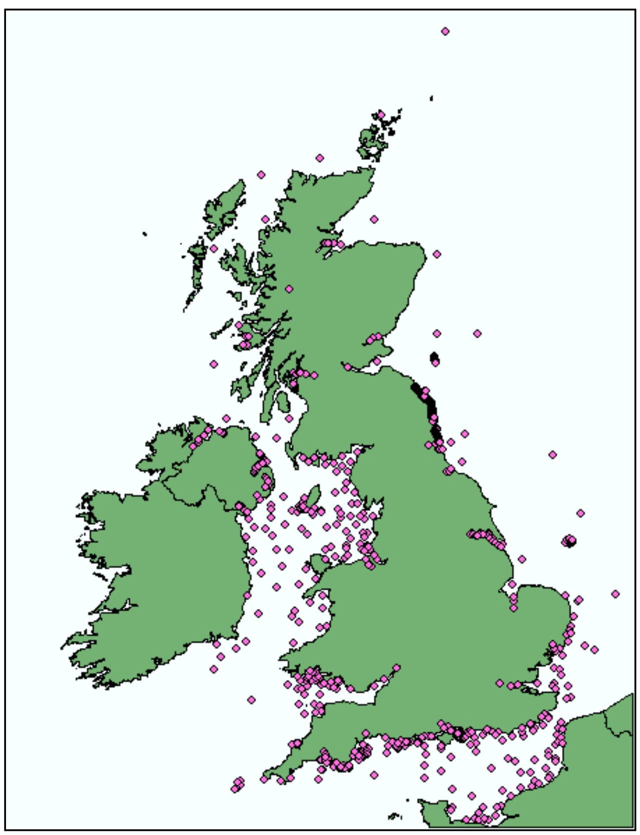

Figure A3.2. Additional survey data hosted by *MarLIN*.

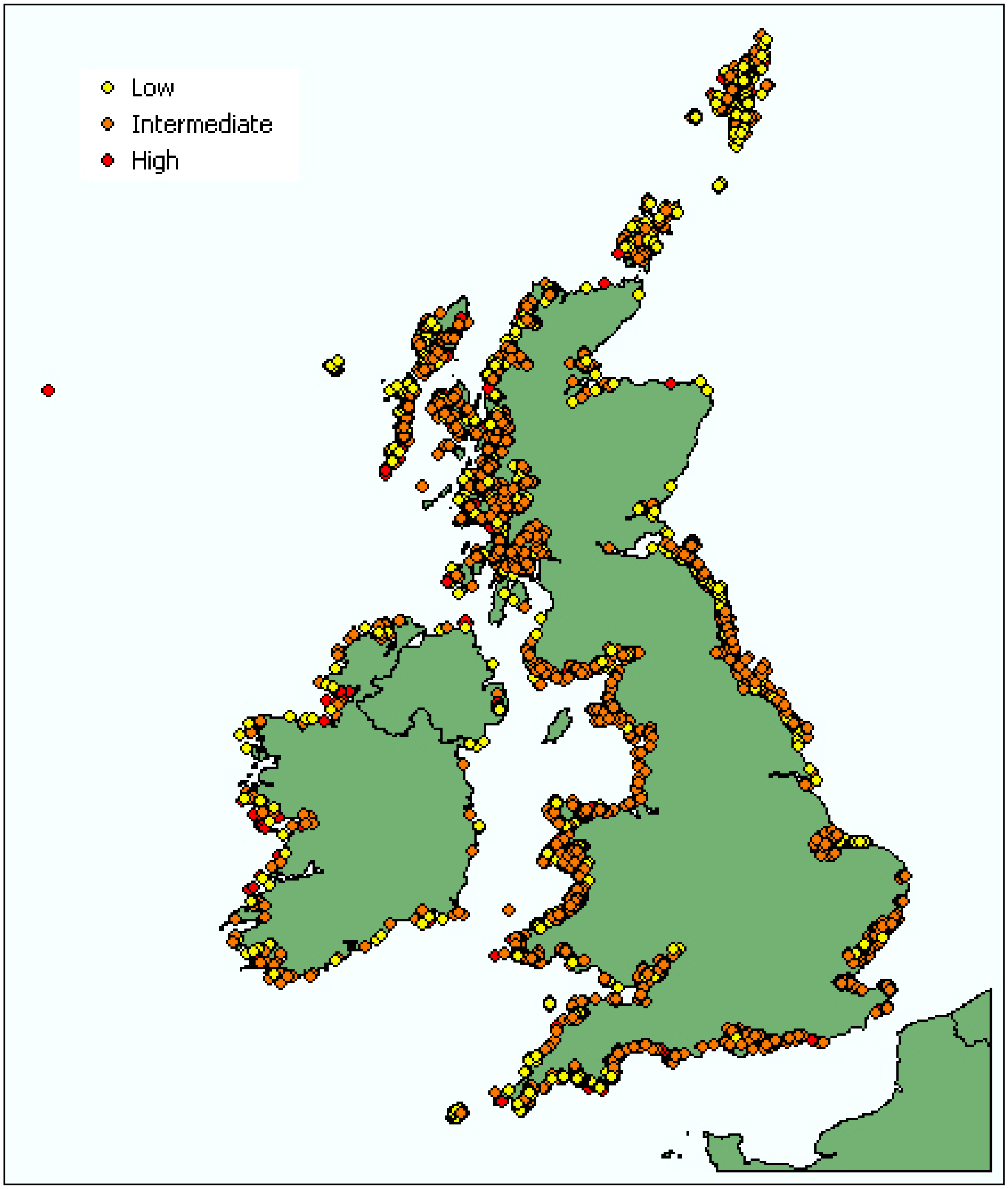

Figure A3.3. Location where seabed biotopes assessed to be sensitive to physical disturbance are recorded. (The development of mapping sensitivity by linking survey data and *MarLIN* sensitivity reviews is in progress and this figure is a demonstration of potential output).

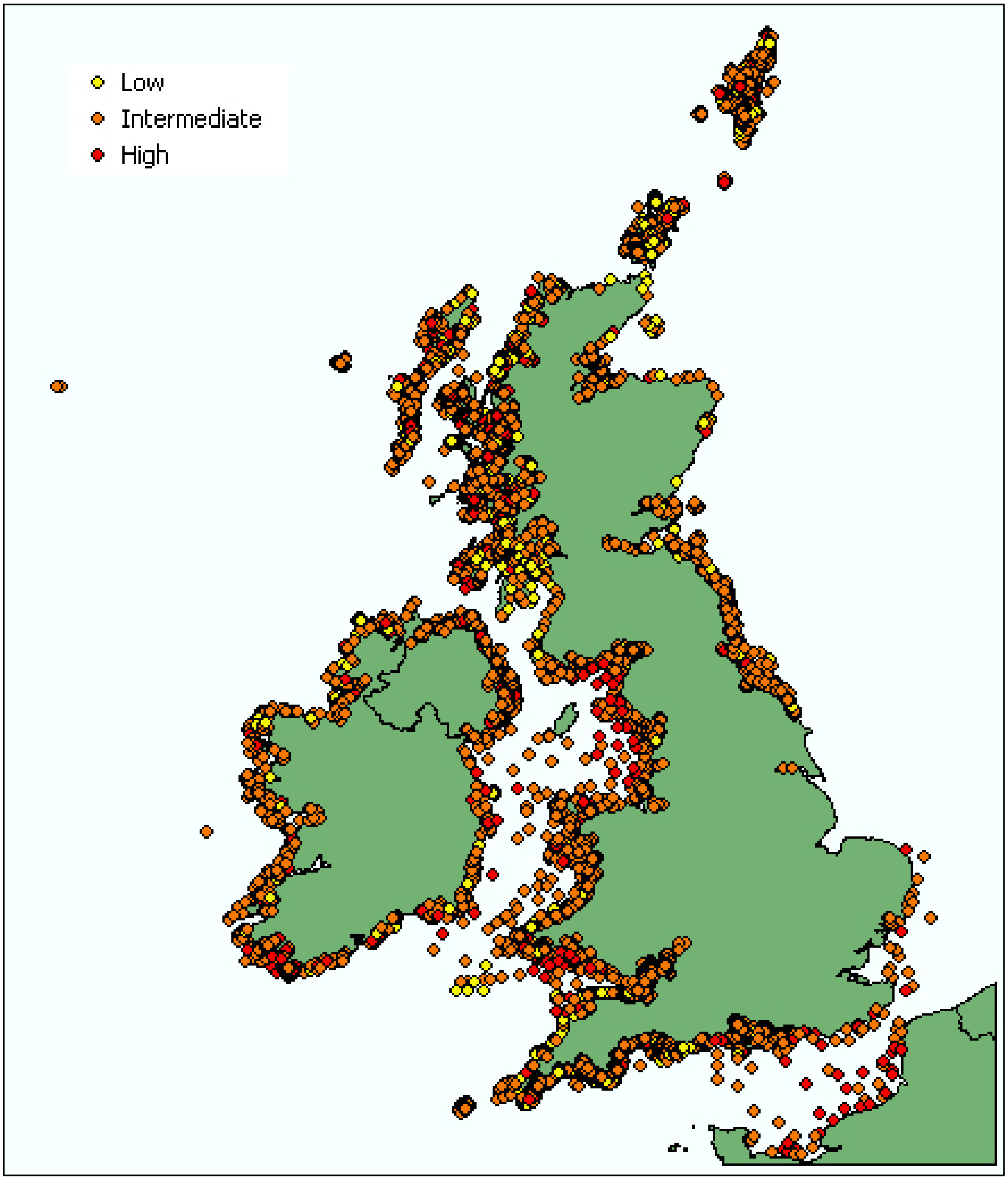

Figure A3.4. Location where seabed species assessed to be sensitive to physical disturbance are recorded. (The development of mapping sensitivity by linking survey data and *MarLIN* sensitivity reviews is in progress and this figure is a demonstration of potential output).

Bonsdorf (1983; cited in Hall, 1994) reported that benthic communities recovered from sediment removal in shallow brackish water sites of Finland within 6 years, while at a second site it took 4-5 years for the original community to return. Kenny & Rees (1994; 1996) noted that while dominant species began to recolonize at a suction dredged site within 7 months of dredging, many of the rarer species did not and that biomass was still reduced 2 years later. Overall, in most of the vulnerable sediment communities studied (see Table A3.2) recoverability has been estimated to be within ca 5 years.

Communities that include slow growing, long lived species, which take many years to reach maturity and/or with limited dispersal or sporadic recruitment, e.g. the heart urchin *Echinocardium cordatum*, the brittlestar *Amphiura filiformis* or sea pen *Virgularia mirabilis*, may show prolonged recovery. If a community is dependant on a keystone species that is a slow growing long lived species with poor recruitment, e.g. *Modiolus modiolus*, a population of the keystone species will need to develop before its associated community can recover, and the overall community recovery many take many years (ca. 10-25 years) (see Table A3.2).

Epifaunal communities of sublittoral rock, dominated by bryozoans and hydroids may take up to 5 years to recover as a recognizable community. The slower growing species such as horned wrack (*Flustra foliacea*), sponges, anemones, soft corals will probably take longer to recover their original abundance (Sebens, 1985, 1986; Hartnoll, 1998). Recovery by rare and scarce species in sedimentary or rock communities may take considerably longer.

Fish and shellfish. Most fish species are probably mobile enough to avoid substratum loss. However, dredging was reported to remove and destroy large numbers of the burrowing sand eel *Ammodytes* spp (Eleftheriou & Robertson, 1992; Elliot *et al.*, 1998). Coull *et al.* (1998) noted that loss of substratum could adversely affect the reproductive success of fish species that lay their eggs on sediment, especially if sediment removal occurred shortly after spawning and removed or damaged the eggs. A reduction in reproductive success, even in the short term may adversely affect the fish population, their predators and catch sizes in the longer term.

Fish species are likely to be indirectly affected due to loss of the benthic community, an import food source for many species. Loss of suitable feeding habitat will displace the fish populations to other areas, perhaps with indirect effects on feeding in their predators such as seabirds and sea mammals.

Birds. The potential effects of offshore wind farm developments on bird population have been extensively reviewed recently by Percival (2001). The reported effects of wind farm development in which studies have been conducted are summarized in table A3.13. Offshore and onshore wind farms may result in the following effects on bird populations:

- loss of habitat or feeding grounds;
- displacement of bird populations or flight routes, and
- direct mortality due to collision or bird strike (Percival, 2001; Parkinson, 2002).
- Percival (2001) includes locations of important offshore bird sites, migratory routes and nature conservation sites in the UK, together with a proposed rationale for the assessment of the sensitivity of bird populations and identification of sites inappropriate for offshore wind development.
- A limited number of studies of the effects of offshore wind farms on bird populations have been conducted so far, primarily on small wind farm developments, which may not be representative of the effects of larger developments with more turbines. Offshore wind farms are likely to be larger, and use quieter turbines with slower rotation speeds than onshore wind farms (Percival, 2001).

The general lack of information on the effects of offshore wind farms on birds suggests that the precautionary approach should be taken to avoid conflict between developments and important seabird breeding colonies

Offshore wind farms may effectively result in loss of habitat by displacing bird populations from preferred feeding habitats. Percival (2001) suggested that wind farm development should assess the importance of the proposed site as a local resource relative to alternative feeding or roosting sites, based on ecological models to integrate information on birds behaviour and habitat use. The importance of offshore sites to local bird population varies with species and depends on its proximity to breeding colonies, water depth and substrate type. Seabirds vary in their foraging range, and their ability to hunt at water depth. Substrate types has been shown to linked to habitat preferences of several seabirds preferred prey, e.g. sand eels are an important component of many seabird species diet and are found primarily on sandy substrata (Percival, 2001).

English Nature have also identified likely important areas for common scoter as sites of 5-15m deep and up to 2km offshore of the Northumberland and Durham coasts, the Wash and north Norfolk coasts, the Thames estuary, Liverpool Bay, Morecambe Bay and Solway Firth (Percival, 2001).

Table A3.13. Reported effects of offshore and onshore wind farm developments on bird populations (abridged from Percival, 2001).

Wind farm study	Bird species studied/affected	Effects and comments
Offshore		
Lely, Ijsselmeer, The Netherlands	Diving ducks, tufted dusks, pochard	Ducks flew around the outside of the wind farm, rather than between turbines, avoiding the wind farm by a great distance, especially on dark nights. Suggested that lines of turbines may act as a barrier to flight route (Dirksen *et al.,* 1998).
Tunø Knob, Baltic Sea, Denmark	Eider duck	An initial post-construction decline in eider duck numbers in vicinity of turbine was attributed to natural fluctuations in food (mussel) supplies rather than the presence of the wind farm. However, eider avoided flying and landing within within 100m of the wind farm, although no effect on their feeding distribution was detected (Guillemette *et al.,* 1998, 1999).
Tunø Knob, Baltic Sea, Denmark	Eider duck and common scoter	Nocturnal flight activity within 1,500m of wind farm was reduced but no affect was observed at dawn. Eider maintain a greater distance in poor visibility conditions. No effects on common scoter were observed although the sample size was small. Eider preferred to fly between turbines where the gap between them was 400m rather than 200m. It was suggested that wind farms may act a barrier to flight paths (Tulp *et al*., 1999).
Onshore		
Blyth, North Sea, United Kingdom	Cormorants, gulls, purple sandpipers, and eiders	Wind farm related mortality due to collisions was less than background mortality due to other sources (e.g. predation, disease, over-head wires etc.). Construction disturbance affected cormorants only, and no detectable effect was observed on purple sandpiper, eider and gulls (Still *et al.,* 1996; Painter, *et al.,* 1999).

Where offshore wind farms develop artificial reefs, the increase in shellfish and fish populations, may be beneficial to bird populations, e.g. guillemot were observed feeding on fish in within 20m of the wind turbines at Blyth, Northumberland (Vella *et al.,* 2001).

Sea mammals. Substratum loss may indirectly affect sea mammals by displacing preferred prey species from the area in the short term or by affecting the available fish population.

Smothering

Benthos. The physical covering of the species or community and its substratum with additional sediment (silt), spoil, detritus, litter, oil or man-made objects. Major storms may naturally deposit a layer of additional material of several centimetres at 20m depth and several millimetres at 40m (Hall, 1994). For example, storms were reported to deposit 4-10cm of sand at 28m in the Helgoland in German Bight and up to 11cm of sand off the Schleswig-Holstein coast (Hall, 1994). Storm activity probably also removes layers of sediment from other areas. Subtidal sedimentary communities in moderately exposed or exposed areas are probably adapted to natural levels of sediment disturbance.

Smothering by re-suspended sediment as it settles or by deposited spoil has direct mechanical effects on the epifauna and infauna and may result in modification of the substratum. Deposited spoil may directly clog the feeding or respiratory apparatus of suspension feeders.

For example, Maurer *et al.,* (1986) reported that epifaunal or deep-burrowing siphonate suspension feeders were unable to escape burial by >1cm of sediment. Infaunal non-siphonate suspension feeders tolerated burial by 5cm but <10cm of sediment. Shallow burrowing siphonate suspension feeders and the young of otherwise deep burrowing species surviving burial by 10 and 50cm of their native sediment. Mucous tube feeders and labial palp deposit feeders (e.g. tubeworms and other polychaetes) were the most sensitive (Maurer *et al.,* 1986). The effects of were exacerbated if the sediment differed from the native sediment as many species are adapted to burrow through specific types of sediment. For example, haustoriid amphipods were capable of rapid burrowing up through deposited sediment but if the sediment differed from its native sediment then burrowing was 'seriously curtailed' (Maurer *et al.,* 1986). Maurer *et al.,* (1986) suggested that bivalves with a reduced foot or byssate attachment may have limited burrowing capability and be susceptible to smothering. Epifaunal communities of hard substrata may be particularly sensitive since many epifaunal species are adapted to low silt conditions e.g. *Amphisbeti*a (as *Sertularia*) *operculata* (Round *et al.,* 1961).

In addition, smothering may modify the sediment structure and dynamics if the sediment deposited differed from that already present (SOAEFD, 1996; Elliot *et al.,* 1998). Deposited spoil may also create a disturbed benthic community, possibly reduce the abundance and diversity of species and affect larval recruitment (Elliot *et al.*, 1998). For example, long term spoil disposal was reported to have changed sediment dynamics and altered the macrofaunal community (e.g. Little, 1987; Johnson & Frid, 1995; Herrando-Pérez & Frid, 1998).

Overall, the significance of the impact will depend on the volume of spoil and its sediment type. The adverse affects may be offset by using a licensed dump site. The potential sensitivities of biotopes identified as vulnerable to wind farm developments are shown in Table A3.3.

If the species are able to burrow up through the deposited sediment or the affected area is a subject to strong currents that remove or re-distribute the deposited material, then recoverability is likely to be rapid. But, where the sediment is modified or in sheltered conditions, recovery may not begin until the deposited material is removed by natural processes. For example, recovery of the macrobenthic community was reported to have begun 7.5 years after cessation of coal waste dumping at Horden, Northumberland. But at Blackhall, currents transported the existing coal waste to the site, and the community at Blackhall was still disturbed 12.5 years after dumping had stopped (Johnson & Frid, 1995).

Suspended sediment

Suspended sediment is included as a factor for those species likely to be sensitive to clogging of respiratory or feeding apparatus by silt or species that require a supply of sediment for tube construction such as *Sabellaria* spp. The resultant effects on light attenuation are addressed under turbidity below, and the effects of rapid settling out of suspended sediment are addressed under smothering above.

The effects of suspended sediment on marine organisms were reviewed by Moore (1977). An increase in suspended sediment is likely to adversely affect the feeding or respiratory apparatus of suspension feeding invertebrates. Respiratory or suspension feeding apparatus may be clogged leading to smothering or starvation and death. Suspended sediment may decrease feeding efficiency, or increase the energetic demands on the organism by increasing the production of pseudofaeces and clearing or cleaning mechanisms, resulting in reduced condition and reproduction. An increase in suspended sediment will also result in an increase in the local siltation rate and scour by sediment in some conditions.

Benthos. Benthic communities, especially epifaunal communities vary in the degree of suspended sediment and siltation they are able to tolerate. Siltation and a resultant layer of sediment on hard substrata may deter settlement by larvae, reducing recruitment of some species. However, infaunal species are probably tolerant of changes in suspended sediment, although in the long term any resultant modification of the substratum may alter the benthic communities present, e.g. from suspension or filter feeder dominated communities to deposit feeding communities.

Foundation construction and cable laying will probably result in local re-suspension of sediment. The extent of the suspended sediment plume will depend on the grain size of the substratum, with large particles (e.g. coarse sands and gravels) settling quickly while fine particulates (e.g. muds and clay) could be deposited over a wide area, depending on the local water currents. The effect is likely to be short term, and localized. Adoption of standard operating procedures for dredging activities should minimize the impact (see Yell & Riddell, 1995).

Fish. Moore (1977) suggested that bottom dwelling fish were most tolerant of suspended sediment while filter-feeding fish were most sensitive. Within a given species while juveniles were the most sensitive, since they cannot withstand the same amount of gill clogging as the adult. Sublethal and lethal effects of suspended solids in fish result from clogging of or damage to the gills. However, the deleterious concentration varies with species, and many commercially important fish tolerate the very turbid waters of estuaries, e.g. herring, whiting, codling, flounders, plaice, soles and dabs (Moore, 1977). Cole *et al.* (1999) concluded that little information on the effects of suspended solids on fish was available for UK species.

Sea mammals. High concentrations of suspended sediment may scatter and attenuate the high frequency echolocation signals used by dolphins and porpoise (odontocetes) to navigate and hunt, although no evidence of this effect was found. Dolphin and porpoise would probably simply avoid the affected area.

Turbidity

The turbidity (clarity or opacity) of water is dependent on the concentration of substances that absorb or scatter light; for example, inorganic or organic particulates (suspended matter), plankton and dissolved substances. Dissolved substances may include natural organic materials (e.g. humic acids) or discharged chemicals. The turbidity determines the depth of water that light can penetrate and therefore the amount of light available for primary production by phytoplankton, benthic microalgae and macroalgae. At high levels, the suspended sediment that causes turbidity may clog feeding apparatus but this effect is included in 'suspended sediment'. Coastal waters are likely to absorb 10-60% of incident light per metre at a wavelength of 500 nm (Kinne, 1970). Assuming that coastal waters absorb, on average, 30% of incident light, then this is approximately equivalent to a suspended sediment concentration of 10-50 mg /l (extrapolated from Clarke, 1996). Cole *et al.* (1999) report average mean levels of turbidity of 1-110 mg/l around the English and Welsh coasts.

Marine benthic invertebrates generally have poor if any visual acuity and are unlikely to be adversely affected by an increase in turbidity. The decrease in light reaching the sublittoral will decrease primary productivity in phytoplankton, marine benthic microalgae and macroalgae (seaweeds). However, the increase in turbidity due to increased suspended sediment is likely to be short term, and no significant adverse effect on the benthic community is expected.

Species that depend on sight to hunt, such as cephalopods (squid and octopus), fish, seals and seabirds may be affected by increased turbidity. Seabirds tend to hunt in the topmost layer of water, so that turbidity would have to be extremely high to prevent hunting (Moore, 1977). Similarly, seals are known to hunt successfully in dimly lit waters under pack ice (Moore, 1977). Turbid conditions may provide some protection for fish species from their predators (Cole *et al.*, 1999). Therefore, an increase in turbidity is unlikely to affect species significantly.

Emergence

Sediment disturbance by dredging and trenching activities is likely to destroy sedimentary bed forms (e.g. scour hollows, sand ribbons, or ripples) and result in raised banks of sediment or trenches, pits or tracks in the sediment (Elliot *et al.,* 1998*;* Newell *et al.,* 1998). In the shallow subtidal, the influence of wave action, resulting in oscillatory water flow, is partly dependent on depth. Therefore, an increase or decrease in bed height will result in a locally altered hydrographic regime and hence altered sedimentary particle size, sorting, oxygenation and nutrient levels. The benthic invertebrate communities are likely to be altered in the short term. However, communities of mobile sandbanks are adapted to physical disturbance, probably recover quickly and may not be significantly altered (Elliot *et al.,* 1998).

Recovery will depend on the time taken for the sediment to recover its original condition, which will in turn depend on the hydrographic regime, and probably be more rapid in high energy (exposed to water flow and wave action) conditions. For example, in the Baltic dredged tracks may still be detectable 12 months later.

The time taken for dredged pits to fill in the Dutch Wadden Sea was ca 1 year in high currents, 5-10 years in lower currents and up to 15 years on tidal flats (Newell *et al.,* 1998).

Changes to the benthic invertebrate communities may indirectly affect fish and hence seabirds and sea mammals. Benthic invertebrates are an important food source for many fish species (Cole *et al.,* 1999). Therefore, altered benthic communities may affect the food supply of several fish species, depending on if preferred prey are lost or encouraged.

Water flow (tidal currents)

Tidal flow is usually fairly weak offshore. Strong tidal streams result in areas where water is forced through or over restrictions (e.g. gullies or narrows) or around offshore obstructions.

The hydrographic regime is a key determinant in sediment dynamics and sedimentary habitats. The degree of water flow and water movement determine:

- the type (grain size, sorting and porosity) of sediment that accumulates in an area and hence organic content and oxygen levels;
- the stability of the sediment;
- accretion and erosion rates, and
- the topography of the seabed and bed forms.

Type of sediment is also dependant on the regional availability of sediments of particular types.

Infaunal invertebrates are sensitive to changes in sediment and many species are adapted to burrow through and feed in certain grades of sediment (Elliot *et al.,* 1998). For example, fine sediments tend to have high a organic content and be dominated by deposit feeding species such as polychaetes and oligochaetes. Coarser sediments (e.g. sands) have a lower organic content and are dominated by suspension feeders such as tube worms (e.g. *Lanice conchilega*). Epifaunal communities are also affected by water flow rates, due to increased siltation in low water flow, the importance of water flow to provide adequate food supplies and physical tolerance of water flow (drag) and scour where sediment is present. For example, *Tubularia indivisa* and *Flustra foliacea* are tolerant of strong water flow while *Alcyonium glomeratum* or *Ascidia mentul*a prefer more sheltered conditions (Hiscock, 1983). For a detailed discussion, see Elliot *et al*. (1998), Hughes (1998) and Hartnoll (1983, 1998).

Any fixed structure placed on the seabed will affect the water flow around it, resulting in localized scour and substratum loss (Parkinson, 2002). The towers of turbines will probably accelerate water flow through the wind farm but may also attenuate wave energy by diffraction or interference. Therefore, the sediment dynamics within the site, and hence the benthic communities may be altered, depending on the habitat preferences of the communities present.

Changes in the benthic communities may have indirect effects on fish communities and their predators (seabirds and sea mammals). In addition, changes in the water flow through the wind farm may alter the sediment dynamics over a wide area with ramifications for coastal processes. The potential sensitivities of vulnerable biotopes are shown in Tables A3.4 and A3.5.

Wave action

The strength of wave action is dependent upon the distance of open water over which wind blows to generate waves (the fetch) and the strength and incidence of the winds. Wave action generates oscillatory water movement on the seabed. The strength of water movement on the seabed becomes less with increasing depth to the seabed (Hiscock, 1983). Wave generated water movement therefore becomes increasingly important in shallow water and the intertidal. Wind farm towers may 'block' wave action causing increased shelter inshore of the development. Changes in the degree of exposure to wave action may have long term effects on subtidal and intertidal communities over a wide area. The potential sensitivities of vulnerable biotopes are shown in Tables A3.6 and A3.7.

Physical disturbance and displacement

This factor includes mechanical interference, crushing, physical blows against, or rubbing and erosion of the organism of interest. Protrusive species may be crushed, and delicate organisms with a fragile skeleton or soft bodies may be physically damaged or broken. Physical disturbance is likely to result form the activities that deposit objects on the seabed (e.g. lobster pots, creels, drilling rig legs), scrape across or through the sea bed (e.g. anchors, scallop dredges, beam or otter trawls) or that result in substantial sediment disturbance and re-suspension (e.g. drilling, dredging, hydraulic or suction dredging, or cable laying). Most evidence of physical disturbance is derived from studies of the impacts of dredging and fishing gear. The level of impact being dependent on the extent of the affected area, how often the area is impacted, the season, the sediment types and its communities and the presence or absence of sensitive species or habitats, commercial fisheries or shellfisheries, or species or habitats of conservation importance.

Benthos. The effects of sediment disturbance and fishing gear in subtidal habitats have been extensively reviewed (see Jennings & Kaiser, 1998; Elliot *et al*., 1998; Hughes, 1998; Hartnoll, 1998; Gubbay & Knapman, 1999; Kaiser & de Groot, 2000). The relevant effects of physical disturbance and abrasion are summarized below.

- Re-suspension of sediment (see above).
- Alteration of sediment structure and hence the resident communities.
- Significant reduction in biomass of species displaced or damaged as a result on the physical disturbance immediately after the activity.
- Damage to epifaunal species especially (see Service & Magorrian, 1997; Veale *et al.,* 2000).
- Damage to fragile species especially tall, erect growth forms and/or rigid skeletons, e.g. sea urchins, sea fans and ross *Pentapora fascialis*.
- Damage to biogenic reef forming species (e.g. the ross worm *Sabellaria spinulosa*, the horse mussel *Modiolus modiolus*,) resulting in decreased productivity and biodiversity including possible loss of nursery habitats in the affected area.
- Reduction in community diversity and species richness (Elliot *et al.,* 1998).
- Attraction of scavenging species such as starfish, the common whelk *Buccinum undatum* and fish (Ramsay *et al*., 2000)
- The direct effects of fishing gear on benthic communities tends to increase with depth and stability of the substratum, e.g. in sheltered areas where complex habitats develop at minimal depth (Jennings & Kaiser, 1998).
- Mobile sediments and their infauna may be more resistant to physical disturbance (Elliot *et al*., 1998).

Species and individuals may survive physical disturbance but be displaced. Displacement to unsuitable substrata will probably result in death of sedentary or slow moving species. Species may survive displacement onto suitable substrata if they are able to burrow or reattach. Permanently attached species (e.g. hydroids, bryozoans, and sponges are unlikely to be able to reattach. Displacement will result in increased mortality due to vulnerability to predation until the species is able to construct a burrow.

The likely sensitivities of the biotopes identified as vulnerable to wind farm development are shown in Table A3.8 and A3.9. The sensitivities are assessed with respect to physical disturbance by an anchor and the biotopes may be more sensitive to the substantial sediment disturbance likely to occur during wind farm construction.

The recoverability of subtidal habitats was discussed under substratum loss above. Most habitats would probably recover within about 5 years but biotopes dominated or characterized by slow growing, long lived species (e.g. sea pens or horse mussel beds) with slow or sporadic recruitment rates would probably take much longer to recover.

Fish. The majority of fish species are sufficiently mobile to avoid physical disturbance. However, dredging was reported to remove and destroy large numbers of the burrowing sand eel *Ammodytes* spp. (Eleftheriou & Robertson, 1992; Elliot *et al*., 1998). Coull *et al.* (1998) noted that sediment disturbance could adversely affect the reproductive success of fish species that lay their eggs on sediment, especially if sediment disturbance occurred shortly after spawning and removed or damaged the eggs. A reduction in reproductive success, even in the short term may adversely affect the fish population, their predators and catch sizes in the longer term. In addition, fish populations could be indirectly affected by changes in benthic communities due to the loss or gain of preferred prey species.

Birds. The potential effects of offshore wind farm developments on bird population have been extensively reviewed by Percival (2001). The reported effects of wind farm development in which studies have been conducted are summarized in Table A3.13. Physical disturbance and displacement result from avoidance of the wind farm and direct mortality by collisions (see Percival, 2001). The following points itemise possible effects.

- Long lines of turbines may act as barrier to flight or migration routes, especially if perpendicular to flight lines and should be avoided. Distances between turbines could be minimized to reduce the overall area of the wind farm
- Studies of bird collisions have suggested that the mortalities are minimal and less than the background mortality rates and below levels likely to result in significant effects on bird populations. However, any increase in mortality may be detrimental to sensitive species, which are rare or scarce, in decline, have restricted distributions, or very specific (limited) habitat requirements for feeding, roosting or breeding.
- No evidence of major disturbance effects were reported up to 800m from wind turbines in operation.
- Migrating birds have only been an issue at existing wind farms when very large numbers have moved through wind farms with large numbers of turbines, and especially where sensitive species were involved. But land birds migrants tend to move across a broad front and are not expected to move through offshore wind farms in large numbers.
- Coastal water bird movements within and between estuaries may be more important, although only low collision rates have been detected in existing wind farms. Wind farms should be sited away from major local flight routes.
- Navigational lighting may increase the risk of collision or bird strike. Artificial light has been show to attract birds to tall communication towers and lighthouses, especially in inclement weather. The use of flashing white lights of low intensity as possible was suggested to reduce the risk of bird collisions.
- Where the offshore electrical cable comes ashore, the use of overhead lines to connect to the national grid should be avoid since overhead lines may pose a greater collision threat than the wind farm itself.

Present guidance from English Nature (cited in Percival, 2001) recommends that offshore wind farms are:

- sited more than 1km from important gull or tern communities, and
- sited more than 20km of other seabirds colonies.

However, Percival (2001) suggested that offshore wind farm developments should avoid important bird sites wherever possible.

Sea mammals. Sea mammals may be displaced by construction and operational noise (see below).

Noise and visual presence

The following information was derived from detailed reviews of the potential effects of noise and vibration generated by offshore wind farms on marine wildlife by Vella *et al.* (2001), together with reviews of the effects of marine noise on sea mammals by Richardson *et al.* (1995) and Gordon & Moscrop (1996), and the effects of survey vessels on fish by Mitson (1995).

Offshore wind farm developments are likely to result in noise (defined as unwanted sound) and vibration during all phases of development (see above). Pre-installation exploration will involve acoustic surveys and survey vessels, construction will probably involve dredging, drilling, pile-driving and in some circumstance explosives, while the wind turbines generate noise and vibration in operation. The characteristics of the major sources of underwater noise are summarized in Box A3.3 and A3.4.

The relative intensity of the marine noise is demonstrated by Table A3.14. As expected seismic surveys are extremely high in intensity, while the construction related activities are likely to produce more intense (louder) sound than the operating turbines.

Box A3.3. Major sources and characteristics of ambient marine noise (summarized from Mitson, 1995; Richardson *et al.*, 1995 and Vella *et al.*, 2001).

- **wind and waves** create broadband noise, the sound level increasing with wind speed, and wave height but decreasing with frequency, e.g. sound levels in the 100Hz third octave band (ca 70 -140Hz) range from 74dB re 1µPa in calm seas to >100dB re 1µPa in rough seas (Vella *et al.,* 2001).
- **rain and hail** generate noise at the water surface, detectable above ambient at >500Hz.
- **sediment movement (e.g. gravel)** a significant contribution to ambient noise especially in the vicinity of estuaries (Vella *et al.,* 2001).
- **natural seismic activity** resulting form underwater volcanos and earthquakes may generate low frequency ambient noise in geologically active areas but is unlikely to occur in British water (Vella *et al.,* 2001)

Note on units: The sound pressure level is expressed in decibels (dB) calculated against a reference pressure level of 1µ Pascal (Pa). The decibel scale is logarithmic. Therefore, a doubling of the sound level results in a 3dB increase, while a ten fold increase results in a 10dB increase in sound level. The range of frequencies produced by any given sound source is highly variable, with some frequencies dominating with higher sound levels than other frequencies. The sound level perceived by the receiving organism is dependent on its hearing sensitivity to different frequencies.

Table A3.14. Relative peak intensity of man-made underwater sound sources (adapted from Vella *et al.,* 2000).

Sound source (see text)	Sound level in dB (Dominant frequency in Hz).
Seismic airgun	210 dB (50Hz)
Dredging	185 dB (160 Hz)
Tanker	177 dB (100 Hz)
Tug	162 dB (630Hz)
Zodiac (5m) boat	152 dB (6300Hz)
Piling	135 dB (30-100Hz)
Drilling platform	127 dB (5Hz)
Svante Offshore Windfarm	ca 120 dB (<100Hz)
Highest level of Ocean Noise	ca 100 dB (70-140Hz)

Airborne noise from wind turbines is generated by the generator and gearbox machinery in the turbine housing and the passing of the rotor through the air, and increases with air turbulence. Airborne noise tends to occupy the range 650-8000Hz with a peak at 1-2kHz. Onshore wind farms typically produce 90-100dB at 500-2kHz. Offshore wind farms are likely to produce lower sound levels due to reduced turbulence in the marine environment (Vella *et al.,* 2001).

Box A3.4. Major sources and characteristics of man-made marine noise (summarized from Mitson, 1995; Richardson *et al.*, 1995 and Vella *et al.*, 2001).

- **motor vessels and shipping** generate noise by cavitation of the propeller, and from transmission of machinery noise (i.e. engines and gearboxes) through the hull. In general, the larger the ship the higher sound the levels and the lower the frequency range, although sound level also increases with speed, and ranges between 10 -10kHz. For example, a 5m Zodiac with outboard may produce a sound level of 152dB at a dominant frequency range of 6300Hz, while a tug/barge may generate 162dB at 630Hz at 18km/hr, and a large tanker 177dB in the 100Hz third octave band (Mitson, 1995; Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **seismic surveys** use air guns to produce sudden, short bursts of sound at high sound levels over a range of low frequencies between 10-1000Hz with most energy between 10-20Hz, although in surveys air-guns may fire every few seconds, e.g. a 32 air gun array may produce a peak sound level of 210dB at 50Hz, with large arrays producing up to 259 dB (Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **drilling platforms** produce continuous sound due to drilling work and machinery. A single study demonstrated dominant tones in the very low to infrasound frequencies, e.g. 119-127dB at 5Hz at a range of 9-61m (Gales, 1982 cited in Richardson *et al.*, 1995).
- **trawls** such as pelagic or bottom trawls (e.g. beam trawls) create noise as they pass through the water column or across the sea bed. Data is limited but Mitson (1995) reported that a beam trawl produced between ca 130-150dB at a frequency range of 30Hz - >10kHz, at 1m when towed at 3.6 knots, although the trawl noise was less than the vessel noise below 500Hz.
- **dredging** activities generate continuous sounds, dominated by low frequencies although higher frequencies may be present, e.g. a typical noise spectrum peaks at 178dB at 160Hz with a overall source level 185dB (Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **pile-driving** results in acute short term sounds over considerable distances, e.g. the hammering associated with a conductor pipe installation was reported to be as high as 131-135 dB at **1 km,** blows occurring every 3 seconds and lasting 0.2 seconds with frequencies of 30-40Hz and ca 100Hz (Miles *et al.*, 1987 cited in Richardson *et al.*, 1995).
- **airborne sound from ships, industry and aircraft** may penetrate the water column, however most will reflect of the water surface, e.g. a significant amount of sound from a passing aircraft will only pass into the water column when directly overhead, and at speed is likely to be transient. For example, overflight by a fixed wing aircraft was reported to produce underwater sound with peak levels of 152dB at 63Hz, while a helicopter produced 159dB at 16Hz (Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **sonar** utilize very short, intense sound pulses to detect underwater objects for navigation, depth sounding etc, and produce sound frequencies between a few hundred Hz to several thousand kHz, and although the sound levels may be up to 230dB total sound energy is low since the pulses are so transient and the directional nature of pulse ensures only a narrow cone of water is affected (Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **explosions** produced by underwater explosives in underwater demolition, sound sources and military applications produce high intensity but short term sounds, e.g. the sound impulse may be up to 279dB with most of the sound energy in the very low frequency to infrasound range (<20Hz). (Richardson *et al.*, 1995; Vella *et al.*, 2001).
- **biological sources** include communication and social vocalization of cetaceans and seals, the ultrasonic echolocation sounds of toothed whales (Odontocete), and sounds produced by fish and some marine species of unknown function. For example, toothed whales produce sound of up to 230dB between 1-150Hz; baleen whales produce up to 188dB between 0.01 - 3kHz (including infrasound), while fish have been reported to produce up to 140dB at ranges of 1-5kHz and 0.5-3KHz depending on source (Richardson *et al.*, 1995; Vella *et al.*, 2001).

Little information on the sound produced by operating turbines was found and most environmental assessments assume that the underwater noise is not significant (Vella *et al.*, 2001). Based on a single study, Vella *et al.* (2001) estimated the sound level to be approximately 115-120 dB at 1m, significantly lower than other man-made noise sources (see Table A3.14), although they point out that many assumptions were made in derivation of the estimate. Vella *et al.* 2001 reported that sound levels were about 80dB above ambient above 100Hz, and ranged from 80-100dB below 100Hz, with a peak of 103dB at 16Hz. Overall, operational underwater noise is likely to be minimal and mainly at low frequencies (Vella *et al.*, 2001).

Sound propagates differently in water than in air due to its increased density. The density of water means that a given sound source produces a greater pressure wave in water than in air, that sound travels faster (1550 m/s) and with greater wavelengths. Low frequency sounds travel great distances while high frequencies are attenuated quickly and do not propagate well in shallow water. In shallow water a sloping seabed may channel the sound and propagate the sound over greater distances. Similarly, differences in temperature, salinity, and/or pressure may refract sound. Sound level reduces with distance from its source (attenuation), roughly equivalent to a 6 dB drop in sound level for every doubling of distance from the source if allowed to spread evenly in all directions. But if channelled by the seabed and water surface attenuation may be only 3 dB. With increasing pressure and hence depth the attenuation rate of sound is increased.

The effect of noise depends on its intensity, the sensitivity of the receiving organisms to the relevant frequencies and the distance from the sound source. For example, Vella *et al.,* (2001) identified several 'zones' of noise influence.

- **Zone of audibility -** the widest area in which an organism can perceive or hear the noise.
- **Zone of responsiveness -** the area in which the organism reacts behaviourally or physiologically.
- **Zone of masking -** the area in which the noise is intense (loud) enough to interfere with communication.
- **Zone of physiological effect -** the area in which the sound level is great enough to cause physiological damage such as hearing loss or injury to internal organs.

Benthos. Little information on the effects of noise on marine invertebrates is available. A few species have been shown to respond to sound (see Box A3.5; Vella *et al.,* 2001). Few marine invertebrate possess sensory organs designed to perceive sound but do possess receptors of pressure and mechanical disturbance. Invertebrates may respond to high amplitude, low frequency sounds (<100Hz) similar to the hydrodynamic flow of water currents and eddies (McCauley, 1994; Vella *et al.,* 2001). It is generally assumed that sound has few behavioural or physiological effects on marine invertebrates (Vella *et al.,* 2001). However, close proximity to powerful sound sources such as seismic survey arrays or underwater explosions will probably cause physical damage due to the pressure wave generated (Vella *et al.,* 2001). The effects of sound from other loud sound sources such as pile driving may have detrimental effects but probably only in the immediate vicinity.

Box A3.5. Reported responses to sound in marine invertebrates (from Vella *et al*., 2001).

- The heart beat of the lobster *Homarus americanus* slow down in response to sound in the frequency of 10-75Hz.
- The brittlestar *Opiura ophiura* detects near-field vibrations down to a few Hz and far-field pressure waves.
- The octopus *Octopus vulgaris* and the squid *Loligo vulgaris* detect sound below 100Hz and are particularly sensitive below 10Hz, although the stimulus is probably caused by the passing sound wave moving water particles.
- The squid *Todarodes pacificusis* was attracted to sound of 160dB at 600Hz, a technique used to catch squid commercially.

Developed epifaunal communities have been reported from artificial structures such as oil drilling rigs and the monopile foundations of Horns Rev offshore wind farm in Denmark. Therefore, it seems unlikely that epifaunal and typical fouling species are sensitive to vibration generated by operational offshore wind farm developments (Vella *et al.,* 2001).

Fish. Fish hear in the range of 60-3000 Hz but respond to infrasound e.g. the plaice *Pleuronectes platessa* was reported to be sensitive to low frequencies of 30-100Hz. Hearing specialists have been reported to be detect 50 dB while other species can only detect down to 110 dB (Vella *et al.,* 2001). The sensitivity of fish species depends on their hearing thresholds, which have only been studied in a few species such as cod, salmon, haddock, plaice, pollock and dab (see Mitson, 1995 and Vella *et al*., 2001). Swim bladders may resonate at low frequencies so that fish with swim bladders may be more sensitive to low frequency sound than fish without swim bladders, e.g. sharks and rays. Similarly, larger fish with larger swim bladders may be more sensitive, e.g. larger cod avoided areas subject to seismic surveys more than small cod (Engas *et al.*, 1995 cited in Mitson, 1995). Vella *et al*.,(2001) suggested that fish in which the swim bladder is physically coupled to the ear would be more sensitive still.

Vella *et al.* (2001) suggested that fish only responded consistently to very low or very high frequency sound. The following effects of noise on fish have been reported.

- **Avoidance -** includes formation of tighter schools, rapidly descending or turning away from the sound source, increased swimming speed, and panic fleeing.
    - Pelagic fish (e.g. cod and capelin) dived to deeper water to avoid approaching vessels while demersal fish probably avoided its path. Schools of fish avoid the vessels path at distances of 100 - 200m but up to 400m from noisy vessels, shoals often divide to allow the ship to pass (Mitson, 1995).
    - Cod and herring avoid the sound of vessel noise at 118dB at 60-3000Hz, while sounds in the range of 20-60Hz have no effect (Engas *et al*., 1995 cited in Vella *et al.,* 2001).
    - Herring, cod and polar cod were reported to exhibit a behavioural reaction to the continuous sound produced by vessels at 120-130dB (Vella *et al.,* 2001).
    - Similar avoidance reactions were reported for cod, polar cod, capelin, herring, pacific mackerel, sardine, mackerel, herring, and sprat. Fish avoidance reactions are probably due to high levels of low frequency noise in the most sensitive frequency range for fish (approximately 150-250Hz depending on species) (Mitson, 1995).
    - Infrasound (<20Hz) emitters are also used to deter fish from installations such as power station uptakes at relatively low power levels (Knudsen *et al*., 1994, 1995; Sand *et al*., 2000).
    - An echo-sounder signal at 45m caused a hibernating herring shoal at 60-95m to split to its full depth to allow the signal to pass. However, acoustic survey techniques use frequencies above 10kHz, and probably outside the hearing thresholds of fish for which data were found (Mitson, 1995).
    - Loud, abrupt sounds are likely to startle and ellicit alarm responses in fish species (e.g. Pearson *et al*., 1992; Skalski *et al*., 1992). A single air-gun was shown to produce startle and alarm responses after 10 minutes of exposure in rockfish (*Sebastes* spp.) and reduced catch-efficiency by hook-and-line fishing in experimental conditions. The effects were short term, in the region of minutes but in acoustic surveys the number of air-guns used and duration of surveys were likely to be significantly longer (Pearson *et al*., 1992; Skalski *et al*., 1992).
    - Seismic surveys were implicated in a reduction in local catch rates of redfish in the north Pacific and large cod and haddock in the Barents Sea, while no effects on catch rates of bass was noted during seismic testing in Poole Bay (Mitson, 1995; Vella *et al*., 2001).
    - Morris (1995) suggested that seismic surveys off the Llyn Peninsula drove away fish and dolphin from the area, with a resultant reduction in foraging seabirds.
- **Physical damage**
    - Underwater explosions can kill fish with swim bladders at ranges of up to several kilometres, which are particularly vulnerable due to the density differences between tissue and the gas-filled swim bladder (Gordon & Moscrop, 1995). Sudden intense sound waves are used by a variety of predatory species (e.g. dolphin) to stun fish.

Vella *et al.* (2001) noted that fish are a large group that varies in their behavioural responses and sensitivity to sound. McCauley (1994 cited in Vella *et al*., 2001) suggested zones or ranges of effect on fish to the sound produced by seismic testing (see Box A3.6).

Box A3.6. Suggested zones of influence of seismic testing in fish. Zones based on large seismic arrays with source levels of >200dB (McCauley, 1994 cited in Vella *et al.*, 2001).

- Zone of audibility - 10m-10km.
- Zone of response - 10m-10km.
  - Subtle responses - 2-10m.
  - Alarm response - 600m -1km.
  - Startle responses - 150-300m.
- Zone of avoidance - 10 -1km (most reaction at 200m -1km).
- Zone of physiological effects - 10-200m (most reaction at 50-200m).

The effects of offshore wind farms on fish population have been investigation in two studies around the Svante Wind Farm, Sweden (Westerberg, 1999 cited in Vella *et al.* 2001).

- No difference in behaviour of migrating eels was noted in response to the wind farm, during operation at a distance of 500-2000m.
- No significant difference in eel catches was found between 5 years before and 5 years after construction an operation of the wind farm.
- No effect on pre-construction and post-construction catch per unit effort (CPUE) of eels was detected at wind speeds of 5m/s but at wind speeds of 10-15m/s a significant, 22% reduction in CPUE was detected.
- The CPUE of cod, sculpin and roach was highest within 200m of the wind farm than at 200-800m when the turbines were idle. Although the CPUE within 200m decreased when the turbines were operating, the CPUE was still greater within 200m than at 200-800m from the wind farm. Vella *et al.* (2001) suggested that the wind farm was attracting fish.
- Fish have also been reported in close association with the wind turbines at Blyth, Northumberland, attracting feeding guillemot within 20m of the turbines (Vella *et al.,* 2001).

Overall, Vella *et al.* (2001) noted that only the hearing sensitivities of cod overlapped with the sound produced by the operation of the Svante Wind Farm, and the evidence of cod and other fish species in the vicinity of the wind farm suggested that effects were minimal. However, the effects of construction related noise, and especially seismic survey are likely to be more significant and influence a wider area, causing avoidance and behavioural responses up to 1km or 10km from the site (see Box A3.6). Vella *et al.* (2001) noted that the alarm or startle responses may interfere with schooling behaviour, and in species where schooling is important for reproduction, or that use nursery areas (e.g. commercial species such as herring, cod, haddock, whiting and flat fish), behavioural responses to noise may interfere with reproductive success and hence population dynamics.

Many species of commercially important fish use spawning or nursery areas e.g. mackerel, herring, cod, whiting and plaice (Coull *et al.,* 1998). Spawning varies with season depending on species, and the size of the spawning area will depend on the stock or population size and are therefore, not rigidly set. Coull *et al.* (1998) note that fish eggs and larvae may be particularly vulnerable to seismic survey, since air gun arrays are usually towed just below the water surface, the area when fish larvae and other zooplankton are found. For example Vella *et al*., (2001) reported the following effects exposure to sound levels of 242dB at 0.75m and 220dB at 6m (Boorman *et al*., 1999) on fish eggs and larvae:

- no effects on cod and saithe eggs;
- no effects on cod embryos from the above sound levels but mortality in saithe embryos;
- cod yolk sac fry experienced mortalities within 0.75m;
- death of turbot fry in increasing numbers out to 3m;
- mortalities of herring fry out to 2-5m,
- while older cod fry were only susceptible at close range (1.7m).

Therefore, the precautionary approach suggest that any seismic survey activity and potentially construction activities, e.g. pile driving should avoid spawning areas or nursery areas and should be timed to avoid breeding seasons of fish likely to be within the vicinity. Seismic survey exclusion areas or windows should be adopted as recommended by regulatory agencies for oil and gas exploration.

The United Kingdom Offshore Operators Association (UKOOA) has recently published a detailed report and maps of fisheries sensitivity by Coull *et al.* (1998) on its Web site (www.ukooa.co.uk). The maps include estimates of the spawning or nursery areas for the commercially important fish and shellfish, together with seasonal seismic survey sensitive area and maps of areas of 'relative fisheries value' in which damaging effects may be significant. Examples of the fisheries sensitivity maps are given in Figures A3.5 to A3.7.

Pearson *et al.* (1992) and Skalski *et al.* (1992) reported that alarm and startle response of fish caused by a singe airgun. The effects were short term, in the region of minutes but in acoustic surveys the number of air-guns used and duration of surveys were likely to be significantly longer (Pearson *et al.*, 1992; Skalski *et al.*, 1992). Santulli *et al.* (1999) also noted that Atlantic salmon was reported to recover from physiological stress within a week. Therefore, it is likely that the effects are relatively short term and only apparent during noise production.

Operational noise is a continuous source but the evidence above suggests that effects may be minimal and offset by the development of an artificial reef on the wind farm foundations.

Whales and dolphins (cetaceans). The effects of underwater noise on sea mammals has extensively reviewed by Richardson *et al*. (1995) and others (see Grellier *et al.*, 1995; Gordon & Moscrop, 1996, and Vella *et al.,* 2001), although further research on the long term effects of noise is probably required (Richardson *et al.,* 1995; Gordon & Moscrop, 1996, Vella *et al.,* 2001).

Cetaceans in particular use sound for communication and socializing, echolocation and hunting. The toothed whales (odontocetes) use high frequency sound (from a few kHz to 150kHz) for echolocation to 'visualize' their environment as well as an extensive repertoire of clicks and whistles used in social and reproductive interaction. Baleen whales (mysticetes) use sound to communicate their position, the presence of food or danger, territory and reproductive status. Baleen whales use low frequency sound from below 10Hz to 25kHz, detectable over hundreds or thousands of kilometres, presumably designed for communication in the open sea. Sound is an important tool in communication, breeding and hunting in these species, so that they are likely to be sensitive to changes in ambient noise. The hearing range of odontocetes ranges from 1kHz to 100kHz, and is good in the range 10-60kHz but is only affected by low frequency sound at high sound levels, e.g. 130dB in the bottlenose dolphin. Mysticetes have good hearing in the low frequency range, although the hearing sensitivity of only a few species have been examined.

The following effects of noise on cetaceans have been reported.

- **Physical damage**
    - Two humpback whales were reported to have badly damaged internal ear structures after exposure to excavations, explosions and drilling, consistent with blast injuries (Gordon & Moscrop, 1996).
    - Experimental evidence suggested that dolphin would experience tissue injury within 0.5-0.6m of an explosion from a Class-C seal bomb.
    - Thomas *et al.* (1990 cited in Gordon & Moscrop, 1996) suggested that cetaceans would exhibit physiological stress in response to noise but did not detect a physiological response in captive beluga whales exposed to a play back of drilling rig noise.

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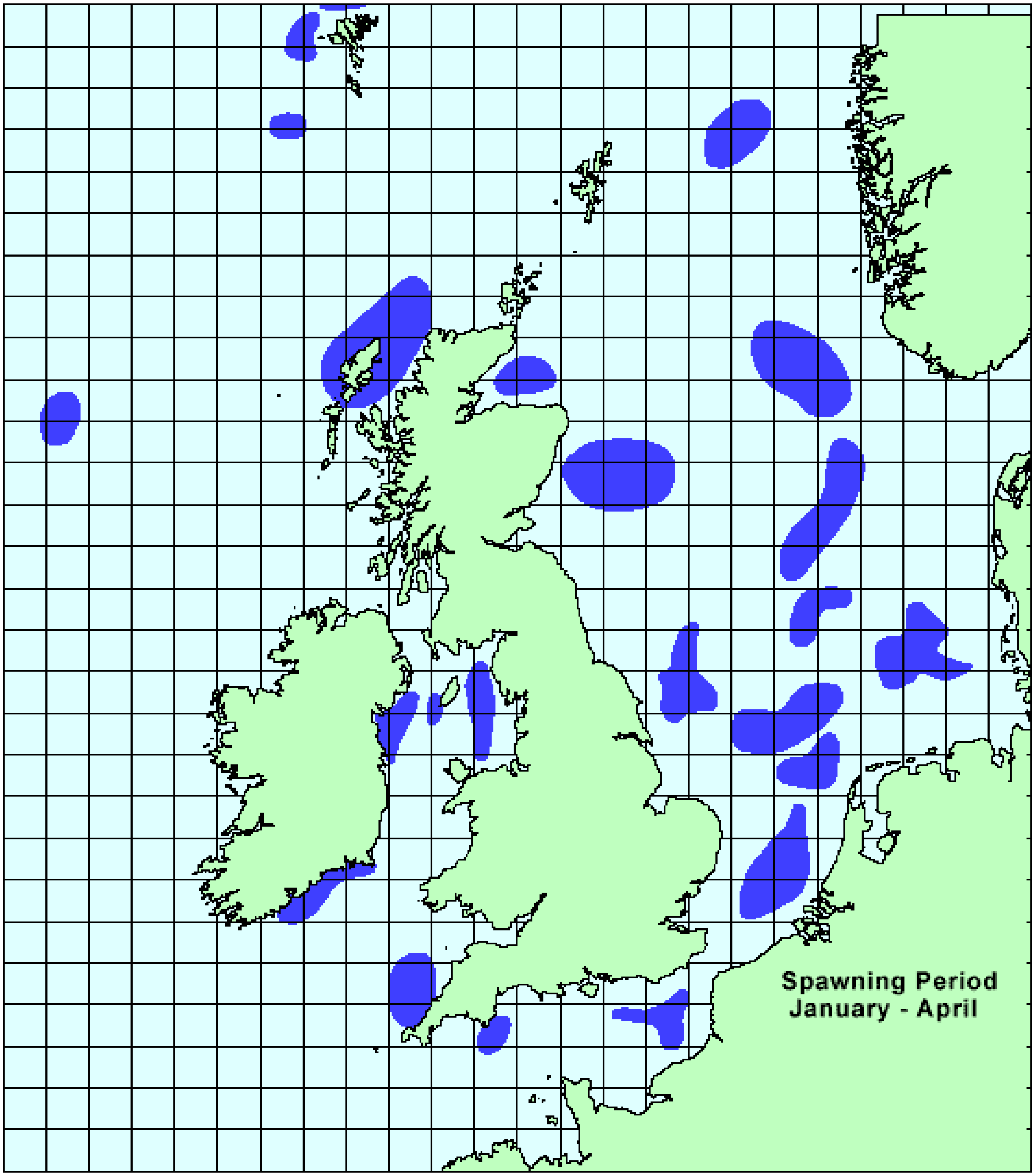

Figure A3.5. Fisheries sensitivity maps in British Waters. This example shows cod spawning areas (Coull *et al*., 1998)

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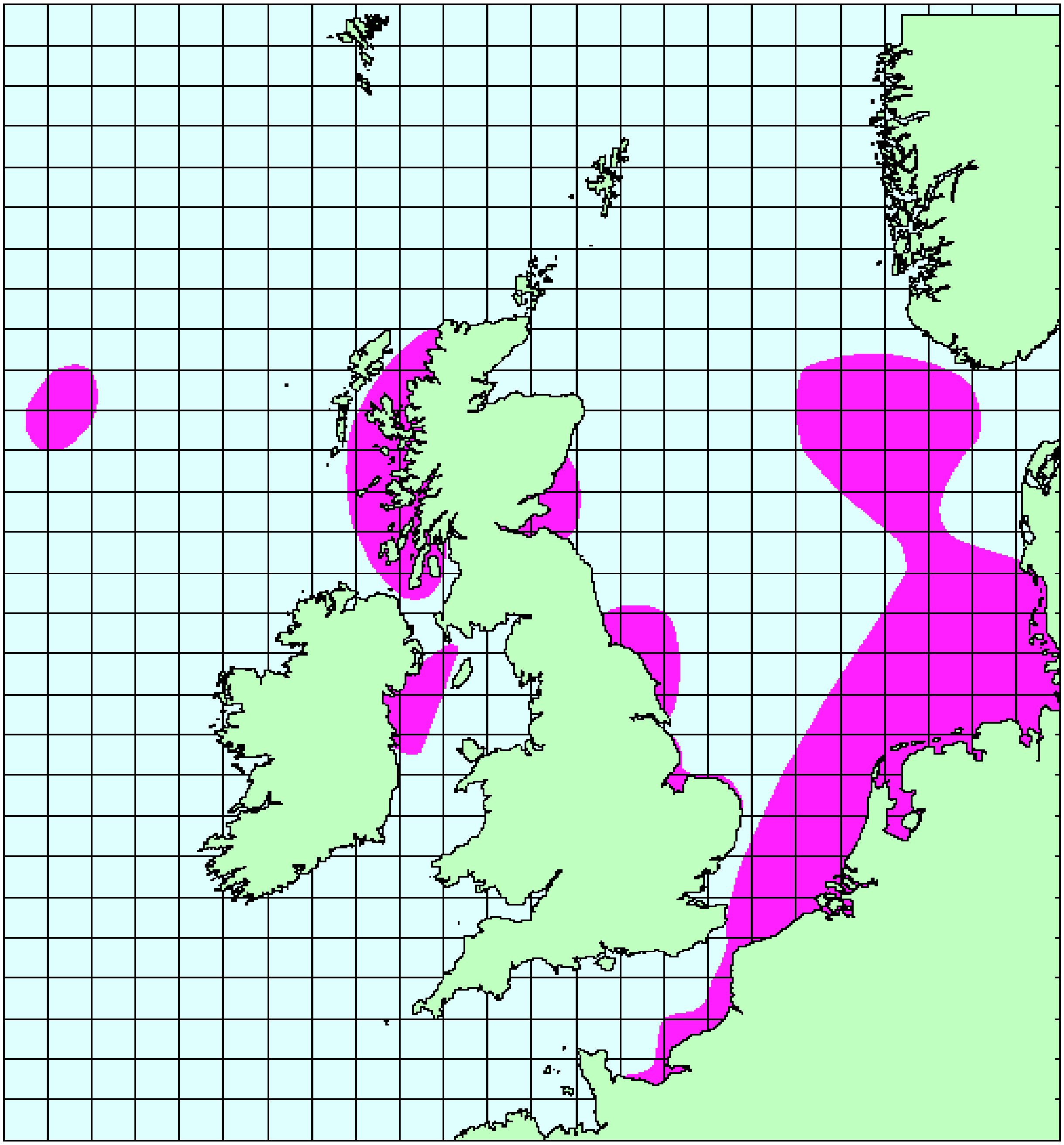

Figure A3.6. Fisheries sensitivity maps in British waters. This example shows cod nursery areas (Coull *et al.*, 1998).

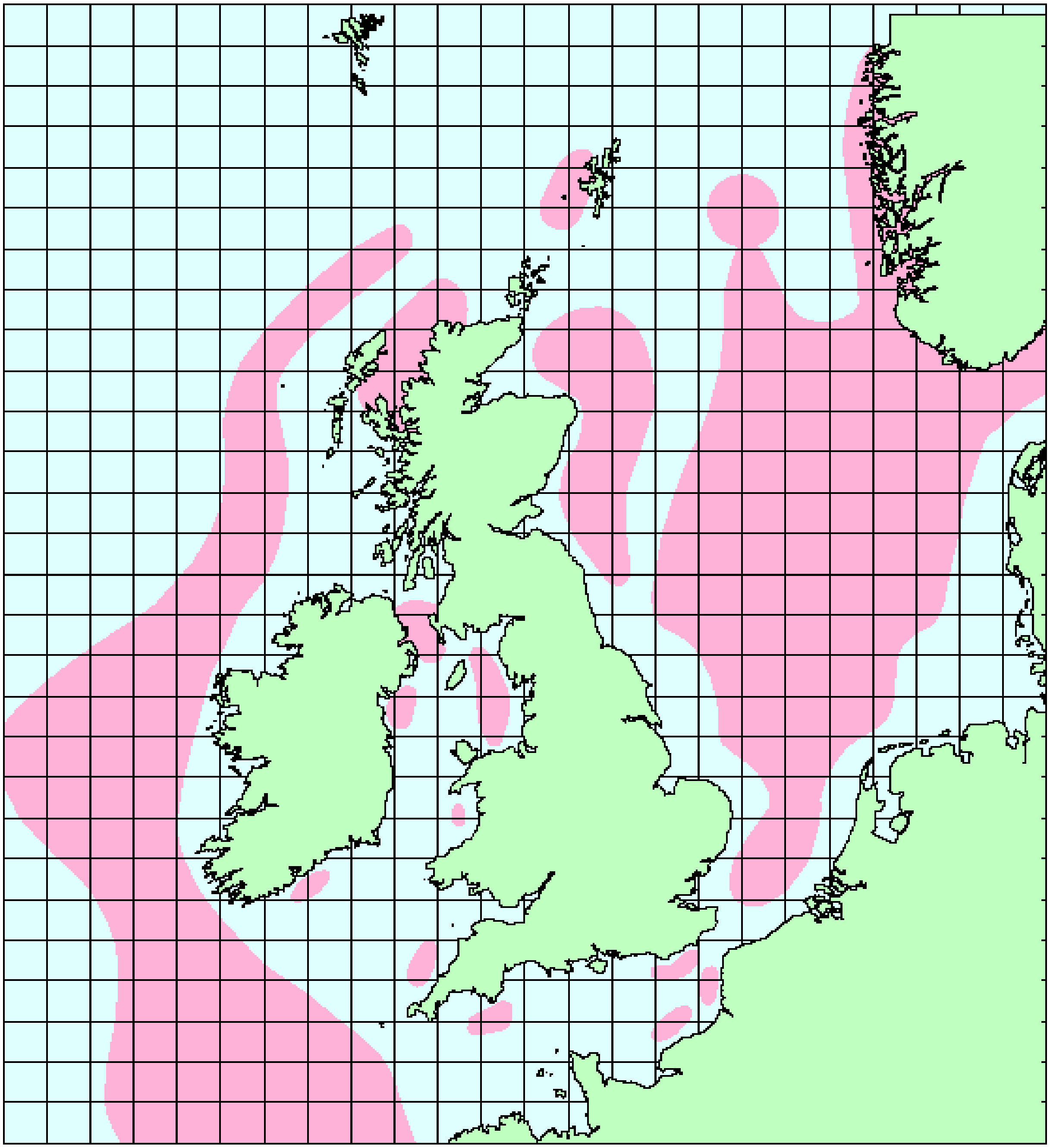

Figure A3.7. Fisheries sensitivity maps in British waters. This example shows seismic sensitivity areas in June (Coull *et al.*, 1998).

- **Behavioural responses** include changes in blow rates, diving times and direction in the short term or displacement from areas in the long-term.
  - Beluga whales transferred from San Diego Bay to Kanehoe Bay, Hawaii with a 12-17dB higher level of background noise shifted their echolocation signal frequency and sound level to compensate for the 'masking' effect of the background noise.
  - Payne & Webb (1971 cited in cited in Gordon & Moscrop, 1996) suggested that continuous low frequency infrasound from heavy shipping would interfere with long range communication in mysticetes, although the hypothesis has not been adequately researched (Gordon & Moscrop, 1996).
  - Artic belugas avoided approaching ships at a range of 45-60km, were displaced by up to 80km and took up to 48 hrs to return to normal activities (Gordon & Moscrop, 1996).
  - Narwhals where observed to 'freeze', exhibiting slow or no movement and huddling in response to approaching vessels (Finley et al., 1990 cited in Gordon & Moscrop, 1996).
  - Dolphins are known to approach and bow-ride vessels, and bottlenose dolphin frequent areas used by pleasure boats and tankers.
  - Short-term flight responses and startle responses are related to the speed of the vessel, e.g. speed boats and jetski, especially when the vessels are driven erratically or directly at the whales or dolphin. Startle and flight responses to speed boats have been shown in grey, fin and blue whales in the USA and in bottlenose dolphin at ranges of 150-300m at in Cardigan Bay, Wales (Evans et al., 1992; Gordon & Moscrop, 1996).
  - Humpback whales were reported to respond to vessels at up to 4km, exhibit longer dives times and shorter blow rates at <2km and attempted to avoid vessels at 0.5-1m, sometimes directing threat behaviour towards the vessels (Bauer & Herman, 1986 cited in Gordon & Moscrop, 1996).
  - Migrating grey whales were reported to avoid playback of oil exploration and producton noise at 110-130dB, and 10% of avoided an air gun array at 164 dB, equivalent to <5km away from a 65.5litre array of 20 air guns, while 90% showed avoidance at 180dB.
  - Bowhead whales were observed to avoid seismic airgun arrays at 2km and reacted to drilling ships and dredging at a received sound level of 115dB, while migrating bowheads were observed to swim rapidly away from a seismic survey vessel 24km away. Bowheads were reported to react to a air gun array fired at 7.5 km, being displaced by 2km and their behaviour affected by at least several hours (Gordon & Moscrop, 1996).
  - Norwegian whalers were reported to have developed multibeam sonar arrays to frighten baleen whales. Sperm whale scattered in response to military sonar arrays between 3.25 – 8.4 Hz and were more timid and less vocal afterwards. Similarly, humpback whales avoid sonar sweeps of 3.1-3.6Hz (Gordon & Moscrop, 1996). Simmonds & Lopez-Jurado (1991) suggested an association between strandings of beaked whales and the operation of naval fleets, which drove the whales shoreward and caused them to strand.
  - Morris (1995) suggested that seismic surveys off the Llyn Peninsula drove away fish and dolphin from the area, with a resultant reduction in foraging seabirds.

Behavioural responses are dependent on the whales activity and habitat and prior experience in association with the sound source, e.g. prior harassment associated with a vessel type. For example, socializing dolphin may approach vessels while feeding or resting dolphin avoid them (Richardson *et al.*, 1995). It can also been seen from above that behavioural responses vary between species.

The zones of influence of noise source will vary with the noise source, the season (and hence temperature, salinity, density and currents of the sea), and species of cetacean. Limited information is available (Richardson *et al.*, 1995) but Vella *et al.* (2001) cite a software model to estimate zones of impact on marine mammals developed by Erbe & Farmer (2000).

The long-term effects of noise related behavioural change or stress has been little studied (Gordon & Moscrop, 1996). Behavioural responses such as stress, flight and deeper diving result in an increased energy demands while the noise disturbance may interfere with feeding. Interference with feeding and hence health, together with disturbance during mating could potentially have long term effects on the reproductive success, and growth and/or recovery of cetacean populations. For example:

- increased shipping noise was implicated in a reduction in humpback numbers in Glacier Bay, Alaska,
- while increased human activities and recreational craft were implicated in the displacement, and reduced numbers of breeding humpback whales off Hawaii (Gordon & Moscrop, 1996).

However, evidence for habituation has also been reported (Vella *et al.,* 2001):

- baleen whales continue to use shipping lanes with heavy traffic;
- bowhead whales continue to return to the Canadian Beaufort Sea even after considerable seismic survey activity in previous years;
- humpback whales tolerated exposure to noise from nearby explosions, and
- grey whales continue to migrate through heavily used shipping lanes on the west coast of North America (Vella *et al.,* 2001).

Richardson *et al.* (1995) reported that toothed whales (odontocetes) generally habituate to areas of consistent noise even after original avoidance.

Man-made noise is likely to cause short term behavioural reactions and temporary displacement of certain cetaceans (Vella *et al*., 2001). Loud, abrupt noise e.g. from seismic survey arrays, underwater explosives, other construction activities and fast moving vessels probably have the most significant effects. Vella *et al*. (2001) suggested that baleen whales that communicate at low frequencies would be the most sensitive cetaceans to operational noise from turbines (also in the low frequency range).

Seismic survey guidelines, intended to minimise acoustic disturbance to marine mammals, suggest (Coull *et al.*, 1998):

- survey vessels will not start up a survey line if cetaceans are seen within 500m;
- survey vessels wait for 20 minutes after the last sighting before proceeding, and
- airgun firing begins with a slow build up of power to allow cetaceans to leave the area.

However, Grellier *et al.* (1995) suggested that a minimum safe distance of 1500m should be adopted as a precaution. JNCC data indicates that there is no evidence of any cetacean suffering injury as a result of seismic operation in UK waters (Coull *et al.*, 1998). In addition, the precautionary approach suggests that:

- acoustic survey, seismic survey, and construction activities should avoid known or suspected breeding areas during the breeding season;
- acoustic survey, seismic survey, and construction activities should avoid cetacean migration routes where known;
- long term studies of the breeding success of resident species should be investigated (e.g. resident bottlenose dolphin in Cardigan Bay and Moray Firth), and
- the cumulative impact of multiple wind farm sites with any given region (e.g. the Irish Sea, North Sea or other sea area) should be investigated especially in the low frequency range, which may interfere with baleen whale migration or communication.

Seals. The effect of underwater noise on sea mammals has been extensively reviewed by Richardson *et al*. (1995). Seals (pinnipeds) vocalize in and out of water and use calls to determine territory and dominance out of water. Underwater hearing sensitivities suggest that seal can hear between 1kHz and 50kHz with threshold sensitivities of 60-82dB but may be able to hear down to 100Hz at 96dB although they may be unable to distinguish low frequency sound above ambient background noise (Vella *et al.,* 2001). However, individuals may exhibit considerable intraspecific variability (Richardson *et al.,* 1995). In air the hearing sensitivities of seals are similar to humans, ranging between about 2kHz and 20kHz, and can perceive sound down to 100Hz at sound levels above 96dB.

Little evidence of physical damage was reported (Vella *et al.,* 2001). In their recent review, Vella *et al.* (2001) reported the following points concerning the effects of noise on seals (cited references in brackets).

- Little is known concerning the effects of underwater noise on seals.
- Underwater communication in seals may be masked by 16dB above ambient at 1100Hz, although operational wind farm noise is unlikely to generate noise of the masking sound level at the above frequency.
- Seals will probably hear air-borne operational wind farm noise, although it was estimated to be only 10-20dB above their lowest audibility threshold at the based of the turbine, and hence probably not significant.
- The most common reaction of seals to noise or visual presence is to enter the water
- Once seals realize a sound source is not a threat they are thought to habituate.
- Artificial island construction and operation had little effect on ringed seal and harbour seals in Alaska which continued to haul out during construction of a hydroelectric facility within 1.6km (Richardson *et al.*, 1995).
- Northern fur seals only displayed an alert posture due to heavy equipment operating within 100m (Gentry *et al.,* 1990).
- Harbour and grey seals displayed a short term avoidance reaction to simulated air gun noise (215-224dB) with no apparent long term effects (Richardson *et al.*, 1995).
- Richardson *et al.* (1995) suggested that seals in water and air may tolerate intense noise pulses from non-explosive and explosive scaring devices, especially if the seal were attracted to an area for feeding or reproduction.
- Seals may habituate to scaring devices attached to fishing nets that emit strong noise pulses of 187-195dB between 11-17kHz.
- No obvious effects were noted due to construction and the first year of operation of the presence of Näsrevet Wind farm, 3km offshore of Gotland, Sweden. The wind farm comprised 5 turbines within 1.5km of a well-established grey seal colony. But seals did avoid vessels that came close to their haul-outs during construction.

Vella *et al.* (2001) concluded that most common effects of noise and vibration on seals was a short term avoidance response, and that they generally habituated to noise once no threat was perceived. They concluded that the effects of noise form offshore wind farm developments on seals was minimal.

The most significant potential impact from noise and visual disturbance is probably due to noise and visual presence (e.g. close inshore boats and human disturbance) at or close to pupping sites. Grey seal pups stay on land for the first weeks of their life and if the mother is disturbed during this period, the mother may retreat to sea and abandon her pups (DWT, 1995). Therefore, pupping sites may be particularly sensitive and should be avoided, especially as sites for land fall of electrical cables from wind farm developments.

Birds. The potential effects of offshore wind farm developments on bird populations have been extensively reviewed by Percival (2001). The reported effects of wind farm development in which studies have been conducted are summarized in table A3.13.

The effect of noise and visual disturbance on birds is not explicit in the studies of the effects of wind farms on bird populations. The avoidance reaction of birds flying around wind farms is probably due to a combination of visual presence and noise, e.g. reduced flight activity within 100m of turbines exhibited by eider duck, although sensitivity probably varies with species. Therefore, the effects of operational noise are probably minimal.

The effect of construction noise and visual presence is likely to be more disruptive but short term. Disturbance is species dependant, some bird species habituating to noise and visual disturbance while others become more nervous. For example, brent geese, redshank, bar-tailed godwit and curlew are more 'nervous' than oystercatcher, turnstone and dunlin. Turnstones will often tolerate one person within 5-10m. However, one person on a tidal flat can cause birds to stop feeding or fly off affecting ca 5 ha for gulls, ca 13ha for dunlin, and up to 50 ha for curlew (Smit & Visser 1993). Goss-Custard & Verboven (1993) report that 20 evenly spaced people could prevent curlew feeding over 1000 ha of estuary (see Elliot *et al.,* 1998). Therefore, increased vessel traffic during construction may disturb bird populations in the vicinity of the chosen harbour/port used to support the development. Although no evidence was found on the sensitivity of disturbance in sea birds offshore, is likely that feeding will be disturbed during construction.

Disturbance may force birds to use other feeding sites and increase their energetic demands and survival (Elliot *et al.,* 1998). While little direct mortality is likely, there may be indirect effects on breeding success. Therefore, breeding and feeding sites for important bird species should be avoided or construction timed to avoid the breeding season. Information on the location of important offshore bird sites and breeding seasons may be obtained from the Sea Bird team at the JNCC.

Chemical contamination

Laboratory or field experiments and observations provide a starting point for assessing if species are adversely affected by the sorts of concentrations of any chemical that occur as a result of human activities or in accidents. The behaviour of chemicals in the marine environment is extremely complex and it is difficult to quantify the most likely effect of an activity. For example, a contaminant concentration at discharge may differ significantly from that experienced by an organism, due to dilution, dissipation, adsorption, absorption, flocculation, sedimentation, chemical change or degradation (of the contaminant), or bioaccumulation. Similarly, the environmental concentration of any given contaminant may be the result of several activities, including aerial deposition.

A very large number of chemicals might affect marine species. The effects of some, such as tri-butyl tin (TBT), are well known. Environmental Quality Standards (EQSs) or Environmental Assessment Levels (EALs) or World Health Organisation Guidance values are available for many contaminants (Environment Agency, 1998) (see Cole *et al.,* 1999 for review). However, scientific knowledge is incomplete or insufficient for many marine species. Contaminants may also exhibit antagonistic or synergistic effects, which are difficult to predict and poorly studied.

Information on the potential sensitivity of the biotopes vulnerable to wind farm developments is shown in Table A3.10 for synthetic chemicals, Table A3.11 for heavy metals and Table A3.12 for hydrocarbons.

Wind farm developments are unlikely to result in significant chemical contamination except from accidental discharges or because of collisions with shipping. The use of cement and grouts may release organic polymers and heavy metals into the local environment (Metoc, 2000). The effects of these contaminants will probably be very localized and depend on the species present in the surrounding sediment. The sensitivities of the benthos and fish species should be assessed on a site-by-site basis. However, the re-suspension of contaminated sediment could potentially re-distribute chemical contaminants over a wide area, and /or contaminate licensed spoil disposal sites. Therefore, sites containing contaminated sediments should be avoided.

The use of anti-fouling paints on turbine structures would be likely to cause adverse environmental effects. For example, TBT based anti-foulants are known to cause a variety of chronic effects (e.g. endocrine disruption) and acute effects (toxicity) in a wide variety of marine organisms at very low concentrations (in the order of nanogrammes per litre) (see Bryan & Gibbs, 1991 and Cole *et al*., 1999 for reviews). In addition, the use of anti-fouling paints may prevent any beneficial impacts resulting from the development of epifaunal communities on the foundations.

Electromagnetic fields

Fish. Sharks and ray are able to detect weak electromagnetic fields. Sharks and rays are able to detect the weak electromagnetic fields generated by muscular activity in other organisms and use the electromagnetic fields to hunt and locate prey (Kalmijn, 1966, 1982).

It has also been suggested that electromagnetic fields influence short range nocturnal migration in the small spotted catshark (dogfish) *Scyliorhinus canicula* and may affect migration in numerous fish species e.g. eels, Atlantic salmon, blue shark, blue fin tuna and plaice (Pals *et al*., 1982; Metcalfe *et al.,* 1993).

The potential effects of electromagnetic fields generated by cabling between wind turbines were reviewed recently by Gill & Taylor (2001). Their experimental work and review concluded that:

- the maximum predicted electric fields emitted by an **un-buried** 3-core undersea 150kV, 600A undersea cable was 1000µV/cm;
- in experiments the small-spotted catshark avoided fields of 1000µV/cm, although the response was highly variable between individuals;
- in experiments, individual small-spotted catshark were attracted to electric fields consistent with prey species, and
- there was a dearth of objective and definitive information relating to the effect of electric fields produced by underwater cables on electrosensitive species.

Gill & Taylor (2001) suggested that further research on the likely electric fields generated by undersea cables was required, together with further research on their potential effects.

Overall, sharks and rays are potentially sensitive to the electromagnetic fields generated by undersea electrical cabling, although the nature of any effects require further study. The cumulative effects of numerous wind farm developments in UK waters, and any potential effect on fish migration should be investigated.

A3.7 Explanatory notes to Table A3.2 to A3.12.

The sensitivity of biotopes likely to be found in areas of wind farm developments to factors likely to occur as a result of wind farm developments are listed in Tables A3.2 to A3.12 below. The appendices include only those biotope researched to date as a part of the Marine Life Information Network (*MarLIN*) Biology and Sensitivity Key Information sub-programme. The sensitivity assessments are extracted from the Microsoft Access database that underpins information presented on the *MarLIN* Web site (www.marlin.ac.uk). The full reviews of the ecology and sensitivity of the biotopes listed are published on the *MarLIN* Web site. Some biotopes have not themselves been researched but their sensitivity is represented by that of a similar biotope.

The *MarLIN* approach to sensitivity assessment is detailed in Tyler-Walters *et al.,* (2001) and on the *MarLIN* Web site. Sensitivity is assessed against 'benchmark' levels of effects, against which the predicted effect of the proposed development, and hence the sensitivity, can be compared. The following sensitivity benchmarks are used for the environmental factors shown in Tables A3.2 to A3.12.

- **Substratum loss** All of substratum occupied by the species or biotope under consideration is removed.
- **Smothering** All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month.
- **Changes in water flow rate** A change of two categories year in water flow rate for one for 1 year. For example from moderately strong (1-3 knots) to very weak (negligible) (see the MNCR scale, Hiscock, 1996).
- **Changes in wave exposure** A change of two ranks on the wave exposure scale e.g., from 'exposed' to 'extremely exposed' for a period of 1 year (see the MNCR scale, Hiscock, 1996).
- **Physical disturbance** Force equivalent to a standard boat anchor landing on or being dragged across the organism e.g., a 5 –10 kg anchor and its chain (used by a 7-8m boat). A single event is assumed for assessment.
- **Displacement** Removal of the organism from the substratum and displacement from its original position onto a suitable substratum.
- **Chemical contaminants** Sensitivity is assessed against the available evidence for the effects of contaminants on the species of interest (or closely related species at low confidence). For example:
  - **high sensitivity** = evidence of mass mortality of a population of the species or community of interest (either short or long term) in response to a contaminant;
  - **intermediate sensitivity** = evidence of reduced abundance, or extent of a population of the species or community of interest (either short or long term) in response to a contaminant, and
  - **low sensitivity** = evidence of sub-lethal effects or reduced reproductive potential of a population of the species or community of interest.

It is accepted that considerable extrapolation is required in our assessments of sensitivity to chemical contaminants and that our levels of evidence and confidence are likely to be low.

The above benchmarks are summarized and further detail and explanation is available in Tyler-Walters *et al.*, (2001) and from *MarLIN* (2002).

Key to the appendices and sensitivity and recoverability scales.

E.C. Hab. Dir = Biotope that is a component of one of the Annex 1 habitats listed in the EC Habitats Directive.

UK BAP = Biotope that is a component of one of the Habitat Action Plans developed as a part of the UK Biotope Action Plans (Convention on Biological Diversity).

Biotope sensitivity (Tyler-Walters *et al.*, 2001).

BIOTOPE SENSITIVITY The intolerance of a habitat or community of species to damage, or death, from an external factor.	
Rank	**Definition (adapted from Hiscock *et al.*, 1999)**
High	Keystone/dominant species in the biotope or habitat are likely to be killed/destroyed by the factor under consideration.
Intermediate	The population(s) of keystone/dominant species in a community may be reduced/degraded by the factor under consideration, the habitat may be partially destroyed or the viability of a species population, diversity and function of a community may be reduced.
Low	Keystone/dominant species in a community or the habitat being considered are unlikely to be killed/destroyed by the factor under consideration and the habitat is unlikely to be damaged. However, the viability of a species population or diversity / functionality in a community will be reduced.
Not sensitive	The factor does not have a detectable effect on structure and functioning of a biotope or the survival or viability of keystone/important species
Not sensitive*	The extent or species richness of a biotope may be increased or enhanced by the factor.
Not relevant	Sensitivity may be assessed as not relevant where communities and species are protected or physically removed from the factor (for instance circalittoral communities are unlikely to be effected by increased emergence regime).

Recoverability potential (*MarLIN*, 2002).

BIOTOPE RECOVERABILITY The ability of a habitat, community or individual (or individual colony) of species to redress damage sustained as a result of an external factor.	
Recoverability is only applicable if and when the impacting factor has been removed or has stopped. Recoverability of a biotope is based on the recoverability of component species but takes into account the time that it is likely to take for the usual proportions of different species to develop. A biotope is considered to have 'recovered' once the habitat and its associated community of species can be recognized as that biotope. However, some species may not have returned to full abundance or might have not returned at all even though the biotope is considered to have 'recovered'.	
Rank	**Definition (adapted from Hiscock *et al.*, 1999)**
None	Recovery is not possible.
Very low	Partial recovery is only likely to occur after about ten years and full recovery may take over 25 years.
Low	Only partial recovery is likely within ten years and full recovery is likely to take up to 25 years.
Moderate	Only partial recovery is likely within five years and full recovery is likely to take up to ten years.
High	Full recovery will occur but will take many months (or more likely years) but should be complete within about five years.
Very high	Full recovery is likely within a few weeks or at most six months.
Immediate	Recovery immediate or within a few days

Evidence / Confidence levels for sensitivity and recoverability assessments.

EVIDENCE / CONFIDENCE The scale indicates an appraisal of the specificity of the information (data) available to support the assessment of sensitivity and recoverability.	
Evidence / Confidence	**Definition (adapted from Hiscock *et al.*, 1999)**
High	Assessment has been derived from sources that specifically deal with sensitivity and recoverability to a particular factor. Experimental work has been done investigating the effects of such a factor.
Moderate	Assessment has been derived from sources that consider the likely effects of a particular factor.
Low	Assessment has been derived from sources that only cover aspects of the biology of the species or from a general understanding of the species. No information is present regarding the effects of factors.
Very low	Assessment derived by 'informed judgement' where very little information is present at all on the species.
Not relevant	The available information does not support an assessment, the data is deficient or no relevant information has been found.
In some cases, it is possible for limited evidence to be considered 'high' for the assessment of sensitivity to a specific factor. For example, if a species is known to lack eyes (or equivalent photoreceptors) then it could confidently be considered 'not sensitive' to visual disturbance and the level of evidence would be recorded as 'high'.	

Table A3.2. Sensitivity to substratum loss.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	High	Very low	Removal of the substratum would result in the loss of *the Modiolus modiolus* bed and its associated community. Therefore, a sensitivity of high has been recorded. The epifaunal organisms such as anthozoans, hydroids, barnacles, ascidians and brittlestars are likely to take some time to recolonize but could potentially recover within five years. However, *Modiolus modiolus* beds, are likely to take considerable time the recolonize and to develop into a bed similar in size and in the diversity and species richness they support. Therefore, a recoverability of very low has been recorded.	High
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Moderate	Most species in the CMS.AfilEcor biotope are infaunal or epifaunal and will be lost if the substratum is removed so the overall sensitivity of the biotope is high. Although there are some mobile species in the biotope, such as the polychaete *Nephtys hombergii*, they are not very fast moving and so are also likely to be removed. They key species do not reach sexual maturity for several years. For example, it takes approximately 5-6 years for *Amphiura filiformis* to grow to maturity and about 3 years for *Echinocardium cordatum*. However, it has been observed that subtidal populations of *Echinocardium cordatum* appear never to reach sexual maturity (Buchanan, 1967) and recruitment is often sporadic, with reports of the species recruiting in only 3 years over a 10 year period (Buchanan, 1966). Intertidal individuals reproduce more frequently so recruitment may be dependent on intertidal populations. The burrowing mud shrimp reaches sexual maturity within the first year, possibly breeding twice a year and producing planktonic larvae so recovery is expected to be rapid. Immigration of adult mud shrimps can also aid recovery. The remaining megafauna in the biotope vary in their longevity and reproductive strategies and some species will reach sexual maturity very rapidly. However, as the key species take a long time to reach sexual maturity it seems likely that a community of *Amphiura filiformis* and *Echinocardium cordatum* may take longer than five years to recover and so a score of moderate is reported.	High
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	Moderate	Most species are infaunal or epifaunal and will be lost if the substratum is removed so the overall sensitivity of the biotope is high. Although some of the mobile species in the biotope may be able to escape, most, such as the harbour crab *Liocarcinus depurator*, the common starfish *Asterias rubens* and the brittlestars are not very fast moving and so are also likely to be removed. Recovery from complete loss of fauna in the sediment is likely to take a long time and so a score of moderate has been reported - see additional information below for full recovery rationale.	High
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	High	Moderate	The species in the biotope are burrowing and will be lost if the substratum is removed so the overall sensitivity of the biotope is high. Recovery could be very slow and is reported to be moderate.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	High	High	Removal of the substratum will result in removal of all the sessile attached species, together with most of the slow mobile species (crustacea, sea urchins and starfish) and a sensitivity of high has been recorded. Recoverability will depend on recruitment from neighbouring communities and subsequent recovery of the original abundance of species, which may take many years, especially in slow growing sponges, anthozoa and *Flustra foliacea*. Therefore, a recoverability of high has been recorded.	High
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	High	High	Characterizing species in the biotope are infaunal and would therefore be removed along with the substratum. Some epifaunal and swimming species, such as amphipods and the harbour crab *Liocarcinus depurator*, may be able to avoid the factor. However, because the species that characterize the biotope would be lost, sensitivity has been assessed to be high and there would be a major decline in species richness. Recoverability has been assessed to be high.	Moderate
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	High	High	The majority of species in the biotope are infaunal and would therefore be removed along with the substratum. Some epifaunal and swimming species, such as amphipods and the harbour crab *Liocarcinus depurator*, may be able to avoid the factor. Because the species that characterize the biotope would be lost, sensitivity is assessed as high and there would be a major decline in species richness. Recoverability is recorded as high.	High
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	High	High	Removal of the substratum would also remove entire populations of the infauna and sessile epifauna in the biotope. Sensitivity is therefore assessed as high and there would be a major decline in species richness. Recoverability is assessed as high.	High
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	High	High	Muddy sand communities are highly sensitive to substratum loss because most species are infaunal and so will be removed. A few mobile demersal species like the shrimp *Crangon crangon* may be able to avoid the factor. However, owing to the loss of the characterizing and important functional infaunal species the biotope would not be recognized so sensitivity has been assessed to be high. Recoverability has been assessed to be high.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	High	High	Removal of the substratum would remove the entire benthic population. Significant recolonization by many species in the biotope might occur within a few months but the biotope would be unlikey to be recognised until after six months. Recoverability is therefore recorded as high.	High
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	High	High	Removal of the substratum would result in removal of the *Limaria hians* byssal carpet and the associated community. Therefore, a sensitivity of high has been recorded. Recoverability would depend on recruitment from the surrounding area and subsequent growth of the *Limaria hians* population and its associated community, and has been assessed as high.	High
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	High	High	Removal of the substratum would remove entire populations of infauna, epifauna and macroalgae. Sensitivity is therefore assessed as high and there would be a major decline in species richness. Recoverability is assessed as high.	High
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	Very High	Biotopes occurring within sandy substrata risk the loss of substratum through both physical (hydrodynamic regime) and anthropogenic activities e.g. aggregate extraction. Under normal circumstances, the sediment is subject to a high level of physical disturbance as a consequence of the hydrodynamic regime, and during storms the upper most layers of sand may be removed, retained in suspension and deposited later. At the benchmark level, sensitivity to substratum loss has been assessed to be intermediate as, whilst the species are mobile and would survive displacement, they would lack a substratum within which to seek protection from predators and within which to feed for the duration of the disturbance event. However, such disturbance is normal and the sand is retained within the system, although the spatial extent and surface form of the substratum may change. Recoverability would be expected to be very high on return to prior conditions, as displaced infauna would re-enter the sand. In contrast, aggregate extraction may be responsible for degradation of the biotope, as sand with associated fauna is lost from the system. Sensitivity would be expected to be higher because a proportion of the population would die and displaced fauna suffer a reduction in habitat.	Low

Table A3.3. Sensitivity to smothering.

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	10. Recovery	Explanation	Evidence / Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Intermediate	High	This biotope is characteristic of areas subject to sediment scour and siltation. Holme & Wilson (1985) reported *Flustra foliacea* dominated communities that were subject to periodic smothering by thin layers of sand, up to ca 5cm in the central English Channel. *Flustra foliacea* and hydroids such as *Nemertesia* spp. and *Tubularia* sp., the bryozoan *Vesicularia spinosa*, the ascidians *Ascidia mentula* and *Dendrodoa grossularia* and the anemone *Urticina felina* were noted in their sand scoured communities. Smothering with a layer of sediment will prevent or reduce feeding and hence growth and reproduction. The biotope will probably survive smothering by 5cm of sediment but the species richness of the biotope will probably decline due to the loss of more sensitive species such as the bryozoan *Bugula* spp., sponges (e.g. *Halichondria panicea*) some ascidians (e.g. *Clavelina lepadiformis* and reduced abundance of *Alyconium digitatum* and the ascidian *Molgula manhattensis*, due to clogging of their filtration apparatus, interrupted feeding and hence reduced growth, and potential short term anoxia under the sediment layer. In addition, associated small species such as prosobranchs, amphipods and worms may be sensitive. Therefore, a sensitivity of intermediate is suggested to reflect the reduced species richness. Recoverability is likely to be prolonged, smothering, however, is likely to favour biotopes dominated by *Urticina felina* (e.g. MCR.Urt.Urt).	Low
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	Very High	The characterizing species are all mobile and capable of burrowing through 5 cm of smothering sediment. Some mortality of the population may, however occur. Tube building polychaetes, including *Polydora ciliata*, would be covered and the population would have to build new tubes at the new sediment surface, with some energetic cost. *Hydrobia ulvae* may not be able to reach the sediment surface. The infaunal burrowing polychaetes would probably be able to relocate to their preferred depth and hence are unlikely to be sensitive. Based on the likelihood that some individuals of some species would perish, the biotope sensitivity is assessed as intermediate but there is unlikely to be a decline in species richness. Recoverability is recorded as very high.	High
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	Intermediate	High	Minchin (1995) reported that degradation of the *Limaria hians* bed resulted in patches of exposed shell-sand, destabilization of the seabed and subsequent burial of surviving *Limaria hians*, which contributed to the decline of the bed. Smothering by 5cm of sediment will probably prevent water flow through the intricate byssal nests of *Limaria hians*, preventing feeding and resulting in local hypoxia. *Limaria hians* is capable of swimming, and some individuals may be able to evacuate their nests. However, a proportion of the *Limaria hians* may be lost. Interstitial or infaunal species are unlikely to be adversely affected, although feeding may be interrupted and mobile species will avoid the effects. Loss of a proportion of the gaping file shell population and resultant degradation of the byssal carpet and loss of some associated epifauna, will result in the loss of species richness. Therefore, a sensitivity of intermediate has been recorded. Recovery of the *Limaria hians* bed will depend on recruitment from outside the population and from survivors and is likely to be rapid.	Low

Biotope Name	**Biotope code**	**Represented by Biotope**	**E.C. Hab. Dir.**	**UK BAP**	**Sensitivity**	**10. Recovery**	**Explanation**	**Evidence/ Confidence**
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Intermediate	High	*Venerupis senegalensis* typically burrows to a depth of 3-5 cm and is often attached to small stones or shell fragments by byssal threads. It is an active suspension feeder and therefore requires its siphons to be above the sediment surface in order to maintain a feeding and respiration current. Kranz (1972) (cited in Maurer *et al.*, 1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. This is likely to apply to the proportion of the *Venerupis senegalensis* population that is not firmly attached by byssal threads. However, those individuals which are attached may be inhibited from relocating rapidly following smothering with 5 cm of sediment and some mortality is expected to occur. Emerson *et al.* (1990) examined smothering and burrowing of *Mya arenaria* after clam harvesting. Significant mortality (2 -60%) in small and large clams occurred only at burial depths of 50 cm or more in sandy substrates. However, they suggested that in mud, clams buried under 25 cm of sediment would almost certainly die. Dow & Wallace (1961) noted that large mortalities in clam beds resulted from smothering by blankets of algae (*Ulva* sp. and *Enteromorpha* sp.) or mussels (*Mytilus edulis*). In addition, clam beds have been lost due to smothering by 6 cm of sawdust, thin layers of eroded clay material, and shifting sand (moved by water flow or storms) in the intertidal. The more mobile burrowing infauna, such as polychaetes, are likely to be able to relocate to their preferred depth following smothering with little or no loss of fitness.Due to their requirement for light for photosynthesis, macroalgae, and especially the encrusting and low growing species such as the Corallinaceae, are likely to be highly sensitive to smothering. Due to the sensitivity of the important characterizing species, *Venerupis senegalensis*, sensitivity for the biotope is assessed as intermediate. Populations of epifauna and macroalgae may be lost so species richness is expected to decline. Recoverability is recorded as high.	Low
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	Holt *et al*. (1998) point out that the deposit of spoil or solid wastes (e.g. from capital dredging) that settle as a mass will smother any habitat it lands on. MCR.ModT beds usually occur in areas of moderate to strong water flow (Holt *et al*., 1998) where accretion is probably reduced. Biogenic reef formation involves the build up of faecal mud, suggesting that adults can move up through the accreting mud to maintain their relative position within the growing mound. However, no information on natural accretion rates was found. Holt *et al*.,(1998) note that there are no studies of the accretion rates that *Modiolus modiolus* beds can tolerate. Therefore, smothering by 5cm of sediment for a month (the benchmark level) is likely to remove a proportion of the horse mussel population. Red algae such as *Delesseria sanguinea* and *Phycodrys rubens* are probably large enough to tolerate smothering by 5cm of sediment, and encrusting coralline algae would probably survive under sediment for one month *Ophiothrix fragilis* and *Balanus crenatus* are likely to be smothered by 5cm of sediment, and are not able to crawl up through the sediment. Hydroids are likely to be sensitive to smothering and siltation, e.g. *Sertularia operculata* were reported to have died when covered by a fine layer of silt during periods of low water movement (Gili & Hughes, 1995). Therefore, a proportion of the horse mussel population and its associated community may be lost due to smothering and a sensitivity of intermediate has been recorded. Hydroids and brittle stars may be more sensitive, therefore, species richness is likely to decline. Recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years. Therefore, a recoverability of low has been recorded.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Low	Intermediate	Smothering by 5 cm of sand is unlikely to adversely affect the important characterizing species that are able to burrow. At the benchmark level sensitivity has been assessed to be low as the mobile polychaetes and crustaceans would burrow through the sediment and recoverability has been assessed to be immediate. However, biotope sensitivity is likely to be higher if the smothering sediment is atypical for the biotope e.g. fine silt or shingle (arising from dredging spoil), and assuming that the smothering materials were not rapidly removed or dispersed by the hydrographic regime, the atypical substrata would dramatically change the nature of the surface substratum. Over the duration of one month species not normally found within the biotope may find conditions favourable for colonization and a transitional community may result and the biotope begin to change to another.	Moderate
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	IGS.Lcon		Yes	Yes	Low	Very high	The biotope will have low sensitivity to smothering by 5cm of sediment because many of the species are burrowing and live within the sediment anyway. The seapen *Virgularia mirabilisis* able to withdraw rapidly into the sediment and appears to be able to recover from smothering (see species review). The brittlestar *Amphiura filiformis*, which inhabits the top 3-4cm of sediment, is also not likely to be sensitive to smothering as it is able to move up through sediment. Many of the other infaunal organisms, such as the polychaetes and bivalves, should also survive smothering. However, some species may be unable to self-clean or dig out and so a small decline in species diversity may occur. However, as most species in the biotope are not especially sensitive to smothering by sediment the sensitivity of the biotope is recorded as low. Sensitivity to other smothering factors, oil for example, may be higher. Recovery should be rapid as species move through the sediment and self clean.	Moderate
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Low	Very high	The majority of the species in the biotope are infaunal. Bivalves, such as *Fabulina fabula*, require their inhalant siphon to be above the sediment surface for feeding and respiration, while the deposit feeding *Magelona mirabilis* extends its contractile palps to the sediment surface in search of food. Smothering with 5 cm of sediment would temporarily halt feeding and respiration and require the infauna to relocate to their preferred depth. The bivalves, polychaetes and amphipods are active burrowers and would be unlikely to suffer mortality. Kranz (1972) (cited in Maurer *et al*., 1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. However, feeding and respiration may be compromised by smothering and so sensitivity is assessed as low. Feeding and respiration would be likely to return to normal soon after relocation and so recoverability is recorded as very high. The epifaunal echinoderms, such as *Astropecten irregularis*, are probably large, mobile and flexible enough to relocate to the surface following smothering. Species richness is likely to remain unchanged.	Low
Venerid bivalves in circalittoral coarse sand or gravel	CGS.Ven		Yes	Yes	Low	Very high	The venerid bivalves are shallow burrowing infauna. They are active suspension feeders and therefore require their siphons to be above the sediment surface in order to maintain a feeding and respiration current. Kranz (1972) (cited in Maurer *et al*, 1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. Smothering will result in temporary cessation of feeding and respiration. The energetic cost may impair growth and reproduction but is unlikely to cause mortality. Biotope sensitivity is therefore assessed as low. The effect on growth and reproduction will probably not extend beyond 6 months and therefore recoverability is assessed as very high. Similarly, the other infaunal species in the biotope are likely to be able to relocate to their preferred depth with only minor energetic cost. *Spatangus purpureus*, for example, together with species in similar biotopes (for instance *Neopentadactyla mixta* and *Branchiostoma lanceolatum*) are mobile and would burrow upwards. Sessile epifauna, will be most affected by smother, such as *Hydroides norvegica*. These species would not be able to relocate following smothering and would not be able to feed or respire. There is therefore likely to be a minor decline in species richness in the biotope.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Amphiura filiformis and *Echinocardium cordatumin* circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	Low	Immediate	The biotope will have low sensitivity to smothering by 5cm of sediment because most species are burrowing and live within the sediment anyway. *Amphiura filiformis* lives within the top 3-4cm of sediment and *Echinocardium cordatum* and *Callianassa subterranea* create burrows in the sediment and many other species in the biotope are also infaunal. There may be an energetic cost expended to either re-establish burrow openings, to self-clean feeding apparatus or to move up through the sediment though this is not likely to be significant. Most animals will be able to re-burrow or move up through the sediment within hours or days so recovery is set at immediate. Sensitivity to smothering by other factors such as oil may be higher.	High
Virgularia mirabilis and *Ophiura* spp. on circalittoral sandy or shelly mud	CMS.VirOph		Yes	Yes	Low	Very high	The biotope will have low sensitivity to smothering by 5cm of sediment because many of the species are burrowing and live within the sediment anyway. The seapen *Virgularia mirabilis* is able to withdraw rapidly into the sediment and appears to be able to recover from smothering (see species review). The brittlestar *Amphiura filiformis*, which inhabits the top 3-4cm of sediment, is also not likely to be sensitive to smothering, as it is able to move up through sediment. Many of the other infaunal organisms, such as the polychaetes and bivalves, should also survive smothering. However, some species may be unable to self-clean or dig out and so a small decline in species diversity may occur. However, as most species in the biotope are not especially sensitive to smothering by sediment the sensitivity of the biotope is recorded as low. Sensitivity to other smothering factors, oil for example, may be higher. Recovery should be rapid as species move through the sediment and self clean.	Moderate

Table A3.4. Sensitivity to increased water flow rates.

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	High	High	This biotope is characterized by species that are tolerant of moderately strong to strong tidal streams and associated sediment scour. *Flustra foliacea* colonies are flexible, robust and reach high abundances in areas subject to strong tidal streams (Stebbing, 1971a; Eggleston, 1972b; Knight-Jones & Nelson-Smith, 1977; Hiscock, 1983, 1985; Holme & Wilson, 1985) and occur in areas subject to very strong tidal streams. While *Flustra foliacea* may not be adversely affected by an increase in water flow to very strong, other species in the biotope such as hydroids and erect bryozoans may be adversely affected by the physical drag caused by very strong water flow, e.g. *Bugula* species or *Molgula manhattensis*. Increased water flow is likely to reduce predation by *Asterias rubens* and large sea urchins, e.g. *Echinus esculentus* was observed to be rolled along the substratum by currents of 2.6 knots or above (Comely & Ansell, 1988). But the increased sediment scour likely to accompany increased water flow rates may be more damaging, resulting in an increase in the extent of biotopes found in higher scour, such as found at the sediment /rock interface, e.g. *Urticina felina* dominated MCR.Urt.Urt. In severe scour, the community may become impoverished, consisting of *Pomatoceros* spp., encrusting bryozoans, encrusting coralline algae and *Balanus crenatus* , e.g. ECR.PomByC. Where the biotopes occur on stones or boulders, increased water flow may result in movement or rolling of the stones and boulders, and hence severe scour and abrasion. The likely associated scour and displacement of some species in the biotope over the year is likely to change the biotope to a different one. Therefore, a sensitivity of high has been recorded. Recoverability is likely to be high.	Low
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	High	High	The nature of the substratum is determined, in part, by the hydrographic regime including water flow rate. Changes in the water flow rate will change the sediment structure and have concomitant effects on the community, as many sediment dwelling species have defined substratum preferences (e.g. *Bathyporeia pelagica*). However, moderate to high velocities of water flow have been reported to enhance settlement of *Lanice conchilega* larvae (Harvey & Bourget, 1995). But an increase in water flow from e.g. moderately strong to very strong, would probably winnow away smaller particulates, increasing average particle size in favour of gravels and pebbles. Therefore, the density of the *Lanice conchilega* population may decline, in part due to lack of suitable substrata with which to build its tubes, and partly from interference with its feeding. The community would probably become dominated by water flow tolerant species, that prefer coarse substratum, while species such as *Arenicola marina* , *Abra alba* , and *Spiophanes bombyx* may be excluded. The biotope may start to resemble the burrowing anemone dominated community IGS.HalEdw. Therefore, a sensitivity of high has been recorded. On return to prior conditions, recoverability is likely to be high.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag	Representative of: SSA.ImuSa.FabMaG SSA.ImuSa.AreFaS SSA.ImuSa.Mellina	Yes	Yes	High	High	Tidal currents determine to a large degree the nature of the substratum, but in addition, they influence the stability of the sediment, the nature of the food supply for benthic organisms, and, in extreme cases may impose direct physical stresses on the community (Warwick & Uncles, 1980). IGS.FabMag typically occurs in areas of 'weak' water flow, where tidal currents are less than 0.5 m/s (Connor *et al*., 1997a). An increase in water flow rate to 'strong' (1.5-3 m/s) for 1 year is likely to have profound effects on the biotope. Erosion of fine sand occurs at 0.3 m/s (Elliott *et al*., 1998) and so substratum characteristics are likely to change significantly. Mackie et al. (1995) noted that the species composition of sandy biotopes varies according to sand grain size and stability. Finer compacted sands favour *Fabulina fabula* and *Magelona sp*. whereas generally coarser looser sands influenced by greater water movement tend to have *Spisula elliptica* and *Nephtys cirrosa*. Warwick & Uncles (1980) recorded the Tellina subcommunity (characterized by *Fabulina fabula* and *Magelona mirabilis*) from sheltered areas of the Bristol Channel with least tidal stress (0-2.5 dynes/cm^2). In areas of greater tidal stress the community was replaced, with the *Spisula* sub-community occuring at 6-7 dynes/cm^2. The benchmark increase in water flow, therefore, is likely to result in the loss of the fine sand substratum along with its characteristic species and replacement with a community adapted for life in more mobile, coarser sands. Sensitivity is therefore assessed as high. Recoverability is recorded as high. Some species will be lost from the biotope (e.g. *Fabulina fabula*) while others are ubiquitous (e.g. *Spiophanes bombyx* and *Abra alba*). There is therefore expected to be a decline in species richness.	Moderate
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	High	High	The intensive working of the uppermost few centimetres of the sediment by the largely deposit feeding community, especially bivalves, produces a fluid faecal-rich surface that is easily re-suspended by even low velocity tidal currents (Rhoads & Young, 1970). The biotope is found in locations of weak (0.5 m/sec) water flow, so the benchmark increase would expose the biotope to strong currents (1.5 -3 m/sec). Over the period of one year loss of the muddy sand surface substratum is likely along with much of the organic matter which the infaunal deposit feeders consume. Whilst infaunal species buried relatively deeply, such as *Echinocardium cordatum* are unlikely to be washed out, smaller bivalves buried at shallower depths may be periodically displaced. The sensitivity of the biotope has been assessed to be high owing to the fact that the biotope may begin to change to another and that benthic food deposits may become limiting. Recoverability has been assessed to be high as a result of recruitment and probable migration from surrounding areas.	Moderate
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Moderate	The biotope is generally found in areas of weak or very weak tidal streams and so is likely to be sensitive to increases in water flow. However, in Scottish sealochs, Howson *et al*. (1994) also found the biotope in areas of moderately strong tidal streams. Tidal currents keep most of the organic particles in the sediment in suspension, which can support suspension feeders such as *Amphiura filiformis* even in low organic content sediments. The horizontal supply of small and light nutritious particles by re-suspension and advective transport has been shown to influence the growth rate of suspension-feeding benthos (Dauwe, 1998). As a suspension feeder without any self-produced feeding current water flow rate will be of primary importance to *Amphiura filiformis*. Individuals respond rapidly to currents by extending their arms vertically to feed. Under laboratory conditions they were shown to maintain this vertical position at currents of 30 cm/s (approx 0.6 knots) (Buchanan, 1964). If water movement were to increase to strong (3-6 knots), individuals would be unlikely to maintain this position and so would retract their arms. Other suspension feeders in the biotope will also be unable to feed if the water flow rate increases by two categories in the water flow scale . The sea pen *Virgularia mirabilis*, for example, would be unable to feed in water flow increased by the benchmark level. A long term increase (i.e. the benchmark level of one year) will change the nature of the top layers of sediment, becoming coarser and possibly unsuitable for some shallow burrowing species such as the brittle stars *Amphiura*. High density aggregations of *Amphiura filiformis* seem to be characteristic of fine sediments with silt/clay values of 10 to 20 % (O'Conner *et al*., 1983) so removal of the finer matter is likely to reduce abundance. In more exposed and coarser sediments *Amphiura filiformis* may	High

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							be replaced by *Amphiura brachiata* that may change the nature of the biotope because *Amphiura brachiata* is a suspension, rather than deposit feeder. Deeper burrowing species such as the thalassinidean crustaceans *Callianassa subterranea* are not likely to be affected by sediment changes at the surface. The overall impact of an increase in water flow rate on the biotope may be the loss of some key species, such as *Amphiura filiformis*, which changes the biotope, and some other species such as sea pens so sensitivity is assessed as high. Recovery is moderate.	
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	Moderate	The biotope is only found in areas of weak or very weak tidal streams and so is likely to be sensitive to increases in water flow. Some tidal flow is necessary for the horizontal supply of small and light nutritious particles by re-suspension and advective transport, influencing the growth rate of suspension-feeding benthos (Dauwe, 1998). However, some suspension feeders in the biotope will be unable to feed if the water flow rate increases by two categories in the water flow scale. The sea pen *Virgularia mirabilis* for example, will retract into the sediment at water currents speeds greater than 0.5m/s (i.e. 1 knot) (Hiscock, 1983). If water speeds remain at this level or above, sea-pens will be unable to extend above the sediment, will be unable to feed and will probably die. Suspension feeding brittlestars have no self-produced feeding currents and so water flow rate will be of primary importance. For example, individuals of *Amphiura filiformis* respond rapidly to currents by extending their arms vertically to feed. Under laboratory conditions, they were shown to maintain this vertical position at currents of 30 cm/s (approx 0.6 knots) (Buchanan, 1964). If water movement were to increase to strong (3-6 knots), individuals would be unlikely to maintain this position and so would retract their arms. Other suspension feeders in the biotope will also be unable to feed if the water flow rate increases by two categories in the water flow scale. A long term increase (i.e. the benchmark level of one year) in water flow will change the nature of the top layers of sediment, becoming coarser and possibly unsuitable for some shallow burrowing species such as the brittle stars *Amphiura*. Therefore, a long term increase in water flow rates would probably result in the loss of many of the key species, and hence the biotope, so sensitivity is reported to be high. Recovery would probably take a long time and is set a moderate.	Low
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	High	High	The biotope occurs in areas of 'weak' to 'moderately strong' tidal streams (Connor *et al.*, 1997b) and is therefore likely to be sensitive to increases in water flow to some degree. An increase in water flow of 2 categories could place the biotope in areas of 'very strong' flow. Although muddy sediments are cohesive and may resist winnowing by strong currents, the turbulence involved in tidal flows of 3 knots and more will most likely alter the substratum. The increase would change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). There would be a decrease in tube building material and the lack of deposition of particulate matter at the sediment surface would reduce food availability for the deposit feeders in the biotope. The resultant energetic cost over one year would be likely to result in some mortality of tube builders and infauna. Overall, the biotope is likely to change to one that is characteristic of coarser sediments. A biotope sensitivity of high is therefore recorded and species richness is expected to decline. Recoverability is assessed as high (see additional information below) especially as silt, from typically high turbidity estuarine conditions, is likely to redeposit rapidly.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	High	Moderate	Eleftheriou & Basford (1983) observed *Cerianthus lloydii* feeding under a wide range of hydrodynamic conditions which showed a great degree of adaption to the prevailing conditions. Under conditions of heavy swell, *Cerianthus lloydii* exhibited behaviour to minimize drag by clumping tentacles in a semi-expanded state with the animal progressively withdrawing into the tube as velocity increased. When a threshold of between 2 and 3 knots was reached the species withdrew totally into the tube. Therefore, the species can tolerate some increase in water flow rate however, if water flow increases to strong then *Cerianthus lloydii* will be unable to feed and if such an increase lasted for a year the species would probably die. The athenarian burrowing anemones in the biotope however, prefer stable sediments that are rarely disturbed by strong water. Therefore, an increase in water flow rates is likely to result in the loss of many species of anemone reducing species diversity. Sensitivity is therefore, reported to be high.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	High	High	This biotope occurs in weak to moderately strong tidal streams. An increase in water flow rate to strong or very strong is likely to physically damage the bed due to drag and modify the substratum in favour of coarser sediments, boulders and bedrock. The additional drag caused by emergent epifauna attached to the carpet, especially if kelps are present, is likely to cause the carpet to be removed in lumps. Holes in the carpet, may then allow mobilization of the sediment, resulting in further damage (see Minchin, 1995). Loss of the carpet will entail loss of its associated community, although individual gaping file shells will probably survive and be transported. Therefore, a sensitivity of high has been recorded. Recoverability is likely to be high.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	High	High	IMX.VsenMtru occurs in sheltered inlets and sea lochs and is characteristic of mixed substrata (Connor *et al.*, 1997a). This suggests that the biotope would be sensitive to wave exposure to some degree. An increase in wave exposure by two categories for one year would be likely to affect the biotope in several ways. Fine sediments would be eroded (Hiscock, 1983) resulting in the likely reduction of the habitat of the infaunal species, e.g. *Venerupis senegalensis*, and a decrease in food availability for deposit feeders. Gravel and cobbles are likely to be moved by strong wave action resulting in damage and displacement of epifauna. Species may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action. For example, large macroalgae, such as *Fucus serratus*, are particularly vulnerable and are likely to suffer damaged fronds and dislodged plants. Furthermore, strong wave action is likely to cause damage or withdrawal of delicate feeding and respiration structures of species within the biotope resulting in loss of feeding opportunities and compromised growth. It is likely that high mortality would result and therefore a sensitivity of high is recorded and species richness is expected to decline. Recoverability is recorded as high.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	High	The biotope typically occurs in locations with a range of wave exposures. Wave action is a particularly important physical factor in the shallow subtidal as oscillatory wave action disturbs the sand and can cause large scale sediment transport. Although, the biotope is dominated by errant polychaetes and small crustacean species tolerant of abrupt changes in wave exposure, over the period of one year it is likely that the sand would be disrupted to a greater degree and the finest grades lost. Consequently, some species may begin to experience conditions outside of their habitat preferences e.g. *Bathyporeia pelagica*, and decline in abundance. Sensitivity has been assessed to be intermediate and recoverability high as, on return to prior conditions adults are likely to migrate into the biotope.	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	Intermediate	High	CGS.Ven occurs in areas of 'moderately strong' or 'weak' flow (Connor et al., 1997a). The benchmark change in water flow rate would place the biotope in areas of 'strong' or 'very strong' flow for one year. The increased water flow rate will change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles, and may also create a high sediment mobility (Hiscock, 1983). The habitat would therefore become less suitable for burrowing deposit feeders, e.g. *Spatangus purpureus*, due to the change in substratum characteristics and decreased food supply. The very strong tidal stream would also place the suspension feeders outside their habitat preferences and it is likely that there would be some energetic cost, probably due to interference with respiration and feeding. These changes are likely to result in some mortality, particularly of deposit feeders, and a decline in species richness. Recoverability is assessed as high.	Low
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	MCR.ModT occurs in tide swept locations in moderately strong to strong tidal streams. An increase in water flow may interfere with feeding in *Modiolus modiolus* since in flume studies the inhalant siphon closed by about 20 % in currents above 55 cm/sec (Wildish *et al*., 2000). Similarly, fouling of the horse mussels increases their sensitivity to dislodgement by strong tidal streams (Witman, 1985). Comely (1978) suggested that areas exposed to strong currents required an increase in byssus production, at energetic cost, and resulted in lower growth rates. Therefore, an increase in water flow rates to very strong may result in loss of a proportion of the population, depending on the size of the beds, the level of fouling or the nature of the substratum. Horse mussel beds on coarse or hard substrata may be less sensitive than beds on mobile, fine sediments. Epifauna such as hydroids may be damaged, or their feeding prevented by strong water flow (Gili & Hughes, 1995). The characterising hydroids may be replaced by hydroid species more tolerant of strong water flow such as *Tubularia indivisa*. Brittlestars such as *Ophiothrix fragilis* may be swept away by increased water flow, e.g. above a certain water speed (25 cm/s) the feeding arms are withdrawn from the water column (Warner & Woodley, 1975; Hiscock, 1983). At water speeds above about 28 cm/s individuals or even small groups may be displaced from the substratum and they have been observed being rolled along the seabed by the current (Warner, 1971). Living in dense aggregations may reduce displacement of brittlestars by strong currents (Warner & Woodley, 1975) and living within crevices in the horse mussel beds will presumably provide some protection. Sea urchins, such as *Echinus esculentus*, are known to be swept away by strong currents and, although not killed, may be removed from the community and unable to return until water flow rates return to prior conditions. Overall, therefore a proportion of the horse mussel population may be removed, together with several members of the community and a sensitivity of intermediate has been recorded. The biotopes SCR.ModCvar and SCR.ModHAs may be more sensitive to dislodgement due to there muddy substratum. The associated community will probably change from species tolerant of siltation and low water flow to species tolerant of higher water flow, perhaps coming to resemble MCR.ModT. Horse mussel recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years Therefore, a recoverability of low has been recorded.	Moderate

Table A3.5. Sensitivity to decreases in water flow.

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Amphiura filiformis and *Echinocardium cordatumin* circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Moderate	*Amphiura filiformis* shows a lack of activity in still water and low current speeds can impede feeding because it may reduce the transport of organic particles. Therefore, if water flow rate changes by the benchmark level of two categories for a year feeding would be significantly impaired and viability of the population reduced. Over the period of a year many individuals would be likely to die so sensitivity is assessed as high. In slightly less energetic conditions and finer sediment the biotope CMU.SpMeg, which includes high abundance of sea pens and burrowing megafauna such as *Callianassa subterranea*, is more likely to be present.	High
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	High	High	This biotope is characterized by species that are tolerant of moderately strong to strong tidal streams and associated sediment scour. A decrease in water flow rates will decrease sediment sour, however, in the proximity of sediment is likely to result in greater siltation. Water movement is essential for suspension feeders such as hydroids, bryozoans, sponges, amphipods and ascidians to supply adequate food, remove metabolic waste products, prevent accumulation of sediment and disperse larvae or medusae. In addition, water flow was shown to be important for the supply of suitable hard substrata for colonization, and hence the development of bryozoan communities (Eggleston, 1972b; Ryland, 1976). Hydroids are also expected to be abundant where water movement is sufficient to supply adequate food but not cause damage (Hiscock, 1983; Gili & Hughes, 1995). For example, Sertularia operculata was observed to die within a few months when transplanted from Lough Ine rapids to sheltered water, due to the build up of a layer of silt (Round, *et al.*, 1961). Therefore, a decrease in water flow from e.g. moderately strong to very weak is likely to encourage colonization by other species of hydroids, ascidians, sponges and anemones, and may increase the risk of sea urchin predation, resulting in significant changes in the community and possibly the loss of the dominant hydroid/ bryozoans turf. Therefore, a sensitivity of high has been recorded. Recoverability is likely to take up to 5 years	Low
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	IGS.Lcon		Yes	Yes	High	High	The nature of the substratum is determined, in part, by the hydrographic regime including water flow rate. Changes in the water flow rate will change the sediment structure and have concomitant effects on the community. Reduced water flow is a factor that has been identified as affecting the density *of Lanice conchilega*. Recruitment to the benthos is reduced under low flow as a result of reduced turbulence (Harvey & Bourget, 1995) (see recruitment processes). Furthermore, at the benchmark level, decreased water flow rate would probably increase deposition of finer sediments, and increase siltation. The sediment would probably begin to favour deposit feeders and detritivores, to the detriment of the suspension feeders. The average grain size of the sediment would be reduced, and the community may start to be replaced over a period of one year by communities characteristic of muddy sands, with a higher proportion of deposit feeding species, perhaps e.g. IMS.MacAbr or IMS.EcorEns. Therefore, a sensitivity of high has been recorded. On return to prior conditions recoverability has been assessed to be high	Low
Virgularia mirabilis and *Ophiura* spp. on circalittoral sandy or shelly mud	CMS.VirOph		Yes	Yes	High	Moderate	The biotope exists in habitats such as sea lochs, where tidal streams are already very weak so a decrease in flow rate would result in almost non-moving water. In these enclosed or semi-enclosed water bodies, negligible water flow may result in some deoxygenation of the overlying water and the loss of some sensitive species. The sea pen *Virgularia mirabilis* for example, has high sensitivity to deoxygenation and may die. Tidal currents keep most of the organic particles in the sediment in suspension, which can support suspension feeders even in low organic content sediments. Therefore, if water movement becomes negligible suspended organic particles available to filter feeders such as the sea pens will decline. Growth and fecundity will be affected, and over a period of a year may result in the death of sea pens. *Amphiura filiformis* shows a lack of activity in still water and low current	Moderate

Biotope Name	**Biotope code**	**Represented by Biotope**	**E.C. Hab. Dir.**	**UK BAP**	**Sensitivity**	**Recovery**	**Explanation**	**Evidence/ Confidence**
							speeds can impede feeding because it may reduce the transport of organic particles. Therefore, if water flow rate changes by the benchmark level of two categories for a year feeding would be significantly impaired and viability of the population reduced. The overall impact on the biotope is likely to be the loss of a few key species such as sea pens and so sensitivity is assessed as high. Recovery may take longer than five years and so is assessed as moderate.	
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	High	Very High	The type of sediment present is determined by the type of substratum available and strength of water movement, so that sediments within an area reflect the average energy conditions of that area (Hiscock, 1983). In the IGS.NcirBat biotope water flow may fluctuate between weak to strong and well sorted medium and fine grained sands are typical of the biotope. A reduction in the water flow rate for a period of one year would probably reduce the degree of sorting of grain size as current velocity within the close proximity of the seabed drops below the critical erosion velocity causing bedload transport of medium and coarse grained sands to cease. During periods of low wave action, deposition of finer sediments from suspension may occur so that the composition of the substratum begins to change. Finer sediments and increased stability may enhance the survival of more sedentary forms of polychaete and bivalves and the biotope begin to change to another. Species richness is likely to rise. Sensitivity has been assessed to be high as considerable changes in community composition may occur and the biotope no longer be recognized. On return to prior conditions, recoverability has been assessed to be very high.	Moderate
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Intermediate	High	IGS.FabMag typically occurs in areas of 'weak' water flow (Connor *et al.*, 1997a). The benchmark reduction in water flow would place the biotope in the 'very weak' category for 1 year. The likely result would be increased deposition of fine particles altering the substratum characteristics. Deposit feeders tend to dominate over suspension feeders in areas of higher proportions of silt and clay, as muddy sediment and high turbidity tend to clog filtering organs (Elliott *et al.*, 1998). The characterizing species, *Fabulina fabula* and *Magelona mirabilis*, are deposit feeders and are not likely to be sensitive to the change. The suspension feeding venerid bivalves, such as *Chamelea gallina*, are capable of generating their own feeding and respiration currents but may be inhibited by clogging of feeding and respiration structures. They are probably capable of clearing these structures (e.g. Grant & Thorpe, 1991; Navarro & Widows, 1997), but the energetic cost over a year may result in some mortality and so the biotope sensitivity is assessed as intermediate with a minor decline in species richness. Recoverability is assessed as high.	Low

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Venerid bivalves in circalittoral coarse sand or gravel	CGS.Ven		Yes	Yes	Intermediate	High	CGS.Ven occurs in areas of 'moderately strong' or 'weak' flow (Connor *et al.*, 1997a). The benchmark change in water flow rate would place the biotope in areas of 'very weak' flow for one year. The venerid bivalves are capable of generating their own feeding and respiration currents but may be inhibited by clogging of feeding and respiration structures. They are probably capable of clearing these structures (e.g. Grant & Thorpe, 1991; Navarro & Widows, 1997), but the energetic cost over a year may result in some mortality and so the biotope sensitivity is assessed as intermediate with a minor decline in species richness. Recoverability is assessed as high. The community is likely to undergo a shift in composition with deposit feeders becoming more prevalent.	Low
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	Flume experiments suggested that *Modiolus* sp. could deplete the seston directly over dense beds when water flow is low, resulting in a reduction in the density of the mussel bed (Wildish & Kristmanson, 1984, 1985: Holt et al., 1998). *Alcyonium digitatum* prefers areas of high water flow, and its abundance may decline in reduced water flow. Brittlestars such as *Ophiothrix fragilis* are passive suspension feeders and require water flow to supply them with food particles. A reduction in water flow may reduce food availability, however *Ophiothrix fragilis* can survive considerable loss of body mass during reproductive periods (Davoult *et al.*, 1990) so restricted feeding may be tolerated, and this species is found in sheltered areas of reduced water flow. Hydroids and bryozoans also require water flow to provide them with food particles but hydroid species in deeper water, with generally less water movement, have higher biomass, are larger and longer-lived than in shallower waters. Therefore, a reduction in water flow may reduce the density of the horse mussel bed, and may change the associated community favouring species that prefer low water flow. The biotope MCR.ModT may come to resemble the sheltered horse mussels beds (SCR.ModCvar or SCR.ModHAs). In addition, in the sheltered biotopes decreased water flow will increase the risk of deoxygenated conditions. Overall, therefore, a sensitivity of intermediate has been recorded. Horse mussel recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years. Therefore, a recoverability of low has been recorded.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	Intermediate	High	This biotope occurs in weak to moderately strong tidal streams. Decreases in water flow will favour epifaunal species tolerant of reduced water flow over species that prefer high water flow rates, so that the composition of the epifaunal species will change. A decrease in water flow to negligible in the absence of wave induced water movement may result in a stagnant deoxygenated water and increased siltation. Although, *Limaria hians* probably produces a strong ventilation current for feeding it require water flow to remove waste products and provide adequate food. Therefore, a proportion of the population, and the associated species may be lost and a sensitivity of intermediate has been recorded.	Very Low
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud	IMS.MacAbr		Yes	No	Low	Very High	The IMS.MacAbr biotope occurs in areas of weak water flow so the benchmark decrease in water flow rate will expose the community to conditions of almost negligible water flow. Whilst a decreased water flow would favour the deposition of particulate organic matter from suspension, the additional food resource is unlikely to be of any particular significance in this already organically enriched environment. More importantly, a decreased water flow rate may limit the dispersion of planktonic larve, to the extent that larvae settle back into the parent population where larvae in the earliest stages are likely to be preyed upon by deposit feeders, including their parents. A sensitivity assessment of low has been made owing to the reduced viability of the population that may result from poor larval recruitment. Recovery has been assessed to be very high as the adults of the important characterizing species will remain and produce again, with the exception of *Lagis koreni*, which reproduces once then dies. However, larval plankton of this species are likely to be transported into the biotope from other locations and re-colonization of the substrata may also occur through re-distribution of adults.	Moderate

Biotope Name	Biotope code	Represented by Biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	Low	Very High	The biotope is found in areas of moderately strong and weak tidal currents and so is not likely to be very sensitive to a decrease in water flow. The supply of food particles may decrease in low flow conditions but this should only affect sub-lethal processes of growth and reproduction so sensitivity of the biotope is expected to be low. The species composition within the biotope may change. On return to pre-impact conditions, normal growth etc. should recover rapidly.	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Not Sensitive	Not Relevant	IMX.VsenMtru occurs in low energy environments such as sheltered beaches where the water flow is typically "weak" (Connor *et al.*, 1997a). The majority of species in the biotope are infaunal and are capable of generating their own respiration and feeding currents. These species are unlikely to be sensitive to a decrease in water flow rate. However, decreased water flow rate is likely to lead to increased deposition of fine sediment (Hiscock, 1983) and therefore decreased availabilty of suitable substrata for the attachment of macroalgae and epifauna. Therefore there may be a minor decline in species richness in the biotope.	Low
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Not sensitive	Not relevant	The biotope occurs in areas of 'weak' tidal streams (Connor *et al.*, 1997b), the characterizing species are adapted to low flow conditions and hence the biotope is unlikely to be sensitive to a further reduction in water flow.	Moderate

Table A3.6. Sensitivity to increased wave action.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	High	High	This biotope occurs in weak to moderately strong tidal streams. An increase in water flow rate to strong or very strong is likely to physically damage the bed due to drag and modify the substratum in favour of coarser sediments, boulders and bedrock. The additional drag caused by emergent epifauna attached to the carpet, especially if kelps are present, is likely to cause the carpet to be removed in lumps. Holes in the carpet, may then allow mobilization of the sediment, resulting in further damage (see Minchin, 1995). Loss of the carpet will entail loss its associated community, although individual gaping file shells will probably survive and be transported elsewhere. Therefore, a sensitivity of high has been recorded. Recoverability is likely to be high.	Low
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	High	High	The biotope occurs in 'sheltered', 'very sheltered' and 'extremely sheltered' locations (Connor *et al.*, 1997a). An increase in wave exposure is likely to have adverse effect on the biotope. Rees *et al.* (1977) found that only 1% of the *Lanice conchilega* population in Colwyn Bay apparently survived after winter storms. Presumably, the oscillatory action on the prominent tube served to dislodge the species. An increase in wave exposure would also lead to erosion of the substratum in the shallowest locations, which will alter the extent of suitable habitat available for the community. Sensitivity has been assessed to be high as important characterizing species would be lost and the habitat damaged. On return to prior conditions recoverability is likely to be high	Moderate
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	High	High	The benchmark increase in wave exposure would place the biotope in the 'exposed' and 'very exposed' categories (see glossary) (Connor *et al.*, 1997a). Oscillatory water movement occurs down to about 60m when a force 8 wind is blowing at the sea surface (Hiscock, 1983) and therefore the biotope will definitely experience the effects of increased wave exposure. Hiscock (1983) reviewed the effects: • fine sediments would be eroded resulting in the likely reduction of the habitat of many infaunal species and a decrease in food availability for deposit feeders; • species may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action; • strong wave action is likely to cause damage or withdrawal of delicate feeding and respiration structures of species within the biotope resulting in loss of feeding opportunities and compromised growth. Warwick & Uncles (1980) noted that the *Tellina* sub-community in Camarthen Bay only occurs in the sheltered areas. The characterizing species are described as being fragile, for instance, *Fabulina fabula* with a "thin, brittle shell" and *Magelona mirabilis* with "long, delicate palps". It is likely that the benchmark increase in wave exposure would precipitate a shift in substratum type and associated community and the development of a more dynamic biotope with high sediment transport and more robust species, such as *Spisula elliptica* and *Nephtys cirrosa*. Biotope sensitivity is therefore assessed as high with a major decline in species richness. Recoverability is recorded as high	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	High	Intermediate	Eleftheriou & Basford (1983) observed *Cerianthus lloydii* feeding under a wide range of hydrodynamic conditions and showed a great degree of adaption to the prevailing conditions. Under conditions of heavy swell, *Cerianthus lloydii* exhibited behaviour to minimize drag by clumping tentacles in a semi-expanded state with the animal progressively withdrawing into the tube as velocity increased. When a threshold of between 2 and 3 knots was reached, the species withdrew totally into the tube. Therefore, the species can tolerate some increase in water flow rate however, if water flow increases to strong then *Cerianthus lloydii* will be unable to feed and if such an	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							increase lasted for a year the species would probably die. The athenarian burrowing anemones in the biotope however, prefer stable sediments that are rarely disturbed by strong water. Therefore, an increase in water flow rates is likely to result in the loss of many species of anemone reducing species diversity. Sensitivity is therefore, reported to be high. See additional information for recovery.	
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Moderate	The biotope is generally found in areas of weak or very weak tidal streams and so is likely to be sensitive to increases in water flow. However, in Scottish sealochs, Howson *et al.* (1994) also found the biotope in areas of moderately strong tidal streams. Tidal currents keep most of the organic particles in the sediment in suspension which can support suspension feeders such as *Amphiura filiformis* even in low organic content sediments. The horizontal supply of small and light nutritious particles by resuspension and advective transport has been shown to influence the growth rate of suspension-feeding benthos (Dauwe, 1998). As a suspension feeder without any self-produced feeding current water flow rate will be of primary importance to *Amphiura filiformis*. Individuals respond rapidly to currents by extending their arms vertically to feed. Under laboratory conditions they were shown to maintain this vertical position at currents of 30 cm/s (approx 0.6 knots) (Buchanan, 1964). If water movement were to increase to strong (3-6 knots), individuals would be unlikely to maintain this position and so would retract their arms. Other suspension feeders in the biotope will also be unable to feed if the water flow rate increases by two categories in the water flow scale (see benchmarks). The sea pen *Virgularia mirabilis*, for example, would be unable to feed in water flow increased by the benchmark level. A long term increase (i.e. the benchmark level of one year) will change the nature of the top layers of sediment, becoming coarser and possibly unsuitable for some shallow burrowing species such as the brittle stars *Amphiura*. High density aggregations of *Amphiura filiformis* seem to be characteristic of fine sediments with silt/clay values of 10 to 20% (O'Conner *et al*., 1983) so removal of the finer matter is likely to reduce abundance. In more exposed and coarser sediments *Amphiura filiformis* may be replaced by *Amphiura brachiata* that may change the nature of the biotope because *A. brachiata* is a suspension, rather than deposit feeder. Deeper burrowing species such as the thalassinidean crustaceans *Callianassa ubterranean* are not likely to be affected by sediment changes at the surface. The overall impact of an increase in water flow rate on the biotope may be the loss of some key species, such as *Amphiura filiformis*, which changes the biotope, and some other species such as sea pens so sensitivity is assessed as high. Recovery is moderate.	High
Virgularia mirabilis and *Ophiura spp*. On circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	Moderate	The biotope is only found in areas of weak or very weak tidal streams and so is likely to be sensitive to increases in water flow. Some tidal flow is necessary for the horizontal supply of small and light nutritious particles by re-suspension and advective transport, influencing the growth rate of suspension-feeding benthos (Dauwe, 1998). However, some suspension feeders in the biotope will be unable to feed if the water flow rate increases by two categories in the water flow scale. The sea pen *Virgularia mirabilis* for example, will retract into the sediment at water currents speeds greater than 0.5m/s (i.e. 1 knot) (Hiscock, 1983). If water speeds remain at this level or above, sea-pens will be unable to extend above the sediment, will be unable to feed and will probably die. Suspension feeding brittlestars have no self-produced feeding currents and so water flow rate will be of primary importance. For example, individuals of *Amphiura filiformis* respond rapidly to currents by extending their arms vertically to feed. Under laboratory conditions, they were shown to maintain this vertical position at currents of 30 cm/s (approx 0.6 knots) (Buchanan, 1964). If water movement were to increase to strong (3-6 knots), individuals would be unlikely to maintain this position and so would retract their arms. Other suspension feeders in the biotope will also be unable to feed if the water flow rate increases by two categories in the water flow scale. A long term increase (i.e. the benchmark level of one year) in water flow will change the nature of the top layers of sediment, becoming coarser and possibly unsuitable for some shallow burrowing species such as the brittle stars *Amphiura*. Therefore, a long term increase in water flow rates would probably result in the loss of	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							many of the key species, and hence the biotope, so sensitivity is reported to be high. Recovery would probably take a long time and is set a moderate.	
Nephtys cirrosa and *Bathyporeia* spp. In infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	High	The biotope typically occurs in locations with a range of wave exposures. Wave action is a particularly important physical factor in the shallow subtidal as oscillatory wave action disturbs the sand and can cause large scale sediment transport. Although, the biotope is dominated by errant polychaetes and small crustacean species tolerant of abrupt changes in wave exposure, over the period of one year it is likely that the sand would be disrupted to a greater degree and the finest grades lost. Consequently, some species may begin to experience conditions outside of their habitat preferences e.g. *Bathyporeia pelagica*, and decline in abundance. Sensitivity has been assessed to be intermediate and recoverability high, as on return to prior conditions adults are likely to migrate into the biotope.	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	Intermediate	High	CGS.Ven occurs in areas of 'moderately strong' or 'weak' flow (Connor *et al.*, 1997a). The benchmark change in water flow rate would place the biotope in areas of 'strong' or 'very strong' flow for one year. The increased water flow rate will change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles, and may also create a high sediment mobility (Hiscock, 1983). The habitat would therefore become less suitable for burrowing deposit feeders, e.g. *Spatangus purpureus*, due to the change in substratum characteristics and decreased food supply. The very strong tidal stream would also place the suspension feeders outside their habitat preferences and it is likely that there would be some energetic cost, probably due to interference with respiration and feeding. These changes are likely to result in some mortality, particularly of deposit feeders, and a decline in species richness. Recoverability is assessed as high.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Intermediate	High	IMX.VsenMtru occurs in wave protected areas where water flow is typically "weak" (Connor *et al.*, 1997). An increase in water flow of 2 categories would place the biotope in areas of "strong" flow. The increase would change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). The underlying sediment in the biotope has a high silt content; a substratum which would not occur in very strong tidal streams. Therefore, the infaunal species, such as *Venerupis senegalensis*, would be outside their habitat preferences and some mortality would be likely to occur, probably due to interference with feeding and respiration. Additionally, the consequent lack of deposition of particulate matter at the sediment surface would reduce food availability for the deposit feeders in the biotope. The resultant energetic cost over one year would also be likely to result in some mortality. A biotope sensitivity of intermediate is therefore recorded and species richness is expected to decline. Recoverability is assessed as high. The expected change in sediment composition would favour the epifauna and macroalgae which would probably become more abundant.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence

Biotope Name	**Biotope code**	**Represented by biotope**	**E.C. Hab. Dir.**	**UK BAP**	**Sensitivity**	**Recovery**	**Explanation**	Evidence/ Confidence
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	Intermediate	High	The intensive working of the uppermost few centimetres of the sediment by the largely deposit feeding community, especially bivalves, produces a fluid faecal-rich surface that is easily re-suspended by even low velocity tidal currents (Rhoads & Young, 1970). The biotope is found in locations of weak (< 0.5 m/sec) water flow, so the benchmark increase would expose the biotope to strong currents (1.5 –3 m/sec). Over the period of one year loss of the muddy sand surface substratum is likely along with much of the organic matter which the infaunal deposit feeders consume. Whilst infaunal species buried relatively deeply, such as *Echinocardium cordatum* are unlikely to be washed out, smaller bivalves buried at shallower depths may be periodically displaced. The sensitivity of the biotope has been assessed to be high owing to the fact that the biotope may begin to change to another and that benthic food deposits may become limiting. Recoverability has been assessed to be high as a result of recruitment and probable migration from surrounding areas.	Moderate
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	MCR.ModT occurs in tide swept locations in moderately strong to strong tidal streams. An increase in water flow may interfere with feeding in *Modiolus modiolus* since in flume studies the inhalent siphon closed by about 20% in currents above 55 cm/sec (Wildish *et al.*, 2000). Similarly, fouling of the horse mussels increases their sensitivity to dislodgement by strong tidal streams (Witman, 1985). Comely (1978) suggested that areas exposed to strong currents required an increase in byssus production, at energetic cost, and resulted in lower growth rates. Therefore, an increase in water flow rates to very strong may result in loss of a proportion of the population, depending on the size of the beds, the level of fouling or the nature of the substratum. Horse mussel beds on coarse or hard substrata may be less sensitive than beds on mobile, fine sediments. Epifauna such as hydroids may be damaged, or their feeding prevented by strong water flow (Gili & Hughes, 1995). The characterising hydroids may be replaced by hydroid species more tolerant of strong water flow such as *Tubularia indivisa*. Brittlestars such as *Ophiothrix fragilis* may be swept away by increased water flow, e.g. above a certain water speed (25 cm/s) the feeding arms are withdrawn from the water column (Warner & Woodley, 1975; Hiscock, 1983). At water speeds above about 28 cm/s individuals or even small groups may be displaced from the substratum and they have been observed being rolled along the seabed by the current (Warner, 1971). Living in dense aggregations may reduce displacement of brittlestars by strong currents (Warner & Woodley, 1975) and living within crevices in the horse mussel beds will presumably also provide some protection. Sea urchins, such as *Echinus esculentus*, are known to be swept away by strong currents and, although not killed, may be removed from the community and unable to return until water flow rates return to prior conditions. Overall, therefore a proportion of the horse mussel population may be removed, together with several members of the community and a sensitivity of intermediate has been recorded. The biotopes SCR.ModCvar and SCR.ModHAs may be more sensitive to dislodgement due to there muddy substratum. The associated community will probably change from species tolerant of siltation and low water flow to species tolerant of higher water flow, perhaps coming to resemble MCR.ModT. Horse mussel recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years. Therefore, a recoverability of low has been recorded.	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	Very High	Many species in the biotope are vulnerable to physical abrasion. The tubes of the polychaetes are bound only with mucous and are therefore likely to damaged by the benchmark level of abrasion. The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a dragging anchor. Biotope sensitivity is therefore recorded as intermediate. Recoverability is recorded as very high as damage at the benchmark level will be restricted in extent. For large scale physical disturbance, sensitivity will be more similar to 'substratum removal' above.	Low
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Low	Very High	The strong tidal streams that typify this biotope are probably more important as water movement than wave induced oscillatory flow. Therefore, a decrease in wave action may allow more delicate species, such as *Nemertesia ramosa*, ascidians and sponges to increase in abundance. Decreased wave action may allow the biotope to extend into shallower water (e.g. MCR.Flu.Hocu). But reduced wave action may result in an increase in sea urchin predation and hence increased patchiness and species richness (Sebens, 1985; Hartnoll, 1998). Overall, a decrease in wave action may not adversely affect the biotope while strong tidal flow maintains adequate water exchange and, although some species in the biotope may change, *Flustra foliacea* and the biotope will probably survive. Therefore, a sensitivity of low has been recorded.	Low

Table A3.7. Sensitivity to decreased wave action.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Moderate	*Amphiura filiformis* shows a lack of activity in still water and low current speeds can impede feeding because it may reduce the transport of organic particles. Therefore, if water flow rate changes by two categories for a year feeding would be significantly impaired and viability of the population reduced. Over the period of a year many individuals would be likely to die so sensitivity is assessed as high. In slightly less energetic conditions and finer sediment the biotope CMU.SpMeg, which includes high abundance of sea pens and burrowing megafauna such as *Callianassa subterranea*, is more likely to be present.	High
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	Moderate	The biotope exists in habitats such as sea lochs, where tidal streams are already very weak so a decrease in flow rate would result in almost non-moving water. In these enclosed or semi-enclosed water bodies, negligible water flow may result in some deoxygenation of the overlying water and the loss of some sensitive species. The sea pen *Virgularia mirabilis* for example, has high sensitivity to deoxygenation and may die. Tidal currents keep most of the organic particles in the sediment in suspension that can support suspension feeders even in low organic content sediments. Therefore, if water movement becomes negligible suspended organic particles available to filter feeders such as the sea pens will decline. Growth and fecundity will be affected and over a period of a year may result in the death of sea pens. *Amphiura filiformis* shows a lack of activity in still water and low current speeds can impede feeding because it may reduce the transport of organic particles. Therefore, if water flow rate changes by the benchmark level of two categories for a year feeding would be significantly impaired and viability of the population reduced. The overall impact on the biotope is likely to be the loss of a few key species such as sea pens and so sensitivity is assessed as high. Recovery will probably take longer than five years and is assessed as moderate.	Moderate
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	High	Very High	A decrease in wave exposure would be expected to bring about significant changes in the physical composition of the biotope and the colonizing fauna. Over a year the composition of the substratum would be expected to change owing to poorer sorting and elevated sedimentation of silt and organic matter bringing about changes of the chemical environment of the substratum. The substratum would be disturbed less frequently and would allow less mobile and sessile species, e.g. tube building polychaetes and bivalves, to colonize the biotope. A transitional community would develop. Important characterizing species of the IGS.NcirBat biotope would probably remain but may no longer be numerically dominant. Sensitivity has been assessed to be high as the biotope may no longer be recognized. On return to prior conditions, recoverability has been assessed to be very high.	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Intermediate	High	This biotope occurs in moderately wave exposed habitats. The sub-biotope MCR.Flu.HByS is also found in wave exposed habitats and includes robust hydroids (e.g. *Nemertesia antennina*, and *Abietinaria abietina*) and sponges such as *Dysidea fragilis*, *Polymastia boletiformis* and *Cliona celata* (Conner *et al.*, 1997a). The oscillatory flow generated by wave action is potentially more damaging than unidirectional flow but is attenuated with depth (Hiscock, 1983). Many of the species in the biotope are likely to be able to tolerate an increase in wave exposure from moderately exposed to very exposed, for example, *Alcyonium digitatum*, *Urticina felina*, *Bugula* species, the sponges *Halichondria panicea* and *Esperiopsis fucorum*, and probably the hydroids *Nemertesia antennina* and *Sertularia argentea* *Abietinaria abietina*. *Flustra foliacea* is found in very wave exposed site, although probably in deeper waters. However, less flexible or weaker hydroids and bryozoans may be removed, e.g. *Nemertesia ramosa*. Increased wave action may decrease sea urchin and starfish predation, perhaps allowing larger, massive species (e.g. sponges, anemones and ascidians) increase in dominance. Therefore, it is likely that some species within the biotope, especially hydroids may be lost, and some of the *Flustra foliacea* turf may also be damaged and a sensitivity of intermediate has been recorded. Recoverability is likely to be high.	Low
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Intermediate	High	The benchmark decrease in wave exposure would place the biotope in the 'very sheltered' or 'extremely sheltered' category (see glossary) (Connor *et al.*, 1997a). The decrease in water movement would result in increased siltation and a consequent change in sediment characteristics (Hiscock, 1983). A substratum with a higher proportion of fine sediment would probably result in an increase in abundance of the deposit feeders in the biotope, particularly species that favour finer sediments, such as the polychaete *Aphelochaeta marioni* and the echinoid *Echinocardium cordatum*. The increase is likely to be at the expense of suspension feeders, such as the venerid bivalves. There is likely to be some mortality of suspension feeders and hence sensitivity is assessed as intermediate with a minor decline in species richness. Recoverability is assessed as high.	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	Intermediate	High	CGS.Ven occurs in areas of 'moderately strong' or 'weak' flow (see glossary) (Connor *et al.*, 1997a). The benchmark change in water flow rate would place the biotope in areas of 'very weak' flow for one year. The venerid bivalves are capable of generating their own feeding and respiration currents but may be inhibited by clogging of feeding and respiration structures. They are probably capable of clearing these structures (e.g. Grant & Thorpe, 1991; Navarro & Widows, 1997), but the energetic cost over a year may result in some mortality and so the biotope sensitivity is assessed as intermediate with a minor decline in species richness. Recoverability is assessed as high (see additional information below). The community is likely to undergo a shift in composition with deposit feeders becoming more prevalent.	Low
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	Flume experiments suggested that *Modiolus* sp. could deplete the seston directly over dense beds when water flow is low, resulting in a reduction in the density of the mussel bed (Wildish & Kristmanson, 1984, 1985: Holt et al., 1998). *Alcyonium digitatum* prefers areas of high water flow, and its abundance may decline in reduced water flow. Brittlestars such as *Ophiothrix fragilis* are passive suspension feeders and require water flow to supply them with food particles. A reduction in water flow may reduce food availability, however *Ophiothrix fragilis* can survive considerable loss of body mass during reproductive periods (Davoult *et al.*, 1990) so restricted feeding may be tolerated, and this species is found in sheltered areas of reduced water flow. Hydroids and bryozoans also require water flow to provide them with food particles but hydroid species in deeper water, with generally less water movement, have higher biomass, are larger and longer-lived than in shallower waters. Therefore, a reduction in water flow may reduce the density of the horse mussel bed, and may change the associated community favouring species that prefer low water flow. The biotope MCR.ModT may come to resemble the sheltered horse mussels beds (SCR.ModCvar or SCR.ModHAs). In addition, in the sheltered biotopes decreased water flow will increase the risk of deoxygenated conditions (see below). Overall, therefore, a	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							sensitivity of intermediate has been recorded. Horse mussel recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years (see additional information below). Therefore, a recoverability of low has been recorded.	
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	Intermediate	High	This biotope occurs in weak to moderately strong tidal streams. Decreases in water flow will favour epifaunal species tolerant of reduced water flow over species that prefer high water flow rates, so that the composition of the epifaunal species will change. A decrease in water flow to negligible in the absence of wave induced water movement may result in a stagnant deoxygenated water (see deoxygenation) and increased siltation (see above). Although, Limaria hians probably produces a strong ventilation current for feeding it require water flow to remove waste products and provide adequate food. Therefore, a proportion of the population and the associated species may be lost and a sensitivity of intermediate has been recorded.	Very Low
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	Low	Very High	The biotope is found in areas of moderately strong and weak tidal currents so is not likely to be very sensitive to a decrease in water flow. The supply of food particles may decrease in low flow conditions but this should only affect sub-lethal processes of growth and reproduction so sensitivity of the biotope is expected to be low. The species composition within the biotope may change. On return to pre-impact conditions normal growth etc. should recover rapidly.	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Not sensitive	Not relevent	IMX.VsenMtru occurs in wave protected areas where water flow is typically "weak" (Connor *et al.*, 1997). An increase in water flow of 2 categories would place the biotope in areas of "strong" flow. The increase would change the sediment characteristics in which the biotope occurs, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). The underlying sediment in the biotope has a high silt content; a substratum which would not occur in very strong tidal streams. Therefore, the infaunal species, such as *Venerupis senegalensis*, would be outside their habitat preferences and some mortality would be likely to occur, probably due to interference with feeding and respiration. Additionally, the consequent lack of deposition of particulate matter at the sediment surface would reduce food availability for the deposit feeders in the biotope. The resultant energetic cost over one year would also be likely to result in some mortality. A biotope sensitivity of intermediate is therefore recorded and species richness is expected to decline. Recoverability is assessed as high (see additional information below). The expected change in sediment composition would favour the epifauna and macroalgae which would probably become more abundant .	High
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	Not sensitive	Not relevant	The biotope occurs in 'sheltered', 'very sheltered' and 'extremely sheltered' locations (Connor *et al.*, 1997a). A further decrease in wave exposure may result in increased siltation and a consequent change in sediment characteristics (Hiscock, 1983). A substratum with a higher proportion of fine sediment would probably result in the increased abundance of the deposit feeders within the biotope, particularly species which favour finer sediments, such as the polychaete *Aphelochaeta marioni* and the echinoid *Echinocardium cordatum.* However, in the absence of wave action, tidal flow is likely to be a more significant factor structuring the community, replenishing oxygen, supplying planktonic recruits and would maintain a supply of suspended organic matter in suspension for suspension feeders. Therefore the biotope has been assessed not to be sensitive.	Low
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	Not sensitive	Not relevant	The biotope occurs in locations sheltered from wave exposure so is unlikely to be sensitive to a further decrease this factor.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Not sensitive	Not relevant	The biotope occurs in areas of 'weak' tidal streams (Connor *et al*., 1997b), the characterizing species are adapted to low flow conditions and hence the biotope is unlikely to be sensitive to a further reduction in water flow.	Moderate

Table A3.8. Sensitivity to physical disturbance

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	Moderate	*Virgularia mirabilis* is able to retract into the sediment and so some individuals may be able to avoid some forms of abrasion or physical disturbance. However, sea pens retract slowly and are likely to be sensitive to abrasion by trawling for instance, which is likely to break the rachis of *Virgularia mirabilis*. Species obtained by dredges were invariably damaged (Hoare & Wilson, 1977). Displaced individuals that are not damaged will re-burrow but those that are damaged are likely to die. Ramsay *et al*. (1998) suggest that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. Bergman & Hup (1992) for example, found that beam trawling in the North Sea had no significant direct effect on small brittle stars. Brittle stars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. The sensitivity of *Amphiura filiformis* to abrasion and physical disturbance is recorded as low. However, since sea pens are likely to be highly sensitive to abrasion and loss of these species changes the nature of the biotope sensitivity of the biotope is also reported to be high. Recovery of sea pens may take a long time so a score of moderate is reported.	Moderate
Shallow mixed sediment faunal communities	IMX.FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	High	High	Hall-Spencer & Moore (2000b) concluded that *Limaria hians* beds were sensitive to physical disturbance by mooring chains, hydraulic dredges or towed demersal fishing gear. Hall-Spencer & Moore (2000b) reported that a single pass of a scallop dredge at Creag Gobhainn, Loch Fyne ripped apart and mostly removed the *Limaria hians* reef. Damaged file shells were consumed by scavengers (e.g. juvenile cod *Gadus morhua*, whelks *Buccinum undatum*, hermit crabs *Pagurus bernhardus* and other crabs) within 24 hrs. Hall-Spencer & Moore (2000b) noted that although *Limaria hians* was able to swim, the shell was thin and likely to damaged by mechanical impact. Damage of the *Limaria hians* carpet would probably result in exposure of the underlying sediment and exacerbate the damage resulting in the marked loss of associated species (Hall-Spencer & Moore, 2000b). Species with fragile tests such as *Echinus esculentus* and the brittlestar *Ophiocomina nigra* and edible crab *Cancer pagurus* were reported to suffer badly from the impact of a passing scallop dredge (Bradshaw *et al.*, 2000). Scavenging species would probably benefit in the short term, while epifauna would be removed or damaged with the byssal carpet. Therefore, a sensitivity of high has been recorded. Severe physical disturbance would be similar to substratum removal in effect. Recoverability from a single event would probably be rapid.	High

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	High	Low	*Modiolus modiolus* are large and relatively tough bivalves. Holt *et al*. (1998) suggested that horse mussel beds were not particularly fragile, even when epifaunal, with semi-infaunal and infaunal population being less vulnerable to physical disturbance. Clumps of horse mussels of muddy substrata may be more sensitive. However, impacts from towed fishing gear (e.g. scallop dredges) are known to flatten clumps and aggregations, may break off sections of raised reefs and probably damage individual mussels (Holt *et al*., 1998). The shells of older specimens can be very brittle due to infestations of the boring sponge *Cliona celata* (Comely, 1978; Holt *et al*., 1998). Holt *et al*. (1998) suggested that scallop dredging on areas adjacent to beds in the south east of the Isle of Man had 'nibbled away at the edges' of dense beds, which had become less dense and more scattered. Extensive beds were present in the north of the Isle of Man where scallop dredging has apparently not occurred (Holt *et al*., 1998). Magorrian & Service (1998) reported that trawling fro queen scallops resulted in flattening of the horse mussel bed and disruption of clumps of horse mussels and removal of emergent epifauna in Strangford Lough. They suggested that the emergent epifauna such as *Alcyonium digitatum* were more sensitive than the horse mussels themselves and reflected early signs of damage and were able to identify different levels of impact from impacted but largely intact to heavily trawled areas with few *Modiolus modiolus* intact, lots of shell debris and little epifauna (Service & Magorrian, 1997; Magorrian & Service, 1998; Service 1998). Veale *et al*., 2000 reported that the abundance, biomass and production of epifaunal assemblages, including *Modiolus modiolus* and *Alcyonium digitatum* decreased with increasing fishing effort. Species with fragile hard tests such as echinoids are known to be sensitive to scallop dredges (see Eleftheriou & Robertson, 1992; Veale *et al*., 2000). Scavengers such as *Asterias rubens* and *Buccinum undatum* were reported to be fairly robust to encounters with trawls (Kaiser & Spencer, 1995) may benefit in the short term, feeding on species damaged or killed by passing dredges. However, Veale *et al*. (2000) did not detect any net benefit at the population level. Scallop dredging was found to damage many of the epibenthic species found in association with *Modiolus* beds (Hill *et al*., 1997; Jones *et al*., 2000). Holt *et al*. (1998) suggested that damage by whelk potting was not likely to be severe but also noted that epifaunal populations may be more sensitive. Scallop dredging or otter trawling are a more intense disturbance than the benchmark level (an anchor). Disruption of the clumps or beds may result in loss of some individual horse mussels suggesting a sensitivity of intermediate, however, given the sensitivity of epifauna suggested above an overall sensitivity of high is recorded. Horse mussel recruitment is sporadic, varies with season, annually and with location and hydrographic regime and is generally low, therefore it may take many years for a population to recover from damage and a recoverability of low (10-25 years) has been recorded.	Moderate
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Intermediate	High	The species that characterize this biotope are tolerant of sediment scour and unlikely to be damaged by abrasion. However, physical disturbance by an anchor and mobile fishing gear may be more damaging. Erect epifaunal species are particularly vulnerable to physical disturbance. Hydroids and bryozoans are likely to be detached or damaged by bottom trawling or dredging (Holt *et al*., 1995). Veale *et al*. (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort. Hydroid and bryozoan communities were reported to be greatly reduced in fished areas (Jennings & Kaiser, 1998 and references therein). Mobile gears also result in modification of the substratum, including removal of shell debris, cobbles and rocks, and the movement of boulders (Bullimore, 1985; Jennings & Kaiser, 1998). The removal of rocks or boulders to which species are attached results in substratum loss. Magorrian & Service (1998) reported that queen scallop trawling flattened horse mussel beds and removed emergent epifauna in Strangford Lough. They suggested that the emergent epifauna such as *Alcyonium digitatum*, a frequent component of this biotope, were more sensitive than the horse mussels themselves and reflected early signs of damage. However, *Alcyonium digitatum* is more abundant on high fishing effort grounds, which suggests that this seemingly fragile species is more resistant to abrasive disturbance than might be assumed (Bradshaw *et al*., 2000), presumably owing to good recovery due to its ability to replace senescent cells and regenerate damaged tissue, together with early larval	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							colonization of available substrata. Species with fragile tests such as *Echinus esculentus* and the brittlestar *Ophiocomina nigra* and edible crabs *Cancer pagurus* were reported to suffer badly from the impact of a passing scallop dredge (Bradshaw *et al*., 2000). Scavengers such as *Asterias rubens* and *Buccinum undatum* were reported to be fairly robust to encounters with trawls (Kaiser & Spencer, 1995) may benefit in the short term, feeding on species damaged or killed by passing dredges. However, Veale *et al*. (2000) did not detect any net benefit at the population level. Overall, physical disturbance by an anchor or mobile fishing gear is likely to remove a proportion of all groups within the community and attract scavengers to the community in the short term. Therefore, a sensitivity of intermediate has been recorded. Recoverability is likely to be high due to repair and re-growth of hydroids and bryozoans (e.g. *Flustra foliacea*), and recruitment within the community from surviving colonies and individuals.	
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	Intermediate	High	*Lanice conchilega* inhabits a permanent tube and is likely to be damaged by any object that penetrates and or drags through the sediment, as are all other infaunal polychaetes. Despite their apparent robust body form, bivalves are also vulnerable to physical abrasion. For example, mortality and shell damage was reported in *Mya arenaria* and *Cerastoderma edule* as a result of dredging activity (Cotter *et al*., 1997). However, anchorage is a less severe impact. The most sensitive species identified was *Echinocardium cordatum* has a fragile test that is likely to be damaged by an abrasive force such as movement of trawling gear over the seabed. A substantial reduction in the numbers of *Echinocardium cordatum* due to physical damage from scallop dredging has been observed (Eleftheriou & Robertson, 1992). The species has a high fecundity, normally reproduces every year and has pelagic larvae so recovery would be expected. Sensitivity has been assessed to be intermediate as the benchmark level of abrasion and physical disturbance is less severe, but some mortality would be expected as a result of abrasion and physical disturbance. Recoverability has been assessed to be high.	Low
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Intermediate	High	Despite their robust body form, bivalves are vulnerable to physical abrasion. For example, mortality and shell damage were reported in Mya arenaria and *Cerastoderma edule* due to dredging activity (Cotter *et al*., 1997). Physical abrasion from, for example, the dragging of an anchor is less severe. However, venerid bivalves are generally shallow burrowers and *Fabulina fabula* has a fragile shell (Fish & Fish, 1996). The bivalves that characterize the biotope may therefore be damaged by physical abrasion. The polychaete, *Magelona mirabilis*, is a soft bodied organism which lives within a few centimetres of the sediment surface and exposes its palps at the surface while feeding. It is, therefore, also likely to be damaged by the benchmark physical abrasion. Eleftheriou & Robertson (1992) performed experimental scallop dredging in a sandy bay in Scotland. They observed that the action of the dredge resulted in damage and mortality *of Echinocardium cordatum, Asterias rubens, Astropecten irregularis, Cancer pagurus* and *Ammodytes* sp. The authors suggested that the infaunal invertebrates with behavioural or morphological adaptations to the rigours of life in high energy environments, such as amphipods, were not affected by dredging operations in any significant way. The sessile infauna, however, along with large infaunal and epifaunal forms, such as molluscs, decapods, echinoderms and some polychaetes, demonstrated their vulnerability. It seems likely that the characterising species will suffer some mortality due to physical abrasion and so sensitivity is assessed as intermediate. Recoverability is recorded as high. Particularly vulnerable forms, such as the epifaunal echinoderms, may be eliminated so there may be a minor decline in species richness in the biotope.	Low
Venerid bivalves in circalittoral	CGS.Ven		Yes	Yes	Intermediate	High	Ramsay *et al*. (2000b) investigated using dog cockles, *Glycymeris glycymeris*, as indicators of physical disturbance. They reported that the incidence of scars on the shells was significantly higher in areas heavily exploited by beam trawlers and concluded that trawling causes damage and possibly mortality of these robust	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
coarse sand or gravel.							bivalves. The same is likely to occur to the venerids in the biotope. The echninoid, *Spatangus purpureus*, is particularly susceptible to physical abrasion. Damage and mortality caused by beam trawling has been reported by Kaiser & Spencer (1994) and Evans *et al*. (1996). In both reports, damaged urchins were opportunistically predated by fish and mobile epifauna. The benchmark disturbance is less severe than beam trawling, for example, the dragging of an anchor and chain, but it is still likely to cause some damage or mortality, particularly of the smaller, thinner shelled bivalves and echinoderms. Biotope sensitivity is therefore recorded as intermediate. Recoverability is assessed as high. It is unlikely that any species would be eradicated from the biotope and hence there would be no change in species richness.	
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	Intermediate	High	The biotope is not generally subject to much physical disturbance because it does not support any commercial species. Consequently, there is little information on effects of physical disturbance on the CMS.AfilEcor community. However, there is information on individual species. *Echinocardium cordatum*, for example, has a fragile test that is likely to be damaged by an abrasive force such as movement of trawling gear over the seabed. A substantial reduction in the numbers of the species due to physical damage from scallop dredging has been observed (Eleftheriou & Robertson, 1992). Ramsay *et al*. (1998) suggest that *Amphiura* spp. may be less susceptible to beam trawl damage than other species like echinoids or tube dwelling amphipods and polychaetes. Bergman & Hup (1992) for example, found that beam trawling in the North Sea had no significant direct effect on small brittle stars. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. The sensitivity of Amphiura filiformis to abrasion and physical disturbance is recorded as low. Individuals can still function whilst regenerating a limb so recovery will be rapid. The factor is not relevant *to Callianassa subterranea* because the species rarely leaves its burrows under normal circumstances and burrows are deep enough, sometimes up to 80cm, to avoid trawls and dredges. Thus, physical disturbance like trawling is unlikely to affect *Callianassa subterranea* to any great extent. Other species, also found in this biotope, that were observed to be sensitive include the bivalves *Nucula nitidosa* and *Corbula gibba* and the polychaetes *Nephtys* sp. and *Terebellides stroemi*. For epifaunal species, no long-term effects on the total number of species or individuals were detected, but individual species did show effects, notably an increase in the density of *Ophiura* sp. and a decrease in numbers of the fish *Hippoglossoides platessodies* and the whelk *Buccinum undatum*. Other authors have also suggested that increases in echinoderm populations in the North Sea are associated with fishing disturbance (Aronson, 1990; Lindley *et al*., 1995). Therefore, the overall effect on the biotope would be a reduction in species diversity and the loss of a number of individuals of the key species *Echinocardium cordatum* so the sensitivity of the biotope is reported to be intermediate. Recovery of *Echinocardium cordatum* should be possible within five years so a score of high is reported.	Moderate
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	Very High	Many species in the biotope are vulnerable to physical abrasion. The tubes of the polychaetes are bound only with mucous and are therefore likely to damaged by the benchmark level of abrasion. The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a dragging anchor. Biotope sensitivity is therefore recorded as intermediate. Recoverability is recorded as very high as damage at the benchmark level will be restricted in extent (see additional information below). For large scale physical disturbance, sensitivity will be more similar to 'substratum removal' above.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Intermediate	High	Many species in the biotope are vulnerable to physical abrasion. The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a dragging anchor. Despite their robust body form, bivalves are also vulnerable. For example, because of dredging activity, mortality and shell damage have been reported in *Mya arenaria* and *Cerastoderma edule* (Cotter *et al.*, 1997). Epifauna and macroalgae risk being damaged and/or dislodged by physical abrasion. Some mortality is likely to result from physical abrasion so sensitivity is recorded as intermediate and species richness may suffer a minor decline. Recoverability is assessed as high.	Low
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Low	Very High	Amphipod crustaceans such as *Bathyporeia pelagica* are not of a growth form that are likely to be damaged by abrasion caused by the dropping and dragging of an anchor and are sufficiently mobile to avoid the disturbance. Important characterizing polychaete worms, such as the Nephtyidae, live in the sediment between a depth of 5-15 cm and are therefore protected from most sources of abrasion and disturbance caused by surface action. But Ferns *et al.* (2000) recorded significant losses of infaunal polychaetes from areas of muddier sand worked with a tractor-towed cockle harvester; 31% of *Scoloplos armiger* and 83% of *Pygospio elegans*, whose populations remained depleted for between 50 and 100 days indicating that abrasion and physical disturbance can be responsible for the deterioration of infaunal polychaete populations. However, such disturbance is greater than that expected due to anchorage alone and sensitivity has been assessed to be low with a very high recoverability.	Low
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	Low	High	The relatively delicate shells of the bivalves that characterize this biotope are vulnerable to physical damage but at the benchmark level (the dropping and dragging of an anchor) the effects on the population are likely to be insignificant as the species tend to occur at high densities (>1000 /m^2). Therefore, sensitivity to anchorage has been assessed to be low and the biotope would not be changed. Recoverability has been assessed to be high. However, the biotope community may be subjected to more intense abrasive / physical disturbance from otter and beam trawls used to capture the brown shrimp, *Crangon crangon*. The small size of *Macoma balthica* and *Abra alba* relative to the gear and meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through. Effects on other infauna would depend upon the depth penetration of the gear, relative to the distribution of animals in the sediments, but significant trawl-induced mortality has been reported for *Echinocardium cordatum* (de Groot & Apeldoorn 1971; Rauck, 1988). Furthermore, *Lagis koreni* is incapable of reconstructing its delicate sand-tube once removed from it (Schafer, 1972), and hence mortality following physical disturbance would be expected to be high for this species in particular. Therefore, the biotope would have a higher sensitivity to factors causing more intense abrasion / physical disturbance in comparison to the benchmark level.	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	Low	Intermediate	Burrowing and tube dwelling infauna, such as burrowing anemones, may be less affected by dredging than other epifauna (Gubbay & Knapman, 1999). In a study carried out in the Skomer Marine Nature Reserve the numbers of sea anemones, *Cerianthus lloydii* and *Mesacmaea mitchelli*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. Thus, it seems likely that the biotope will have low sensitivity to the effects of anchorage. Recovery is expected to be good as withdrawn individuals reappear and dislodged individuals re-burrow. Damaged anemones may be subject to predation by fish or other animals.	Moderate

Table A3.9. Sensitivity to displacement.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	No	High	Intermediate	The species in the biotope are either mobile and capable of re-burrowing or, mainly, capable of re-building tubes. Following displacement of key or characterizing species, the biotope would have to be structurally re-established - there may be succession of species before IMU.AphTub is recognized. Sensitivity is identified as high and recoverability moderate but with low confidence.	Low
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	High	High	Most permanently fixed, sessile species, such as bryozoans (e.g. *Flustra foliacea* and *Bugula* species), sponges (e.g. *Halichondria panicea*), ascidians (e.g. *Molgula manhattensis*) and hydroids (e.g. *Nemertesia* species) cannot reattach to the substratum if removed, and may be damaged or destroyed in the process. Hydroids and sponges may be able to grow from fragments, aiding recovery. Mobile species, such as amphipods, gastropods, small crustacea, crabs and fish are likely to survive displacement. Anemones (e.g. *Urticina felina*) are strongly but not permanently attached and will probably reattach to suitable substrata. However, the dominant bryozoans and hydroids are likely to be lost and a sensitivity of high has been recorded. Recovery of the *Flustra foliacea* abundance is likely to take many years and a recoverability of high has been recorded	Moderate
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Intermediate	High	*Fabulina fabula, Chamelea gallina* and *Magelona mirabilis* are all active burrowers and are capable of reburying themselves if displaced to the surface of a suitable substratum (Jones, 1968; Salzwedel, 1979). However, while at the sediment surface they are vulnerable to predation from echinoderms (Aberkali & Trueman, 1985) and bottom feeding fish (Hunt, 1925; Hayward & Ryland, 1995) so there is likely to be some mortality. Sensitivity is therefore assessed as intermediate. Recoverability is recorded as high	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	Intermediate	High	The majority of the infauna in the biotope is likely to be able to rebury following displacement to the sediment surface, for example, following washing out by a storm event. This has been observed in the venerid bivalve, *Venerupis senegalensi*s (Kaschl & Carballeira, 1999), and the heart urchin, *Echinocardium cordat*um. However, while at the sediment surface, the infauna are vulnerable to predation and it is likely that some mortality would occur. Biotope sensitivity is therefore recorded as intermediate. Recoverability is assessed as high. Permanently attached species, such as the tube worm *Hydroides norvegica*, would not be able to reattach following displacement and hence there would be a minor decline in species richness in the biotope.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Intermediate	High	*Venerupis senegalensis* is the only important characterising species in the biotope. When displaced and returned to the surface of the substratum, it is able to re-bury itself (e.g. Kaschl & Carballeira, 1999). This probably occurs naturally due to shifting sediments caused by storms. However, while exposed at the sediment surface, the species is more vulnerable to predation and some mortality may occur. Sensitivity is therefore recorded as intermediate. Recoverability is recorded as high.	Low
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	Intermediate	Intermediate	The majority of the infauna in the biotope is likely to be able to rebury following displacement to the sediment surface, for example, following washing out by a storm event. This has been observed in the venerid bivalve, *Venerupis senegalensis* (Kaschl & Carballeira, 1999), and the heart urchin, *Echinocardium cordatum*. However, while at the sediment surface, the infauna are vulnerable to predation and it is likely that some mortality would occur. Biotope sensitivity is therefore recorded as intermediate. Recoverability is assessed as high. Permanently attached species, such as the tube worm *Hydroides norvegica*, would not be able to reattach following	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							diplacement and hence there would be a minor decline in species richness in the biotope.	
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	Low	Holt *et al.* (1998) noted the survival of clumps torn from a horse mussel bed was not known. *Modiolus modiolus* displaced from the beds will probably be able to re-attach to suitable substratum using their byssus threads, although no information was found concerning their ability to burrow. The ability of clumps or individuals to maintain a viable population will depend on the location and depth of the new habitat, food supply, and the local hydrographic regime. Displacement of important species such as sea urchins may increase fouling by epiflora and epifauna increasing the risk of dislodgement and further displacement in the strong currents characteristic of this biotope (MCR.ModT). Most sessile, permanently attached epifauna are likely to be highly sensitive to displacement in their own right, e.g. *Alcyonium digitatum*. Mobile epifauna, e.g. crabs, whelks and lobsters will probably be largely unaffected. Overall, displacement of *Modiolus modiolus* is likely to result in loss in a proportion of the biotope and a sensitivity of intermediate has been recorded. Recovery of the biotope will depend on re-colonization and re-growth of clumps of horse mussels or the closure of gaps in the bed, which is likely to take considerable time and a recoverability of low has been recorded.	Low
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	Intermediate	Intermediate	Yonow (1989) observed *Lanice conchilega* re-establishing tubes immediately after removal from the sediment, when placed on suitable sediment in the laboratory. *Abra alba, Fabulina fabula* and *Magelona mirabilis* are all active burrowers and are capable of reburying themselves if displaced to the surface of a suitable substratum (Jones, 1968; Salzwedel, 1979). However, while at the sediment surface they are vulnerable to predation from crabs, echinoderms (Aberkali & Trueman, 1985) and bottom feeding fish (Hunt, 1925; Hayward & Ryland, 1995) so there is likely to be some mortality. Sensitivity has been assessed to be intermediate. However, it is likely that the majority of displaced specimens would obtain protection within the substratum relatively quickly so recoverability has been assessed to be immediate.	Moderate
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	Low	Intermediate	Most species in the biotope are burrowing and have low sensitivity to displacement, such as that caused by a passing trawl that does not kill species but throws them into suspension, because animals can re-burrow into suitable substrata. Displaced individuals of *Amphiura filiformis* that are not damaged (see Abrasion above) can right themselves if displacement caused them to be inverted and they can rapidly re-burrow into the sediment as can *Echinocardium cordatum*. Sea pens such as *Virgularia mirabilis* will re-burrow (Jones *et al*., 2000) and recover completely within 72 hours after displacement provided the basal peduncle remains in contact with the sediment surface. Burrowing crustaceans such as *Callianassa subterranea* can re-burrow immediately although full burrow construction may take longer. Infaunal organisms that move through the sediment but do not construct permanent burrows, such as errant polychaetes will return to the sediment after displacement. Therefore, provided individuals are not damaged most species within the biotope are able to rapidly re-burrow after displacement so sensitivity is assessed as low and recovery will be immediate.	High

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	Low	Intermediate	Displaced individuals of *Virgularia mirabilis*, which are not destroyed will re-burrow (Jones *et al*., 2000) and recover completely within 72 hours, provided the basal peduncle remains in contact with the sediment surface. The other important characterizing species associated with this biotope, such as brittlestars, also have the ability to re-burrow, provided they have not been damaged. Displaced individuals of *Amphiura filiformis* that are not damaged can right themselves if displacement caused them to be inverted and they can rapidy re-burrow into the sediment. Sensitivity of the biotope to displacement is therefore low and recovery is recorded as immediate.	Low
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	Low	Intermediate	Individual *Limaria hians* removed from their nests, e.g. by physical disturbance but not damaged are capable of swimming. *Limaria hians* exudes an irritating, sticky mucus which renders it distasteful to most predators. On settling onto suitable substratum the gaping file shell burrows and constructs a nest (see Gilmour, 1967 for details). Merrill & Turner (1963) noted that *Limaria hians* was able to build a protective nest more rapidly than *Musculus discors* because the file shell utilized the surrounding substrata. Therefore, a sensitivity of low has been recorded to represent the energetic costs of displacement.	Low
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Low	Intermediate	Owing to the high energy environment, species that characterize the biotope are predominantly mobile forms (swimming and burrowing) that are able to re-enter the substratum following disturbance. Sensitivity has been assessed to be low as displacement itself is unlikely to have a detectable effect on the infauna. Recoverability has been assessed to be immediate. However, whilst briefly exposed at the surface the infauna would be potentially predated upon by the epibenthos and fish.	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	Low	Intermediate	Cerianthid anemones are capable of burrowing again and constructing a new tube if dug up. The other burrowing anemones do not build tubes and therefore, to a greater or lesser extent, are able to shift their position. Thus, if displaced the anemones in the biotope should be able to re-burrow. *Peachia hastata* for example, is able to re-burrow in about one hour (Trueman & Ansell, 1969). The time taken for some other species, such as *Cerianthus lloydii*, to reburrow is longer and may place individuals at greater risk of predation. Although anthozoans do not feature prominently on the menu of many predatory animal, they have been found amongst the stomach contents of fish. Most other species likely to occur in the biotope, for instance worms and bivalve molluscs, will be able to re-burrow. However, the sensitivity of the biotope is reported to be low because it is likely that many individuals can re-burrow and survive displacement. Recovery is expected to be immediate as individuals are likely to re-burrow as soon as they have been displaced.	Moderate

Table A3.10. Sensitivity to synthetic chemical contamination.

Biotope Name	**Biotope code**	**Represented by biotope**	**E.C. Hab. Dir.**	**UK BAP**	**Sensitivity**	**Recovery**	**Explanation**	Evidence/ Confidence
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	High	Very Low	No information concerning the effects of synthetic contaminants on *Modiolus modiolus* was found. However, it is likely to have a similar metabolism to that of *Mytilus edulis* and hence, possibly, a similar tolerance to chemical contaminants. Livingstone & Pipe (1992) cite Palmork & Solbakken (1981) who reported that *Modiolus modiolus* accumulated poly-aromatic hydrocarbons (PAHs) and examined the depuration of phenanthrene from horse mussel tissue. However, no effects on the horse mussel were documented. PAHs contribute to a reduced scope for growth in *Mytilus edulis* (Widdows *et al.*, 1995) and probably have a similar effect in the horse mussel but to an unknown degree. Tri butyl-tin (TBT) has been reported to affect bivalve molluscs as follows: reduced spatfall in *Pecten maximus*, *Musculus marmoratus* and *Limaria hians*; inhibition of growth in *Mytilus edulis* larvae, and inhibition of growth and metamorphosis in *Mercenaria mercenaria* larvae (Bryan & Gibbs, 1991). Therefore, it is likely that TBT may interfere with growth and settlement of *Modiolus modiolus* larvae. Horse mussel populations exhibit sporadic recruitment, therefore any factor that adversely affects recruitment will have an adverse effect on the population, although the effects may not be observed for some time since the species in so long lived. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction, and that the filamentous forms were the most sensitive. However, most evidence relates to dispersants, e.g. heavy mortality of *Delesseria sanguinea* occurred down to 12 m after the *Torrey Canyon* oil spill (probably due to a mixture of wave action and dispersant application) (Smith, 1968). Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy, 1984 cited in Holt *et al.*, 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Smith (1968) reported dead colonies of *Alcyonium digitatum* and dead *Echinus esculentus* at a depths of up to 16m in the locality of Sennen Cove (Pedu-men-du, Cornwall) resulting from the offshore spread and toxic effect of detergents e.g. BP 1002. Cole *et al.* (1999) suggested that herbicides, such as simazina and atrazine were very toxic to macrophytes. Hoare & Hiscock (1974) noted that *Delesseria sanguinea* was excluded from Amlwch Bay, Anglesey by acidified halogenated effluent discharge. In addition *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez, 1999). Loss of epifaunal grazers such as sea urchins may adversely affect the horse mussel population due to fouling. Therefore, evidence suggests that horse mussels are of intermediate sensitivity to synthetic chemicals, however, given the additional high sensitivity of *Echinus esculentus* and red algae an overall sensitivity of high has been recorded albeit at low confidence. Horse mussel recruitment is sporadic, varies with season, annually and with location and hydrographic regime and is generally low, therefore it may take many years for a population to recover from damage and a recoverability of low (10 -25years) has been recorded.	Very Low
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed	Yes	No	High	High	In the Moross Channel, Mulroy Bay, an intensive settlement of *Limaria hians* spat occurred in 1982 followed by five years of failed settlement, which coincided with the use of TBT in fish farms in the area. *Limaria hians* samples in 1985 contained 0.2 µg/g tri-butyl tin oxide and similar levels were found in the Pacific oyster, scallops and mussels in the same area. *Limaria hians* larvae were detected again after the use of TBT was discontinued in	High

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
		sediment IMX.Lim					1985 (Minchin *et al.*, 1987; Minchin, 1995). Minchin (1995) suggested that TBT contamination was the most likely cause of the disappearance of larvae from the plankton. *Mytilus edulis* continued to settle during the impacted period suggesting that *Limaria hians* was more sensitive. Minchin (1995) noted that good recruitment was necessary to maintain the byssal carpet. Poor recruitment resulted in weakening of the byssal carpet, which was pulled away in tufts due to drag by kelps in the strong currents, mobilization of the sediment and resultant smothering, and loss of the carpet, its attached kelps and associated community and the population was reduced to 1.6% of its 1980 abundance. Therefore, while numerous species have been shown to be sensitive to TBT contamination to varying degrees, loss of the *Limaria hians* population and its associated community would result in loss of the biotope and a sensitivity of high has been recorded. Minchin (1995) reported that once recruitment began again in 1989, with settlement of larvae from adults in other areas of the bay, and recovery was rapid, so that by 1994 the population and an extensive carpet of byssal nests indicated recovery to the earlier 1980 state. Therefore, a recoverability of high has been recorded	
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	High	High	No evidence of the effects of chemical contaminant on *Lanice conchilega* was found. However, exposure of *Hediste diversicolor* and *Arenicola marina* to Ivermecten resulted in significant mortality (see *MarLIN* reviews; Collier & Pinn, 1998). Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum suggesting that TBT had an effect on the larval and/or juvenile stages of these polychaetes. Bryan & Gibbs (1991) reported that *Arenicola costata* larvae were unaffected by 168 hr exposure to 2000 ng TBT/ l seawater and were probably relatively tolerant, however in another study, *Scoloplos armiger* exhibited a dose related decline in numbers when exposed to TBT paint particles in the sediment. Møhlenberg & Kiørboe (1983) demonstrated that pesticide contamination impaired or prevented burrowing in *Abra alba*, which would probably result in the species being exposed to predatory starfish and fish. Beaumont *et al.* (1989) concluded that bivalves are particularly sensitive to tri-butyl tin (TBT). For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scrobicularia plana* suffered 100 % mortality after 2 weeks and 10 weeks respectively. There is also evidence that TBT causes recruitment failure in bivalves, due to either reproductive failure or larval mortality (Bryan & Gibbs, 1991). Pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods, isopods, mysids, shrimp and crabs) and fish (Cole *et al.*, 1999). Cole *et al.* (1999) suggested that TBT was very toxic to algae (including microalgae), molluscs, crustaceans and fish, with observable endocrine disrupting effects in gastropods. Waldock *et al.* (1999) examined recovery of benthic infauna of the Crouch estuary after a ban on the use of TBT on small boats. They observed marked increase in species diversity, especially of Ampeliscid amphipods and polychaetes (e.g. *Tubificoides* species and *Aphelochaeta marioni*) which mirrored the decline in sediment TBT concentration. Whilst a causal link could not be shown, the study by Waldock *et al.* (1999) suggested that crustacean and polychaete diversity may be inhibited by TBT contamination. Polychaete species vary greatly in their tolerance of chemical contamination. However, evidence suggests that the polychaetes within this biotope, including the dominant species *Lanice conchilega*, are potentially highly sensitive to chemical contamination from pesticides or TBT. The abundance and reproduction of bivalves, crustaceans and other species in the biotope may also be adversely affected. Therefore, a sensitivity of high has been recorded, albeit at low confidence. Species richness is likely to decline markedly, due to the dominance of	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							fewer tolerant species. On return to prior conditions and assuming deterioration of the contaminants recoverability is likely to be high	
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	High	High	No information was found concerning the effects of synthetic chemicals specifically on *Fabulina fabula* or *Chamelea gallina*. However, inference can be drawn from related species. Beaumont *et al*. (1989) concluded that bivalves are particularly sensitive to tri-butyl tin (TBT), the toxic component of many antifouling paints. For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scobicularia plana* suffered 100% mortality after 2 weeks and 10 weeks respectively. There is also evidence that TBT causes recruitment failure in bivalves, due to either reproductive failure or larval mortality (Bryan & Gibbs, 1991). Stirling (1975) investigated the effects of phenol, a non-persistent, semi-synthetic organic pollutant, on *Tellina tenuis*. Exposure to phenol produced a measurable effect on burrowing at all concentrations tested, i.e. 50 mg/l and stronger. Sub-lethal effects of exposure to phenol included delayed burrowing and valve adduction to exclude the pollutant from the mantle cavity. After exposure to 100 mg/l for 24 hours, the majority of animals were extended from their shells and unresponsive to tactile stimulation. Following replacement of the phenol solution with clean seawater, good recovery was exhibited after 2 days for animals exposed to 50 mg/l and some recovery occurred after 4 days for animals exposed to 100 mg/l. Similarly, no evidence was found directly relating to the effects of synthetic chemicals on *Magelona mirabilis*. However, there is evidence from other polychaete species. Collier & Pinn (1998) investigated the effect on the benthos of ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids. The polychaete *Hediste diversicolor* was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m² of ivermectin in a microcosm. *Arenicola marina* was also sensitive to ivermectin through the ingestion of contaminated sediment (Thain *et al.*, 1998; cited in Collier & Pinn, 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. Beaumont *et al.* (1989) investigated the effects of tri-butly tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages. Detergents used to disperse oil from the *Torrey Canyon* oil spill caused mass mortalities of *Echinocardium cordatum* (Smith, 1968) and its sensitivity to TBT is similar to that of other benthic organisms with LC_{50} values of 222ng Sn/l in pore water and 1594ng Sn/g dry weight of sediment (Stronkhorst *et al.*, 1999). Gammaridean amphipods have also been reported to be sensitive to TBT with 10 day LC_{50} values of 1-48 ng/l (Meador *et al.*, 1993). In light of the likely sensitivity of the important characterising species in the biotope, sensitivity is assessed as high and there is likely to be a major decline in species richness. Recoverability is recorded as high	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	High	High	There was no information found on the effect of chemical contaminants on the biotope. However, effects on some of the individual species in the biotope have been reported. Dahllöf *et al*. (1999) studied the long term effects of tri-n-butyl-tin (TBT) on the function of a marine sediment system. TBT spiked sediment was added to a sediment that already had a TBT background level of approximately 27ng g-1 (83 pmol TBT g-1) and contained the following fauna: *Amphiura* spp., the bivalve *Abra alba* and several species of polycheate. Within two days of treatment with a TBT concentration above 13.7 µmol / m² all species except the polychaetes had crept up to the surface and after six weeks these fauna had started to decay. Thus, increased contamination from TBT is likely to result in the death of some sensitive species such as brittle stars and heart urchins. Bryan & Gibbs (1991) report that crabs appear to be relatively resistant to TBT although some deformity of regenerated limbs has been observed. However, arthropods are very sensitive to the insecticide carbaryl (1-napthol n-methyl carbamate; sold under the trade name Sevin®) which has been used to control burrowing shrimp in oyster farms (Feldman *et al*., 2000). There is no information available on the possible consequences of chemicals to British sea pens. Different species will be affected by different chemicals but a general trend in areas of increasing pollution is a reduction in species diversity with habitats becoming dominated by pollution tolerant polychaete worms. However, Ivermectin, an anti-louse treatment coming into use in the salmon fish farming industry, has been shown to be highly toxic to sediment dwelling polychaetes (Hughes, 1998(b)). The dominant trophic group associated with this biotope are suspension feeders and therefore have the ability to accumulate pollutants although effects are uncertain. Growth and regeneration are decreased in species such as *Pecten maximus* and *Amphiura filiformis*. Sensitivity of the biotope is reported to be high.	Low
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	High	Intermediate	There was no information found on the effect of chemical pollutants on the biotope. However, effects on some of the individual species in the biotope have been reported from which impacts on the biotope can be extrapolated. Dahllöf ***et al.*** (1999) studied the long term effects of tri-n-butyl-tin (TBT) on the function of a marine sediment system. TBT spiked sediment was added to a sediment that already had a TBT background level of approximately 27ng g^{-1} (83 pmol TBT g^{-1}) and contained the following fauna: *Amphiura* spp., *Brissopsis lyrifera* and several species of polycheate. Within two days of treatment with a TBT concentration above 13.7 µmol / m^2 all species except the polychaetes had crept up to the surface and after six weeks these fauna had started to decay. Thus, increased contamination from TBT is likely to result in the death of some sensitive species such as brittle stars and heart urchins. *Echinocardium cordatum* was also found to be highly sensitive to detergents used to disperse oil from the *Torrey Canyon* oil spill that caused mass mortalities of the species (Smith, 1968). Thus, the key species seem to be highly sensitive to some chemical pollutants and may be lost from the biotope. Loss of the key species means loss of the biotope so sensitivity is assessed as high. On return to normal conditions, recovery may take many years and recovery is reported to be moderate.	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	High	High	No evidence was found concerning the sensitivity of the venerid bivalves in the biotope. However, Beaumont *et al.* (1989) concluded that bivalves in general are particularly sensitive to tri-butyl tin (TBT), the toxic component of many antifouling paints. For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scobicularia plana* suffered 100% mortality after 2 weeks and 10 weeks respectively. Furthermore, there is evidence that TBT causes recruitment failure in bivalves, due to either reproductive failure or larval mortality (Bryan & Gibbs, 1991). The sensitivity of *Spatangus purpureus*, would be expected to be similar to another heart urchin, *Echinocardium cordatum*. Detergents used to disperse oil from the *Torrey Canyon* oil spill caused mass mortalities of *Echinocardium cordatum* (Smith, 1968) and its sensitivity to TBT is similar to that of other benthic organisms with LC_{50} values of 222ng Sn/l in pore water and 1594ng Sn/g dry weight of sediment (Stronkhorst *et al*., 1999). Given the likely sensitivity of the venerid bivalves, biotope sensitivity is assessed as high and species richness is expected to decline. Recoverability is recorded as high	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	High	High	Deposit feeding may be a particularly important route for exposure to toxins within this biotope. Beaumont *et al.* (1989) concluded that bivalves were particularly sensitive to tri-butyl tin (TBT), the toxic component of many antifouling paints. For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scobicularia plana* suffered 100% mortality after 2 weeks and 10 weeks respectively. There is also evidence that TBT caused recruitment failure in bivalves, due to either reproductive failure or larval mortality (Bryan & Gibbs, 1991). *Abra alba* failed to burrow into sediment contaminated with pesticides (6000 ppm parathion, 200 ppm methyl parathion and 200 ppm malathion) (Møhlenberg & Kiørboe, 1983), which would make it prone to predation. Detergents used to disperse oil from the Torrey Canyon oil spill caused mass mortalities of *Echinocardium cordatum* (Smith, 1968) and its sensitivity to TBT was similar to that of other benthic organisms with LC_{50} values of 222 ng Sn/l in pore water and 1594 ng Sn/g dry weight of sediment (Stronkhorst *et al.*, 1999). Owing to evidence of mortalities, recruitment failure and disrupted behaviour experienced by key and important functional species of the biotope, sensitivity has been assessed to be high. Recovery would be expected following degradation of the contaminants and recoverability has been assessed to be high	Moderate
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	High	High	Beaumont *et al.* (1989) concluded that bivalves are particularly sensitive to tri-butyl tin (TBT), the toxic component of many antifouling paints. For example, when exposed to 1-3 µg TBT/l, *Cerastoderma edule* and *Scobicularia plana* suffered 100% mortality after 2 weeks and 10 weeks respectively. Furthermore, there is evidence that TBT causes recruitment failure in bivalves, due to either reproductive failure or larval mortality (Bryan & Gibbs, 1991). Beaumont *et al.* (1989) also concluded that TBT had a detrimental effect on the larval and/or juvenile stages of infaunal polychaetes. Collier & Pinn (1998) investigated the effect on the benthos of ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids and a common contaminant in sea lochs. The polychaete *Hediste diversicolor* was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m² of ivermectin in a microcosm. *Arenicola marina* was also sensitive to ivermectin through the ingestion of contaminated sediment (Thain *et al.*, 1998; cited in Collier & Pinn, 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. Given the sensitivity of infaunal bivalves and polychaetes, overall biotope sensitivity is assessed as high and there is likely to be a decline in species richness in the biotope. Recoverability is assessed as high	Very Low
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	High	Sedimentary biotopes in sheltered, low energy areas, such as those in the intertidal zones of estuaries and bays are more susceptible to chemical pollution than high energy sedimentary biotopes such as this. The coarser sediments and hydrodynamic regime, including high dispersion, serves to hinder cases of severe pollution (Elliott *et al*., 1998). No evidence concerning the specific effects of chemical contaminants on *Nephtys* species was found. Boon *et al.* (1985) reported that *Nephtys* species in the North Sea accumulated organochlorines but, based on total sediment analyses, organochlorine concentrations in *Nephtys* species were not correlated with the concentrations in the (type of) sediment that they inhabited. Specific effects of synthetic chemicals have been reported for other species of polychaete. Exposure of *Hediste diversicolor* and *Arenicola marina* to Ivermecten resulted in significant mortality (see *MarLIN* reviews; Collier & Pinn, 1998). Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum suggesting that TBT had an effect on the larval and/or juvenile stages of these polychaetes. Bryan & Gibbs (1991) reported that *Arenicola costata* larvae were unaffected by 168 hr exposure to 2000 ng TBT/ l seawater and were probably relatively tolerant, but in another study, *Scoloplos*	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							armiger exhibited a dose related decline in numbers when exposed to TBT paint particles in the sediment. In general, crustaceans are widely reported to be sensitive to synthetic chemicals (Cole *et al*., 1999) and sensitivity to some specific chemicals has been observed in amphipods. Gammarid amphipods have been reported to be sensitive to TBT with 10 day LC_{50} values of 1-48ng/l (Meador *et al.*, 1993). Sensitivity has been assessed to be intermediate owing to the fact that different chemicals are likely to have different modes of action and effect on different species of polychaete and crustacean. Important characterizing species may demonstrate similar sensitivities as the species mentioned above but little evidence was found and a low confidence is recorded. Assessment of recovery assumes deterioration of contaminants (likely in a high energy environment) and recoverability has been assessed to be high as recolonization is likely via adult migration and larval settlement.	
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	High	Some species in the biotope are known to be adversely affected by synthetic chemicals. For instance, *Scoloplos armiger* (frequently found in the biotope) exhibited 'moderate' sensitivity to tributyl tin antifoulants (Bryan & Gibbs, 1991). Collier & Pinn (1998) investigated the effect on the benthos of Ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids. The polychaete *Hediste diversicolor* (frequently found in the biotope) was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m² of Ivermectin in a microcosm. On the other hand, Beaumont *et al.* (1989) investigating the effects of tri-butly tin (TBT) on benthic organisms found that at concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* (an infrequent componant of the biotope) after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages of these polychaetes. *Polydora ciliata* was abundant at polluted sites close to acidified, halogenated effluent discharge from a bromide-extraction plant in Amlwch, Anglesey (Hoare & Hiscock, 1974). Spionid polychaetes, oligochaetes (principally *Tubificoides benedeni*) and *Hydrobia ulvae* were found by McLusky (1982) to be amongst the most tolerant species in the vicinity of a of a petrochemical industrial waste in the Firth of Forth, Scotland. The biotope occurs in polluted conditions and overall, a sensitivity of intermediate is suggested reflecting the likelhood that some chemicals might adversely affect some species reducing abundance and viability but the biotope would persist. For recoverability, see additional information. Recovery would require synthetic chemicals to have depurated from the sediment.	Moderate
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Intermediate	High	Bryozoans are common members of the fouling community, and amongst those organisms most resistant to antifouling measures, such as copper containing anti-fouling paints (Soule & Soule, 1979; Holt *et al.*, 1995). However, Hoare & Hiscock (1974) suggested that Polyzoa (Bryozoa) were amongst the most sensitive species to acidified halogenated effluents in Amlwch Bay, Anglesey and reported that *Flustra foliacea* did not occur less than 165m from the effluent source and noted that *Bugula flabellata* did not occur within the bay. *Urticina felina* survived near to the acidified halogenated effluent discharge in a 'transition' zone where many other species were unable to survive, suggesting a tolerance to chemical contamination but did not survive closer to the effluent source (Hoare & Hiscock, 1974). Moran & Grant (1993) reported that settlement of marine fouling species, including *Bugula neritina* was significantly reduced in Port Kembla Harbour, Australia, exposed to high levels of cyanide, ammonia and phenolics. The species richness of hydroid communities decreases with increasing pollution (Boero, 1984; Gili & Hughes, 1995). Stebbing (1981) reported that Cu, Cd, and tributyl tin fluoride affected growth regulators in *Laomedea* (as *Campanularia*) *flexuosa* resulting in increased growth. *Alcyonium digitatum* at a depth of 16m in the locality of Sennen Cove (Pedu-men-du, Cornwall) died resulting	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							from the offshore spread and toxic effect of detergents e.g. BP 1002 sprayed along the shoreline to disperse oil from the *Torrey Canyon* tanker spill (Smith, 1986). Possible sub-lethal effects of exposure to synthetic chemicals, may result in a change in morphology, growth rate or disruption of reproductive cycle. Smith (1968) also noted that large numbers of dead *Echinus esculentus* were found between 5.5 and 14.5 m in the vicinity of Sennen, presumably due to a combination of wave exposure and heavy spraying of dispersants in that area (Smith, 1968). Smith (1968) also demonstrated that 0.5 -1ppm of the detergent BP1002 resulted in developmental abnormalities in echinopluteus larvae of *Echinus esculentus*. Tri-butyl tin (TBT) has a marked effect on numerous marine organisms (Bryan & Gibbs, 1991). The encrusting bryozoan *Schizoporella errata* suffered 50% mortality when exposed for 63 days to 100ng/l TBT. Bryan & Gibbs (1991) reported that virtually no hydroids were present on hard bottom communities in TBT contaminated sites and suggested that some hydroids were sensitive to TBT levels between 100 and 500 ng/l. Copepod and mysid crustacea were particularly sensitive to TBT while crabs were more resistant (Bryan & Gibbs, 1991), although recent evidence suggests some sublethal endocrine disruption in crabs. The effect of TBT on *Nucella lapillus* and other neogastropods is well known (see review), and similar effects on reproduction may occur in other gastropod molluscs, including nudibranchs. Rees *et al.* (2001) reported that the abundance of epifauna had increased in the Crouch estuary in the five years since TBT was banned from use on small vessels. Rees *et al.* (2001) suggested that TBT inhibited settlement in ascidian larvae. This report suggests that epifaunal species (including, bryozoan, hydroids and ascidians) may be at least inhibited by the presence of TBT. Therefore, hydroids crustacea, gastropods, and ascidians are probably sensitive to TBT contamination while bryozoans are probably sensitive to other chemical pollution and a sensitivity of intermediate has been recorded, albeit at low confidence. A recoverability of moderate has been recorded.	
Shallow mixed sediment faunal communities	IMX. FaMx	Burrowing anemones in sublittoral muddy gravel IMX.An	Yes	No	Low	Intermediate	Burrowing and tube dwelling infauna, such as burrowing anemones, may be less affected by dredging than other epifauna (Gubbay & Knapman, 1999). In a study carried out in the Skomer Marine Nature Reserve the numbers of sea anemones, *Cerianthus lloydii* and *Mesacmaea mitchelli*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. Thus, it seems likely that the biotope will have low sensitivity to the benchmark level of abrasion. Recovery is expected to be good as withdrawn individuals reappear and dislodged individuals reburrow. Damaged anemones may be subject to predation by fish or other animals.	Moderate

Table A3.11. Sensitivity to heavy metal contamination.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	High	High	The capacity of bivalves to accumulate heavy metals in their tissues, far in excess of environmental levels, is well known. Reactions to sub-lethal levels of heavy metal stressors include siphon retraction, valve closure, inhibition of byssal thread production, disruption of burrowing behaviour, inhibition of respiration, inhibition of filtration rate, inhibition of protein synthesis and suppressed growth (see review by Aberkali & Trueman, 1985). No evidence was found directly relating to *Fabulina fabula*, However, inferences may be drawn from studies of a closely related species. Stirling (1975) investigated the effect of exposure to copper on *Tellina tenuis*. The 96 hour LC_{50} for Cu was 1000 µg/l. Exposure to Cu concentrations of 250 µg/l and above inhibited burrowing behaviour and would presumably result in greater vulnerability to predators. Similarly, burial of the venerid bivalve, *Venerupis senegalensis*, was inhibited by copper spiked sediments, and at very high concentrations, clams closed up and did not bury at all (Kaschl & Carballeira, 1999). The copper 10 day LC_{50} for *Venerupis senegalensis* was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999). Echinoderms are also regarded as being sensitive to heavy metals (e.g. Bryan, 1984; Kinne, 1984) while polychaetes are tolerant (Bryan, 1984). Given the likely sensitivity of the bivalves, biotope sensitivity is assessed as high and species richness is expected to decline. Recoverability is recorded as high. It should be noted that experimental exposures to heavy metals in the laboratory are likely to be far higher than those encountered in the sea and therefore the real effect *in vivo* may be far less.	Low
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	High	High	Bryan (1984) suggests that the larval and embryonic stages of bivalves are particularly sensitive to heavy metal contamination. Kaschl & Carballeira (1999) investigated the effect of sediment contamination on the venerid bivalve, *Venerupis senegalensis* by exposing the species to sediments spiked with copper sulphate. Slowing of clam burial correlated positively with copper concentration and at very high concentrations, clams closed up and did not bury at all. Spiking of the sediments with copper also resulted in re-emergence between 24 and 120 hours after burial, a behaviour not observed in controls. The copper 10 day LC_{50} for *Venerupis senegalensis* was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999). Echinoderms are also regarded as being sensitive to heavy metals (e.g. Bryan, 1984; Kinne, 1984) while polychaetes are tolerant (Bryan, 1984). Given the likely sensitivity of the venerid bivalves, biotope sensitivity is assessed as high and species richness is expected to decline. Recoverability is recorded as high	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	High	High	Kaschl & Carballeira (1999) investigated the effect of sediment contamination on *Venerupis senegalensis* (studied as *Venerupis pullastra*) by exposing the species to sediments spiked with copper sulphate. Following placement of clams on the sediment surface, slowing of burial was observed in proportion to the concentration of copper added to the sediment. The effect was detectable at a pore water concentration of 95 µg Cu/l. At the highest copper concentrations (spiking solution concentration > 125 mg Cu/l), the majority of clams closed up and did not bury. Spiking of the sediments with copper also resulted in re-emergence between 24 and 120 hours after burial, a behaviour not observed in controls. The proportion of clams re-emerging increased with the copper concentration in the sediment, and was concluded to be an avoidance behaviour. Kaschl & Carballeira (1999) suggested that the delay in burial at low copper concentrations was due to physiological disruption as it did not avoid exposure to the toxin and further increased the risk of predation. At higher concentrations, there was a payoff between toxin avoidance (by valve closure or re-emergence) and predator avoidance. The copper 10 day $LC_{50}$for *Venerupis senegalensis* was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999). For reference to polluted UK sediments, copper concentration in the interstitial water of Restronguet Creek sediments has been measured at 100µg/l (Bryan & Langston, 1992). Eisler (1977) exposed *Mya arenaria* to a mixture of heavy metals in solution at concentrations equivalent to the highest recorded concentrations in interstitial waters in the study area. At 0°C and 11°C (winter temperatures) 100% mortality occurred after 4-10 weeks. At 16-22°C (summer temperatures) 100% mortality occurred after 6-14 days, indicating greater sensitivity at higher temperatures. Generally, polychaetes (e.g. Bryan, 1984), gastropods (e.g. Bryan, 1984) and macroalgae (e.g. Strömgren, 1979) are regarded as being tolerant of heavy metal contamination. In light of the high sensitivity of bivalves, including the important characterising species, overall biotope sensitivity is assessed as high and species richness is expected to decline. Recoverability is recorded as high.	High

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	High	Higher energy sedimentary biotopes such as IGS.NcirBat are less likely to concentrate heavy metal contaminants than low energy muddy sediments. The coarser sediment grade and the hydrographic conditions are responsible for a high dispersion, so that instances of severe pollution are less in comparison to sheltered sand and mudflats, e.g. Bryan & Gibbs (1983; table 5) reported lower sediment-metal concentrations in sandy areas than mud near the mouth of Restronguet Creek, a branch of the Fal Estuary system which is heavily contaminated with metals. Although heavy metals may not accumulate in the substratum to the extent that they would in muddy substrata, characterizing infauna are likely to be susceptible. Bryan & Gibbs (1983) suggested metal resistance could be acquired in populations of polychaetes exposed to heavy metal contamination for a long period,. For example, *Nephtys hombergii* from Restronguet Creek seemed able to regulate copper. The head end of the worm became blackened and x-ray microanalysis by Bryan & Gibbs (1983) indicated that this was caused by the deposition of copper sulphide in the body wall. In the same study, Bryan & Gibbs (1983) presented evidence that *Nephtys hombergii* from Restronguet Creek possessed increased tolerance to copper contamination. Specimens from the Tamar Estuary had a 96 h LC_{50} of 250 µg/l, whilst those from Restronguet Creek had a 96 h LC_{50} of 700 µg/l (35 psu; 13 °C). For most metals, toxicity to crustaceans increases with decreased salinity and elevated temperature. Consequently amphipod species living within their normal salinity range may be less susceptible to heavy metal pollution than those living in salinities near the lower limit of their salinity tolerance (McLusky *et al.*, 1986). Sensitivity of the IGS.NcirBat community has been assessed to be intermediate. Infaunal population of polychaetes may be sensitive to pulses of heavy metals in solution entering the biotope, as in the absence of mud and silts in combination with the highly dispersive hydrographic regime, concentrations in the substratum are likely to be low and populations not develop resistance. Whilst many individuals may survive by escaping from the vicinity, some mortality would be expected and defaunation of the sediment occur. However, a low confidence is reported owing to limited evidence. On return to prior conditions (which assumes deterioration of the contaminant) recolonization of polychaetes and amphipod crustaceans would be expected to be rapid via adult migration and juvenile recruitment.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	Intermediate	High	Bryan (1984) suggested that polychaetes are fairly resistant to heavy metals based on the species studied. Short term toxicity in polychaetes was highest to Hg, Cu and Ag, declined with Al, Cr, Zn and Pb whereas Cd, Ni, Co and Se were the least toxic. However, polychaete species vary in their tolerance to heavy metals. For example, exposure to 10 ppm Cd in seawater halted feeding in *Arenicola marina* was also found to accumulate As, Cd, Sb, Cu, and Cr when exposed to pulverised fuel ash (PFA) in sediments (Jenner & Bowmer, 1990). The spionid polychaete, *Aphelochaeta marioni,* is apparently very tolerant of heavy metal contamination, occurring in sediments with very high concentrations of arsenic, copper, tin, silver and zinc (Bryan & Gibbs, 1983) and accumulating remarkable concentrations of arsenic (Gibbs *et al*., 1983). *Hediste diversicolor* has been found successfully living in estuarine sediments contaminated with copper ranging from 20 µm Cu/g in low copper areas to >4000 µm Cu/g where mining pollution is encountered e.g. Restronguet Creek, Fal Estuary, Cornwall (Bryan & Hummerstone, 1971). Bryan (1984) stated that Hg was the most toxic metal to bivalve molluscs while Cu, Cd and Zn seem to be most problematic in the field. In bivalve molluscs, Hg was reported to have the highest toxicity, mortalities occurring above 0.1-1 µg/l after 4-14 days exposure (Crompton, 1997), toxicity decreasing from Hg > Cu and Cd > Zn > Pb and As > Cr (in bivalve larvae, Hg and Cu > Zn > Cd, Pb, As, and Ni > to Cr). However, bivalves vary in their tolerance to heavy metals. Cole ***et al.*** (1999) suggested that Hg, Pb, Cr, Zn, Cu, Ni, and Ar were very toxic to invertebrates. Crustaceans are generally regarded to be sensitive to cadmium (McLusky *et al.*, 1986). In laboratory investigations Hong & Reish (1987) observed 96 hour LC_{50} (the concentration which produces 50% mortality) of between 0.19 and 1.83 mg/l in the water column for several species of amphipod. Overall, polychaetes and bivalves vary in sensitivity but may exhibit at least intermediate sensitivity to some heavy metals, especially Hg. Amphipods are probably more sensitive, and heavy metal contamination is likely to result in a decline in species richness. On return to prior conditions, and assuming deterioration of the contaminants, recoverability has been assessed to be high.	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	Intermediate	High	There is evidence of both lethal and sub-lethal effects upon *Macoma balthica* due to exposure to heavy metal pollution (McGreer, 1979; Luoma *et al*., 1983; Boisson *et al*., 1998). Other bivalves in the biotope are also likely to be sensitive to heavy metal pollution, as bivalves tend to accumulate heavy metals in their tissues far in excess of environmental levels. Reactions to sub-lethal levels of heavy metal stressors include siphon retraction, valve closure, inhibition of byssal thread production, disruption of burrowing behaviour, inhibition of respiration, inhibition of filtration rate, inhibition of protein synthesis and suppressed growth (see review by Aberkali & Trueman, 1985). Bryan (1984) stated that Hg was the most toxic metal to bivalve molluscs while Cu, Cd and Zn seemed to be most problematic in the field. In bivalve molluscs Hg was reported to have the highest toxicity, mortalities occurring above 0.1-1 181;g/l after 4-14 days exposure (Crompton, 1997), toxicity decreasing from Hg >Cu and Cd >Zn >Pb and As >Cr (in bivalve larvae, Hg and Cu >Zn >Cd, Pb, As, and Ni >to Cr). Owing to evidence in the literature of sub-lethal effects and mortality of bivalves, the sensitivity of the characteristic bivalve community inhabiting this biotope to heavy metal contamination has been assessed to be intermediate and species richness is expected to decline. In the absence of bivalves the biotope may begin to change to another. Furthermore, echinoderms are also regarded as being sensitive to heavy metals (e.g. Bryan, 1984; Kinne, 1984) while polychaetes are often more tolerant (Bryan, 1984). Recovery is likely to be high but would be dependent on the removal of the contaminant.	Moderate
Amphiura filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	CMS.AfilEcor		Yes	No	Intermediate	High	In Norwegian fjords, Rygg (1985) found a relationship between species diversity in benthic fauna communities and sediment concentrations of heavy metals Cu, Pb and Zn. Cu in particular showed a strong negative correlation and the author suggested a cause-effect relationship. Those species not present at sites where Cu concentrations were greater than ten times higher than the background level, such as *Amphiura filiformis* and several bivalves including *Nucula sulcata* were assessed as non-tolerant species. The tolerant species were all polychaete worms. Therefore, increased heavy metal contamination in sediments may change the faunal composition of the community and decrease overall species diversity. Some burrowing crustaceans, brittle stars and bivalves may disappear from the biotope and lead to an increasing dominance of polychaetes.	Moderate
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	Intermediate	High	There was no information found on the effect of heavy metals on sea pens. In Norwegian fjords Rygg (1985) found a relationship between species diversity in benthic fauna communities and sediment concentrations of heavy metals Cu, Pb and Zn. Copper in particular showed a strong negative correlation and the author suggested a cause-effect relationship. Those species not present at sites where Cu concentrations were greater than ten times higher than the background level, such as *Amphiura filiformis* and several bivalves including *Nucula sulcata* and *Thyasira equalis*, were assessed as non-tolerant species. The tolerant species were all polychaete worms. Therefore, increased heavy metal contamination in sediments may change the faunal composition of the community and decrease overall species diversity. However, effects of heavy metals are generally sub-lethal so a sensitivity score of intermediate is recorded.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	High	The majority of species in this biotope are polychaetes and evidence suggests that they are "fairy resistant" to the effects of heavy metals (Bryan, 1984). However, Hall & Frid (1995) found that the four dominant taxa in their study (species typically found in this biotope including *Tubificoides* spp. and *Capitella capitata*) were reduced in abundance in copper-contaminated sediments and that recovery took up to one year after the source of contamination ceased. Some other species (for instance *Carcinus maenas*) , may adapt to high metal concentrations (Bryan, 1984). *Polydora ciliata*, one of the species that occurs frequently in the biotope, occurs in an area of the southern North Sea polluted by heavy metals but was absent from sediments with very high heavy metal levels (Diaz-Castaneda *et al*., 1989). However, *Hediste diversicolor* has been found successfully living in estuarine sediments contaminated with copper ranging from 20 µm Cu/g in low copper areas to >4000 µm Cu/g where mining pollution is encountered e.g. Restronguet Creek in the Fal Estuary, Cornwall (Bryan & Hummerstone, 1971). Taking account of the low salinity conditions that affect this biotope (in general, for estuarine animals, heavy metal toxicity increases as salinity decreases and temperature increases: McLusky *et al*., 1986), it seems possible that some species in the biotope might be adversely affected by high contamination by heavy metals. The assessment of intermediate sensitivity is 'precautionary' and the specific levels at a location would need to be matched to experimental or field studies to assign a more accurate rank. For recoverability, see additional information below. Recovery of species in the biotope would be influenced by the length of time it would take for the habitat to return to a suitable state (e.g. factors such as the decline of bio-available metals within the marine environment), recolonization by adult and juvenile specimens from adjacent habitats, and the establishment of a breeding population.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Low	Very High	Various heavy metals have been show to have sublethal effects on growth in the few hydroids studied experimentally (Stebbing, 1981; Bryan, 1984; Ringelband, 2001). Bryozoans are common members of the fouling community and amongst those organisms most resistant to anti-fouling measures, such as copper containing anti-fouling paints. Bryozoans were also shown to bio-accumulate heavy metals to a certain extent (Soule & Soule, 1979; Holt *et al.*, 1995). However, *Bugula neritina* was reported to survive but not grow exposed to ionic Cu concentrations of 0.2-0.3 ppm (larvae died above 0.3ppm) but die where the surface leaching rate of Cu exceeded 10µg Cu/cm²/day (Ryland, 1967; Soule & Soule, 1979). Ryland (1967) also noted that *Bugula neritina* was less sensitive to Hg than Cu. *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton and their tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez 1999). Waters containing 25 µg / l Cu caused developmental disturbances in *Echinus esculentus* (Kinne, 1984) and heavy metals caused reproductive anomalies in the starfish *Asterias rubens* (Besten, *et al.*, 1989, 1991). Sea urchin larvae have been used in toxicity testing and as a sensitive assay for water quality (reviewed by Dinnel *et al.* 1988), so that echinoderms are probably sensitive to a heavy metal contamination. Gastropod molluscs have been reported to relatively tolerant of heavy metals while a wide range of sublethal and lethal effects have been observed in larval and adult crustaceans (Bryan, 1984). Overall, the dominant bryozoans may be tolerant and hydroids manifest only sublethal effects. The sea urchin *Echinus esculentus* is probably highly sensitive to heavy metal contamination. Heavy metals contamination may therefore, reduce reproduction and recruitment in starfish and sea urchins, potentially reducing predation pressure in the biotope. Therefore, a sensitivity of low has been recorded to represent the sublethal effects on dominant bryozoans and hydroids. Loss of predatory sea urchins may result in an increased dominance by some species and a slight decrease in species richness.	Very Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Shallow mixed sediment faunal communities	IMX. FaMx	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment IMX.Lim	Yes	No	Low	Very High	No information concerning the effects of heavy metals on *Limaria hians* was found. However, Bryan (1984) stated that Hg was the most toxic metal to bivalve molluscs while Cu, Cd and Zn seemed to be most problematic in the field. In bivalve molluscs Hg was reported to have the highest toxicity, decreasing from Hg > Cu and Cd > Zn > Pb and As > Cr (in bivalve larvae, Hg and Cu > Zn > Cd, Pb, As, and Ni > to Cr). Crompton (1997) reported that adult bivalve mortalities occurred after 4-14 day exposure to 0.1-1 µg/l Hg, 1-10 µg/l Cu and Cd, 10-100 µg/l Zn but 1-10 mg/l for Pb and Ni. Various heavy metals have been show to have sublethal effects on growth in the few hydroids studied experimentally (Stebbing, 1981; Bryan, 1984; Ringelband, 2001). Bryozoans are common members of the fouling community and amongst those organisms most resistant to anti-fouling measures, such as copper containing anti-fouling paints. Bryozoans were also shown to bio-accumulate heavy metals to a certain extent (Soule & Soule, 1979; Holt *et al.*, 1995). The sea urchin *Echinus esculentus* and starfish *Asterias rubens* were reported to show developmental or reproductive abnormalities in response to heavy metal contamination. In addition, sea urchin larvae are used a sensitive assay for water quality so that echinoderms are probably sensitive to a heavy metal contamination. Gastropod molluscs have been reported to relatively tolerant of heavy metals while a wide range of sublethal and lethal effects have been observed in larval and adult crustaceans (Bryan, 1984). Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. Overall, there was insufficient information to assess sensitivity to heavy metals in *Limaria hians*. However, the above evidence suggests that echinoderms are probably sensitive while other epifaunal species will probably exhibit at least sub-lethal effects. Therefore, a sensitivity of low has been recorded at very low confidence to represent the likely decrease in abundance of some species in the biotope.	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Low	High	*Modiolus modiolus* may exhibit tolerance to heavy metals similar to that of *Mytilus edulis*. The tissue distribution of Cd, Zn, Cu, Mg, Mn, Fe and Pb was examined in *Modiolus modiolus* by Julshamn & Andersen (1983) who reported the presence of Cd binding proteins but did not document any adverse affects. Richardson *et al.* (2001) examined the presence of Cu, Pb and Zn in the shells of *Modiolus modiolus* from a relatively un-contaminated site and from a site affected by sewage sludge dumping. The persistence of a population of horse mussels at the sewage sludge dumping site suggests that tolerance to heavy metal contamination levels at that site. Holt *et al.* (1998) reported that long-term changes in contaminant loads associated with spoil dumping were detectable in the shells of horse mussels in a bed off the Humber estuary. This observation showed survival of horse mussels in the vicinity of a spoil dumping ground but no information on their condition was available (Holt *et al.*, 1998). Little information on the effects of heavy metal contamination of other members of the community was found. However, *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez, 1999). Bryan (1984) reported that early work had shown that echinoderm larvae were sensitive to heavy metals. However, it is unlikely that established sea urchins would be adversely affected and there is no evidence to suggest that mortality would occur in associated species in the biotope. Heavy metal contamination may affect the condition of species in the biotope and, therefore, a sensitivity of low has been recorded. Recovery of the biotope will depend on depuration or detoxification of the heavy metals and recovery of condition, therefore a recovery of high has been reported.	Very Low

Table A3.12. Sensitivity to hydrocarbon contamination.

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Macoma balthica and *Abra alba* in infralittoral muddy sand or mud.	IMS.MacAbr		Yes	No	High	High	Stekoll *et al.* (1980) reported a range of behavioural, physical, physiological and biochemical changes prior to death following exposure to Prudhoe Bay crude oil at varying concentrations (0.03; 0.3 and 3.0 mg /l). Effects included inhibition of growth, re-absorption and abnormalities of the gonads, emergence from the substratum and poor orientation in addition to increased mortality at the highest concentration. Stekoll *et al*. (1980) concluded that chronic exposure of *Macoma balthica* to oil-in-seawater concentrations even as low as 0.03 mg/l would in time lead to population decreases. The specimens used by Stekoll *et al*., (1980) were not subjected to any of the stresses that normally occur in their natural environments so sensitivity would be expected to be higher in field conditions. *Macoma balthica* was considered a key functional species of this biotope and is also characteristic. If *Macoma balthica* was lost from the biotope as a result of hydrocarbon pollution, the biotope would not be recognized so sensitivity has been assessed to be high. Recoverability has been assessed to be high assuming contamination is removed	High
Venerid bivalves in circalittoral coarse sand or gravel.	CGS.Ven		Yes	Yes	High	High	Suchanek (1993) reviewed the effects of oil on bivalves. Sublethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates have increased at low concentrations and decreased at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Axiak *et al.* (1988) investigated the physiological response of *Venus verrucosa* to oil contamination. Long term exposure (150 days) to low levels (100 µg/l) of the water accommodated fraction of oil resulted in atrophy of digestive cells and reduced membrane stability. These responses caused a significant reduction in the scope for growth. Exposure to high concentrations of oil (420 µg/l) resulted in increased cellular volume, damage to the epithelial lining of the foot, stomach and style sac and atrophy of digestive cells. These responses were detected after 144 hours of exposure and would be expected to result in mortality. Dauvin (1998) reported the effects of the *Amoco Cadiz* oil spill on the fine sand *Abra alba* community in the Bay of Morlaix. Reductions in abundance, biomass and production of the community were very evident through the disappearance of the dominant populations of the amphipods *Ampelisca* sp. which are very sensitive to oil contamination. The spill occurred in 1978 and after 2 weeks, the level of hydrocarbons in subtidal sediments reached 200 ppm (Dauvin, 1984; cited in Poggiale & Dauvin, 2001). This caused the disappearance of the *Ampelisca* populations, leaving behind a single species, *Ampelisca sarsi*, in very low densities. The sediment rapidly depolluted and in 1981 benthic recruitment occurred in normal conditions (Dauvin, 1998). However, the recovery of the *Ampelisca* populations took up to 15 years. This was probably due to the amphipods' low fecundity, lack of pelagic larvae and the absence of local unperturbed source populations (Poggiale & Dauvin, 2001). Echinoderms also seem to be especially sensitive to the toxic effects of oil, probably because of the large amount of exposed epidermis (Suchanek, 1993). The high sensitivity of *Echinocardium cordatum* to hydrocarbons was seen by the mass mortality of animals, down to about 20m, shortly after the *Amoco Cadiz* oil spill (Cabioch *et al*., 1978). The biotope generally appears to be very sensitive to pollution by hydrocarbons, so sensitivity is assessed as high, and there would be a decline in species richness. The majority of the species are likely to recover relatively quickly, with the exception of the amphipods *Ampelisca* sp., and so recoverability is recorded as high.	Low
Amphiura	CMS.AfilEcor		Yes	No	High	Moderate	There was no information found on the effect of hydrocarbon pollution on the biotope. The best documented oil	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
filiformis and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand							spill for protected habitats with soft mud/sand substrates is the West Falmouth, Florida spill of 1969. Immediately after the spill virtually the entire benthic fauna was eradicated immediately following the incident and populations of the opportunistic polychaete *Capitella capitata* increased to abundances of over 200,000/m² (Sanders, 1978). The key species in the biotope, *Amphiura filiformis* and *Echinocardium cordatum* and also *Callianassa subterranea* are very sensitive to hydrocarbon pollution and so the sensitivity of the biotope is recorded as high. Mass mortality of *Echinocardium cordatum*, down to about 20m, was observed shortly after the *Amoco Cadiz* oil spill (Cabioch *et al*., 1978). However, oil from spills would have to be dispersed deep into the water column to affect the biotope and since the biotope occurs in very sheltered conditions this is unlikely to occur. However, the key species in the biotope have been observed to be sensitive to chronic oil pollution. For example, reduced abundance of *Echinocardium cordaturm* was detectable up to > 1000m away one year after the discharge of oil-contaminated drill cuttings in the North Sea (Daan & Mulder, 1996). *Callinanassa subterranea* also appears to be highly sensitive to sediment contaminated by oil-based drilling muds (Daan *et al*., 1992) and in a study of the effects of oil exploration and production on benthic communities Olsgard & Gray (1995) found *Amphiura filiformis* to be very sensitive to oil pollution. Oil polluted sediments may remain so for many years so recovery may be protracted. For example, persistent toxicity of *Amoco Cadiz* oil in sediment prevented the start of the recovery period (Clark, 1997). On return to normal conditions, recovery may take many years because of the life-history of the key species. Recovery is recorded to be moderate.	
Shallow mixed sediment faunal communities	IMX. FaMx	***Venerupis senegalensis*** and ***Mya truncata*** in lower shore or infralittoral muddy gravel IMX.VsenMtru	Yes	Yes	Intermedaite	Moderate	Oil spills resulting from tanker accidents can cause large-scale deterioration of communities in shallow subtidal sedimentary systems. The majority of benthic species often suffer high mortality, allowing a few tolerant opportunistic species to proliferate. For example, after the *Florida* spill of 1969 in Massachusetts, the entire benthic fauna was eradicated immediately following the spill and populations of the opportunistic polychaete *Capitella capitata* increased to abundances of over 200,000/m² (Sanders, 1978). Suchanek (1993) reviewed the effects of oil on bivalves. Sublethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates have increased at low concentrations and decreased at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Mortality following oil spills has been recorded in *Mya arenaria* (Dow, 1978; Johnston, 1984), *Ensis* sp. (SEEC, 1998) and *Cerastoderma edule* (SEEEC, 1998). Suchanek (1993) reported that infaunal polychaetes were also vulnerable to hydrocarbon contamination. For example, high mortality has been demonstrated in *Arenicola marina* (Levell, 1976). However, deposit feeders, such as *Aphelochaeta marioni*, are likely to be less vulnerable due to the feeding tentacles being covered with a heavy secretion of mucus (Suchanek, 1993). As the biotope occurs subtidally, it is likely to avoid the worst impact of an oil spill and therefore the sensitivity is recorded as intermediate. Some of the more sensitive species are likely to be eradicated so there may be a minor decline in species richness. Oil has the capacity to persist for a long time in soft sediments and so recoverability is assessed as moderate.	Moderate

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Virgularia mirabilis and *Ophiura spp*. on circalittoral sandy or shelly mud.	CMS.VirOph		Yes	Yes	Intermediate	High	There is very little information available on the impact of hydrocarbons on the species in the biotope. Nothing could be found for *Virgularia mirabilis* or other sea pens. In a study of the effects of oil exploration and production on benthic communities Olsgard & Gray (1995) found *Amphiura filiformis* to be very sensitive to oil pollution. The overall impact of oil contamination on the biotope is likely to be a loss of species diversity as very sensitive species are lost and so sensitivity of the biotope is reported to be intermediate but with a very low confidence. However, the biotope is found in the circalittoral and so any oil from spills would have to be dispersed deep into the water column to affect them. In addition the biotope occurs in sheltered locations and storms would be unlikely to disperse oils to these depths and so the biotope is not particularly vulnerable to this particular factor.	Very Low
Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand.	IGS.Lcon		Yes	Yes	Intermediate	High	Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general, on soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected. A 20 year study investigating community effects after the *Amoco Cadiz* oil spill of 1978 (Dauvin, 2000) found that a population of *Lanice conchilega* was established between 1978-84 but disappeared after 1985. Hailey (1995) cited substantial kills of *Hediste diversicolor*, *Cerastoderma edule*, *Macoma balthica*, *Arenicola marina* and *Hydrobia ulvae* as a result of the Sivand oil spill in the Humber estuary in 1983. Levell (1976) examined the effects of experimental spills of crude oil and oil: dispersant (BP1100X) mixtures on *Arenicola marina*. Single spills caused 25-50 % reduction in abundance and additional reduction in feeding activity. Up to four repeated spillages (over a 10 month period) resulted in complete eradication of the affected population due to either death or migration out of the sediment. Levell (1976) also noted that recolonization was inhibited but not prevented. Prouse & Gordon (1976) found that *Arenicola marina* was driven out of the sediment by waterborne concentration of >1 mg/l of fuel oil or sediment concentration of >100 µg/g fuel oil. Seawater oil concentrations of 0.7 mg oil /l reduced feeding after five hours and all worms exposed for 22 hours to 5mg/l oil left the sediment and died after three days. However, the sample size, in the experiment, was very small (6 worms). Sediment concentration >10g/g could reduce feeding. However, *Nephtys hombergii*, cirratulids and capitellids were largely unaffected by the *Amoco Cadiz* oil spill Conan (1982). Generally, contact with oil in bivalves causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce infaunal burrowing rates. After the *Amoco Cadiz* oil spill *Fabulina fabula* (studied as *Tellina fabula*) started to disappear from the intertidal zone a few months after the spill and from then on was restricted to subtidal levels. In the following two years, recruitment of *Fabulina fabula* was very much reduced (Conan, 1982). The *Amoco Cadiz* oil spill also resulted in reductions in abundance, biomass and production of the community through the disappearance of the dominant populations of the amphipods *Ampelisca* sp. which are very sensitive to oil contamination (Dauvin, 1998) The sediment rapidly de-polluted and, in 1981, benthic recruitment occurred under normal conditions (Dauvin, 1998). However, the recovery of *Ampelisca* populations took up to 15 years. This was probably due to the amphipods' low fecundity, lack of pelagic larvae and the absence of local unperturbed source populations (Poggiale & Dauvin, 2001). The above evidence suggests that soft sediment communities are highly sensitive to perturbation by oil spills. However, the biotope occurs subtidally and so the majority of the biotope is unlikely to be affected directly but may be exposed to water soluble fractions of hydrocarbons, and oils adsorbed onto particulates. Therefore, a sensitivity of intermediate has been recorded. Recovery of amphipods to the biotope is likely to be slow. However, *Lanice conchilega* was shown to be relatively opportunistic after the *Amoco Cadiz* oil spill, colonizing shortly after the spill (Dauvin, 2000). Therefore, recoverability is likely to be high.	High

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
Sertularia cupressina and *Hydrallmania falcata* on tide-swept sublittoral cobbles or pebbles in coarse sand.	IGS.ScupHyd	MCR.Flu	Yes	No	Intermediate	High	*Flustra foliacea* dominated communities are likely to be protected from the direct effects of oil spills by its subtidal habit but may be exposed to emulsified oil treated with dispersants, especially in areas of turbulence, or exposed to water soluble fractions of oils, PAHs or oil adsorbed onto particulates. For example: • Species of the encrusting bryozoan *Membranipora* and the erect bryozoan *Bugula* were reported to be lost or excluded from areas subject to oil spills. (Mohammad, 1974; Soule & Soule, 1979). Houghton *et al.* (1996) also reported a reduction in the abundance of intertidal encrusting bryozoa (no species given) at oiled sites after the *Exxon Valdez* oil spill. • The water soluble fractions of Monterey crude oil and drilling muds were reported to cause polyp shedding and other sublethal effects in the athecate hydroid *Tubularia crocea* in laboratory tests (Michel & Case, 1984; Michel *et al.*, 1986; Holt *et al.*, 1995). • Suchanek (1993) reported that the anemones *Anthopleura* spp. and *Actinia* spp. survived in waters exposed to spills and chronic inputs of oils. Similarly, one month after the *Torrey Canyon* oil spill the dahlia anemone, *Urticina felina*, was found to be one of the most resistant animals on the shore, being commonly found alive in pools between the tide-marks which appeared to be devoid of all other animals (Smith, 1968). • Amphipods, especially ampeliscid amphipods, are regarded as especially sensitive to oil (Suchanek, 1993). • Smith (1968) reported dead colonies of *Alcyonium digitatum* at depth in the locality of Sennen Cove (Pedu-men-du, Cornwall) resulting from the combination of wave exposure and heavy spraying of dispersants sprayed along the shoreline to disperse oil from the *Torrey Cannon* tanker spill (see synthetic chemicals). • Crude oil from the *Torrey Canyon* and the detergent used to disperse it caused mass mortalities of echinoderms; *Asterias rubens*, *Echinocardium cordatum*, *Psammechinus miliaris*, *Echinus esculentus*, *Marthasterias glacialis* and *Acrocnida brachiata* (Smith, 1968). *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez, 1999). • *Halichondria panicea* survived in areas affected by the *Torrey Canyon* oil spill, although few observations were made (Smith 1968). If the physiology within different animals groups can be assumed to be similar, then bryozoans, amphipods, echinoderms and soft corals may be sensitive to hydrocarbon contamination, while hydroids may demonstrate sublethal effects and anemones and some species of sponge are relatively tolerant. Some members of the bryozoan turf and some members of the community may be lost or damaged as a result of acute hydrocarbon contamination, although a recognisable biotope may remain. Therefore, a sensitivity of intermediate has been suggested, albeit at very low confidence. Recoverability is likely to be moderate.	Low
Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	IGS.FabMag		Yes	Yes	Intermediate	High	Suchanek (1993) reviewed the effects of oil on bivalves. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Conan (1982) investigated the long term effects of the *Amoco Cadiz* oil spill at St Efflam beach in France. It was estimated that the delayed mortality effects on sand and mud biotas were 1.4 times as large as the immediate effects. *Fabulina fabula* (studied as *Tellina fabula*) started to disappear from the intertidal zone a few months after the spill and from then on was restricted to subtidal levels. In the following 2 years, recruitment of *Fabulina fabula* was very much reduced. The author commented that, in the long term, the biotas most severely affected by oil spills are low energy sandy and muddy shores, bays and estuaries. In such places, populations of species with	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							long and short term life expectancies (e.g. *Fabulina fabula, Echinocardium cordatum* and *Ampelisca* sp.) either vanished or displayed long term decline following the *Amoco Cadiz* oil spill. Polychaetes, however, including *Nephtys hombergii*, cirratulids and capitellids were largely unaffected. Dauvin (1998) reported the effects of the *Amoco Cadiz* spill on the fine sand community in the Bay of Morlaix. Reductions in abundance, biomass and production of the community were very evident through the disappearance of the dominant populations of the amphipods *Ampelisca* sp. which are very sensitive to oil contamination. 2 weeks after the spill, the level of hydrocarbons in subtidal sediments reached 200 ppm (Dauvin, 1984; cited in Poggiale & Dauvin, 2001). This caused the disappearance of the *Ampelisca* populations, leaving behind a single species, *Ampelisca sarsi*, in very low densities. The sediment rapidly depolluted and in 1981 benthic recruitment occurred in normal conditions (Dauvin, 1998). However, the recovery of the *Ampelisca* populations took up to 15 years. This was probably due to the amphipods' low fecundity, lack of pelagic larvae and the absence of local unperturbed source populations (Poggiale & Dauvin, 2001). Echinoderms also seem to be especially sensitive to the toxic effects of oil, probably because of the large amount of exposed epidermis (Suchanek, 1993). The high sensitivity of *Echinocardium cordatum* to hydrocarbons was seen by the mass mortality of animals, down to about 20m depth, shortly after the *Amoco Cadiz* oil spill (Cabioch *et al.*, 1978). Many species in the biotope are highly sensitive to hydrocarbon contamination. However, the biotope occurs subtidally in low energy environments and so the majority of the biotope is likely to remain unaffected. Biotope sensitivity is therefore assessed as intermediate with no change in species richness. Recoverability is likely to be limited by slow recovering species such as the amphipods. However, persistence of local populations should ensure that recovery occurs within 5 years and so recoverability is recorded as high.	
Modiolus modiolus beds on circalittoral mixed sediment.	CMX.ModMx	MCR.ModT.	Yes	Yes	Intermediate	High	Horse mussel beds are protected from the direct effects of oil spills due to their subtidal habitat, although shallow subtidal populations will be more vulnerable. Horse mussel beds may still be affected by oil spills and associated dispersants where the water column is well mixed vertically, e.g. in areas of strong wave action. Oils may be ingested as droplets or adsorbed onto particulates. Hydrocarbons may be ingested or absorbed from particulates or in solution, especially PAHs. Suchanek (1993) noted that sub-lethal levels of oil or oil fractions reduce feeding rates, reduce respiration and hence growth, and may disrupt gametogenesis in bivalve molluscs. Widdows *et al.* (1995) noted that the accumulation of PAHs contributed to a reduced scope for growth in *Mytilus edulis*. Holt & Shalla (unpublished; cited in Holt *et al.*, 1998) did not observe any visible affects on a population of *Modiolus modiolus* within 50m of the wellhead of a oil/gas exploration rig (using water based drilling muds) in the north east of the Isle of Man. Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995). *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez 1999). The sub-cuticular bacteria that are symbiotic with *Ophiothrix fragilis* are reduced in number following exposure to hydrocarbons. Exposure to 30,000 ppm oil reduces the bacterial load by 50 % and brittle stars begin to die (Newton & McKenzie, 1995). However, there are no field observations of mortalities caused by exposure to hydrocarbons. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy 1984 cited in Holt *et al.* 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. O'Brien & Dixon	Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
							(1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction, and that the filamentous forms were the most sensitive. Therefore, is it possible that hydrocarbon contamination may reduce reproductive success and growth rates in horse mussel populations. Reduced scope for growth may be of particular importance in juveniles that are subject to intense predation pressure, resulting in fewer individuals reaching breeding age. However, May & Pearson (1995) reported that stations in the vicinity of ballast water diffuser, probably containing fresh petrogenic hydrocarbons, showed a consistently high diversity (since surveys started in 1978) and included patches of *Modiolus* sp. beds. The strong currents in the area probably flushed polluting materials away from the station, and hence reduced the stress on the population (May & Pearson, 1995). The persistence of a highly diverse community suggests low sensitivity to hydrocarbon contaminated effluent. However, red algae are likely to be highly sensitive to hydrocarbon contamination (see benchmark), suggesting that while overall species richness and diversity may not be reduced significantly, some characterising species may be lost, or their abundance reduced. Therefore, an overall biotope sensitivity of intermediate has been recorded. Recovery would depend on growth of surviving epifauna, or re-colonization and would probably require up to 5 years	
Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud	IMU.AphTub	IMU.NhomTub	Yes	N/A	Intermediate	High	The biotope is predominantly subtidal and component species are protected from the direct effects of oil spills by their depth but are likely to be exposed to the water soluble fraction of oils and hydrocarbons, or hydrocarbons adsorbed onto particulates. Some of the polychaetes in this biotope proliferate after oil spills: for instance *Capitella capitata* (Suchanek, 1993) and *Aphelochaeta marioni* (Dauvin, 1982, 2000). Cirratulids (but these are not a major component of the biotope) seem mostly immune probably because their feeding tentacles are protected by mucus (Suchanek, 1993). Nevertheless it might be expected that some of the species in the biotope may be affected and the increase in abundance of some species sugests reduced competion with others. However, because some species in the biotope may increase in abundance following a spill, and because of the subtidal character of the biotope, it is expected that adverse effects from hydrocarbons may reduce abundance and viability of some species but the biotope would persist. A sensitivity of Intermediate is therefore suggested but with a high recoverability	Moderate
Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand	IGS.NcirBat		Yes	Yes	Intermediate	High	Oil spills resulting from tanker accidents have caused deterioration of sandy communities in the intertidal and shallow sublittoral. Subtidal sediments, however, may be at less risk from oil spills unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil in to the sediment (Elliott *et al.*, 1998). Microbial degradation of the oil within the sediment would increase the biological oxygen demand and oxygen within the sediment may become significantly reduced. Species within the biotope have been reported to be sensitive to oil pollution, e.g. amphipods (Suchanek, 1993). After the *Amoco Cadiz* oil spill there was a reduction in both the number of amphipod species and the number of individuals (Cabioch *et al.*, 1978). Initially, significant mortality would be expected, attributable to toxicity. Amphipod populations have been reported not return to pre-spill abundances for five or more years, which is most likely related to the persistence of oil within sediments (Southward, 1982). *Nephtys* species were amongst the fauna that was eradicated from sediments following the 1969 West Falmouth spill of Grade 2 diesel fuel documented by Saunders (1978). Sensitivity to hydrocarbon contamination has been assessed to be high even though in the sublittoral oil may not reach the benthos as readily. Recoverability has been assessed to be moderate owing to evidence that following oil spills amphipod communities have not rapidly recovered.	Very Low
Shallow mixed sediment faunal	IMX. FaMx	*Limaria hians* beds in tide-	Yes	No	Low	Very High	No information concerning the effects of heavy metals on *Limaria hians* was found. However, Bryan (1984) stated that Hg was the most toxic metal to bivalve molluscs while Cu, Cd and Zn seemed to be most problematic	Very Low

Biotope Name	Biotope code	Represented by biotope	E.C. Hab. Dir.	UK BAP	Sensitivity	Recovery	Explanation	Evidence/ Confidence
communities		swept sublittoral muddy mixed sediment IMX.Lim					in the field. In bivalve molluscs Hg was reported to have the highest toxicity, decreasing from Hg > Cu and Cd > Zn > Pb and As > Cr (in bivalve larvae, Hg and Cu > Zn > Cd, Pb, As, and Ni > to Cr). Crompton (1997) reported that adult bivalve mortalities occurred after 4-14 day exposure to 0.1-1 µg/l Hg, 1-10 µg/l Cu and Cd, 10-100 µg/l Zn but 1-10 mg/l for Pb and Ni. Various heavy metals have been show to have sublethal effects on growth in the few hydroids studied experimentally (Stebbing, 1981; Bryan, 1984; Ringelband, 2001). Bryozoans are common members of the fouling community and amongst those organisms most resistant to anitfouling measures, such as copper containing anti-fouling paints. Bryozoans were also shown to bioaccumulate heavy metals to a certain extent (Soule & Soule, 1979; Holt *et al.*, 1995). The sea urchin *Echinus esculentus* and starfish *Asterias rubens* were reported to show developmental or reproductive abnormalities in response to heavy metal contamination. In additon, sea urchin larvae are used a sensitive assay for water quality so that echinoderms are probably sensitive to a heavy metal contamination. Gastropod molluscs have been reported to relatively tolerant of heavy metals while a wide range of sublethal and lethal effects have been observed in larval and adult crustaceans (Bryan, 1984). Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. Overall, there was insufficient information to assess sensitivity to heavy metals in *Limaria hians*. However, the above evidence suggests that echinoderms are probably sensitive while other epifaunal species will probably exhibit at least sub-lethal effects. Therefore, a sensitivity of low has been recorded at very low confidence to represent the likely decrease in abundance of some species in the biotope.	

APPENDIX 4. European Marine Sites

The European Union Habitats and Birds Directives are international agreements that set out a number of actions to be taken for nature conservation. The Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements, and set out measures to maintain or restore, natural habitats and species of European Union interest at favourable conservation status. The Bird Directive protects all wild birds and their habitats within the European Union, especially migratory birds and those that are considered rare and vulnerable.

The Habitats and Birds Directives include requirements for the designation of conservation areas. In the case of the Habitats Directive these are Special Areas of Conservation (SACs) which support certain natural habitats or species, and in the Birds Directive, Special Protection Areas (SPAs) which support wild birds of European Union interest. These sites will form a network of conservation areas to be known as "Natura 2000". Where SACs or SPAs consist of areas continuously or intermittently covered by tidal waters or any part of the sea in or adjacent to Great Britain up to the limit of territorial waters, they are referred to as 'European Marine Sites'.

The requirements of the Habitats Directive are transposed into UK legislation through the *Conservation (Natural Habitats, &c.) Regulations 1994 (SI 1994/2716)*. The equivalent legislation in Northern Ireland is the *Conservation Regulations (Natural Habitats, &c.) (Northern Ireland) 1995*. See www.jncc.gov.uk/SACselection

Further guidance on European marine sites is contained in the Department of the Environment, Transport and Regions/Welsh Office document: *European marine sites in England and Wales: A guide to the Conservation (Natural Habitats &c.) Regulations 1994 and to the preparation and application of management schemes.*

European Marine Site	**Habitats and species** **(Interest features)**	**Interest sub-features**
Moray Firth	• Sandbanks which are slightly covered by seawater all the time • Bottlenose dolphins (*Tursiops truncatus*)	
Northumbria coast	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species	• Sandy beaches • Shallow inshore waters • Rocky shores with associated boulder and cobble beaches
Teesmouth and Cleveland coast	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species	• Sand and shingle areas • Intertidal sandflat and mudflat • Shallow coastal waters • Rocky shores • Intertidal sandflat and mudflat • Saltmarsh

Wash & North Norfolk Coast	• Large shallow inlets and bays • Sandbanks which are slightly covered by seawater all the time • Mudflats and sandflats not covered by seawater at low tide • Samphire (glasswort) *Salicornia* spp. and other annuals colonising mud and sand • Atlantic salt meadows (*Glauco-Puccinellietalia*) • Mediterranean and thermo-Atlantic halophilous scrubs (*Arthrocnemetalia fructicosae*) • Common seal (*Phoca vitulina*) • Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl, including the internationally important populations of regularly occuring migratory bird species	• Subtidal boulder and cobble communities • Subtidal mixed sediment communities • Gravel and sand communities • Muddy sand communities • Mud communities • Annual *Salicornia* saltmarsh community • Annual seablite (*Sueada maritima*) saltmarsh community • Ephemeral saltmarsh vegetation with *Sagina maritima* saltmarsh community • Low marsh communities • Mid and upper marsh communities • Transitional communities • Shrubby seablite (*Sueada vera*) saltmarsh community • Shrubby seablite (*Sueada vera*) and rock sea lavender *Limonium binervosum* saltmarsh community • Intertidal mudflats and sandflats • Coastal waters • Saltmarsh • Sand and shingle • Tidal reedbed
Great Yarmouth North Denes	• Internationally important populations of regularly occurring Annex I [bird] species	• Sand/shingle areas • Shallow coastal waters
Minsmere to Walberswick	• Internationally important populations of regularly occurring Annex I [bird] species • Annual vegetation of drift lines	• Shingle • Shallow coastal waters
Alde-Ore Estuary	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • Annual vegetation of drift lines	• Perennial vegetation of stony banks • Lagoons • Shingle areas • Intertidal mudflats • Saltmarsh communities • Shallow coastal waters
Deben Estuary	• Internationally important populations of regularly occurring Annex I [bird] species	• Intertidal mudflats communities • Saltmarsh communities
Stour and Orwell Estuary	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species	• Intertidal mudflats • Saltmarsh communities

Hamford Water	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species	• Intertidal sandflats and mudflats • Saltmarsh communities • Shell, sand and gravel shores • Shallow coastal waters
Benfleet and Southend marshes	• Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl	• Shell banks • Saltmarsh • Intertidal mudflat and sandflat communities • Eelgrass beds (*Zostera* beds)
Thames Estuary	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl	• Intertidal mudflats • Intertidal saltmarsh • Intertidal shingle
Swale and Medway	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl	• Intertidal mudflats • Intertidal saltmarsh • Shallow coastal waters • Shingle beaches
Mersey Estuary	• Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl	• Intertidal sediments • Rocky shores • Saltmarsh
Ribble and Alt Estuaries	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species	• Intertidal sands and mudflats • Saltmarsh

Morecambe Bay	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • An internationally important assemblage of waterfowl • Large shallow inlets and bays • Mudflats and sandflats not covered by seawater at low tide • Glasswort *Salicornia spp.* And other annuals colonising mud and sand • Atlantic salt meadows *Glauco-Puccinellietalia*	• Intertidal boulder and cobble skear communities • Subtidal boulder and cobble skear communities • Brittlestar bed communities • Intertidal boulder clay communities • Coastal lagoons communities • Intertidal mudflat and sandflat communities • Pioneer saltmarsh communities • Saltmarsh communities • Sand communities • Mud communities • Eelgrass bed communities • Glasswort *Salicornia spp.* communities • Low marsh communities • Mid marsh communities • High marsh communities • Transitional high marsh communities • Shingle areas • Coastal lagoons communities
Duddon Estuary	• Internationally important populations of regularly occurring Annex I [bird} species	• Shallow coastal waters • Intertidal sandflat and mudflat communities • Intertidal and subtidal boulder & cobble skear communities. • Saltmarsh communities
Drigg Coast	• Estuaries.	• Intertidal mudflats and sandflats communities • Saltmarsh communities • Boulder and cobble scars with mussel beds
Solway Firth	• Internationally important populations of regularly occurring Annex I [bird] species • Internationally important populations of regularly occurring migratory [bird] species • Estuaries	• Atlantic salt meadows communities • *Salicornia* spp. communities. • Pioneer saltmarsh communities • Intertidal mudflats and sandflats communities. • Subtidal sandbank communities • Rocky scar communities

Appendix 5. Nationally rare & scarce species

Nationally rare and scarce species are defined as follows (from Sanderson, 1996):

Nationally rare benthic marine species are those native species that occur in eight or fewer of the 10 km x 10 km squares (of the Ordnance Survey national grid) containing sea within the three-mile territorial limit for Great Britain.

Nationally scarce species are those that occur in nine to 55 such squares.

Uncommon species occur in 56 to 150 **such squares**

The list of nationally rare and scarce species given below was derived by JNCC in 1997 from Sanderson (1996) and the JNCC *Coastal Directories* series with further advice from W. G. Sanderson and J. Plaza. As work on rarity assessment is still underway the list will need amendment in the light of further research. In the list a # symbol indicates the species is protected under the Wildlife & Countryside Act 1981.

Key: UR = Under-recorded; R = rare; S = scarce; NN = non native; UC = uncommon

Species	Type of organism / Common name	Diagnosis	Rare	Scarce
Porifera (sponges)				
Stelletta grubii	Sponge	UR		*
Stryphnus ponderosus	Sponge	UR	*	
Thymosia guernei	Sponge	UR		*
Suberites massa	Sponge	R/(NN?)	*	
Adreus fascicularis	Sponge	R	*	
Axinella damicornis	Sponge			*
Phakellia ventilabrum	Sponge			*
Mycale lingua	Sponge			*
Desmacidon fruticosum	Sponge		*	
Stylostichon dives	Sponge	UR		
Clathria barleei	Sponge			*
Plocamilla coriacea	Sponge			*
Tethyspira spinosa	Sponge			*
Dysidea pallescens	Sponge		*	
Hydroids (sea firs)				
Diphasia alata	Hydroid			*
Tamarisca tamarisca	Hydroid			*
Aglaophenia kirchenpaueri	Hydroid			*
Lytocarpia myriophyllum	Hydroid			*
Hartlaubella gelatinosa	Hydroid			*
Laomedea angulata	Hydroid			*
Obelia bidentata	Hydroid		*	
Soft and horny corals				
Parerythropodium coralloides	Soft coral			*
Eunicella verrucosa#	**Pink sea fan**	UC		
Sea anemones & corals				
Pachycerianthus multiplicatus	Fireworks anemone			*
Arachnanthus sarsi	Sea anemone		*	
Parazoanthus anguicomus	Sea anemone	UR		*
Parazoanthus axinellae	Sea anemone			*
Anthopleura thallia	Red spotted sea anemone			*
Aiptasia mutabilis	Trumpet anemone			*
Cataphellia brodricii	Latticed corklet sea anemone			*
Amphianthus dohrnii	Sea fan anemone		*	
Halcampoides elongatus	Sea anemone		*	

Anemonactis mazeli	Sea anemone			*
Mesacmaea mitchellii	Sea anemone			*
Nematostella vectensis#	Starlet anemone			*
Edwardsia ivelli#	Ivell's sea anemone		*	
Edwardsia timida	Sea anemone			*
Scolanthus callimorphus	Sea anemone		*	
Caryophyllia inornata	Cup coral		*	
Hoplangia durotrix	Weymouth carpet coral		*	
Balanophyllia regia	Scarlet & goldstar coral)			*
Leptopsammia pruvoti	Sunset cup coral		*	
Echiura				
Amalosoma eddystonense	Echiuran worm	UR		*
Annelida (polychaete worms)				
Sternaspis scutata	Polychaete worm		*	
Baldia johnstoni	Polychaete worm			*
Ophelia bicornis	Polychaete worm		*	
Armandia cirrhosa#	Lagoon sand worm)		*	
Alkmaria romijni#	Tentacled lagoon worm			*
Crustacea (barnacles shrimps, crabs and lobsters				
Mitella pollicipes	Goose barnacle		*	
Rissoides desmaresti	Mantis shrimp			*
Apherusa clevei	Amphipod		*	
Apherusa ovalipes	Amphipod			*
Monoculodes gibbosus	Amphipod		*	
Monoculodes packardi	Amphipod		*	
Metopa robusta	Amphipod		*	
Harpinia laevis	Amphipod			*
Menigrates obtusifrons	Amphipod		*	
Nannonyx spinimanus	Amphipod		*	
Sophrosyne robertsoni	Amphipod		*	
Austrosyrrhoe fimbriatus	Amphipod		*	
Acanthonotozoma serratum	Amphipod		*	
Pereionotus testudo	Amphipod		*	
Gammarus chevreuxi	Amphipod			*
Gammarus insensibilis#	Lagoon sand shrimp			*
Pectenogammarus planicrurus	Amphipod			*
Eriopisa elongata	Amphipod			*
Microdeutopus stationis	Amphipod		*	
Corophium lacustre	Amphipod			*
Paradulichia typica	Amphipod		*	
Synisoma lancifer	Isopod (a sea slater)			*
Typton spongicola	Sponge shrimp		*	
Clibanarius erythropus	Hermit crab		*	
Cestopagurus timidus	Hermit crab		*	
Dromia personata	sponge crab			*
Ebalia granulosa	Crab			*
Achaeus cranchii	Crab			*
Xaiva biguttata	Crab			*
Mollusca				
Leptochiton scabridus	Chiton			*
Jujubinus striatus	Gastropod		*	
Bittium lacteum simplex	Gastropod		*	
Alvania cancellata	Gastropod			*
Hydrobia neglecta	Gastropod	UR		*
Truncatella subcylindrica	Looping snail		*	

Paludinella littorina#	Gastropod		*	
Caecum armoricum#	De Folin's lagoon snail		*	
Circulus striatus	Gastropod		*	
Ocinebrina aciculata	Gastropod		*	
Jordaniella truncatula	Gastropod		*	
Stiliger bellulus	Sea slug		*	
Tritonia manicata	Sea slug		*	
Tritonia nilsodhneri	Sea slug			*
Okenia elegans	Sea slug	UR		*
Okenia leachii	Sea slug		*	
Trapania maculata	Sea slug		*	
Trapania pallida	Sea slug			*
Greilada elegans	Sea slug		*	
Thecacera pennigera	Sea slug			*
Doris sticta	Sea slug			*
Atagema gibba	Sea slug		*	
Proctonotus mucroniferus	Sea slug		*	
Hero formosa	Sea slug	UR		*
Tenellia adspersa#	Lagoon sea slug)		*	
Caloria elegans	Sea slug		*	
Aeolidiella alderi	Sea slug			*
Aeolidiella sanguinea	Sea slug		*	
Onchidella celtica	Sea slug			*
Pteria hirundo	wing shell		*	
Atrina fragilis	Fan mussel	UR		*
Lucinella divaricata	Bivalve		*	
Thyasira gouldi#	Northern hatchet shell	?	*	
Galeomma turtoni	Weasel eye shell		*	
Acanthocardia aculeata	Spiny cockle		*	
Callista chione	Bivalve		*	
Pholadidea loscombiana	Bivalve	UR		*
Sea mats (bryozoans)				
Victorella pavida#	Trembling seamat		*	
Amathia pruvoti	Bryozoan		*	
Hincksina flustroides	Bryozoan		*	
Bugula purpurotincta	Bryozoan	UR		*
Epistomia bursaria	Bryozoan		*	
Plesiothoa gigerium	Bryozoan		*	
Escharoides mamillata	Bryozoan		*	
Porella alba	Bryozoan		*	
Watersipora complanata	Bryozoan		*	
Schizobrachiella sanguinea	Bryozoan		*	
Cylindroporella tubulosa	Bryozoan		*	
Smittina affinis	Bryozoan	UR		*
Turbicellepora magnicostata	Orange peel bryozoan		*	
Hippoporidra lusitania	Bryozoan			*
Echinodermata (starfish, sea urchins, sea cucumbers)				
Asteronyx loveni	Brittlestar			*
Ophiopsila annulosa	Brittlestar	UR		*
Ophiopsila aranea	Brittlestar	UR	*	
Paracentrotus lividus	Purple rock urchin			*
Strongylocentrotus droebachiensis	Green sea urchin			*
Cucumaria frondosa	Sea cucumber			*
Sea squirts				

Synoicum incrustatum	Colonial ascidian		*	
Polysyncraton lacazei	Colonial ascidian		*	
Leptoclinides faeroensis	Colonial ascidian		*	
Phallusia mammillata	Ascidian			*
Styela gelatinosa	Ascidian		*	
Microcosmus claudicans	Ascidian		*	
Red seaweeds				
Gelidium sesquipedale	Red seaweed		*	
Gelidiella calcicola	Red seaweed			*
Lithothamnion corallioides	Maerl			*
Cryptonemia lomation	Red seaweed		*	
Dermocorynus montagnei	Red seaweed		*	
Schmitzia hiscockiana	Red seaweed	UR/UC		*
Cruoria cruoriaeformis	Red seaweed			*
Gigartina pistillata	Red seaweed			*
Tsengia bairdii	Red seaweed		*	
Gracilaria bursa-pastoris	Red seaweed			*
Gracilaria multipartita	Red seaweed			*
Aglaothamnion diaphanum	Red seaweed		*	
Aglaothamnion priceanum	Red seaweed		*	
Anotrichium barbatum	Red seaweed		*	
Bornetia secundiflora	Red seaweed		*	
Dasya corymbifera	Red seaweed		*	
Dasya punicea	Red seaweed		*	
Chondria coerulescens	Red seaweed		*	
Lophosiphonia reptabunda	Red seaweed		*	
Pterosiphonia pennata	Red seaweed			*
Brown seaweeds				
Halothrix lumbricalis	Brown seaweed			*
Pseudolithoderma roscoffense	Brown seaweed			*
Leblondiella densa	Brown seaweed		*	
Asperococcus scaber	Brown seaweed			*
Zanardinia prototypus	Penny weed			*
Choristocarpus tenellus	Brown seaweed			*
Sphacelaria mirabilis	Brown seaweed		*	
Padina pavonica	Turkey feather alga			*
Carpomitra costata	Tassle weed			*
Desmarestia dresnayi	Brown seaweed			*
Green algae				
Stoneworts				
Cladophora battersii	Green alga		*	
Tolypella nidifica	Bird's nest stonewort		*	
Lamprothamnium papulosum#	Foxtail stonewort			*