The Marine Life Information Network® for Britain and Ireland (*MarLIN*)

Irish Sea Pilot – Mapping Sensitivity within Marine Landscapes

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Report to the Joint Nature Conservation Committee

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Executive Summary

The Marine Life Information Network for Britain and Ireland (*MarLIN*) were contracted by English Nature and the Joint Nature Conservation Committee (JNCC) to adapt and apply the methods for sensitivity assessment of habitats and species to the Marine Landscape units developed for the Irish Sea Pilot project. The purpose of the contract was to trial mapping the sensitivity of species, biotopes, and Marine Landscapes within the Irish Sea.

Marine survey data from the Marine Nature Conservation Review database and additional data collated by the Irish Sea Pilot, supplied by the JNCC, together with survey data hosted by *MarLIN,* was 'tagged' with *MarLIN* sensitivity information for 150 species and 117 biotopes. The survey data and sensitivity information were collated in a Geographical Information System (GIS) for mapping.

All of the available survey data was point source data, i.e. no information on the spatial extent of the species or biotopes was available. It was probably unrepresentative to extrapolate directly from biotope or biotope complex level sensitivities to the Marine Landscape level. Therefore, it was decided to assess the intolerance, likely recoverability and hence sensitivity of the Marine Landscapes based on knowledge already researched by *MarLIN* of the effects of environmental perturbation with reference to the *MarLIN* sensitivities of representative component biotopes.

The sensitivity of eleven Marine Landscapes to change in three environmental factors (substratum loss, smothering, and physical disturbance and abrasion) was assessed and mapped in GIS. The sensitivities of all researched species and biotopes, nationally rare and scarce, UK BAP species, UK BAP biotopes, and the provisional list of important species and habitats in the Irish Sea were also mapped. The report and the preliminary sensitivity maps were subject to consultation, including a workshop, the results of which are included in the Annex to the report. The key conclusions and recommendations follow.

- Sensitivity mapping has the potential to 'flag' locations, sites, or areas that are likely to be adversely affected by activities in the marine environment.
- Sensitivity assessments cannot consider every eventuality, and practical decisions and assumptions are required to make the assessments. Therefore, the assessments and sensitivity maps must always be interpreted by marine experts on a site-by-site and activity-by-activity basis.
- Users of sensitivity information based on biotope complexes, biotopes, nationally important features, species etc need to know how they can and cannot be used.
- The proposed sensitivities of Marine Landscapes provide an overall indication of sensitivity to the environmental factors shown based on a limited review of the literature. Sensitivity maps at the Marine Landscape level provide useful information for broad scale spatial planning and management of the marine environment.
- Geographical Information Systems allow sensitivity maps, survey data and sensitivity information to be interrogated at a variety of scales, depending on user requirements, e.g. to provide information for Strategic Environmental Assessment at the broad scale or 'zoom in' to inform local development planning, Environmental Impact Assessment, or emergency response.
- Information on the relative intensity or extent of marine activities and the resultant changes in environmental factors should be used together with sensitivity information to identify 'vulnerable' species, habitats and areas to target environmental management effort effectively.

The preliminary sensitivity maps demonstrate that species and biotope survey data can be 'tagged' with available sensitivity information to identify the location of potentially sensitive habitats and species. In addition, an approach to assessing the sensitivity of Marine Landscapes has also been demonstrated. Geographic Information Systems would allow sensitivity maps to be combined with information on the presence of statutory conservation designations (e.g. SSSIs, SACs, SPAs, MNRs), seal haul out areas, shellfishery and fishery areas, fish spawning areas, other marine activities, and link via the Internet to further information. Overall, sensitivity mapping has been shown to be a potentially powerful tool in Integrated Coastal Zone Management, Strategic Environmental Assessment, and Marine Stewardship.

Irish Sea Pilot – Mapping Sensitivity within Marine Landscapes

1. Background to contract

The Marine Life Information Network for Britain and Ireland (*MarLIN)* has been collating, interpreting and disseminating information on the likely sensitivity of UK marine species and biotopes to a range of factors since August 1999. The *MarLIN* research forms the largest body of collated knowledge on marine species and habitat sensitivity in the UK and it has always been intended to use the assessments as a basis for the development of map-based sensitivity information.

In February 2003, representatives of the nature conservation agencies in the UK, together with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and the Marine Biological Association (MBA), met to consider how the sensitivity assessment work could be utilized and developed further to support the work carried out under the Irish Sea Pilot. In particular, consideration was given to means of determining sensitivities of the broad scale Marine Landscapes to environmental factors and further to human activities in the marine environment.

The purpose of this contract was to adapt and apply the methods for determining sensitivity of biological communities and species to human activities to the scale of Marine Landscapes and to map the identified sensitivities across the Irish Sea. Marine Landscapes are broad scale units based on geophysical, physiographic and hydrodynamic characteristics of the seabed or water column, and are designed to aid management in offshore areas where biological data is lacking and the regulation of human activity needs to be addressed at the broad scale (see Golding *et al.*, 2003).

2. Contract objectives

The objectives were as follows:

i) to reach conclusions on how the sensitivity of marine species and biotopes to environmental factors or human activities can most appropriately be represented in the Irish Sea, including at the broad scale Marine Landscape level, and

ii) following from the above, to provide maps of the Irish Sea showing the distribution of sensitivity to factors or human activities.

3. Timetable

The work began on receipt of the contract on the 30 June 2003. The work timetable was a follows:

i) prepare a consultative paper by 11 July 2003;

ii) organize a workshop and complete a period of consultation by 29 August 2003;

iii) prepare a report of the consultation and workshop, revise the report accordingly by 12 September 2003, and

iv) submit revised sensitivity maps in GIS format and supporting tables by 26 September 2003.

4. Introduction

The development of standard criteria and definitions, sensitivity and recoverability assessment scales and the sensitivity assessment rationale of the *MarLIN* programme are detailed in Hiscock *et al.* (1999), Tyler-Walters & Jackson (1999), Tyler-Walters *et al.* (2001) and on the *MarLIN* Web site (www.marlin.ac.uk). The development of the SensMap approach to sensitivity assessment is detailed by Cooke & McMath (2000) and McMath *et al.* (2000). Their information is not reproduced here, except by way of providing context in relation to the Irish Sea Marine Landscapes. The reader should refer to the above texts for detailed information.

The *MarLIN* approach to sensitivity assessment was amended in March 2003 to take into account the definition of 'sensitivity' developed as part of the Review of Marine Nature Conservation (Laffoley *et al.* 2000). As a result, a single index of 'Sensitivity' derived from assessment of 'Intolerance' ('old' *MarLIN* 'Sensitivity') and 'Recoverability' is now used. The core definitions are shown in Box 1 and a full description of the derivation of the revised sensitivity scale is summarized in Appendix 1.

Box 1. Core definitions

'Biotope' refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. For practical reasons of interpretation of terms used in directives, statutes and conventions, in some documents, 'biotope' is sometimes synonymized with 'habitat'.

'Habitat' the place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum), 'features' (such as crevices, overhangs, or rockpools) and 'modifiers' (for example sand-scour, wave-surge, or substratum mobility).

'Community' refers to a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and identifiable by means of ecological survey from other groups. The community is usually considered the biotic element of a biotope.

'Intolerance' is the susceptibility of a habitat, community, or species (i.e. the components of a biotope) to damage, or death, from an external factor. Intolerance must be assessed relative to specified change in a specific environmental factor.

'Recoverability' is the ability of a habitat, community, or species (i.e. the components of a biotope) to return to a state close to that which existed before the activity or event caused change.

'Sensitivity' is dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery. For example, a "highly sensitive" species or habitat is one that is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover only over a very long period of time, (10 to 25 years: 'low' recoverability). Intolerance and hence sensitivity must be assessed relative to a specified change in a specific environmental factor.

The development of the *MarLIN* approach to sensitivity assessment and the biology and sensitivity key information reviews of species and biotopes have been undertaken in projects that were jointly funded by the Department for the Environment, Food and Rural Affairs (Defra), English Nature (EN) and Scottish Natural Heritage (SNH).

4.1. Sensitivity assessment rationale

Sensitivity assessment involves the review of available literature on the life history characteristics, distribution, environmental preferences and any effects of environmental perturbation on the chosen species. In the case of biotopes, information on the community ecology and structure of the biotope (or similar community) and its associated species is collated. The intolerance and potential recoverability of the species or biotope is then assessed with respect to 24 environmental factors. Precedence is given to direct evidence of the effects of each environmental factor on the species or biotope. Intolerance and recoverability are combined using a defined rationale to give an overall sensitivity rank that represents a species or biotopes susceptibility to damage and the time taken for its subsequent recovery. The sensitivity assessment rationale is summarized in Appendix 1.

4.2. Sensitivity assessment – its assumptions and limitations

Marine organisms may be affected by a number of human activities and natural events. The effects of an activity (or event) are dependant on the receiving environment. The same activity (or event) in different locations may have different effects. For example, an activity that markedly increased siltation may have little effect in a turbid estuary whereas it would probably have significant effects in a sheltered embayment. Therefore, the effects of an activity and the resultant change in environmental factors are site specific and cannot be generalised. Similarly, it is not possible to take into account every set of environmental conditions to which a species or biotope are exposed throughout their range.

In order to achieve a practical, systematic, and transparent approach, the assessment of intolerance, recoverability, and sensitivity required a standard set of definitions and scales (see Appendix 1). Assessment of intolerance required a specified level of environmental perturbation. Therefore, the *MarLIN* programme developed a set of 'benchmark' levels of environmental change in the environmental factors against which to assess sensitivity. The benchmarks also allow intolerance and hence sensitivity to be compared against the predicted effects of planned projects or proposals. The development of the benchmarks and their interpretation is outlined in Appendix 2.

The following decisions and assumptions are inherent in the *MarLIN* approach to sensitivity assessment.

- The intolerance, recoverability, and sensitivity of a species or biotope to a specified level of environmental perturbation are dependent on the biology of the species or ecology of the biotope.
- Intolerance, and hence sensitivity, depends on the magnitude, duration, or frequency of change in a specific environmental factor.
- The effects of an activity or natural event and the resultant change in environmental factors are site specific and cannot be generalised. Therefore, a series of standard level of effect or change in each environmental factor (benchmarks) are used for assessment (see Appendix 2).
- The benchmarks are intended to be pragmatic guidance values for sensitivity assessment; to allow comparison of sensitivities between species, and to allow comparison with the predicted effects of project proposals.
- Species or biotopes are likely to be more intolerant, and hence potentially more sensitive, to any activity or natural event that causes a change in a specific environmental factor of greater magnitude and/or longer duration and/or greater frequency than the benchmark.
- Activities that result in incremental long term change, such as climate change, are difficult to assess since the given level of change varies with time. Synergistic and antagonistic effects are also difficult to predict and are poorly understood, especially for pollutants. These effects have not been addressed within the sensitivity assessments.
- *MarLIN* sensitivity assessments are not site specific. The intolerance of a hypothetical ‘average’ species population is assessed, representing a population in the middle of its range or habitat preferences. Populations at the limits of their environmental preferences are likely to be more intolerant of environmental perturbation.
- Recoverability assumes that the impacting factor has been removed or stopped and the habitat returned to a state capable of supporting the species or biotope in question. The time taken for the habitat to return to a state capable of supporting the species or biotope is not assessed.
- Where the collated key information and other evidence suggests a range of intolerances or recoverabilities, a precautionary approach is taken, and the ‘worst case’ scenario, i.e. the higher sensitivity, is reported.
- In all cases, the explanation behind each sensitivity assessment, the relevant key information and references are highlighted.
- *MarLIN* sensitivity assessments are indicative qualitative judgements based on the best available scientific information and do not allow quantitative analysis. They represent the most likely result of a given change in a factor.

The sensitivity assessments and key information reviews are designed to provide the information required to make scientifically based environmental management decisions. It is not possible for sensitivity assessment to consider every possible outcome and is indicative. Sensitivity assessments require expert interpretation on a site-by-site or activity-by activity basis. *MarLIN* sensitivity assessments should be read in conjunction with the explanation and key information provided, together with the relevant benchmark.

5. Methodology

The large survey data set held within the Marine Nature Conservation Review (MNCR) database was provided by the Joint Nature Conservation Committee (JNCC). Additional survey data collated by the Irish Sea Pilot were also supplied by JNCC. The above data was augmented by survey data held within the *MarLIN* programme.

The JNCC also supplied the map of the proposed broad scale Marine Landscapes developed by the Irish Sea Pilot.

Due to the extremely tight deadlines for this contract, there was not enough time to assess the sensitivity of any additional species or biotopes in order to fill gaps in our sensitivity information. Similarly, there was not enough time to look for inaccuracies or omissions within the field survey data supplied. The report that follows was revised in the light of consultation with representatives of the Irish Sea Pilot, JNCC and the *MarLIN* Sensitivity Mapping Advisory group, and *MarLIN* Technical Management groups. The conclusions and recommendations of the workshop convened to discuss sensitivity assessment of broad scale Marine Landscapes are provided in the Annex to this report. There was not time in the contract to revise the sensitivity maps in light of the revisions to the Marine Landscapes proposed by Golding *et al.* (2003) after the consultation phase.

5.1. Tagging available survey data with sensitivity

All the survey data available, for both biotopes and species, was point data. No information on the spatial extent of biotopes was available. Similarly, where, biotope complex data existed, the data was point data only. Survey data could only be tagged with sensitivity information for the species and biotopes so far researched within the *MarLIN* programme. To trial the approach for the Pilot, it was agreed that the work would focus on the three environmental factors. These factors are linked to human activities of conservation concern in the Irish Sea e.g. some bottom-towed gear fisheries:

- substratum loss, i.e. removal of the substratum;
- smothering, and
- physical disturbance and abrasion.

Each intolerance assessment is made against a specified level of effect, the benchmark level. The benchmark levels of effect for each of the environmental factors above are shown in Table 1 and explained in more detail in Appendix 2. The marine and coastal activities likely to change the above and other environmental factors are shown in Appendix 3.

Table 1. The benchmark level of effect against which sensitivity is ranked.

Environmental factor	Benchmark level of effect
Substratum loss	All of substratum occupied by the species or biotope under consideration is removed. A single event is assumed for sensitivity assessment. Once the activity or event has stopped (or between regular events) suitable substratum remains or is deposited. Species or community recovery assumes that the substratum within the habitat preferences of the original species or community is present.
Smothering	All of the population of a species or an area of a biotope is smothered by sediment, similar to the existing substratum, to a depth of 5 cm above the substratum for one month. **NB** Spoil that differs from the existing sediments (e.g. in grain size, or porosity), and impermeable materials (e.g. concrete, oil, or tar) are likely to have a greater effect.
Physical disturbance or abrasion	This factor includes mechanical interference, crushing, physical blows against, or rubbing and erosion of the organism or habitat of interest. Force equivalent to a standard scallop dredge landing on or being dragged across the organism. A single event is assumed for assessment. Where trampling is relevant, the evidence and trampling intensity will be reported in the rationale.

As noted in section 4.2, species or biotopes are likely to be more intolerant, and hence potentially more sensitive, to any activity or natural event that causes a change in a specific environmental factor of greater magnitude and/or longer duration and/or greater frequency than the benchmark. For example, a species or biotope is likely to be more intolerant of the deposition on spoil that differs in grain size or porosity to the existing substratum, or that smothers the sediment for longer than a month. Similarly, on-going or frequent events, e.g. regular scallop dredging, is likely to be more damaging than the single event described in the benchmark. Regular physical disturbance or substratum loss is also likely to prevent recoverability, or lead to the development of ephemeral communities. Permanent modification of the substratum will also prevent recovery by the prior species of community.

The interpretation of benchmarks is discussed in Appendix 2. While the benchmarks are designed to be pragmatic and provide a standard for sensitivity assessment, they are not prescriptive. The biology of the species or the ecology of the biotope is taken into account in their interpretation. In a few cases, the weight of evidence has suggested that the species or biotope was of higher sensitivity than the benchmark alone suggested. In these few cases, the higher sensitivity has been recorded and the evidence used outlined in the relevant explanation for that sensitivity assessment.

The *MarLIN* Biology and Sensitivity Key Information database contains sensitivity information on 150 species and 117 biotopes (listed on the *MarLIN* Web site). The 117 biotopes researched are used to represent a further 157 biotopes. A biotope was chosen as 'representative' of one or more other biotopes if the 'representative' biotope: occurred in similar habitats; was populated by similar functional groups of organisms, and was populated by the same (or functionally similar) species indicative of sensitivity as the biotope(s) they were chosen to represent.

5.1.1 Species survey data

The species survey data was 'tagged' with available sensitivity information. Each species survey point may represent the presence of one but usually many more species. The sensitivity of each species is unique to that species, being dependent on the biology of the species. Therefore, it was felt inappropriate to aggregate the sensitivity ranks for each data point. However, in GIS, the sensitivity information on each of the species at any given point can be interrogated. Therefore, for simplicity, the colour of each survey point represents the sensitivity of the most sensitive species at that survey point.

5.1.2 Biotope survey data

Biotope data from the MNCR database was directly tagged with biotope sensitivity information for the researched biotopes or the biotopes they were chosen to represent. However, data supplied by the Irish Sea Pilot were provided in the revised, 2003 version of the UK biotope classification (Connor *et al.*, 2003).

No look-up table between the 1997 biotope classification (Connor *et al.*, 1997) and the 2003 classification was available for infralittoral rock or sublittoral sediments. Therefore, the authors used their best judgement to assign the 1997 version biotopes codes to the revised 2003 version biotope codes provided, so that the survey data could be tagged with sensitivity information. Where biotope complex data was supplied the authors again used best judgement to identify component 1997 biotopes, and the sensitivities of these likely component biotopes was plotted for each biotope complex. For simplicity, the colour of each survey point represents the sensitivity of the most sensitive biotope at that survey point.

5.1.3 Nationally important species and biotope complexes

The provisional list of nationally important species and biotope complexes identified within the Irish Sea Pilot, for which sensitivity information was available were plotted as separate maps. No maps were produced for species that were not recorded in the Irish Sea region, based on the available data sets. Although sensitivity information was available, the following nationally important species were not recorded in the Irish Sea region: *Gobius couchi, Tenellia adspersa, Atrina fragilis, Funiculina quadrangularis, Leptopsammia pruvoti,* and *Amphianthus dohrnii.*

The nationally important biotope complexes identified within the Irish Sea region were supplied in the revised biotope classification (Connor *et al.*, 2003). Therefore, the authors used their best judgement to identify their likely component biotopes under the 1997 version of the classification (Connor *et al.*, 1997). Sensitivity information on the 1997 version biotopes identified was then plotted for each of the revised biotope complexes (Connor *et al.* 2003).

In addition, the presence of UK Biodiversity Action Plan species and nationally rare or scarce species (as defined by Sanderson, 1996) were plotted and tagged with sensitivity information where available. Where relevant, the colour of each survey point represents the sensitivity of the most sensitive biotope at that survey point.

5.2. Assessing the sensitivity of Marine Landscapes

The authors felt that biotope sensitivity information was probably the most appropriate to use to assess the sensitivity of broad scale habitats because the biotope sensitivity assessment had already tried to take the community structure and the most important species with respect to sensitivity, within the biotope into account (see Appendix 1).

An initial examination of the available survey data showed that many of the Marine Landscapes (see Figure 1) contained few, if any survey data points for either species or biotopes. For example, the ‘Deep Water Channel’ Marine Landscape contained no survey information. The largest extent of the ‘Deep-Water Mud Basin’ unit, in the north west of the Irish Sea, contained biotope data from only nine survey points. While the MNCR database contained numerous biotope survey data points the vast majority are inshore or intertidal. Although some of the Marine Landscapes contained numerous survey data points, e.g. coarse sediment plains, the survey data was only point source.

Information on the relative proportion of the biotope complexes within records of biotope complexes within each Marine Landscape was prepared by Golding *et al.* (2003, draft version) during the consultation phase of this report. Although, the relative proportion of biotope complexes within a Marine Landscape represented the most likely biological communities present, it was unclear if the proportion accurately represented the relative spatial extent of the biological communities.

Information on the spatial extent of each biotope within an Marine Landscape and its relative contribution to the communities within that biotope could allow either a weighted average to be used, or for the most spatially dominant biotopes to be identified. But information on the spatial extent of biotopes or biotope complexes was not available. Therefore, the authors felt that it would be inappropriate to extrapolate directly from biotope or biotope complex sensitivities to the Marine Landscape scale, given the survey data available.

Reporting the highest sensitivity of a biotope within a Marine Landscape would probably greatly over-estimate the overall sensitivity, especially if the most sensitive biotope only occupied a few percent of the area of the Marine Landscape. A simple averaging of the sensitivity ranks of the biotopes within an Marine Landscape would probably not accurately represent the overall sensitivity of the Marine Landscape and would probably be biased towards either too high or too low a sensitivity, depending on the component biotopes. Again, the overall sensitivity could be biased towards the sensitivity of biotopes that only make up a small fraction of the Marine Landscape, and that may even be unusual biotopes within that unit.

6. Assessing sensitivity to change in environmental factors

Therefore, it was decided to attempt to assess the intolerance, likely recoverability and hence sensitivity of the Marine Landscapes based on the knowledge of the effects of environmental perturbation on similar habitats already researched by *MarLIN*. Due to our time constraints, a short literature review based on readily available literature, our existing biology and sensitivity reviews of species and biotopes, and the Marine SACs project reviews was undertaken.

In order to focus the research, the most likely and most representative component biotopes within each Marine Landscape were identified. In addition, biotopes within biotope complexes that contributed more than 10% of records (see Golding *et al.*, 2003, draft version) within the Marine Landscapes were included. The information on the sensitivity of the component, representative biotopes was used to support our decisions concerning the possible sensitivities of the Marine Landscapes. Therefore, the intolerance, recoverability, and sensitivity of each Marine Landscape unit were assessed in turn. In a few instances, Marine Landscapes were given an overall sensitivity assessment but the presence of particularly sensitive important, rare or scarce habitats or species was indicated by the phrase ‘but high in places’. This procedure added other sensitivity categories to the sensitivity map. However, the authors felt that it was important to ‘flag’ such areas, which may need closer inspection or careful management due to the presence of particularly sensitive important habitats or species.

The evidence used and the suggested broad scale sensitivity assessments are outlined in the following sections.

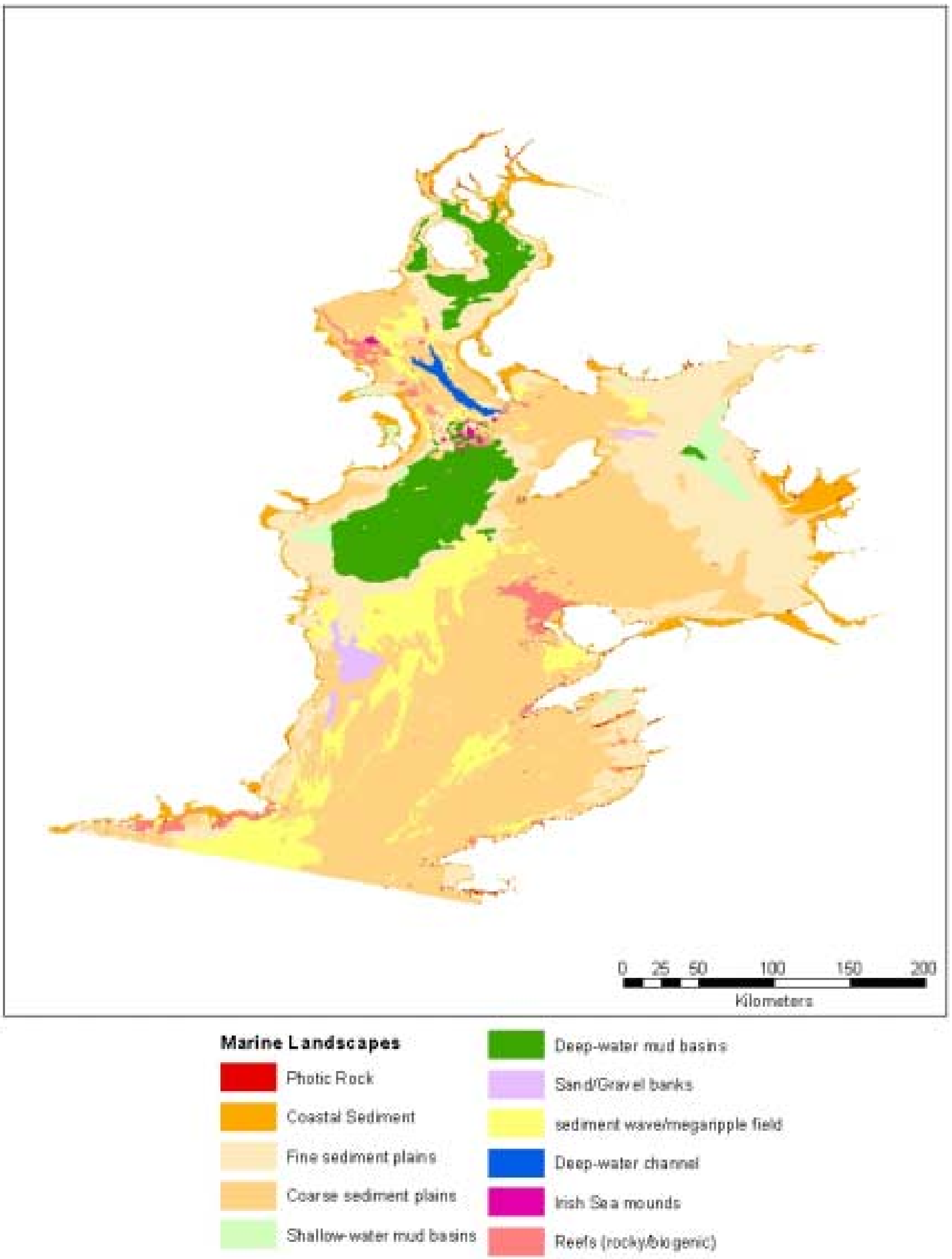

Figure 1. Marine Landscapes identified within the Irish Sea pilot.

6.1. Substratum loss

Introduction. Loss or removal of the substratum will also remove its associated species and community. The sensitivity of the habitat to substratum loss will therefore be primarily dependent on its ability to recover. The best documented evidence of the effects of substratum loss comes from studies of dredging and in particular aggregate dredging.

Intolerance. Newell *et al*. (1998) reviewed the environmental effects of dredging in coastal waters. They reported that trailer suction hopper dredging could result in dredged tracks 2-3 m wide and 0.5 m deep but up to 2 m deep in some cases. In comparison, anchored dredging may result in pits of up to 75 m in diameter and 20 m deep. Trailer dredging for aggregates resulted in troughs 20-25 cm deep and 2.5 m wide (PDE & Hill, 2001). Hall (1994) reported pits 3.5 m wide and 0.6 m deep as a result of suction dredging for *Ensis* in a Scottish sea loch.

Newell *et al.* (1998) stated that removal of 0.5 m of sediment was likely to eliminate benthos from the affected area. Dredging typically results in a reduction in species abundance, biomass, and diversity (Boyd & Rees, 2001). In addition, the removal of sediment will destroy the three dimensional structure of the sediment (for example the presence of intricate burrow systems if present), will rework the sediment affecting its structure and will leave furrows or pits.

Typically, studies indicate that marine aggregate dredging can cause a 30-70% reduction in species diversity and a 40-95% reduction in abundance or biomass within the dredged community (PDE & Hill, 2001). For example, Kenney & Rees (1994) reported a 62% reduction in species, a 94% reduction in abundance and a 90% reduction in biomass after removal of 52,000 tones of material by trailer suction dredge off the east coast of England.

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. The recovery of benthic communities after dredging was reviewed by Newell *et al.* (1998), Boyd & Rees (2001), and PDE & Hill (2001). Long-term recovery of benthic communities was reported to depend on:

- the community diversity and species richness of the habitat prior to impact;
- the physical and hydrodynamic conditions at the site;
- the similarity of the remaining habitat to that present prior to impact;
- the distribution of the component species within the surrounding area;
- the life-cycle and growth rates of the above species, and
- the extent and intensity of the impact.

Recoverability will depend on the time taken for the substratum to return to prior 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 one 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).

Recolonization follows a general pattern, involving initial colonization of the disturbed substratum by opportunistic species such as the barnacle *Balanus crenatus*, polychaete worms, and ascidians. Recruitment may occur from larval stages in the water column, depending on season and life history, or as juveniles and adults from the surrounding areas (if similar habitats are present) due in part to bedload transport (Emerson & Grant, 1991; PDE & Hill, 2001; Boyd & Rees, 2001). Secondly, after initial colonization, the biomass remains reduced until the colonizing species can grow to maturity and reach a population structure and size comparable to original levels (Boyd & Rees, 2001).

Kenny & Rees (1994, 1996) examined recolonization in mixed gravel deposits and noted that the number of species and population density significantly increased within 7 months but that average species abundance and biomass were lower than pre-dredged levels after two years. The dredged and references sites were indistinguishable after three years. Bonsdorff (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.

Boyd & Rees (2001) suggested that substantial progress towards recovery was likely within 2-3 years of cessation of dredging in sandy gravel habitats exposed to moderate wave exposure and tidal currents. However, they also reported that a recent study of a commercial extraction site indicated that recovery may be prolonged (i.e. >4 years), especially in sites subject to repeated dredging. Overall, in most of the sediment communities studied (see Appendices 4 and 5) 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. large bivalves, the heart urchin *Echinocardium cordatum* or sea pen *Virgularia mirabilis,* may only recover after many years. 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 Appendices 4 and 5).

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 horn wrack (*Flustra foliacea*), sponges, anemones, and soft corals will probably take longer to recover their original abundance (Sebens, 1985, 1986; Hartnoll, 1998). Recolonization by rare and scarce species in sedimentary or rock communities may take considerably longer.

Conclusion. Intolerance to substratum loss is likely to be high but recovery may be rapid (< 5 years) in many sediment communities but will be much slower where long-lived, slow growing species are recorded.

6.2. Smothering

Introduction. Smothering includes 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 20 m depth and several millimetres at 40 m (Hall, 1994). For example, storms were reported to deposit 4-10 cm of sand at 28 m in the Helgoland area in the German Bight and up to 11 cm 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.

Intolerance. 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 >1 cm of sediment. Infaunal non-siphonate suspension feeders were able to escape burial by 5 cm but normally <10 cm of sediment. Shallow burrowing siphonate suspension feeders and the young of otherwise deep burrowing species survived burial by 10 and 50 cm 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 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 (SOAFD, 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).

Recoverability. The significance of the impact will depend on the volume of spoil, its sediment type and grain size. 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. However, where the sediment is modified or in sheltered conditions, recovery may not begin until the deposited material is removed by natural processes, and will almost certainly involve re-colonization. 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).

Kukert & Smith (1992) examined the effects of depositing artificial mounds of similar sediment, averaging 5-6 cm thick, on polychaete dominated communities in the Santa Catalina Basin at depths of 1240 m. All trophic groups exhibited a 32% reduction in abundance within the first four days but the macrobenthos reached background levels within 11 months, although community succession continued for 23 months (Kukert & Smith, 1992). The deposited sediment did not disperse during the experiment and recovery involved recolonization of the deposited sediment mounds either via burrowing from below or colonization of the sediment mounds by larvae or mobile juveniles and adults.

Sensitivity has been assessed to a benchmark level of impact equivalent to a 5 cm layer of similar sediment for a period of a month. Benthic communities are likely to be more intolerant, and hence potentially more sensitive, to smothering with spoils of different sediment characteristics or impermeable materials. Smothering with drilling muds or contaminated spoils bring the added burden of chemical contaminants that are not addressed here.

Conclusion. Many species are able to survive smothering by silt or spoil so that intolerance and therefore sensitivity may be low. If species are killed, recovery will depend on recolonization and growth rate of component species.

6.3. Physical disturbance

Introduction. Physical disturbance includes mechanical interference, crushing, physical blows against, or rubbing and erosion of the organism or biotope being considered. 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 and clumsy divers), which 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 type and its communities and the presence or absence of sensitive species or habitats, commercial fisheries or shellfisheries, or species or habitats of conservation importance.

Intolerance. The effects of sediment disturbance and fishing gear in subtidal habitats have been extensively reviewed (see Eno *et al.,* 1996; 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).

Bergman & van Santbrink (2000) suggested that the megafauna such as *Echinocardium cordatum*, *Corystes cassivelaunus*, and bivalves such as *Phaxas pellucidus, Dosinia lupinus, Mactra corallina, Abra alba, Spisula solida and Spisula subtruncata* were amongst the species most vulnerable to direct mortality due to bottom trawling in sandy sediments. Bivalves such as *Ensis* spp., *Corbula gibba* and *Chamelea gallina* together with starfish were relatively resistant (Bergman & van Santbrink, 2000). Bradshaw *et al.* (2000) suggested that fragile species such a urchins (e.g. *Spatangus purpureus* and *Echinus esculentus*), the brittlestar *Ophiocomina nigra*, starfish *Anseropoda placenta* and the edible crab *Cancer pagurus* suffered badly from impact with a passing scallop dredge. More robust bodied or thick shells species were less sensitive. Overall, species with brittle, hard tests are regarded to be sensitive to impact with scallop dredges (Kaiser & Spencer, 1995; Bradshaw *et al.*, 2000).

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 matrices 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 (see above). 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*, were more intolerant than the horse mussels themselves and reflected early signs of damage.

Recoverability. Recovery will depend on repair of damaged tissues, regrowth from remaining tissue or recolonization. *Alcyonium digitatum* is more abundant on high-effort fishing grounds, which suggests that this seemingly fragile species is more resistant to abrasive disturbance than might be assumed presumably owing to good recovery through regeneration of damaged tissue together with early larval colonization of available substrata (Bradshaw *et al*., 2000, 2002). Similarly, in a study of long-term changes in benthic communities in the Irish Sea, impacted by scallop dredging, Bradshaw *et al.* (2002) noted that brittlestars (*Ophiocomina nigra, Ophiura albida* and *Amphiura filiformis*); mobile crustaceans, robust scavengers, and some erect epifauna such as small ascidians (e.g. *Ascidiella* spp.) and hydroids (e.g. *Nemertesia* spp.) increased in abundance in the long term. The ability of these species to increase in abundance on fished grounds was attributed to their good powers of regeneration and/or recolonization.

Scavengers such as *Asterias rubens* and *Buccinum undatum* were reported to be fairly resilient to encounters with trawls (Kaiser & Spencer, 1995) and 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.

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 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.

Conclusion. Damage to benthic habitats from physical disturbance may be significant but many species are capable of repair and regrowth. However, some species displaced or critically damaged by physical disturbance will be lost. The rate of recovery will then depend on larval recruitment and growth rates.

6.4. Sensitivity of the Marine Landscapes

The sensitivity of representative component biotopes, and the explanatory rationale used are given in full in Appendix 4 and summarized in tabular form in the following sections. Additional information on the sensitivity of biotopes and their associated species in specific Marine Landscapes are included. Information on the recoverability of the likely representative component biotopes is shown in Appendix 4.

6.4.1 Photic rock

Photic rock borders much of the Irish Sea coast and includes infralittoral and littoral rock habitats. The component biotopes are likely to be macrophyte dominated communities, although all littoral biotopes would also fall within the photic rock category even if dominated by limpets and barnacles. The photic rock Marine Landscape will therefore contain a wide variety of habitats and associated communities likely to vary widely with wave exposure, tidal streams velocity, salinity, and physiographic features and hence with location. The component biotopes of photic rock and species that occur there may occupy quite small areas. Photic rock is not therefore suited to situations where the identification of sensitivity and regulation of human activities can be addressed on a large scale. Therefore, no overall sensitivity assessment has been attempted. The majority of the biotope survey data occur in inshore and coastal waters and this Marine Landscape will be adequately covered by available sensitivity information at the biotope level.

Photic rock merges into aphotic or sciaphilic (circalittoral) rock dominated by animal species. The transition from infralittoral to circalittoral can be as shallow as about 3 m depth to as deep as about 25 m depth in the Irish Sea. Circalittoral rock/hard substrata is not included in the Marine Landscapes classification and anyway has the same characteristics as photic rock in containing a wide range of biotopes often in small areas.

6.4.2 Coastal sediment

Coastal sediment includes intertidal and shallow (to ca 5 m depth) subtidal sandy and muddy sediments. Coastal sediments are very variable with respect to the biotopes present.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains. The likely dominant biotopes in terms of extent are shown in bold.

LGS.Aeur - Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores

LGS.Lan - Dense *Lanice conchilega* in tide-swept lower shore sand

LMS.MS - Muddy sand shores

LMU.HedMac - *Hediste diversicolor* and *Macoma balthica* in sandy mud shores

CMS.AfilEcor - *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand

CMS.AbrNucCor - *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment

IGS.FabMag - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand

IGS.Lcon - Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand

IGS.NcirBat - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand

IMS.EcorEns - *Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.

IMS.MacAbr - *Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud

IMU.AphTub - *Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud

The sensitivity information for the component biotopes to three environmental factors is shown in Tables 2 - 4.

Sensitivity to substratum loss

The majority of the species typical of fine sand habitats are infaunal and would be removed along with the substratum. A few mobile species such as amphipods, isopods, and swimming crabs may be able to avoid the impact. However, sedimentary communities are likely to be highly intolerant of substratum removal. The life history characteristics of the polychaete and bivalve species that characterize the component biotopes suggest that the biotope would recover from major perturbations within five years (see section 6.1 above).

Table 2. Summary of representative component biotope sensitivities in 'Coastal sediment' to substratum loss.

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	High	High	**Moderate**	High
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	High	High	**Moderate**	Moderate
LMS.MS	Muddy sand shores	High	High	**Moderate**	High
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	High	High	**Moderate**	High
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	High	High	**Moderate**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	High	Moderate	**Moderate**	High
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	High	High	**Moderate**	High
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	High	High	**Moderate**	High
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Intermediate	Very high	**Low**	Low
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand	High	Moderate	**Moderate**	High
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	High	High	**Moderate**	High
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	High	High	**Moderate**	High

For example, Strasser & Pielouth (2001) reported that *Lanice conchilega* larvae were seen to settle in areas where there were no adults but took 3 years to re-establish the population, although larvae settle preferentially in the vicinity of adults. Similarly, *Abra alba* and *Macoma balthica* demonstrate an '*r*' type life-cycle strategy and are able to rapidly exploit any new or disturbed substratum available for colonization through larval recruitment, secondary settlement of post-metamorphosis juveniles or re-distribution of adults. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976 the *Macoma balthica* population had recovered to 51 individuals/m². One year later, there was no detectable difference in the *Macoma balthica* population between the recently dredged area and a reference area elsewhere in the bay. In 1976, 2 generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to 6 generations were identified, giving further evidence of active immigration to the dredged area. *Abra alba* recovered to former densities following loss of a population from Keil Bay owing to deoxygenation within 1.5 years (Arntz & Rumohr, 1986).

Niermann *et al.* (1990) studied the recovery of a fine sand *Fabulina fabula* community from the German Bight following a severe hypoxia event. Re-establishment of faunal composition took approximately 8 months, but biomass did not fully recover for approximately 2 years. However, some of the climax species, including *Fabulina fabula*, were least affected by the hypoxia and therefore did not limit the recovery of the biotope. Diaz-Castaneda *et al.* (1989) studied the colonization of defaunated sediments from a *Venus* community in Dunkerque Harbour, France. The number of species in the experimental substrata increased progressively and reached a stabilized value similar to the number in the surrounding community within 13 to 17 weeks in spring and summer and 16 to 24 weeks in autumn and winter. It was noted that biomass took much longer to recover than species richness as most colonizers were young and small. Indeed, larval recruitment accounted for 70% of colonizers, suggesting that biotope recoverability is likely to be governed by larval dispersal rather than migration of adults. The last species to establish themselves in the successional sequence were equilibrium species such as *Fabulina fabula, Nephtys hombergii* and venerid bivalves.

Hall (1994) reported that suction dredging for *Ensis* species in 7 m of water in a Scottish sea loch resulted in pits in the sediment and significant reductions in the abundance of a large proportion of the species at the experimental site. However, no differences in species abundances between the impacted plots and controls were detectable after 40 days. This rapid recovery was probably due to intense wave and storm activity during the experimental period that transported sediment and animals in suspension and in bedload transport (Hall, 1994).

The biotope LGS.Aeur is characterized by mobile amphipods and isopods, which although removed with the substratum would probably recolonize available substrata quickly. The biotope IGS.NcirBat is typical of disturbed sandy sediments, so that the associated species are probably adapted to disturbed conditions and recovery rates are probably very high.

In the intertidal, mechanical cockle harvesting resulted in significant losses of common invertebrates in muddy sand and clean sand in the Burry Inlet (Ferns *et al*., 2000). For example, losses varied from 31% of *Scoloplos armiger* to 83% of *Pygospio elegans* in dense populations. Populations of *Nephtys hombergii*, *Scoloplos armiger* took over 50 days to recover. However, recovery was more rapid in clean sand than in muddy sand. In muddy sand, *Bathyporeia pilos*a took 111 days to recover while *Pygospio elegans* and *Hydrobia ulvae* had not recovered their original abundance after 174 days (Ferns *et al.*, 2000).

Storms and intense wave action may move or remove substrata in shallow subtidal or intertidal sedimentary habitats. For example, in shallow subtidal sands and muddy sands in Liverpool Bay, Eagle (1973) reported significant fluctuations in the abundance of dominant species (e.g. *Abra alba*, *Lanice conchilega* and *Lagis koreni*). Recolonization of one of the three dominants occurred rapidly, depending on the availability of larvae and redistribution of juveniles or adults by bedload transport (Eagle, 1975; Hall, 1994). Similar observations were reported for *Lagis koreni* and *Abra alba* in the intertidal muddy sands and mobile offshore sands of Red Wharf Bay, Anglesey and the surrounding coast (Rees *et al.*, 1977).

The infaunal deposit feeding polychaetes, such as *Hediste diversicolor*, *Arenicola marina* and *Aphelochaeta marioni*, have similar recoverability characteristics. Theses species do not have a pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles. However, larval *Arenicola marina* migrate to the upper intertidal to feed, returning to the mid to lower shore as juveniles, and post larvae are capable of active migration by crawling, swimming in the water column and passive transport by currents e.g. Günther (1992) suggested that post-larvae of *Arenicola marina* were transported distances in the range of 1 km. Similarly, Davey & George (1986), found evidence that larvae of *Hediste diversicolor* were tidally dispersed within the Tamar Estuary over a distance of 3 km, as larvae were found on an intertidal mudflat that previously lacked a resident population of adults. The dispersal and recoverability of *Arenicola marina* have been well studied. Intensive commercial exploitation in Budle Bay in the winter of 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m^2. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al*. (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Beukema (1995) noted that the lugworm stock recovered slowly after mechanical dredging, reaching its original level in at least three years. Fowler (1999) pointed out that recovery may take a long time on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid. However, where the affected population is isolated or severely reduced, recovery may be extended.

However, areas containing communities similar to the biotopes CMS.AfilEcor and IMS.EcorEns, may take longer to recover. 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*. The first re-population of *Echinocardium cordatum* after the *Torrey Canyon* accident was recorded two years after the oil spill (Southward & Southward, 1978). 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. Therefore, shallow sublittoral communities may take longer to recover.

Overall, the weight of evidence suggests that although sedimentary habitats are **highly intolerant** of substratum loss, **recoverability is probably high**, suggesting a **sensitivity of moderate**.

Sensitivity to smothering

The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Section 6.2). Maurer *et al.* (1986) suggested that mucous tube feeders and labial palp deposit feeders (e.g. tubeworms and other polychaetes) were the most sensitive to smothering. For example, *Aphelochaeta marioni* and *Tubificoides* species are probably more intolerant of smothering but able to recover rapidly.

Cerastoderma edule is characteristic of in LMS.MS and LGS.Lan. The common cockle has short siphons and needs to keep in contact with the surface of the sediment. It will quickly burrow to the surface if covered by as little as 2 cm of sediment (Richardson *et al.*, 1993) but Jackson & James (1979) reported that cockles buried under 10 cm of sediment were unable to burrow back to the surface and over a period of six days 83% mortality was recorded. In the same experiment, most cockles buried to a depth of 5 cm were able to regain contact with the surface. In muddy substrata all cockles died between three and six days. However, juvenile or small adults are likely to be less tolerant of smothering, and therefore, the LMS.MS and LGS.Lan were assessed as of intermediate intolerance to smothering.

However, most of the representative component biotopes were assessed as of low intolerance or tolerant of smothering at the benchmark level, suggesting they the biotopes are probably not sensitive or only low sensitivity (see Table 3). The infauna of coastal sediments is primarily active burrowers, adapted to periodic if unpredictable sediment disturbance due to wave action or storms, and therefore, probably able to tolerate, or to have only a *low intolerance* (representing the increased energetic costs), to smothering at the benchmark level. However, some functional groups such as tube feeders, labial palp deposit feeders or epifaunal siphonate suspension feeders (Maurer *et al.*, 1986) are probably less tolerant. Therefore, an overall **sensitivity of low** is suggested.

Sensitivity to physical disturbance

Shells of bivalves such as *Abra alba*, *Corbula gibba* and *Nucula nitidosa* are probably vulnerable to physical damage (e.g. by otter boards: Rumohr & Krost, 1991) but their small size relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals that pass through. Gaspar *et al*. (1998) also reports high levels of damage in *Ensis siliqua* from fishing.

For other infaunal species that burrow deeper into the sediment, e.g. *Echinocardium cordatum*, immediate effects are dependant on the depth of penetration of an object, e.g. an anchor or fishing gear relative to the distribution of animals in the sediment. Houghton *et al*. (1971), Graham (1955), de Groot & Apeldoorn (1971) and Rauck (1988) refer to significant trawl-induced mortality of *Echinocardium cordatum*. *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 the species due to physical damage from scallop dredging has been observed (Eleftheriou & Robertson, 1992).

Table 3. Summary of representative component biotope sensitivities in 'Coastal sediment' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	Low	High	**Low**	Low
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	Intermediate	High	**Low**	High
LMS.MS	Muddy sand shores	Intermediate	High	**Low**	High
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	Low	Very high	**Very Low**	Moderate
CMS.AbrNuc Cor	*Abra alba, Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	**Not sensitive**	High
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Low	Immediate	**Not sensitive**	High
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Low	Very high	**Very Low**	Low
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Low	Immediate	**Not sensitive**	Moderate
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Immediate	**Not sensitive**	Moderate
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	Tolerant	NR	**Not sensitive**	Moderate
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Tolerant	NR	**Not sensitive**	Low
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	Intermediate	Very high	**Low**	High

Brittlestars such as *Ophiura albida* may be more tolerant of abrasion. Bergman & Hup (1992) for example, found that beam trawling in the North Sea had no significant direct effect on small brittlestars. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. 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. In an analysis of long-term effects of scallop dredging on benthic communities in the Irish Sea, Bradshaw *et al.* (2002) noted a decline in the sedentary, filter feeding brittlestars *Ophiothrix fragilis* and *Ophiopholis aculeata* but and increase in surface detritivores or scavenging brittlestars such as *Amphiura filiformis*, *Ophiocomina nigra* and *Ophiura albida.*

Lanice conchilega inhabits a permanent tube and is likely to be damaged by any activity that penetrates the sediment. Ferns *et al*. (2000) investigated the effect of mechanical cockle harvesting (see extraction below). The tubes of *Lanice conchilega* were damaged but this damage was seen to be repaired. In the intertidal, mechanical cockle harvesting resulted in significant losses of common invertebrates in muddy sand and clean sand in the Burry Inlet (Ferns *et al.*, 2000). For example, losses varied from 31% of *Scoloplos armiger* to 83% of *Pygospio elegans* in dense populations. Populations of *Nephtys hombergii, Scoloplos armiger* took over 50 days to recover. However, recovery was more rapid in clean sand than in muddy sand. In muddy sand, *Bathyporeia pilos*a took 111 days to recover while *Pygospio elegans* and *Hydrobia ulvae* had not recovered their original abundance after 174 days (Ferns *et al.*, 2000). In a similar study Hall & Harding (1997) found that non-target benthic fauna recovered within 56 days after mechanized cockle harvesting. However, Hall & Harding (1997) study took place in summer while Ferns *et al.* (2000) study occurred in winter.

Table 4. Summary of representative component biotope sensitivities in 'Coastal sediment' to physical abrasion and disturbance

Biotope code	**Biotope name**	**Intolerance**	**Recoverability**	**Sensitivity**	**Evidence**
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	Low	High	**Low**	Moderate
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	Intermediate	Very high	**Low**	Moderate
LMS.MS	Muddy sand shores	Low	Very high	**Very Low**	Very low
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	Intermediate	High	**Low**	Low
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Intermediate	High	**Low**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Intermediate	High	**Low**	Moderate
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Intermediate	High	**Low**	Low
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Intermediate	High	**Low**	Low
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Very high	**Very Low**	Low
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	Moderate
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Low	High	**Low**	Moderate
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	Intermediate	Very high	**Low**	Low

Schafer (1972) noted that adults of *Lagis koreni* were incapable of re-constructing their delicate sand-tubes once removed from them, and that mortality following physical disturbance to the substratum, e.g. from trawl/tickler chain damage, is likely to be significant (de Groot & Apeldoorn, 1971).

Storms and intense wave action may move or remove substrata in shallow subtidal or intertidal sedimentary habitats. For example, in shallow subtidal sands and muddy sands in Liverpool Bay, Eagle (1973) reported significant fluctuations in the abundance of dominant species (e.g. *Abra alba*, *Lanice conchilega* and *Lagis koreni*). Recolonization of one of the three dominants occurred rapidly, depending on the availability of larvae and redistribution of juveniles or adults by bedload transport (Eagle, 1975; Hall, 1994). Similar observations were reported for *Lagis koreni* and *Abra alba* in the intertidal muddy sands and mobile offshore sands of Red Wharf Bay, Anglesey and the surrounding coast (Rees *et al.*, 1977). Polychaetes such as *Hediste diversicolor* and *Arenicola marina* are fecund but there eggs develop within the maternal burrow so that dispersal occurs by burrowing. However, larval *Arenicola marina* migrate to the upper intertidal to feed, returning to the mid to lower shore as juveniles, and post larvae are capable of active migration by crawling, swimming in the water column and passive transport by currents e.g. Günther (1992) suggested that post-larvae of *Arenicola marina* were transported distances in the range of 1 km. Similarly, Davey & George (1986), found evidence that larvae of *Hediste diversicolor* were tidally dispersed within the Tamar Estuary over a distance of 3 km, as larvae were found on an intertidal mudflat that previously lacked a resident population of adults. Therefore, in the vicinity of other populations of these species recolonization is potentially rapid.

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. Bergman & van Santbrink (2000) suggested that the megafauna such as *Echinocardium cordatum, Corystes cassivelaunus*, and bivalves such as *Phaxas pellucidus, Dosinia lupinus, Mactra corallina, Abra alba, Spisula solida and S. subtruncata* were amongst the species most vulnerable to direct mortality due to bottom trawling in sandy sediments. Bivalves such as *Ensis* spp., *Corbula gibba* and *Chamelea gallina* together with starfish were relatively resistant (Bergman & van Santbrink, 2000). Bradshaw *et al.* (2000) suggested that fragile species such a urchins (e.g. *Spatangus purpureus* and *Echinus esculentus*), the brittlestar *Ophiocomina nigra*, starfish *Anseropoda placenta* and the edible crab *Cancer pagurus* suffered badly from impact with a passing scallop dredge. More robust bodied or thick shells species were less sensitive. It has been 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 (Eleftheriou & Robertson, 1992). The sessile infauna, however, along with large infaunal and epifaunal forms, such as molluscs, decapods, echinoderms and some polychaetes, demonstrated their vulnerability (Eleftheriou & Robertson, 1992). Overall, species with brittle, hard tests are regarded to be sensitive to impact with scallop dredges (Kaiser & Spencer, 1995; Bradshaw *et al.*, 2000).

The common cockle *Cerastoderma edule* is a characteristic species in LGS.Lan and may occur in LMS.MS biotopes. Hall & Harding (1997) found that *Cerastoderma edule* abundance had returned to control levels within about 56 days and Moore (1991) suggested that recovery was rapid. Cotter *et al.* (1997) noted that tractor dredging reduced the *Cerastoderma edule* stock by 31-49% depending on initial density, while Pickett (1973) reported that hydraulic dredging removed about one third of the cockle fishery. Cockles are often damaged during mechanical harvesting, e.g. 5-15% were damaged by tractor dredging (Cotter *et al*, 1997) and ca 20% were too damaged to be processed after hydraulic dredging (Pickett, 1973). However, most studies concluded that the impact of mechanised dredging on cockle populations and macrofauna in the long term was low (Pickett, 1973; Franklin & Pickett, 1978; Cook, 1990; Moore, 1991; Cotter *et al.*, 1997; Hall & Harding, 1997; Ferns *et al.*, 2000). Time of year of exploitation will influence recovery and avoiding seasonal spawning or larval settlement periods is likely to reduce the time taken for recovery (Gubbay & Knapman, 1999). In good years, *Cerastoderma edule* populations may recover within a year but recruitment is unpredictable and recovery may be more prolonged.

The biotope LGS.Aeur is characterized by mobile amphipods and isopods, a proportion of which are probably small and mobile enough to avoid the effects of a passing dredge, and if killed would probably recolonize available substrata quickly. The biotope IGS.NcirBat is typical of disturbed sandy sediments, so that the associated species are probably adapted to disturbed conditions and recovery rates are probably very high.

Overall, the evidence above (taken together with the overview in Section 6.3) suggests that coastal sediment communities will be damaged and a proportion of the population killed or displaced by a passing scallop dredge. Communities dominated by more sensitive species, such as *Echinocardium cordatum* will exhibit a greater sensitivity. However, most communities will probably recover within about 5 years after the effect suggesting a **recoverability of high** and giving an overall **sensitivity of low**. Coastal sediment communities are likely to be more intolerant, and hence more sensitive to a greater intensity of physical disturbance.

6.4.3 Fine sediment plains

Depositional areas in shallow (ca. 5-50 m) areas are likely to be colonized by burrowing brittle stars and by *Echinocardium cordatum* together with typically inshore burrowing species such as *Goneplax rhomboides* and *Virgularia mirabilis*. Some muddy areas are included.

Component biotopes. The following biotopes are probably representative of fine sediment plains. The likely dominant biotope in terms of extent is shown in bold.

CMS.AbrNucCor - *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment

CMS.AfilEcor - *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand

CMS.VirOph - *Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud

IGS.FabMag - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand

IMS.EcorEns - *Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.

IMS.MacAbr - *Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud

IMU.PhiVir - *Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud

IGS.NcirBat **-** *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand

IGS.Sell - represented by IGS.FabMag

Sensitivity to substratum loss

The information outlined in Section 6.1 above, suggests that benthic sedimentary communities are **highly intolerant** of substratum loss but are likely to recover within about 5 years, i.e. to have a **recoverability of high**, suggesting a **sensitivity of moderate.** But recovery rates will be much slower where long-lived, slow growing species are recorded (see Table 5).

Table 5. Summary of representative component biotope sensitivities in 'Fine sediment plains' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNuc Cor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	High	High	**Moderate**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	High	Moderate	**Moderate**	High
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	High	Moderate	**Moderate**	Low
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	High	High	**Moderate**	High
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Intermediate	Very high	**Low**	Low
IMS.Ecor.Ens	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	High
IMS.Mac.Abr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	High	High	**Moderate**	High
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	High	Moderate	**Moderate**	Low

There is little information on the biology of British sea pens. Data from *Ptilosarcus guerneyi* in the USA suggests that sea pens may live up to 15 years, take 5-6 years to reach sexual maturity and produce large numbers of eggs and larvae (up to 200,000). However, larval settlement was patchy in time and space, with no effective recruitment in some years resulting in a sub-divided population made up of overlapping patches of different size classes (Hughes, 1998). Similarly, species such as *Echinocardium cordatum* show sporadic recruitment and take many years to reach sexual maturity. Therefore, biotopes characterized by these species would probably take a long time to recover, and a recoverability of moderate was suggested (see Table 5). Nevertheless, the available evidence suggests an **overall sensitivity of moderate**.

Sensitivity to smothering

The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Section 6.2). However, the representative component biotopes were assessed as of low intolerance or tolerant of smothering at the benchmark level, suggesting they the biotopes are probably not sensitive or have very low sensitivity (see Table 6).

Table 6. Summary of representative component biotope sensitivities in 'Fine sediment plains' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	**Not sensitive**	High
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Low	Immediate	**Not sensitive**	High
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very Low**	Moderate
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Low	Very high	**Very Low**	Low
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Immediate	**Not sensitive**	Moderate
IMS.Ecor.Ens	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	Tolerant	NR	**Not sensitive**	Moderate
IMS.Mac.Abr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Tolerant	NR	**Not sensitive**	Low
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	Low	Very high	**Very low**	Low

Individual colonies of *Virgularia mirabilis* extend up to 30 cm above the sediment so are unlikely to be significantly affected by smothering by 5 cm of sediment. In addition, *Virgularia mirabilis* is able to withdraw rapidly into the sediment. There may be an increase in the energetic cost of cleaning sediment from the polyps. Eno *et al*., (1996) found that another species of sea pen, *Funiculina quadrangularis* when partially buried still showed signs of polyp activity on parts of the sea pen that were visible. In an investigation into the effect of shellfish traps on benthic habitats (Eno *et al*., 1996) creels were dropped on sea pens and left for extended periods to simulate the effects of smothering which could occur during commercial operations. The sea pens consistently righted themselves following removal of the pots.

The infauna of fine sediment plains are primarily active burrowers and therefore, probably able to tolerate, or to have only a low intolerance (representing the increased energetic costs), to smothering at the benchmark level. However, some species such as sea pens may be more sensitive, and at the Marine Landscape scale an overall **sensitivity of very low** has been suggested, a precautionary approach to highlight the potential presence of more sensitive species.

Sensitivity to physical disturbance

The effects of physical disturbance in sedimentary habitats has been summarized above (see Section 6.2). The sensitivity of likely component biotopes is shown in Table 7.

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. 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). However, the densities of *Virgularia mirabilis* were similar in trawled and untrawled sites in Loch Fyne and no changes in sea pen density was observed after experimental trawling over a 18 month period in another loch (Howson & Davies, 1991; Tuck *et al.,* 1998; Hughes, 1998). Hughes (1998) concluded that *Virgularia mirabilis* and *Pennatula phosphorea*, which can withdrawn into the sediment, were probably less susceptible to the effects of damage by fishing gear than *Funiculina quadrangularis*, which is unable to withdraw. In an investigation into the effect of shellfish traps on benthic habitats (Eno *et al*., 1996), creels were dropped on sea pens and left for extended periods to simulate the effects of smothering which could occur during commercial operations. The sea pens consistently righted themselves following removal of the pots.

Table 7. Summary of representative component biotope sensitivities in 'Fine sediment plains' to physical abrasion

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Intermediate	High	**Low**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Intermediate	High	**Low**	Moderate
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very low**	Moderate
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Intermediate	High	**Low**	Low
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Very high	**Very Low**	Low
IMS.Ecor.Ens	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	Moderate
IMS.Mac.Abr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Low	High	**Low**	Moderate
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	Low	Very high	**Very Low**	Low

Overall, the evidence above (taken together with the overview in section 6.3) suggests that fine sand communities will be damaged and a proportion of the population killed or displaced by a passing scallop dredge (**intermediate intolerance**). Communities dominated by more sensitive species, such as *Echinocardium cordatum* will exhibit a greater sensitivity. However, most communities will probably recover within about 5 years after the effect suggesting a **recoverability of high** and giving an overall **sensitivity of low**. Sediment communities are likely to be more intolerant, and hence more sensitive, to a greater intensity of physical disturbance.

6.4.4 Coarse sediment plains.

Predominantly circalittoral coarse sediments that are colonized by infauna and by transitory epifauna (e.g. tube worms such as *Sabellaria spinulosa*, ascidians such as *Dendrodoa grossularia*, ephemeral hydroids etc.).

Coarse sediment plains probably equate to Assemblage C in Mackie *et al.* (1995), the 'Deep *Venus/*hard' and 'Deep *Venus*' communities of Mackie (1990), and also 'Deep Venus' community of Petersen (1924) and 'Boreal offshore muddy gravel' community of Jones (1950). The most similar or representative biotope is probably 'Venerid bivalves in circalittoral coarse sand or gravel CGS.Ven'.

Although *Modiolus modiolus* reefs are likely to occur on coarse sediment plains, they have their own category (Reefs (rocky/biogenic) and are not included here. CMX.SspiMx is included because *Sabellaria spinulosa* are likely to be crustose rather than reef-forming. The coarse sediments might be stable enough to be colonized by larger epifauna such as *Flustra foliacea* and *Urticina felina*.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains. The likely dominant biotope in terms of extent is shown in bold.

CGS.Ven – Venerid bivalves in circalittoral coarse sand or gravel

IMX.An - Burrowing anemones in sublittoral muddy gravel

MCR.Urt - *Urticina felina* on sand-affected circalittoral rock

MCR.Flu - *Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata

MCR.Oph - *Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata

CMX.SspiMx - *Sabellaria spinulosa* and *Polydora* spp. on stable circalittoral mixed sediment (Represented by MCR.Sspi - *Sabellaria spinulosa* crusts on silty turbid circalittoral rock)

Sensitivity to substratum loss

The review of information suggests that benthic sedimentary communities are **highly intolerant** of substratum loss but are likely to recover within about 5 years, i.e. to have a **recoverability of high**, suggesting a **sensitivity of moderate.** The representative biotopes listed in Table 8 also suggest an overall sensitivity of moderate.

Table 8. Summary of representative component biotope sensitivities in 'Coarse sediment plains' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	High	High	**Moderate**	High
IMX.An	Burrowing anemones in sublittoral muddy gravel	High	Moderate	**Moderate**	Low
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	High	High	**Moderate**	High
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	High	Moderate	**Moderate**	Moderate

Mobile subtidal sandbanks are likely to recover more quickly because the associated fauna is adapted to a dynamic habitat such as mobile swimming species (e.g. amphipods and isopods) and rapid burrowing polychaetes (Elliot *et al.*, 1998; PDE & Hill, 2001). More stable, coarser habitats may include epifaunal species such as hydroids, bryozoans and ascidians (e.g. MCR.Flu). Hydroids and many species of bryozoan and ascidians are generally opportunists and rapid colonizers but larger species such as *Flustra foliacea* are slow growing and likely to take up to 4-5 years to establish and longer to retain their prior cover (see Table 8). Sea anemone and/or sponge dominated communities (e.g. MCR.Urt and IMX.An) may take longer to recover, due to sporadic or patchy recruitment and slow growth. However, recruitment and the life history of many sponges and sea anemones is poorly known.

Faunal crusts of *Sabellaria spinulosa* (rather than reefs) typical of the biotope CMX.SspiMx will be destroyed with removal of the substratum. Holt *et al.* (1998) suggested that *S. spinulosa* was effectively annual in many cases, spawning in winter and settling in spring. After disturbance has ceased, recovery may also be rapid.

Sensitivity to smothering

The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Table 9).

The dominant biotope CGS.Ven is probably of very low sensitivity to smothering at the benchmark level (5 cm of similar sediment for 1 month) (see Table 9). Similarly, where they occur epifaunal communities characterized by *Flustra foliacea* and/or *Urticina felina* (e.g. MCR.Flu and MCR.Urt) are typically tolerant of siltation, sand-scour and smothering, while crusts of *Sabellaria spinulosa* (represented by MCR.Sspi) are probably also of low sensitivity.

Table 9. Summary of representative component biotope sensitivities in 'Coarse sediment plains' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Low	Very high	**Very low**	Low
IMX.An	Burrowing anemones in sublittoral muddy gravel	Intermediate	Moderate	**Moderate**	Low
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Low
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	Intermediate	High	**Low**	High
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate

Brittlestar beds and burrowing anemone communities are, however, probably less tolerant of smothering. Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively attributed this to increased sedimentation caused by the localized dumping of construction materials. Burrowing anemone communities may survive but several species may be lost.

Coarse sediment plains are likely to be dominated by burrowing infaunal species, typical of '*Venus*' communities, and using CGS.Ven as representative, likely to be relatively tolerant of smothering. However, significant areas of the Marine Landscape are likely to be colonized by epifauna. Therefore, an overall **intolerance of intermediate** is suggested with a **recoverability of high** and a **sensitivity of low**.

Sensitivity to physical disturbance

Physical disturbance by passing fishing gear is likely to damage or kill a proportion of the venerid bivalve and heart urchin populations (see Table 10). For example, Ramsey *et al.* (2000) reported that the shells of dog cockles *Glycymeris glycymeris* had a higher incidence of scars in areas heavily exploited by beam trawlers. Similarly, several bivalves and heart urchins were listed as particularly vulnerable above (Bradshaw & van Santbrink, 2000).

Where present, epifaunal communities are likely to be damaged but not destroyed by physical disturbance at the benchmark level. Emergent epifauna, e.g. hydroids and erect bryozoans will probably be damaged or torn off, stones or cobbles to which they are attached turned or removed by passing fishing gear. If present, crusts of *Sabellaria spinulosa* will probably be broken up but recover rapidly from surviving individuals. However, burrowing anemones may be relatively tolerant, as the numbers of *Cerianthus lloydii* and *Mesacmaea mitchellii* within and beside experimental dredge paths in the Skomer Marine Nature Reserve were reported to be similar to pre-dredge levels within several weeks (Gubbay & Knapman, 1999).

Overall, coarse sediment plains are likely to be of **intermediate intolerance** to physical disturbance at the benchmark level, while recoverability is likely to be high, suggesting an overall **sensitivity of low**. Intolerance will depend on intensity of fishing effort, therefore, areas subject to continuous or long-tem fishing effort are likely to be more sensitive.

Table 10. Summary of representative component biotope sensitivities in 'Coarse sediment plains' to physical disturbance and abrasion

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Intermediate	High	**Low**	Moderate
IMX.An	Burrowing anemones in sublittoral muddy gravel	Low	Immediate	**Not sensitive**	Moderate
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	Intermediate	High	**Low**	Low
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate

6.4.5 Shallow water mud basins

Shallow water mud basins composed of 'gravelly or sandy mud', 'slightly gravelly mud', 'slightly gravelly sandy mud' or 'mud', shallower than 50 m water depth.

Component biotopes. The following biotopes are probably representative of shallow water mud basins. The likely dominant biotope in terms of extent is shown in bold.

CMS.AbrNucCor - *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment

CMS.AfilEcor - *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand

CMS.VirOph - *Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud

IMS.EcorEns - *Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.

IMS.MacAbr - *Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud

IMX.An - Burrowing anemones in sublittoral muddy gravel

IMX.VsenMtru - *Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel

Sensitivity to substratum loss

The majority of the associated species are infaunal and likely to be removed with the substratum. Epifaunal small crustaceans, crabs, gastropods and echinoderms are mobile but probably not fast enough swimmers to avoid removal and would probably also be removed. Therefore, shallow water mud basins are likely to have a high intolerance to substratum loss (see Table 11).

Venerupis senegalensis is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973; Perez Camacho, 1980). No information was found concerning number of gametes produced but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. Given these life history features, it is expected that *Venerupis senegalensis* would have strong powers of recoverability. The species exhibits pronounced year class variability in abundance (Johannessen, 1973; Perez Camacho, 1980), which suggests that recruitment is patchy and/or post settlement processes are highly variable. Hence, for *Venerupis* *senegalensis*, an annual predictable population recovery is not certain. However, given the life history characteristics discussed above it is expected that recovery would occur within 5 years.

Table 11. Summary of representative component biotope sensitivities in 'Shallow water mud basins' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	High	High	**Moderate**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	High	Moderate	**Moderate**	High
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	High	Moderate	**Moderate**	Low
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	High
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	High	High	**Moderate**	High
IMX.An	Burrowing anemones in sublittoral muddy gravel	High	Moderate	**Moderate**	Low
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	High	High	**Moderate**	High

Strasser *et al.* (1999) noted that population densities of *Mya arenaria* in the Wadden Sea were patchy and dominated by particular year classes. *Mya arenaria* has a high fecundity and reproductive potential but larval supply is sporadic and juvenile mortality is high, so that although, large numbers of spat may settle annually, successful recruitment and hence recovery may take longer than a year. Beukema (1995) reported that a population of *Mya arenaria* in the Wadden Sea, drastically reduced by lugworm dredging took about 5 years to recover. The recoverability of *Mya truncata* may be similar.

The infaunal deposit feeding polychaetes, such as *Arenicola marina* and *Aphelochaeta marioni*, have similar recoverability characteristics. Neither species has a pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles. The dispersal and recoverability of *Arenicola marina* have been well studied. Intensive commercial exploitation in Budle Bay in the winter of 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m^2. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al*. (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Beukema (1995) noted that the lugworm stock recovered slowly after mechanical dredging, reaching its original level in at least three years. Fowler (1999) pointed out that recovery may take a long time on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid. However, where the affected population is isolated or severely reduced, recovery may be extended.

The above evidence, taken in conjunction with evidence of recovery rates of sedimentary habitats in prior sections, suggests that the majority of species within in the component biotopes are likely to have **high recoverability**. Therefore, an overall **sensitivity of moderate** is suggested.

Sensitivity to smothering

The effects of smothering on sedimentary habitats and their communities have been discussed in prior sections. The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Table 12).

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 that are attached may be inhibited from relocating rapidly following smothering with 5 cm of sediment and some mortality is expected to occur.

Table 12. Summary of representative component biotope sensitivities in 'Shallow water mud basins' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	**Not sensitive**	High
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Low	Immediate	**Not sensitive**	High
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very Low**	Moderate
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	Tolerant	NR	**Not sensitive**	Moderate
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Tolerant	NR	**Not sensitive**	Low
IMX.An	Burrowing anemones in sublittoral muddy gravel	Intermediate	Moderate	**Moderate**	Low
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	Intermediate	High	**Low**	Low

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.

Individual colonies of *Virgularia mirabilis* extend up to 30 cm above the sediment so are unlikely to be significantly affected by smothering by 5 cm of sediment. In addition, *Virgularia mirabilis* is able to withdraw rapidly into the sediment. There may be an increase in the energetic cost of cleaning sediment from the polyps. Eno *et al*. (1996) found that another species of sea pen, *Funiculina quadrangularis* when partially buried still showed signs of polyp activity on parts of the sea pen that were visible. In an investigation into the effect of shellfish traps on benthic habitats (Eno *et al*., 1996) creels were dropped on sea pens and left for extended periods to simulate the effects of smothering which could occur during commercial operations. The sea pens consistently righted themselves following removal of the pots.

The benchmark assumes that smothering lasts for only one month, however, in sheltered muddy habitats deposited sediment is likely to remain for prolonged periods. Nevertheless, Kukert & Smith (1992) reported recovery of the polychaete dominated communities within 23 months due to recolonization of deposited sediment mounds in a deep mud basin by burrowing, larval settlement, and adult or juvenile migration (see section 6.2).

The infauna of fine sediment plains are primarily active burrowers and therefore, probably able to tolerate, or to have only a low intolerance (representing the increased energetic costs), to smothering at the benchmark level. However, some functional groups such as tube feeders, labial palp deposit feeders or epifaunal siphonate suspension feeders (Maurer *et al.*, 1986) and some species, such as sea pens, are probably less tolerant. Therefore, at the Marine Landscape scale an overall **sensitivity of very low** has been suggested, a precautionary approach to highlight the potential presence of more sensitive species. However, more sensitive biotopes, such as IMX.An and IMX.VsenMtru, may occur in some areas.

Sensitivity to physical disturbance

The effects of physical disturbance on most of the characteristic species have been discussed in Section 6.3. The likely sensitivity of representative component biotopes is shown in Table 13.

Physical disturbance by fishing gear, e.g. a scallop dredge, or by suction dredging is likely to have similar effects in shallow muds, muddy sands and muddy gravels as have been detailed in the preceding sections. Shallow mud basin communities are probably of **intermediate tolerance** to physical disturbance at the benchmark level but that most species will probably **recover within ca 5 years**, suggesting a **sensitivity of low** at the benchmark level.

Table 13. Summary of representative component biotope sensitivities in 'Shallow water mud basins' to physical disturbance

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Intermediate	High	**Low**	Moderate
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Intermediate	High	**Low**	Moderate
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very low**	Moderate
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	Moderate
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Low	High	**Low**	Moderate
IMX.An	Burrowing anemones in sublittoral muddy gravel	Low	Immediate	**Not sensitive**	Moderate
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	Intermediate	High	**Low**	Low

6.4.6 Deep water mud basins

Deep water mud basins are likely to be colonized most conspicuously by *Nephrops norvegicus* and by other burrowing organisms including *Brissopsis lyrifera* and *Calocaris macandreae*.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains. The likely dominant biotope in terms of extent is shown in bold.

CMU.BriAchi - *Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud

COS.AmpPar - *Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas

COS.ForThy - Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud

CMU.SpMeg - Seapens and burrowing megafauna in circalittoral soft mud

CMS.AbrNucCor - *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment

Sensitivity to substratum loss

The majority of the associated species are infaunal and likely to be removed with the substratum. Epifaunal small crustaceans, crabs, gastropods and echinoderms are mobile but probably not fast enough swimmers to avoid removal and would probably also be removed. Therefore, deep water mud basins are likely to have a **high intolerance** to substratum loss (see Table 14).

Table 14. Summary of representative component biotope sensitivities in 'Deep water mud basins' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	High	High	**Moderate**	Moderate
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	High	Moderate	**Moderate**	High
CMU.SpMeg	Sea pens and burrowing megafauna in circalittoral soft mud	High	Moderate	**Moderate**	High
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	High	Moderate	**Moderate**	Moderate
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	High	Moderate	**Moderate**	High

The burrowing megafauna that characterise the component biotopes vary in their reproductive strategies and longevity. For instance, *Abra alba* and *Macoma balthica* demonstrate an 'r' type life-cycle strategy and are able to rapidly exploit any new or disturbed substratum available for colonization through larval recruitment, secondary settlement of post-metamorphosis juveniles or re-distribution of adults. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976 the *Macoma balthica* population had recovered to 51 individuals/m². One year later, there was no detectable difference in the *Macoma balthica* population between the recently dredged area and a reference area elsewhere in the bay. In 1976, 2 generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to 6 generations were identified, giving further evidence of active immigration to the dredged area. *Abra alba* recovered to former densities following loss of a population from Keil Bay owing to deoxygenation within 1.5 years (Arntz & Rumohr, 1986). Similarly, *Parvicardium ovale* is very widespread and reproduces every year so populations would be more likely to recover from loss.

Polychaetes probably account for the vast proportion of the biomass, and these are likely to reproduce annually, be shorter lived and reach maturity much more rapidly. However, if the population of *Ampharete falcata* was removed, recovery of its biotope would probably be very poor. Populations are often separated by great distances and recruitment from other populations is unlikely because the dispersal potential of larvae is restricted because the larvae are benthic. Recruitment may be dependent on migration of adults and juveniles from the surrounding area.

Brissopsis lyrifera is short lived (4 years) but fecund and has shown clear evidence of successful and consecutive annual recruitment (Buchanan, 1967). Individuals become sexually mature in their forth year. *Amphiura chiajei* is longer lived than *Brissopsis lyrifera* and reaches sexual maturity in its forth year, thus the population structure of these species will not reach maturity for at least this length of time. Once established, a cohort of *Amphiura chiajei* can dominate a population, even inhibiting its own consecutive recruitment, for up to 10 years.

Time to reach sexual maturity is longer in *Nephrops norvegicus*, about 2.5 -3 years, and for the very long-lived *Calocaris macandreae* individuals off the coast of Northumberland did not become sexually mature until five years of age, and produced only two or three batches of eggs in their lifetime.

Foraminiferans are protists that exhibit alternation of asexual or sexual reproduction, so that reproductive potential is probably high in favourable conditions, although no information on reproductive rates was found. However, they may be extremely abundant in marine sedimentary habitats. Spawning of *Thyasira gouldi* occurs throughout the year, with up to 750 eggs produced each time. Larval development of *Thyasira equalis* is lecithotrophic and the pelagic stage is very short or quite suppressed, which may be typical of other *Thyasira* species. Although, dispersal potential is short, adults and juveniles may be dispersed by bedload transport. For example, after a decline in the abundance of *Thyasira flexuosa* in Penobscot Bay, Maine, after trawler disturbance, populations were reported to recover within 3.5 months (Sparks-McConkey & Watling, 2001). Similarly, Dando & Spiro (1993) reported that although deoxygenation of bottom waters between 1979 and 1980 resulted in the depletion of *Thyasira equalis* and *Thyasira sarsi* from 550 /m² to almost zero, by 1987 200 /m² were present.

Nothing is known about the life cycle and population dynamics of British sea pens. Data from *Ptilosarcus guerneyi* in the USA suggests that sea pens may live up to 15 years, take 5-6 years to reach sexual maturity and produce large numbers of eggs and larvae (up to 200,000). However, larval settlement was patchy in time and space, with no effective recruitment in some years resulting in a sub-divided population made up of overlapping patches of different size classes (Hughes, 1998).

Most of the characterizing species reproduce regularly but recruitment is often sporadic owing to interference competition with established adults of the same and other species. However, owing to the fact that the characteristic species take between 3 and 5 years to reach sexual maturity, it is likely that the time for the overall community to reach a fully diverse state will also be several years. It is likely that the low-energy hydrodynamic regime is an important factor in the maintenance of stable benthic populations in this biotope, as larvae are retained in the vicinity of the parent population.

The information outlined above and in Section 6.1 suggests that benthic sedimentary communities are **highly intolerant** of substratum loss but are likely to recover within about 5 years, i.e. to have a **recoverability of high**, suggesting a **sensitivity of moderate.** The representative biotopes listed in Table 14 also suggest an overall sensitivity of moderate. Recovery will be slower where long-lived, slow growing species are recorded.

Sensitivity to smothering

The effects of smothering on sand and gravel habitats and their communities have been discussed in prior sections. The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Table 15).

Table 15. Summary of representative component biotope sensitivities in 'Deep water mud basins' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	Low	Immediate	**Not sensitive**	Moderate
CMU.SpMeg	Sea pens and burrowing megafauna in circalittoral soft mud	Low	Immediate	**Not sensitive**	High
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	**Not sensitive**	High
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	Intermediate	High	**Low**	Moderate
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	High	Moderate	**Moderate**	Very low

The majority of the characteristic species are infaunal burrowers, unlikely to be affected by smothering at the benchmark level. Burrowing thalassindean crustaceans, the echiuran worm *Maxmuelleria lankesteri*, infaunal polychaetes, brittlestars, and bivalves are not likely to be affected by smothering by 5cm of sediment. There may be some energetic cost expended to either re-establish burrow openings in the case of *Calocaris macandreae* and *Nephrops norvegicus*, or to self-clean feeding apparatus though this is not likely to be significant. Individual colonies of *Virgularia mirabilis* extend up to 30 cm above the sediment so are unlikely to be significantly affected by smothering by 5 cm of sediment. In addition, *Virgularia mirabilis* and *Pennatula phosphorea* are able to withdraw rapidly into the sediment. There may be an increase in the energetic cost of cleaning sediment from the polyps. Although the sea pen *Funiculina quadrangularis* is not able to withdraw into the sediment its height, up to 2 m, means that it is unlikely to be affected by smothering of 5 cm of sediment.

However, polychaete dominated communities in deep muddy habitats may be adversely affected. Kukert & Smith (1992) examined the effects of depositing artificial mounds of similar sediment, averaging 5-6 cm thick, on polychaete dominated communities in the Santa Catalina Basin at depths of 1240 m. All trophic groups exhibited a 32% reduction in abundance within the first four days but the macrobenthos reached background levels within 11 months, although community succession continued for 23 months (Kukert & Smith, 1992).

The benchmark assumes that smothering lasts for only one month, however, in sheltered muddy habitats deposited sediment is likely to remain for prolonged periods. Nevertheless, Kukert & Smith (1992) reported recovery of the polychaete dominated communities within 23 months due to recolonization of deposited sediment mounds in a deep mud basin by burrowing, larval settlement, and adult or juvenile migration (see Section 6.2).

Foraminiferans are epibenthic or infaunal and may occur at high abundances. However, little information concerning their ability to burrow was found and foraminiferan communities, e.g. COS.ForThy, may be adversely affected.

Overall, the majority of the characteristic species are unlikely to be adversely affected and a sensitivity of **not sensitive** has been suggested.

Sensitivity to physical disturbance

The effects of physical disturbance on most of the characteristic species have been discussed in prior sections. The likely sensitivity of representative component biotopes is shown in Table 16.

Deep water mud communities are associated with physically sheltered conditions and are probably not generally subject to physical disturbance by storms, even when they occur in relatively shallow waters (Hughes, 1998).

Table 16. Summary of representative component biotope sensitivities in 'Deep water mud basins' to physical disturbance

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	Intermediate	High	**Low**	High
CMU.SpMeg	Sea pens and burrowing megafauna in circalittoral soft mud	Intermediate	High	**Low**	Moderate
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Intermediate	High	**Low**	Moderate
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	Intermediate	High	**Low**	Low
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	Intermediate	High	**Low**	High

The CMU.BriAchi biotope can be affected by fishing activity in areas such as the northern Irish Sea, where the community may also contain *Nephrops norvegicus* (Mackie *et al.*, 1995). Where intense benthic dredge fishing activity occurs, populations of *Brissopsis lyrifera* may be reduced. Deeper burrowing crustaceans such as *Calocaris macandreae* may occasionally be displaced from burrow openings by towed gear (Atkinson, 1989). However, deep burrowing species such as mud shrimps and the spoon worm *Maxmuelleria lankesteri* are usually too far below the sediment surface to be affected by towed fishing gear, and the upper portions of their burrows soon re-established (Hughes, 1998).

Ball *et al.* (2000) reported a reduction in the abundance of large-bodied fragile fauna (e.g. heart urchins, and large molluscs) and small crustaceans and an increase in the abundance of opportunists due to otter trawling in deep muddy habitats. They reported that otter trawl tracks were still visible 18 months later in sheltered sites. Species abundance, biomass and diversity decreased 24 hr after trawling. Experimental otter trawling in sheltered muddy habitats in Loch Gareloch, resulted in an increased abundance of opportunistic polychaetes, while the bivalves *Nucula nitidosa* and *Corbula gibba*, and the polychaetes *Scoloplos armiger*, *Nephtys cirrosa* and *Terebellides stroemi* were reported to be sensitive to the effects of trawling. Differences between the trawled experimental site and references sites were still detectable after 18 months (Ball *et al.*, 2000).

After a decline in the abundance of *Thyasira flexuosa* in Penobscot Bay, Maine due to trawler disturbance, populations were reported to recover within 3.5 months (Sparks-McConkey & Watling, 2001). Similarly, Dando & Spiro (1993) reported that although deoxygenation of bottom waters between 1979 and 1980 resulted in the depletion of *Thyasira equalis* and *Thyasira sarsi* from 550 /m² to almost zero, by 1987 200 /m² were present.

Overall, the above evidence and the information presented in the prior section, suggested that the deep water mud communities are probably of **intermediate tolerance** to physical disturbance at the benchmark level but that most species would probably **recover within ca 5 years**, suggesting a **sensitivity of low**.

6.4.7 Sand/gravel banks

Whilst gravel banks are likely to be similar to 'Coarse sediment plains', sand banks will have different biotopes and those biotopes are asterixed below.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains. The likely dominant biotopes in terms of extent are shown in bold.

IGS.Lcon* - Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand

IGS.FabMag* - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand

IGS.NcirBat* - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand

CGS.Ven - Venerid bivalves in circalittoral coarse sand or gravel may also occur.

Sensitivity to substratum loss

The effects of substratum loss and subsequent recovery have been discussed in prior sections. The evidence reviewed suggests that sand and gravel habitats and their communities are **highly intolerant** of substratum loss but are likely to recover within about 5 years, i.e. to have a **recoverability of high**, suggesting a **sensitivity of moderate.** The representative component biotopes listed in Table 17 also suggest an overall sensitivity of moderate.

Table 17. Summary of representative component biotope sensitivities in 'Sand/gravel banks' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	High	High	**Moderate**	High
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	High	High	**Moderate**	High
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	High	High	**Moderate**	High
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Intermediate	Very high	**Low**	Low

Sensitivity to smothering

The effects of smothering on sand and gravel habitats and their communities have been discussed in prior sections. The intolerance of the habitat to smothering will depend on the functional groups and hence the species present and is likely to vary between biotopes (see Table 18).

Table 18. Summary of representative component biotope sensitivities in 'Sand/gravel banks' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Low	Very high	**Very low**	Low
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Low	Very high	**Very Low**	Low
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Low	Immediate	**Not sensitive**	Moderate
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Immediate	**Not sensitive**	Moderate

However, the representative component biotopes were assessed as of low intolerance to smothering at the benchmark level, suggesting that the biotopes are probably not sensitive or of very low sensitivity depending on their ability to recover form disturbance (see Table 20). The infauna of sand and gravel banks are primarily active burrowers and therefore, probably have only a low intolerance (representing the increased energetic costs), to smothering at the benchmark level, and overall a **sensitivity of not sensitive** is suggested.

Sensitivity to physical disturbance

The effects of physical disturbance on sand and gravel habitats and their communities have been discussed in prior sections. The likely sensitivity of representative component biotopes is shown in Table 19. Overall, coastal sediment plains are likely to be of **intermediate intolerance** to physical disturbance at the benchmark level, while recoverability is likely to be high, suggesting an overall **sensitivity of low**. Intolerance will depend on intensity of fishing effort, therefore, areas subject to continuous or long-tem fishing effort are likely to be more sensitive.

Table 19. Summary of representative component biotope sensitivities in 'Sand/gravel banks' to physical disturbance

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Intermediate	High	**Low**	Moderate
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Intermediate	High	**Low**	Low
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Intermediate	High	**Low**	Low
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Very high	**Very Low**	Low

6.4.8 Sediment waves/megaripple field

Sand waves are likely to be composed of gravely sand and will be unstable, mobile sedimentary habitats. The most likely biotope to characterize such sediments is CGS.Ven.Neo whilst in shallow depths, IGS.FaS.Mob, may be characteristic.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains.

CMS.AbrNucCor - *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment

CMS.AfilEcor - *Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand

CMS.VirOph - *Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud

CGS.Ven.Neo - *Neopentadactyla mixta* and venerid bivalves in circalittoral shell gravel or coarse sand (Represented by CGS.Ven - Venerid bivalves in circalittoral coarse sand or gravel).

IGS.Mob - Sparse fauna in infralittoral mobile clean sand (Represented by IGS.NeoGam - *Neomysis integer* and *Gammarus* spp. in low salinity infralittoral mobile sand).

Elliot *et al.* (1998) reported that subtidal mobile sand banks were colonized by infaunal or epifaunal small bivalves, crustaceans and polychaetes adapted to a changeable hydrography and substratum. Species living in mobile substrata are able to reburrow quickly after being washed out of the sediment, e.g. *Nephtys cirrhosa* and amphipods. Continual sediment disturbance results in a large number of opportunistic species, e.g. *Chaetozone setosa* (Elliot *et al.*, 1998). Subtidal mobile sandbanks may be similar to the 'boreal offshore sand association' (Jones, 1950) and may contain elements of the 'boreal offshore gravel association' and 'boreal offshore sandy association' (Jones, 1950) depending on the hydrography (Elliot *et al.*, 1998)

Subtidal mobile sandbanks are the result of high energy conditions and naturally disturbed by hydrographic conditions such as storms. Therefore, Elliot *et al.* (1998) suggested that the community is likely to recover from sediment disturbance, since the associated species are predominately mobile, able to tolerate sediment movement, and the influx of sediment from natural or man-made sources (e.g. dredged spoil). For example, Jennings & Kaiser (1998) reported that in experiments in the Irish Sea, the effects of beam trawl disturbance could not be detected in mobile sediments, which was attributed to the levels of natural disturbance in megaripple habitats. Animals living in the troughs of sediment ripples were less likely to be disturbed by since fishing gear rode over the crests of the sand waves (Jennings & Kaiser, 1998).

Therefore, it is unlikely that sediment wave or megaripple fields will be affected by any of the factors under consideration, and a **sensitivity of not sensitive** has been suggested.

6.4.9 Deep water channel and Irish Sea Mounds.

No information on the likely communities present in these Marine Landscapes was found and no overall sensitivity assessment has been attempted.

6.4.10 Reefs (rocky/biogenic)

The Marine Landscape map suggests that reefs are offshore features and not part of coastal rock but include the Sarns. The biotopes suggested below are for the sorts of biotopes that are believed to occur in the areas identified as 'Reefs' on the Marine Landscapes map. They include *Modiolus modiolus* reefs, subtidal *Mytilus edulis* beds, *Musculus discors* crusts and *Sabellaria spinulosa* crusts as the only biogenic reefs. Sensitivity characteristics are likely to be very different for shallow and deep (biogenic) reefs.

Component biotopes. The following biotopes are probably representative of coarse sedimentary plains. The likely dominant biotopes, in terms of extent, are shown in bold.

IR.AlcByH - *Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock (representing, tide swept faunal communities)

MCR.ErSEun - Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.

MCR.Flu - *Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata

MCR.ModT - *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata

MCR.Mus - *Musculus discors* beds on moderately exposed circalittoral rock

MCR.MytHAs - *Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock

MCR.Oph - *Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata

MCR.Urt - *Urticina felina* on sand-affected circalittoral rock

CMX.SspiMx – Represented by **MCR.Sspi** - *Sabellaria spinulosa* crusts on silty turbid circalittoral rock

MIR.LsacChoR - *Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

MIR.HalXK - *Laminaria saccharina*, *Chorda filum,* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles

Sensitivity to substratum loss

Rocky reef habitats or biogenic reefs are likely to be highly intolerant of removal of their substratum (Table 20). Their sensitivity is primarily dependant on their ability to recolonize the remaining substratum if it is suitable. It should be noted of course that some activities, such as land claim or seabed construction are likely to be permanent. Similarly, should any activity be allowed to remove parts of the Sarnau, they are unlikely to recover since they were deposited in the last glaciation. Permanent effects have not been considered here.

Fucoids and opportunistic kelps such as *Laminaria saccharina* and *Saccorhiza polyschides* would probably colonize the remaining substratum relatively quickly and probably within a year. Most red algae also probably recruit relatively rapidly and recover their original cover within about 5 years, although some species would probably take much longer to recover, e.g. *Furcellaria lumbricalis,* which is slow growing with limited dispersal. In most cases, *Sabellaria spinulosa* crusts are probably annual (Holt *et al.*, 1998). Although, *S. spinulosa* reefs (as defined by Holt *et al.,* 1998) are rare and probably take longer to develop, none have been recorded in the Irish Sea. *Mytilus edulis* probably exhibits good powers of recoverability and can build a reef habitat capable of supporting other species relatively quickly.

Epifaunal communities such as MCR.Flu and IR.AlcByH would probably be removed with their substratum and hence highly intolerant of substratum loss. In studies of subtidal epifaunal communities in New England, Sebens (1985, 1986) reported that cleared areas were colonized by erect hydroids, bryozoans, crustose red algae, and tubeworms within 1-4 months in spring, summer, and autumn. Tunicates such as *Dendrodoa carnea* and *Aplidium* spp. appeared within a year, *Aplidium* sp., and *Halichondria panicea* achieved pre-clearance cover within >2 years, while only a few individuals of *Metridium senile* and *Alcyonium* sp. colonized within 4 years. Sebens (1985) suggested that *Alcyonium* spp and *Metridium senile* would probably not recruit to epifaunal communities unless other populations of the species were nearby. Where the populations are removed or destroyed, recolonization of epifauna will depend on recruitment of larvae from other communities. The majority of species are widespread but have poor dispersal so that recruitment rates will depend on the proximity of nearby communities and the hydrographic regime. Exceptions include mobile crustacea and echinoderms with long-lived planktonic larvae, and *Nemertesia antennina* and *Alcyonium digitatum*, which can probably disperse up to 50 m or over 100 km respectively (Hughes, 1977; Hartnoll, 1998).

Encrusting bryozoans, hydroids, and ascidians will probably develop a faunal turf within less than 2 years. *Flustra foliacea* is capable of dispersing over considerable distance, since it colonized the M.V. *Robert* off Lundy and achieved 1-5% (occasional) cover within 4 years (Hiscock, 1981). However, it would probably take many years for *Flustra foliacea* to recover its original cover. *Alcyonium digitatum* is capable of colonizing within 4 years (Sebens, 1985, 1986) but may take longer to achieve its original abundance.

As a brooding species, *Musculus discors* probably exhibits good local recruitment but poor dispersive capabilities. Therefore, if the population is removed it will probably take a long period of time (up to ten years) to recover its former abundance. The main bed forming brittlestar *Ophiothrix fragilis* reproduces occurs annually, is highly fecund, may have multiple recruitment phases and may reach reproductive capability in 6-10 months depending on time of recruitment (Davoult *et al*., 1990). Hence, recovery is likely to be high. However, lost populations may not always be replaced because settlement of larvae of

Ophiothrix fragilis is highly dependent on hydrographic conditions and consequently may be unpredictable (see Hughes, 1998).

Table 20. Summary of representative component biotope sensitivities in 'Reefs (rocky/biogenic)' to substratum loss

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	High	High	**Moderate**	High
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	High	Very low	**Very High**	High
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	High	Very low	**Very High**	High
MCR.Mus	*Musculus discors* beds on moderately exposed circalittoral rock	High	Moderate	**Moderate**	Low
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	High	High	**Moderate**	High
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	High	High	**Moderate**	High
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	High	Moderate	**Moderate**	Moderate
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	High	High	**Moderate**	Moderate
MIR.LsacChoR	*Laminaria saccharina, Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	High	High	**Moderate**	High

However, *Modiolus modiolus* is slow growing and long-lived with sporadic and highly variable (seasonally and with location) recruitment. Although it may recruit in large numbers, there may be long periods of time between recruitment episodes, larval and juvenile mortality is high, and the adults are slow growing so that a biogenic reef habitat, capable of supporting a diverse community will take a very long time to develop. Similarly, *Eunicella verrucosa* is long lived, slow growing, and little is known of its reproduction. It is known to colonize wrecks at least several hundred metres from other hard substrata with sea fans but is thought to have larvae that generally settle near the parent. Recolonization would most likely occur after a few years but growth to a large size will take in excess of 10 years and replacement of very large colonies in excess of 25 years (Hiscock, 2001).

Overall, the majority of the component representative biotopes are likely to be highly intolerant of substratum loss but exhibit reasonable rates of recovery, suggesting moderate sensitivity. Horse mussel beds and communities containing *Eunicella verrucosa* are notable and important exceptions. Therefore, at the Marine Landscape scale **an overall sensitivity of 'moderate but high in places'** has been suggested, a precautionary approach to highlight the potential presence of very high sensitivity habitats.

Sensitivity to smothering

Species characteristic of rocky reef habitats or the formation of biogenic reefs are primarily sedentary or permanently attached, and incapable or avoiding smothering or of burrowing through deposited sediment (see Table 21).

The formation of biogenic reef by mussel species 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 in horse mussel reef was found. Holt *et al.* (1998) note that there are no studies of the accretion rates that *Modiolus modiolus* beds can tolerate. Although, young *Mytilus edulis* can move up through the mussel matrix, intertidal *Mytilus edulis* beds have been reported to suffer mortalities as a result on smothering by large scale movements of sand or sand scour (Holt *et al.*, 1998; Daly & Mathieson, 1977). Similarly, biodeposition within a mussel bed results in suffocation or starvation of individuals that cannot re-surface. Therefore, the deposition of 5 cm of sediment (the benchmark level) is likely to smother and kill a proportion of the mussels within the reef. Larger reefs may avoid the worst affects due to their size and height above the seabed. However, some members of the associated epifauna and infauna may also be adversely affected.

Table 21. Summary of representative component biotope sensitivities in 'Reefs (rocky/biogenic)' to smothering

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	Intermediate	High	**Low**	Moderate
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	Intermediate	Moderate	**Moderate**	Moderate
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Low
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	Intermediate	Low	**High**	Low
MCR.Mus	*Musculus discors* beds on moderately exposed circalittoral rock	High	Moderate	**Moderate**	Low
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	Intermediate	High	**Low**	Moderate
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	Intermediate	High	**Low**	High
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	Intermediate	High	**Low**	Low
MIR.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	Intermediate	High	**Low**	High

Musculus discors beds are composed of byssus nests that would protect the resident individuals from the direct affects of smothering but they would also be incapable of burrowing up through the deposited material and probably succumb to subsequent hypoxic conditions. Smaller epifauna may succumb while larger epifaunal species may survive. However, death of the *Musculus discors* would result in loss of the biotope.

Sabellaria spinulosa crusts themselves are probably tolerant of smothering but other species characteristic of the biotope such as *Ophiothrix fragilis* and *Alcyonium digitatum* are likely to be killed by smothering, resulting in an intolerance rank of intermediate. Upright and branching species e.g. *Axinella dissimilis* and *Eunicella verrucosa* project above the substratum to sufficient height not to be covered completely by 5 cm of sediment and consequently may not be killed by smothering.

Holme & Wilson (1985) reported *Flustra foliacea* dominated communities that were subject to periodic smothering by thin layers of sand, up to ca 5 cm 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 sand scoured communities. Smothering with a layer of sediment will prevent or reduce feeding and hence growth and reproduction. The biotopes MCR.Flu and MCR.Oph will probably survive smothering at the benchmark level. However, 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 *Alcyonium 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. Also, associated small species such as prosobranchs, amphipods and worms may be sensitive. Therefore, an intolerance of intermediate is suggested. The intolerance of *Alcyonium digitatum* with a bryozoan, hydroid, and ascidian turf communities (e.g. IR.AlcByH) is probably similar.

Dense populations of brittlestars (e.g. MCR.Oph) do not persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer, 1962 cited in Aronson, 1992). Therefore, smothering by 5cm of sediment is likely to result in the death of most individuals suggesting a high intolerance. Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively attributed this to increased sedimentation caused by the localized dumping of construction materials.

Sand or gravel-affected or disturbed kelp and seaweed communities (e.g. MIR.HalXK and MIR.LsacChoR) are probably of intermediate tolerance to smothering. Fully grown kelps, fucoids and the larger red algae are probably large enough to be unaffected at the benchmark level and some species as tolerant of sediment associated scour, e.g. *Laminaria saccharina, Ahnfeltia plicata* and *Furcellaria lumbricalis*. However, smothering by a layer of sediment can exclude 98% of the light form the substratum (Vadas *et al.*, 1992). Smothering may be more damaging if it occurs during the settlement phase of most algae, either killing small sporelings or interfering with the settlement of algal spores, and resulting in reduced recruitment of particular importance in annual or short lived species.

Therefore, the majority of the representative component biotopes are of at least intermediate intolerance to smothering and capable of recovering with a reasonable time frame (i.e. 5 years), suggesting a sensitivity of low. Nevertheless, *Musculus discors* beds, brittlestar beds, and especially horse mussel beds are important exception and exhibit a higher sensitivity to smothering. Therefore, at the Marine Landscape scale an overall **sensitivity of 'low but high in places'** has been suggested, a precautionary approach to highlight the potential presence of highly sensitive habitats.

Sensitivity to physical disturbance and abrasion

The sensitivities of the likely component biotopes are shown in Table 22.

Impacts from towed fishing gear (e.g. scallop dredges) are known to flatten clumps and aggregations of horse mussels, may break off sections of raised reefs and probably damage individual mussels (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 queen trawling resulted in flattening of the horse mussel bed and disruption of clumps of horse mussels and removal of emergent epifauna in Strangford Lough. 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. Scallop dredging was found to damage many of the epibenthic species found in association with *Modiolus modiolus* beds (Hill *et al.*, 1997; Jones *et al.*, 2000) and the emergent epifauna were the first indicators of damage (Magorrian & Service, 1998). The level of damage is dependant on fishing intensity or frequency of impact (Service & Magorrian, 1997; Magorrian & Service, 1998; Service 1998; Veale *et al.*, 2000). Although, the benchmark level of impact refers to a single event, the weight of evidence summarized above suggests that horse mussel beds and reefs are highly intolerant of physical disturbance caused by fishing gears.

Table 22. Summary of representative component biotope sensitivities in 'Reefs (rocky/biogenic)' to physical abrasion

Biotope code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	High	High	**Moderate**	High
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	High	Low	**High**	Moderate
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	High	Low	**High**	Moderate
MCR.Mus	*Musculus discors* beds on moderately exposed circalittoral rock	Intermediate	High	**Low**	Low
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	Intermediate	High	**Low**	Low
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	Intermediate	High	**Low**	Low
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	Intermediate	High	**Low**	Low
MIR.LsacCho R	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	Intermediate	High	**Low**	Moderate

Mytilus edulis reefs would probably suffer damage in the same way as horse mussel beds. A scallop dredge is also likely to damage the 'mat' of byssal nests formed by *Musculus discors*, removing sections and increasing their vulnerability to further damage by wave exposure or currents. Similarly, *Sabellaria spinulosa* crusts and seaweed communities would probably be damaged and partially removed by fishing gear suggesting intermediate intolerance.

Eno *et al.* (1996) suggested that *Eunicella verrucosa* was "remarkably resilient" to impact from lobster pots. However, abrasion that removes the coenenchyme may allow the settlement of epibiota that will increase drag and may include species that bore into the skeleton and weaken the colony. However, a passing scallop dredge may remove or damage sea fans. Where individuals are removed, recovery will be prolonged. *Pentapora fascialis* (as *foliacea*) was reported to be damaged by scallop dredges and mobile fishing gear, pots and creels (Bullimore, 1985; DWT, 1993; Eno *et al.*, 1996) and is probably highly intolerant, although its recoverability is probably high.

Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration (Sköld, 1998). Fishermen tend to avoid brittlestar beds since the animals clog their nets (Jones *et al.*, 2000). However, a passing scallop dredge is likely to remove, displace, or damage brittlestars caught in its path. Although several species of brittlestar are reported to increase in abundance in trawled areas, Bradshaw *et al.* (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long term in areas subject to scallop dredging. Overall, a proportion of the population is likely to be damaged or removed and an intolerance of intermediate is suggested.

Holt *et al.* (1998) noted that biogenic reefs, as raised seabed structures, are likely to be sensitive to strong physical disturbance. Holt *et al.* (1998) reported that *M. modiolus* reefs had suffered widespread damage due to scallop dredging in Strangford Lough, and was suspected south east of the Isle of Man and possibly in Shetland Voes. Recovery in horse mussels is likely to be prolonged. Holt *et al.* (1998) also suggested that over-exploitation of *M. edulis* beds could result in a decline in stocks at the local or wider scale. Similarly, *S. spinulosa* reefs in Morecambe Bay, the Wash and southern North Sea had suffered widespread loss due to bottom fishing for the pink shrimp but has not recovered even after fishing had stopped.

Overall, biogenic reefs are likely to be vulnerable to physical disturbance and to suffer damage as a result. Therefore, at the Marine Landscape level, they are likely to of at least intermediate intolerance to physical disturbance at the benchmark level but **highly intolerant** of fishing activities. Potential recovery rates in most of the biogenic reefs forming species or reef habitats are probably high (see Table 24) suggesting an overall sensitivity of low. However, sea fans (e.g. *Eunicella verrucosa*) and horse mussels are notable exceptions in which recovery may be prolonged. Therefore, an overall **sensitivity of 'low but high in places'** has been suggested.

6.4.11 Summary

The evidence summarized above, together with the probably sensitivity of likely representative component biotopes has been used to derive overall sensitivity assessments for the Marine Landscapes wherever possible (Tables 23). The likely sensitivities of the Marine Landscapes to physical disturbance and abrasion are shown in Figure 2 and on the *MarLIN* Web site.

Table 23. Summary of the suggested sensitivities of the Irish Sea Marine Landscapes.

Marine Landscape	Suggested sensitivity to environmental factor		
	Substratum loss	**Smothering**	**Physical disturbance**
Photic rock	Variable (see text)	Variable (see text)	Variable (see text)
Coastal sediment	Moderate	Low	Low
Fine sediment plains	Moderate	Very low	Low
Coarse sediment plains	Moderate	Low	Low
Shallow water mud basins	Moderate	Not sensitive	Low
Deep water mud basins	Moderate	Not sensitive	Low
Sand/gravel banks	Moderate	Not sensitive	Low
Sediment waves/megaripple field	Not sensitive	Not sensitive	Not sensitive
Deep water channel	No information found	No information found	No information found
Irish Sea Mounds	No information found	No information found	No information found
Reefs (rocky/biogenic)	Moderate (High in places)	Low (High in places)	Low (High in places).

6.5. Assessing the sensitivity of Marine Landscapes

The proposed sensitivities of Marine Landscapes (see Table 23) were derived from readily available information and from information collated on representative component biotopes. The biotopes chosen to represent sensitivity within Marine Landscapes need to:

1. be based, as far as possible, on mutually exclusive groups of biotopes;
2. be based on widely occurring biotopes;
3. exclude biotopes that are likely to bias broad sensitivity assessment (e.g. localized high sensitivity habitats);
4. be meaningful in relation to pressures within the region.

Biotopes that may be representative of a Marine Landscape unit but that do not occur in the coastal seas under consideration should not be included in the analysis.

It was felt that while existing survey data for inshore water and the intertidal allowed the distribution and extent of biotopes to be identified, offshore survey data was not detailed enough. However, in offshore areas management requirement are usually at a broad scale (e.g. fisheries), so that broad scale mapping is probably appropriate. Similarly, while biotopes are an appropriate unit for mapping in inshore areas, the biotope complexes adopted by the Irish Sea Pilot were probably a more appropriate level of detail in offshore areas (see Annex). However, biotope complexes were not mapped in this project because it was not possible to quickly tag biotope complexes with sensitivity information. Tagging biotope complexes with sensitivity information would require information on the biotopes present within the revised 2003 classification biotope complexes, which was not available for infralittoral or sediment biotopes. In addition, there was not enough time in the contract to assess the sensitivity of biotope complexes themselves based on their list of characterizing species or species indicative of sensitivity (see Appendix 1), even where the information was available.

The sensitivity assessments of Marine Landscapes are based on the sensitivity of widely occurring biotopes and not of localized features. Therefore, the overall Marine Landscape sensitivity is ‘non-specific’. However, localized sensitive or important features (such as the presence of fragile reefs of *Sabellaria alveolata* or of the nationally rare *Ocnus planci*) can be readily identified in more detailed maps using GIS and be important for Environmental Impact Assessments (EIA’s), for contingency planning and for the management of marine protected areas.

The Marine Landscapes were assessed as of ‘low’ sensitivity (or less) to smothering (see Table 23). It was suggested that the smothering benchmark may not adequately represent smothering in sheltered habitats, i.e. 5 cm is likely to take more than a month to disperse in sheltered habitats such as sheltered or deep water mud basins. However, the limited evidence (see sections, 6.4.5 and 6.4.6; Kukert & Smith, 1992) suggested that these Marine Landscapes were probably of intermediate intolerance to smothering. While the deposited spoil remained, recovery still occurred within less than 5 years, which yields a sensitivity of low.

6.6. Sensitivity maps of the Marine Landscapes within the Irish Sea

The preliminary sensitivity maps are available on the *MarLIN* Web site (www.marlin.ac.uk). The maps are supplied in JPEG format but are best viewed in GIS. The maps show the likely sensitivity of species, biotopes, nationally important species, and biotopes within nationally important biotopes complexes to three separate environmental factors, substratum loss, smothering, and physical disturbance. The biotopes within nationally important biotope complexes are grouped together and plotted as maps for Littoral Rock, Littoral Sediment, Infralittoral Rock, Infralittoral Sediment, Circalittoral Rock and Circalittoral Sediment.

The preliminary sensitivity maps were prepared at the Marine Landscape scale (see Figure 2). Most of the survey data points are inshore, are numerous, and overlap considerably. The symbol size used to plot the survey data points was kept small to minimize the amount of overlap. However, many points are still obscured even though the most sensitive records remain visible, since they have been plotted on the top layer.

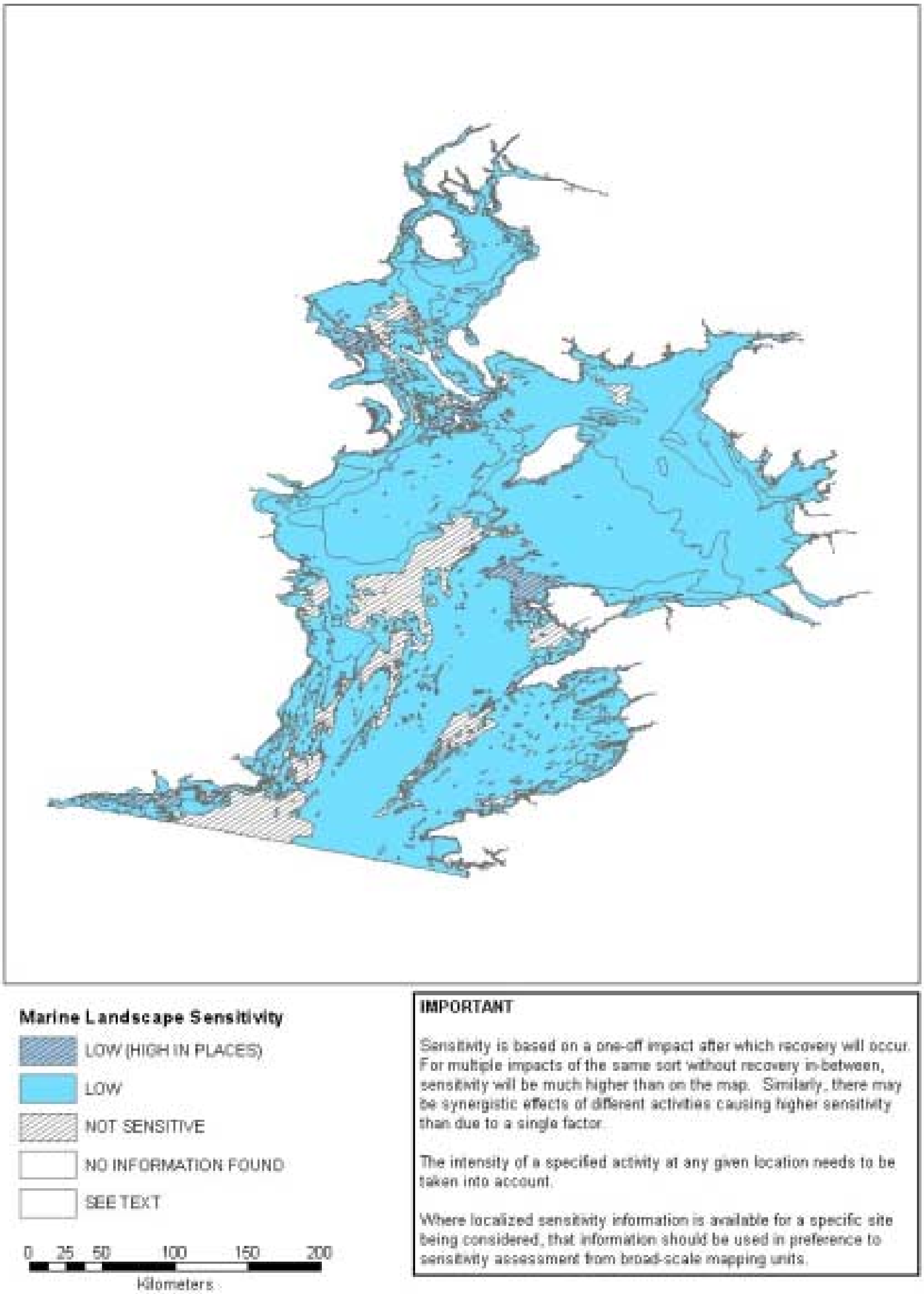

Figure 2. Sensitivity of Marine Landscapes to physical disturbance and abrasion.

For example, Figure 2 shows a map of the Marine Landscapes identified in the Irish Sea and tagged with their likely sensitivity to physical disturbance and abrasion. Figure 3 and 4 show Bardsey Island and part of the Llyn Peninsula together with the distribution of species (Figure 3) and biotopes (Figure 4) likely to be sensitive to physical disturbance. Figure 3 clearly shows the distribution of highly sensitive species or biotopes within the relevant Marine Landscapes but at a scale more appropriate for environmental management. Figure 5 includes nationally scarce species, and UK BAP species on the sensitivity map of Marine Landscape. No sensitivity information was available for the nationally rare species in the Irish Sea.

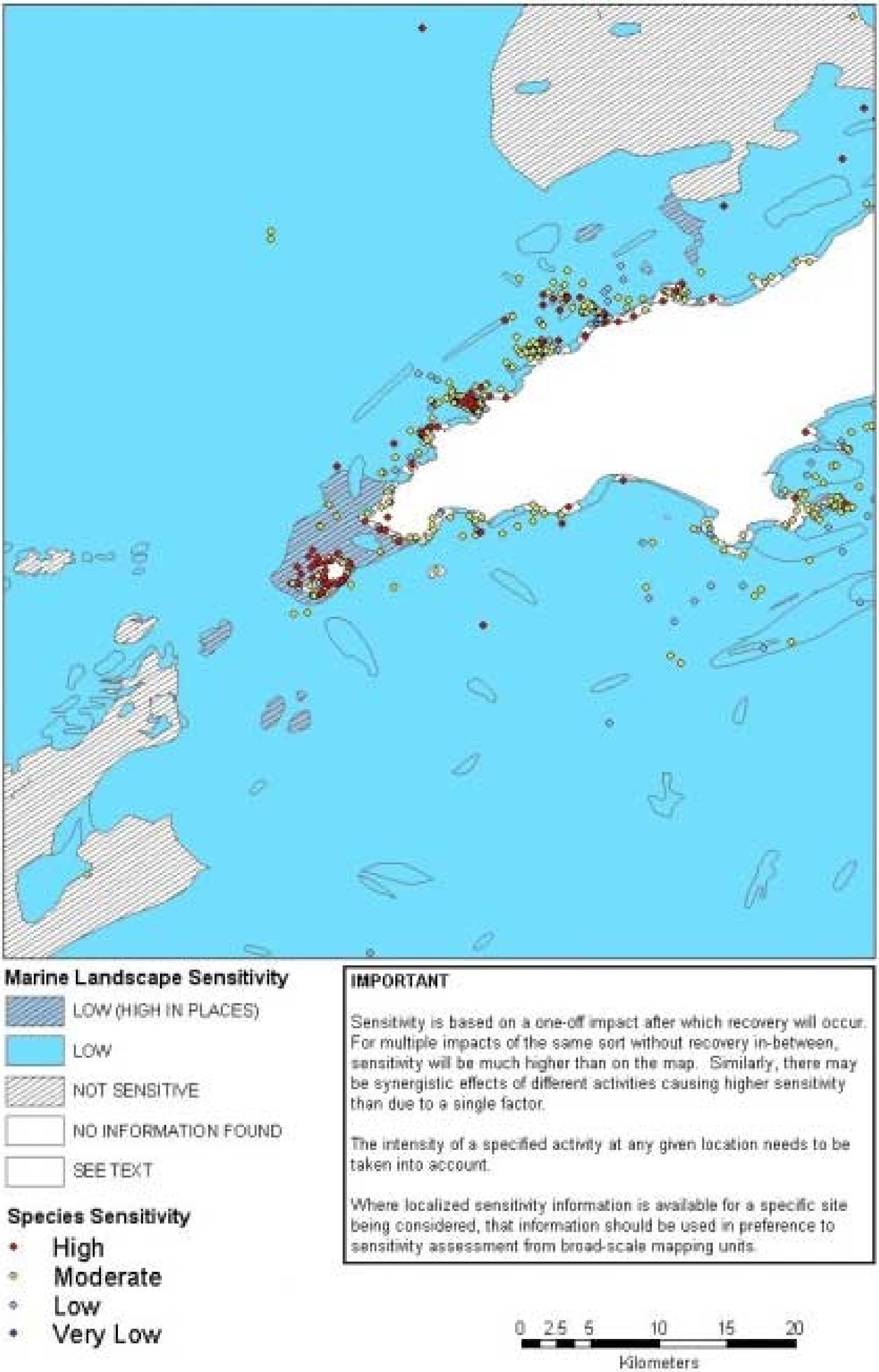

Figure 3. Sensitivity of species to physical disturbance and abrasion within Marine Landscapes in the vicinity of Bardsey Island.

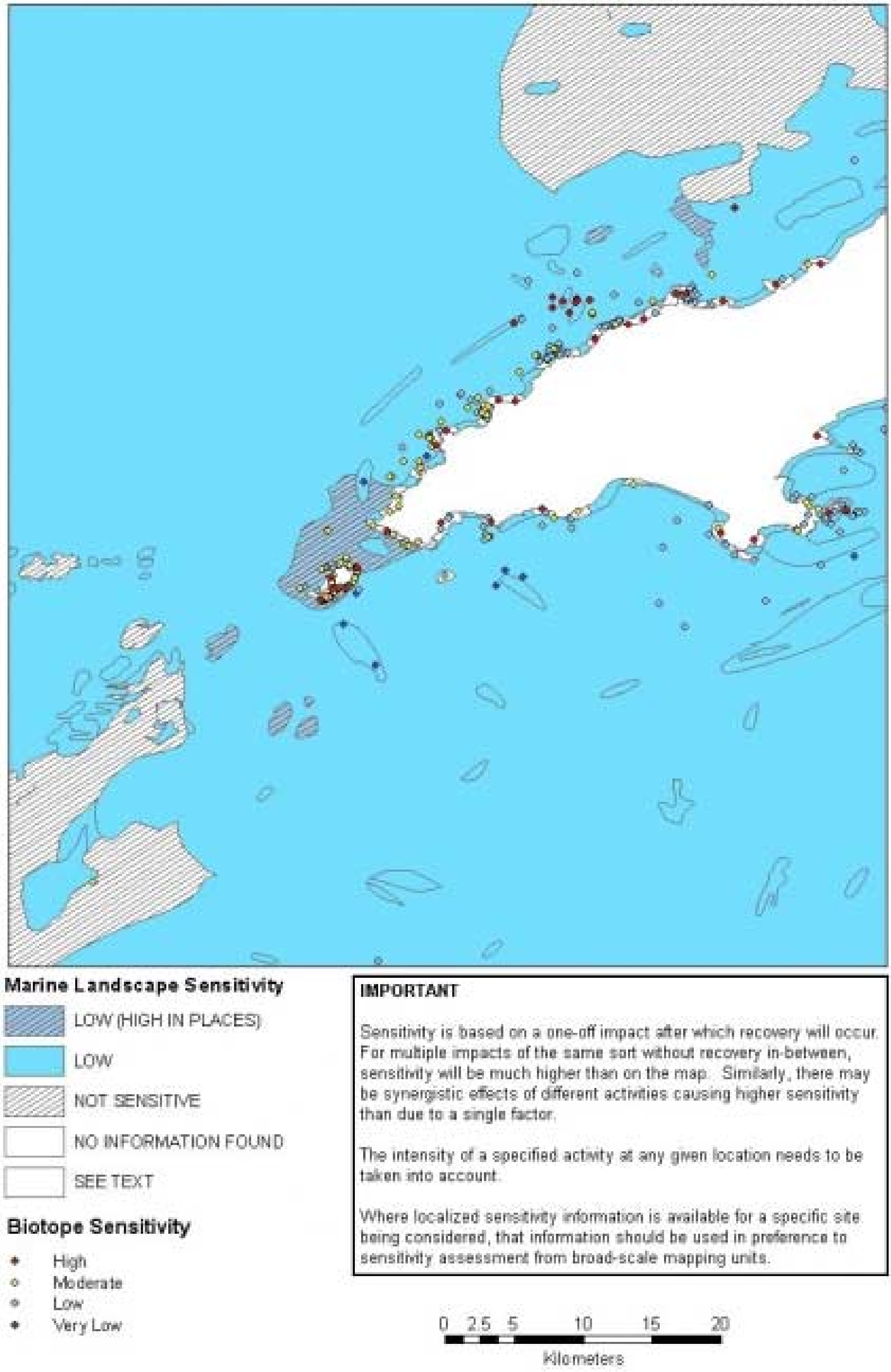

Figure 4. Sensitivity of biotopes to physical disturbance and abrasion within Marine Landscapes in the vicinity of Bardsey Island.

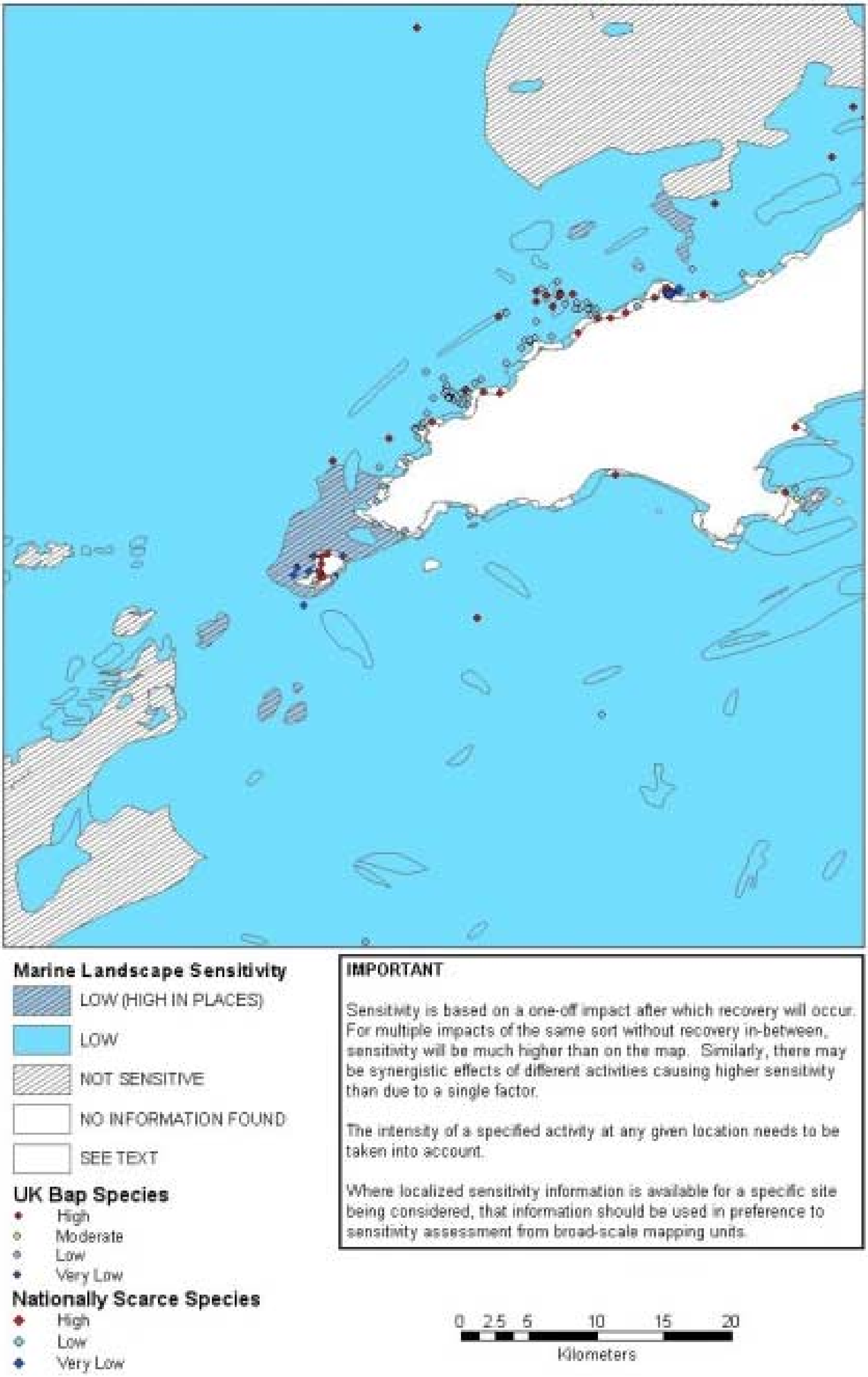

Figure 5. The presence of sensitive nationally scarce species or UK BAP species within Marine Landscapes sensitive to physical disturbance in the vicinity of Bardsey Island

Each of the survey data points shown can be further interrogated to list the biotopes recorded at that site and their sensitivities, as shown in Figure 6. The same information can be obtained at the species level.

A static printed map does not adequately present the data available. To do so would require multiple and numerous maps at larger scales to cover the entire Irish Sea. The utility of sensitivity mapping as a management tool lies in the ability to interrogate the information using GIS and not static maps.

Figure 6. The information available for a single survey data point within GIS.

Figure 3 also demonstrates the presence of several species and biotopes likely to be of moderate or high sensitivity to physical disturbance in the vicinity of Bardsey Island, while the Marine Landscape has been assessed as of ‘low’ or ‘low but high in places’. It should be remembered that *MarLIN* sensitivity assessments, and the proposed Marine Landscape sensitivities are based on a benchmark level of effect, of specified duration and magnitude. The sensitivities do not take into account events of greater magnitude, frequency or duration. In the example given in Figures 2-5, sensitivity to physical disturbance is likely to be greater in areas subject to intense fishing activity, i.e. intolerance will be higher and recoverability delayed until cessation of the activity.

6.7. Utility of mapping scales

The appropriate scale depends on the use for which the information is intended (see Table 24). For example, sensitivity maps at the Marine Landscape level may provide an overall guide to sensitivity for Strategic Environmental Assessment (SEA), Cumulative Environmental Assessment (CEA), or regional management. Mapping at the seascape or Marine Landscape level is probably useful for highlighting similar habitats, the coverage of survey data and where gaps in our knowledge occur. Site management, development planning or emergency response require more detailed local information and would probably require highly detailed data to biotope complex, biotope and species level. Sensitivity maps in GIS provide the facility to ‘zoom’ to a variety of scales depending on user requirements, for instance to display survey data and sensitivity information at the biotope and species level, as shown in Figures 3, 4 and 5.

6.8. The utility of sensitivity maps in regional marine environmental management

Intolerance and recoverability, and hence sensitivity, are dependant on the scale, magnitude, duration and frequency of a change in a specific environmental factor. Similarly, any specific marine activity is likely to affect a number of environmental factors (see Appendix 3). Therefore, sensitivity mapping in environmental management will need to address the vulnerability of the habitats or species.

Vulnerability expresses the likelihood that a habitat, community, or species will be exposed to an environmental factor to which it is sensitive. The degree of vulnerability indicates the likely severity of damage to the species or habitat should the change in the factor occur.

Using information on the sensitivities of Marine Landscapes, combined with information on their exposure to factors or human activities, it should be possible to assess the likely vulnerability of Marine Landscapes to the current changes in factors/levels of human activities. It may be possible to compare vulnerability assessments with direct scientific observations on environmental change. Vulnerability would identify sites or areas in need of direct environmental management action.

Table 24. The utility of mapping survey data and sensitivity at different scales

Map type	Extent of major types visualized	Survey targeting	MPA selection (compare like – like)	Match to fisheries information	Sensitivity mapping and appraisla	Protected areas management	Emergency response	'Special' features (e.g. rare biotopes or species)	Notes
Marine Landscapes /Landscape / Seascape	+	+	+	+	*	-	-	-	*Broad nature of units gives a 'non-specific' sensitivity assessment. Insufficient detail and/or complex inshore areas excluded so unsuitable for localized management.
Physiographic types	+	+	+						Important units for comparing like-with-like and selecting representative MPA's.
Mapable types (visual/acoustic/photographic survey)	+	+	-	+	*	-	-	-	* Only possible if biotopes can be matched to mapping units.
Biotope complexes	+	+	-	-	+	+	-	-	
Biotopes	+	+	+	-	+		+		The most suitable units for assessing sensitivity and natural heritage importance in relation to biotope variety, rarity and species richness.
Target notes (identification of localized features)	-	-	+	+	(+)	+	+	+	Could be used in sensitivity mapping but interpretation needed by expert. The most suitable unit for identifying location of rare and scarce species or small fragile habitats.

Vulnerability will probably vary at scales smaller than the Marine Landscapes for many activities. Matrices have been developed as part of the Regulation 33 advice for European SACs, which could be used to calculate vulnerability indices. This may work better for more uniform offshore landscapes than complex inshore areas. A GIS approach to assessing the vulnerability of habitats and species in Liverpool Bay to marine activities was trialled recently by Oakwood Environmental (2003).

7. Conclusions

This report outlines a preliminary assessment of the use of research to identify the sensitivity of species and biotopes to prepare sensitivity maps within the Irish Sea. The report represents a single trial, as there was not enough time to test multiple approaches. Nevertheless, we have been able to tag the available survey data for species and biotopes with sensitivity information where available and have proposed, and mapped, sensitivity assessments at the Marine Landscape scale. The overall conclusions follow.

- Survey data can be tagged with sensitivity information to provide maps in GIS that show the distribution and location of potentially sensitive habitats and species to different environmental factors.
- Sensitivity mapping of broader scale units, such as biotope complexes and habitat complexes requires spatial information on their distribution and extent.

- Point based survey data alone does not provide information on the spatial extent of a biotope or species within a broader scale unit.
- Reporting the highest sensitivity of a geographically determined list of biotopes (or species) would probably over-estimate the sensitivity of a broader scale unit.
- There may not be enough data in offshore areas to map to the biotope level. However, in offshore areas, management requirements are usually at a broad scale (e.g. fisheries) and broad scale mapping is appropriate. Therefore, while biotopes are an appropriate unit for mapping in inshore areas, biotope complexes may be more appropriate offshore.
- It is probably unrepresentative to extrapolate directly from biotope or biotope complex level sensitivities to the Marine Landscape level.

Therefore, the available field survey data did not allow existing *MarLIN* sensitivity information to be used directly for the derivation of an overall sensitivity of Marine Landscapes. However, a review of the literature allowed an overall sensitivity of the Marine Landscapes to be assessed based on available sensitivities of likely biotopes present.

- The sensitivity assessment of broad scale units as large as the Marine Landscape unit requires expert judgement with reference to existing literature and to the *MarLIN* sensitivities of representative component biotopes.
- The proposed sensitivities of Marine Landscapes provide an overall indication of sensitivity to the environmental factors shown based on a limited review of the literature. Sensitivity maps at the Marine Landscape level provide useful information for broad scale spatial planning and management of the marine environment.
- The presence of highly sensitive species and biotopes, or of species and biotopes of marine natural heritage importance (e.g. UK BAP species), within any broad scale unit can be mapped as point survey data and support more detailed mapping.
- Users of sensitivity information based on biotope complexes, biotopes, nationally important features, species etc need to know how they can and cannot be used. A strength of biotopes is that they allow comparison of like-with-like to assess quality, to identify variety within an area and can be assessed as rare or scarce. However, they do not identify other important features such as biomass, diversity, or functioning of the biology at a location.
- Geographical Information Systems allow sensitivity maps, survey data and sensitivity information to be interrogated at a variety of scales, depending on user requirements, e.g. to provide information for Strategic Environmental Assessment at the broad scale or ‘zoom in’ to inform local development planning, Environmental Impact Assessment, or emergency response.
- The position of locally important features are best included as target notes within the GIS.
- *MarLIN* sensitivity assessments are not site or location specific and any sensitivity maps produced must always be interpreted by marine experts with local knowledge, and the likely effects of the proposed plan, programme or project be compared to the benchmark levels of effect against which sensitivity has been assessed.
- Information on the relative intensity or extent of marine activities and the resultant changes in environmental factors should be used together with sensitivity information to identify vulnerable species, habitats and areas and effectively target environmental management.
- Static versions of the sensitivity maps do not adequately represent the data and their true utility as a management tools is only realised using GIS.

Sensitivity mapping has the potential to identify or ‘flag’ locations, sites, or areas that are likely to be adversely affected by activities in the marine environment. At present, point survey data provides reasonable information on sensitivity at the local or site-based level, which is probably exactly the scale required for emergency response and development planning. However, the more we extrapolate from survey point data to broader scales the less confident we are likely to be in our overall assessment of sensitivity.

While it is possible to extrapolate from species, biotope, or biotope complex sensitivities to broad scale units, it is important to include additional evidence from the literature, the sensitivities of representative component biotopes, and expert judgement to assess the sensitivity of the broad scale unit in question, e.g. the Marine Landscape unit. A similar approach has been used to assess the sensitivity of habitat complexes by Jones *et al.* (2000), the sensitivity of Annex I habitats of the Habitats Directive by the Marine SACs Project and the sensitivity of Marine Landscapes in this report.

Overall, the preliminary sensitivity maps have demonstrated that species and biotope survey data can be 'tagged' with available sensitivity information to identify the location of potentially sensitive habitats and species. In addition, an approach to assessing the sensitivity of Marine Landscapes has also been demonstrated. When combined with information on the level (magnitude, duration or frequency) or known or proposed activities it should be possible to identify particularly 'vulnerable' species or habitats and their location, to target environmental management effort effectively.

Geographic Information Systems would allow sensitivity maps to be combined with information on the presence of statutory conservation designations (e.g. SSSIs, SACs, SPAs, MNRs), seal haul out areas, shellfishery and fishery areas, fish spawning areas, marine activities, and link via the Internet to further information. Further development would produce an integrated information resource of spatial and other information to support Integrated Coastal Zone Management and 'good' Marine Stewardship.

8. Recommendations

The above conclusions suggest the following recommendations.

- The development of sensitivity maps for broader scale units should be undertaken using information on the spatial extent of biotopes and their biotope complexes, for example by using data provided by the phase I or phase II biotope mapping.
- The sensitivities of Marine Landscapes should only be used as broad indicators, and the detailed survey data points and their sensitivity information, where available, should be used to support environmental management decisions.
- The Irish Sea Pilot should seek to identify those additional datasets, surveys, and other sources of information that need to be incorporated into future work including appropriate databases. This could include biological data from EIAs and SEAs. The Pilot should consider how this might be achieved and make appropriate recommendations. The National Biodiversity Network is an obvious repository.
- New datasets will need interpreting as biotopes or biotope complexes and there is a clear question of who will do that. It would greatly help to have a survey data to biotope matching programme.
- Surveys now being undertaken are likely to use cameras rather than grab sampling. It will be important to develop methods to identify biotopes or biotope complexes for matching sensitivity assessments.
- Using information on the sensitivities of Marine Landscapes, combined with information on the exposures of these landscapes to factors / human activities, it should be possible to assess the likely vulnerability of these Marine Landscapes to the current changes in factors/levels of human activities. It may be possible to compare these vulnerability assessments with direct scientific observations on environmental change. This would help give a reality check to the assessments that have been made.
- Sensitivity assessment could be combined with information on the extent and/or intensity of marine and coastal activities to estimate the 'vulnerabilities' of marine species and habitats. For example, the COST-IMPACT project is identifying the impacts of fishing activities on benthic communities and the wider ocean. Matrices have been developed by statutory conservation agencies, as part of the European marine site work, which could be used to calculate vulnerability indices. Estimates of the extent or intensity of marine activities may work better for more uniform offshore landscapes than complex inshore areas.
- It would be useful to access the GIS on-line. The Multi-Agency Geographic Information for the Countryside (MAGIC) and the Interactive Map Services (IMAPS) provided by the UNEP World Conservation Monitoring Centre are possible models.

Overall, sensitivity mapping has been shown to be a potentially powerful tool in Integrated Coastal Zone Management, Strategic Environmental Assessment, and Marine Stewardship. However, further development of an on-line GIS system of sensitivity maps for the British Isles would require additional funding, either by a consortium of interested parties or from the European Commission.

9. References

Arntz, W.E. & Rumohr, H., 1986. Fluctuations of benthic macrofauna during succession and in an established community. *Meeresforschung*, **31**, 97-114.

Aronson, R.B., 1989. Brittlestar beds: low-predation anachronisms in the British Isles. *Ecology*, **70**, 856-865.

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

Aronson, R.B., 1992. Biology of a scale-independent predator-prey relationship. *Marine Ecology Progress Series*, **89**, 1-13.

Atkinson, R.J.A., 1989. Baseline survey of the burrowing megafauna of Loch Sween, Proposed Marine Nature Reserve, and an investigation of the effects of trawling on the benthic megafauna. *Report to the Nature Conservancy Council, Peterborough, from the University Marine Biological Station, Millport,* pp.1-59.

Ball, B.J., Fox, G. & Munday, B.W., 2000. Long- and short-term consequences of a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. *ICES Journal of Marine Science*, **57**, 1315-1320.

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.

Bergman, M.J.N. & van Santbrink, J.W., 2000. Fishing mortality of populations of megafauna in sandy sediments. In *The effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & S.J de Groot), 49-68. Oxford: Blackwell Science.

Beukema, J.J., 1995. Long-term effects of mechanical harvesting of lugworms *Arenicola marina* on the zoobenthic community of a tidal flat in the Wadden Sea. *Netherlands Journal of Sea Research*, **33**, 219-227.

Bonsdorff, E., 1984. Establishment, growth and dynamics of a *Macoma balthica* (L.) population. *Limnologica* (Berlin), **15**, 403-405.

Boyd, S.E. & Rees, H.L., 2001. Towards an understanding of the impacts of marine aggregate extraction on the seabed as a basis for developing an EcoQO approach for management. In *A workshop to discuss the feasibility and practicality of developing Ecological Quality Objectives for aggregate extraction areas, Centre for Environment, Fisheries, and Aquaculture Science, Lowestoft, 11-12 October, 2001,* pp. 41-52.

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 & de S.J.Groot), pp.83-104. Oxford: Blackwell Science.

Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2002. The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. *Journal of Sea Research*, **47**, 161-184.

Brafield, A.E. & Newell, G.E., 1961. The behaviour of *Macoma balthica* (L.). *Journal of the Marine Biological Association of the United Kingdom*, **41**, 81-87.

Brafield, A.E., 1963. The effects of oxygen deficiency on the behaviour of *Macoma balthica*. *Animal Behaviour*, **11**, 245-346.

Broom, D.M., 1975. Aggregation behaviour of the brittle star *Ophiothrix fragilis*. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 191-197.

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.

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.

Caddy, J.F., 1967. Maturation of gametes and spawning in *Macoma balthica* (L.). *Canadian Journal of Zoology*, **45**, 955-965.

Castric, A., 1977. Recrutement et succession du benthos rocheux sublittoral. 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 *et al*.), pp 147-154.

Chia, F.S. & Spaulding, J.G., 1972. Development and juvenile growth of the sea anemone *Tealia crassicornis*. *Biological Bulletin, Marine Biological Laboratory, Woods Hole,* **142**, 206-218.

Churchill, J.H., 1989. The effect of commercial trawling on sediment re-suspension and transport over the Middle Atlantic Bight continental shelf. *Continental Shelf Science*, **9**(9), 841-865.

Clarke, J.R., 1996. *Coastal Zone Management Handbook*. New York: CRC Press.

Cocito, S., Ferdeghini, F., & Sgorbini, S., 1998. *Pentapora fascialis* (Pallas) [Cheilostomata: Ascophora] colonization of one sublittoral rocky site after sea-storm in the northwest Mediterranean. *Hydrobiologia*, **375/376**, 59-66.

Cole, S., Codling, I.D., Parr, W., and Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Report prepared by WRc for UK Marine SACs project,* 441pp.

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

Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. & Sanderson, W.G., 1997. Marine biotope classification for Britain and Ireland. Vol. 1&2. Joint Nature Conservation Committee, Peterborough, JNCC Report no. 230, Version 97.06.

Connor, D.W., Allen, J.H., Golding, N., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2003. [On-line]. *The National Marine Habitat Classification for Britain and Ireland Version 03.02.* Joint Nature Conservation Committee, Peterborough ISBN 1 86107 546 4. Available from <http://www.jncc.gov.uk>

Cook, W., 1990. Studies on the effects of hydraulic dredging on cockle and other macroinvertebrate populations 1989-1990. North Western and North Wales Sea Fisheries Committee.

Cooke, A., & McMath, M., 2000. SENSMAP: Development of a protocol for assessing and mapping 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.

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.

Cryer, M., Whittle, B.N. & Williams, K., 1987. The impact of bait collection by anglers on marine intertidal invertebrates. *Biological Conservation*, **42**, 83-93.

Daly, M.A. & Mathieson, A.C., 1977. The effects of sand movement on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire, USA. *Marine Biology*, **43**, 45-55.

Dame, R.F.D., 1996. *Ecology of Marine Bivalves: an Ecosystem Approach.* New York: CRC Press Inc. [Marine Science Series.]

Dando, P.R. & Spiro, B., 1993. Varying nutritional dependence of the thyasirid bivalves *Thyasira sarsi* and *Thyasira equalis* on chemoautotrophic symbiotic bacteria, demonstrated by isotope ratios of tissue carbon and shell carbonate. Marine Ecology Progress Series, 92, 151-158.

Dare, P.J., 1976. Settlement, growth and production of the mussel, *Mytilus edulis* L., in Morecambe Bay, England. *Fishery Investigations, Ministry of Agriculture, Fisheries and Food, Series II,* **28** (1), 25pp.

Dauvin, J.C., 1985. Dynamics and production of a population of *Venus ovata* (Pennant) (Mollusca-Bivalvia) of Morlaix Bay (western English Channel). *Journal of Experimental Marine Biology and Ecology*, **91**, 109-123.

Dauvin, J.C., 1998. The fine sand *Abra alba* community of the Bay of Morlaix twenty years after the *Amoco Cadiz* oil spill. *Marine Pollution Bulletin*, **36**, 669-676.

Dauvin, J-C. & Bellan-Santini, D., 1990. An overview of the amphipod genus *Haploops* (Ampeliscidae). *Journal of the Marine Biological Association of the United Kingdom*, **70**, 887-903.

Dauvin, J-C. & Gentil, F., 1989. Long-term changes in populations of subtidal bivalves (*Abra alba* and *Abra prismatica*) from the Bay of Morlaix (Western English Channel). *Marine Biology*, **103**, 63-73.

Davey, J.T. & George, C.L., 1986. Specific interactions in soft sediments: factors in the distribution of *Nereis (Hediste) diversicolor* in the Tamar Estuary. *Ophelia*, **26**, 151-164.

Davidson, N.C., Laffoley, D., Doody, J.P., Way, L.S., Key, R., Drake, C.M., Pienkowski, M.W., Mitchell, M.R. & Duff, K.L., 1991. *Nature Conservation and Estuaries in Great Britain.* Peterborough: Nature Conservancy Council.

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.

Defra (Department of the Environment, Food and Rural Affairs), 2002. Safeguarding Our Seas: a strategy for the conservation and sustainable development of our marine environment. London: Crown copyright.

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.

Dittmann, S., Günther, C-P. & Schleier, U., 1999. Recolonization of tidal flats after disturbance. In *The Wadden Sea ecosystem: stability, properties and mechanisms* (ed. S. Dittmann), pp.175-192. Berlin: Springer-Verlag.

Dixon, P.S. & Irvine, L.M., 1977. *Seaweeds of the British Isles. Volume 1 Rhodophyta. Part 1 Introduction, Nemaliales, Gigartinales.* British Museum (Natural History) London.

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.

DWT (Devon Wildlife Trust), 1993. Lyme Bay. A report on the nature conservation importance of the inshore reefs of Lyme Bay and the effects of mobile fishing gear. *Devon 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., 1972a. Patterns of reproduction in marine Ectoprocta off the Isle of Man. *Journal of Natural History*, **6**, 31-38.

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.

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*.

Ellis, D. & Heim, C., 1985. Submersible surveys of benthos near a turbidity cloud. *Marine Pollution Bulletin*, **16**(5), 197-203.

Emerson, C.W. & Grant, J., 1991. The control of soft-shell clam (*Mya arenaria*) recruitment on intertidal sandflats by bedload sediment transport. *Limnology and Oceanography*, **36**, 1288-1300.

Emson, R.H., & Wilkie, I.C., 1980. Fission and autotomy in echinoderms. *Oceanography and Marine Biology: an Annual Review*, **18**, 155-250.

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.

Eno, N.C., MacDonald, D. & Amos, S.C., 1996. A study on the effects of fish (Crustacea/Molluscs) traps on benthic habitats and species. *Final report to the European Commission. Study Contract*, no. 94/076.

EA (Environment Agency), 1998. *Best Practicable Environmental Option Assessments for Integrated Pollution Control.* London: The Stationary Office.

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.

Fell, P.E., 1989. Porifera. In *Reproductive biology of invertebrates* vol. IV, part A. *Fertilization, development and parental care* (ed. K.G & R.G. Adiyodi), pp. 1-41. Chicester: John Wiley & Sons.

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.

Fowler, S.L., 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. *Natura 2000 report prepared by the Nature Conservation Bureau Ltd. for the UK Marine SACs Project,* 132 pp.

Franklin, A. & Pickett, G.D., 1978. Studies of the indirect effects of fishing on stocks of cockles, Cardium edule, in the Thames estuary and Wash. Fisheries Research, Technical Report, no. 42, MAFF, Lowestoft, pp. 9.

Frid, C.L.J., Clark, R.A. & Hall, J.A., 1999. Long-term changes in the benthos on a heavily fished ground off the NE coast of England. *Marine Ecology Progress Series,* **188**, 13-20.

Gage, J.D., 1990. Skeletal growth bands in brittle stars: Microstructure and significance as age markers. *Journal of the Marine Biological Association of the United Kingdom*, **70**, 209-224.

Gaspar, M.B., Castro, M. & Monteiro, C.C., 1998. Influence of tow duration and tooth length on the number of damaged razor clams *Ensis siliqua*. *Marine Ecology Progress Series*, **169**, 303-305.

Gilbert, M.A., 1978. Aspects of the reproductive cycle in *Macoma balthica* (Bivalvia). *The Nautilus*, **29**, 21-24.

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

Golding, N., Vincent, M. & Connor, D.W., 2003. *A Marine Landscape classification for the Irish Sea Pilot: a consultation paper.* Peterborough: Joint Nature Conservation Committee.

Graham, M., 1955. Effects of trawling on animals on the sea bed. *Deep-Sea Research,* **3** (Supplement), 1-6.

Gray, J.S., & Jensen, K., 1993. Feedback monitoring: a new way of protecting the environment. *Trends in Ecology and Evolution,* **8**, 267-268.

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:2, 5 pp. (mimeo).

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).

Guenther, C.P., 1991. Settlement of *Macoma balthica* on an intertidal sandflat in the Wadden Sea. *Marine Ecology Progress Series*, **76**, 73-79.

Guillou, J. & Sauriau, F.G., 1985. Some observations on the biology and ecology of a *Venus striatula* population in the Bay of Douarnenez, Brittany. *Journal of the Marine Biological Association of the United Kingdom*, **65**, 889-900.

Günther, C-P., 1992. Dispersal of intertidal invertebrates: a strategy to react to disturbances of different scales? *Netherlands Journal of Sea Research,* **30**, 45-56.

Hall, S.J. & Harding, M.J.C., 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. *Journal of Applied Ecology*, **34**, 497-517.

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

Harms, J. & Anger, K., 1983. Seasonal, annual, and spatial variation in the development of hard bottom communities. *Helgoländer Meeresuntersuchungen*, **36**, 137-150.

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. & Vincent, B., 1989. Spatial and temporal variations of the reproduction cycle and energy allocation of the bivalve *Macoma balthica* (L.) on a tidal flat. *Journal of Experimental Marine Biology and Ecology*, **129**, 199-217.

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.

Heuers, J. & Jaklin, S., 1999. Initial settlement of *Lanice conchilega*. *Senckenbergiana Maritima*, **29** (supplement), 67-69.

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., 1981. Marine life on the wreck of the M.V. "*Robert*". *Report of the Lundy Field Society*, **32**, 40-44.

Hiscock, K., 1996. Interpretation of data. In: *Marine Nature Conservation Review: Rationale and methods* (ed. K. Hiscock), pp. 73-84. Peterborough: Joint Nature Conservation Committee. [Coasts and seas of the United Kingdom. MNCR Series.]

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

Hiscock, K., 2001. *Eunicella verrucosa*. Pink sea fan. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 19/06/03]. Available from: <http://www.marlin.ac.uk/species/Eunver.htm>

Hiscock, K. ed., 1996. *Marine Nature Conservation Review: rationale and methods.* Peterborough: Joint Nature Conservation Committee. [Coasts and seas of the United Kingdom. MNCR Series].

Hiscock, K, Jackson, A. & Lear, D., 1999. Assessing seabed species and ecosystem sensitivities: existing approaches and development, October 1999 edition. *Report to the Department of Environment, Transport and the Regions form the Marine Life Information Network (MarLIN), Marine Biological Association of the United Kingdom, Plymouth.* [*MarLIN* Report No. 1.]

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., 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)*, 174 pp.

Houghton, R.G., Williams, T. & Blacker, R.W., 1971. Some effects of double beam trawling. *International Council for the Exploration of the Sea* CM 1971/B:5, 12 pp. (mimeo).

Howson, C.M., & Davies, L.M., 1998. Marine Nature Conservation Review, Surveys of Scottish sealochs. A towed video suurvey of Loch Fyne. Volume 1- Report. *Report to the Nature Conservancy Council from the University Marine Biological Station, Millport.*

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.*

Hughes, R.G., 1977. Aspects of the biology and life-history of *Nemertesia antennina* (L.) (Hydrozoa: Plumulariidae). *Journal of the Marine Biological Association of the United Kingdom*, **57**, 641-657.

Jackson, M.J. & James, R., 1979. The influence of bait digging on cockle *Cerastoderma edule*, populations in north Norfolk. *Journal of Applied Ecology*, **16**, 671-679.

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

Johannessen, O.H., 1973. Population structure and individual growth of *Venerupis pullastra* (Montagu) (Lamellibranchia). *Sarsia*, **52**, 97-116.

Johnson, L.J., & Frid, C.L.J., 1995. The recovery of benthic communities along the County Durham coast after cessation of colliery spoil dumping. *Marine Pollution Bulletin*, **30**, 215-220.

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.).*

Jones, N.S., 1950. Marine bottom communities. *Biological Reviews*, **25**, 283-313.

Jones, N.S., 1951. The bottom fauna of the south of the Isle of Man. *Journal of Animal Ecology*, **20**, 132-144.

Kain, J.M., 1975. Algal recolonization of some cleared subtidal areas. *Journal of Ecology*, **63**, 739-765.

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., 1994. A preliminary assessment of the immediate effects of beam trawling on a benthic community in the Irish Sea. In *Environmental impact of bottom gears on benthic fauna in relation to natural resources management and protection of the North Sea.* (ed. S.J. de Groot & H.J. Lindeboom). NIOZ-Rapport, **11**, 87-94.

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

Kaiser, M.J. & Spencer, B.E., 1996. The effects of beam-trawl disturbance on infaunal communities in different habitats. *Journal of Animal Ecology*, **65**, 348-358.

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.

Kinne, O., ed. 1970. *Marine Ecology*. *A Comprehensive, Integrated Treatise on Life in Oceans and Coastal Waters,* Vol. 1. London: Wiley & Sons.

Kinnear, J.A.M., Barkel, P.J., Mojseiwicz, W.R., Chapman, C.J., Holbrow, A.J., Barnes, C. & Greathead, C.F.F., 1996. Effects of *Nephrops* creels on the environment. *Fisheries Research Services Report No. 2/96.*

Kukert, H. & Smith, C.R., 1992. Disturbance, colonization, and succession in a deep-sea sediment community: artificial-mound experiments. *Deep-Sea Research*, **39,** 1349-1371.

Laffoley, 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.

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.

Little, A.E., 1987. Salcombe and Kingsbridge Estuary. Assessment of extent and effects of spoil dumping. Vol. 1. Report ii, 41 pp.

Lutz, R.A. & Kennish, M.J., 1992. Ecology and morphology of larval and early larval postlarval mussels. In *The mussel Mytilus: ecology, physiology, genetics and culture*, (ed. E.M. Gosling), pp. 53-85. Amsterdam: Elsevier Science Publ. [Developments in Aquaculture and Fisheries Science, no. 25]

Mackie, A.S.Y., 1990. Offshore benthic communities of the Irish Sea. In *The Irish Sea: an environmental review. Part 1: nature conservation*, ed. Irish Sea Study Group, pp. 169-218. Liverpool, Liverpool University Press for Irish Sea Study Group.

Mackie, A.S.Y., Oliver, P.G. & Rees, E.I.S., 1995. Benthic biodiversity in the southern Irish Sea. *Studies in Marine Biodiversity and Systematics from the National Museum of Wales. BIOMOR Reports*, no. 1.

MAFF, 1998. Radioactivity in the Environment, 1997. *Ministry of Agriculture Fisheries and Food, Scottish Environmental Protection Agency,* 162pp.

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.

Manuel, R.L., 1988. *British Anthozoa*. Synopses of the British Fauna (New Series) (ed. D.M. Kermack & R.S.K. Barnes), The Linnean Society of London. Avon: The Bath Press. [Synopses of the British Fauna No. 18.]

Martel, A. & Chia, F.S., 1991. Drifting and dispersal of small bivalves and gastropods with direct development. *Journal of Experimental Marine Biology and Ecology*, **150**, 131-147.

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.

McMath, A., Cooke, A., Jones, M., Emblow, C.S., Wyn, G., Roberts, S., Costello, M.J., Cook, B. & Sides, E.M., 2000. Sensitivity mapping of inshore marine biotopes in the southern Irish Sea (SensMap): Final report. *Report by the Countryside Council for Wales (CCW), Ecological Consultancy Services Ltd (Ecoserve), Dúchas, the Heritage Service*, 116 pp. [Maritime Ireland /Wales INTERREG Reference no. 21014001].

Mills, E.L., 1967. The biology of an ampeliscid amphipod crustacean sibling species pair. *Journal of the Fisheries Research Board of Canada*, **24**, 305-355.

Moore, J., 1991. Studies on the Impact of Hydraulic Cockle Dredging on Intertidal Sediment Flat Communities. *A report to the Nature Conservancy Council from the Field Studies Council Research Centre, Pembroke, Wales*, FSC/RC/4/91.

Morris, R.J., 1995. Underwater noise. The forgotten marine pollutant. *North Sea Monitor,* September, p4-8.

Muus, K., 1981. Density and growth of juvenile *Amphiura filiformis* (Ophiuroidea) in the Oresund. *Ophelia*, **20**, 153-168.

Newell, R.C., Seiderer, L.J., & Hitchcock, D.R., 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. *Oceanography and Marine Biology: an Annual Review,* **36**, 127-78.

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.

Norkko, A. & Bonsdorff, E., 1996. Population responses of coastal zoobenthos to stress induced by drifting algal mats. *Marine Ecology Progress Series*, 140, 141-151.

Oakwood Environmental, 2002. Development of a methodology for the assessment of cumulative effects of marine activities using Liverpool Bay as a case study. *Report from Oakwood Environmental Ltd to the Countryside Council for Wales, CCW Contract Science Report,* No. 522.

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

Olive, P.J.W., Porter, J.S., Sandeman, N.J., Wright, N.H. & Bentley, M.G. 1997. Variable spawning success of *Nephtys hombergi* (Annelida: Polychaeta) in response to environmental variation. A life history homeostasis? *Journal of Experimental Marine Biology and Ecology*, **215**, 247-268.

Parr, W., Clarke, S.J., van Dijk, P. & Morgan, N., 1998. Turbidity in English and Welsh waters. *Report prepared for English Nature, Report no*. Co 4301/1., 116 pp. Marlow: Water Research Centre.

PDE (Posford Duvivier Environment) & Hill, M.I., 2001. Guidelines on the impact of aggregate extraction on European Marine Sites. *Countryside Council for Wales* (UK Marine SACs Project).

Perez Camacho, A., 1980. Biology of *Venerupis pullastra* (Montagu, 1803) and *Venerupis decussata* (Linne, 1767) (Mollusca, Bivalvia). Determining factors of production. *Boletin del Instituto Espanol Oceanographica*, **5**, 43-76.

Petersen, C.G.J., 1924. A brief survey of the animal communities in Danish waters, based upon quantitative samples taken with the bottom sampler. *American Journal of Sciences*, **7**, 343-354.

Pickett, G.D., 1973. The impact of mechanised harvesting on the Thames estuary cockle fishery. *MAFF Laboratory Leaflet,* no. 29, Fisheries Laboratory, Lowestoft, pp. 9.

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.

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**(2), 167-176.

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

Rees, E.I.S., Nicholaidou, A. & Laskaridou, P., 1977. The effects of storms on the dynamics of shallow water benthic associations. In *Proceedings of the 11th European Symposium on Marine Biology, Galway, Ireland, October 5-11, 1976. Biology of Benthic Organisms, (ed. B.F. Keegan, P.O Ceidigh & P.J.S. Boaden), pp. 465-474.*

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*.

Richardson, C.A., Ibarrola, I. & Ingham, R.J., 1993. Emergence pattern and spatial distribution of the common cockle *Cerastoderma edule*. *Marine Ecology Progress Series*, **99**, 71-81.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I., and Thomson, D.H, 1995. *Marine Mammals and Noise.* London: Academic Press.

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.

Rumohr, H. & Krost, P., 1991. Experimental evidence of damage to benthos by bottom trawling with special reference to *Arctica islandica*. *Meeresforschung*, **33**, 340-345.

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

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

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.

Seed, R. & Suchanek, T.H., 1992. Population and community ecology of *Mytilus*. In: *The mussel* Mytilus*: ecology, physiology, genetics and culture*, (ed. E.M. Gosling), pp. 87-169. Amsterdam: Elsevier Science Publ. [Developments in Aquaculture and Fisheries Science, no. 25.]

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

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.

Sherman, K.M. & Coull, B.C., 1980. The response of meiofauna to sediment disturbance. *Journal of Experimental Marine Biology and Ecology*, **46**, 59-71.

Sigurdsson, J.B., Titman, C.W. & Davies, P.A., 1976. The dispersal of young post-larval bivalve molluscs by byssus threads. *Nature*, **262** (5567), 386-387.

Sköld, M., 1998. Escape responses in four epibenthic brittle stars (Ophiuroidea: Echinodermata). *Ophelia*, **49**, 163-179.

Smith, J.E., 1955. Salinity variation in interstitial water of sand at Kames Bay, Millport, with reference to the distribution of *Nereis diversicolor Journal of the Marine Biological Association of the United Kingdom*, **34**, 33-46.

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).

Solé-Cava, A.M., Thorpe, J.P., & Todd, C.D., 1994. High genetic similarity between geographically distant populations in a sea anemone with low dispersal capabilities. *Journal of the Marine Biological Association of the United Kingdom*, **74**, 895-902.

Sörlin, T., 1988. Floating behaviour in the tellinid bivalve *Macoma balthica* (L.). *Oecologia*, **77**, 273-277.

Sousa, W.P., Schroeter, S.C. & Daines, S.D., 1981. Latitudinal variation in intertidal algal community structure: the influence of grazing and vegetative propagation. *Oecologia*, **48**, 297-307.

Southward, A.J. & Southward, E.C., 1978. Recolonisation of rocky shores in Cornwall after use of toxic dispersants to clean up the *Torrey Canyon* spill. *Journal of the Fisheries Research Board of Canada*, **35**, 682-706.

Sparks-McConkey, P.J. & Watling, L., 2001. Effects on the ecological integrity of a soft-bottom habitat from a trawling disturbance. *Hydrobiologia*, **456**, 73-85.

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

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.

Strasser, M. & Pielouth, U., 2001. Recolonization pattern of the polychaete *Lanice conchilega* on an intertidal sandflat following the severe winter of 1995/96. *Helgoland Marine Research*, **55**, 176-181.

Strasser, M., Walensky, M. & Reise, K., 1999. Juvenile-adult distribution of the bivalve *Mya arenaria* on intertidal flats in the Wadden Sea: why are there so few year classes. *Helgoland Marine Research*, **53**, 45-55.

Suchanek, T.H., 1985. Mussels and their role in structuring rocky shore communities. In *The Ecology of Rocky Coasts*, (ed. P.G. Moore & R. Seed), pp. 70-96.

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

Svendsen, P., 1972. Some observations on commercial harvesting and regrowth of *Laminaria hyperborea*. *Fisken og Havet*, **2**, 33-45.

Tuck, I.D., Hall, S.J., Robertson, M.R., Armstrong, E. & Basford, D.J., 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. *Marine Ecology Progress Series*, **162**, 227-242.

Tyler-Walters, H. & Jackson, A. 1999. Assessing seabed species and ecosystems sensitivities. Rationale and user guide, January 2000 edition. *Report to English Nature, Scottish Natural Heritage and the Department of the Environment Transport and the Regions from the Marine Life Information Network (MarLIN). Plymouth, Marine Biological Association of the UK. (MarLIN* Report No. 4.).

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

UNEP, 1984. GESAMP (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution): Thermal discharges in the marine environment. *United Nations Environment Programme, UNEP Regional Seas Reports and Studies*, No. 45.

Vadas, R.L., Johnson, S. & Norton, T.A., 1992. Recruitment and mortality of early post-settlement stages of benthic algae. *British Phycological Journal*, **27**, 331-351.

Vader, W.J.M., 1964. A preliminary investigation in to the reactions of the infauna of the tidal flats to tidal fluctuations in water level. *Netherlands Journal of Sea Research*, **2**, 189-222.

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.

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.

Wilson, D.P., 1929. The larvae of the British sabellarians. *Journal of the Marine Biological Association of the United Kingdom*, **16**, 221-269.

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.

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

Appendix 1. Sensitivity assessment rationale - a summary

Introduction

The sensitivity assessment rationale was developed by the *MarLIN* team in consultation with the Biology & Sensitivity Key Information Sub-programme Technical Management Group and ratified by the *MarLIN* programme Steering Group, both of which include representatives of the major users of marine information, statutory agencies, regulators, and marine research institutes. The *MarLIN* sensitivity assessment rationale, definitions of terms and scales used prior to March 2003 are given by Tyler-Walters *et al.* (2001) and their development in Tyler-Walters & Jackson (1999) and Hiscock *et al.* (1999). The definitions of sensitivity used after March 2003 are based on definitions suggested by the RMNC (Laffoley *et al.*, 2000) and developed by *MarLIN* in consultation with our Biology & Sensitivity Key Information Sub-programme Technical Management Group and Sensitivity Mapping Advisory Group.

The *MarLIN* approach to assessing sensitivity is built on a review of the strengths and weaknesses of existing and prior approaches to sensitivity assessment, especially earlier work by Holt *et al.* (1995, 1997), which thought through many of the concepts of vulnerability, sensitivity, and recoverability. Studies commissioned or undertaken by the nature conservation agencies in the UK, the ICES Benthos Working Group workshops and meetings of the OSPAR IMPACT group, the recent Review of Marine Nature Conservation (RMNC) (Laffoley *et al.*, 2000), together with subsequent development by *MarLIN*, have all contributed to the standard terms shown in Box 1.

Box 1. Core definitions

'Biotope' refers to the combination of physical environment (habitat) and its distinctive assemblage of conspicuous species. For practical reasons of interpretation of terms used in directives, statutes and conventions, in some documents, 'biotope' is sometimes synonymized with 'habitat'.

'Habitat' the place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum), 'features' (such as crevices, overhangs, or rockpools) and 'modifiers' (for example sand-scour, wave-surge, or substratum mobility).

'Community' refers to a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and identifiable by means of ecological survey from other groups. The community is usually considered the biotic element of a biotope.

'Intolerance' is the susceptibility of a habitat, community, or species (i.e. the components of a biotope) to damage, or death, from an external factor. Intolerance must be assessed relative to specified change in a specific environmental factor.

'Recoverability' is the ability of a habitat, community, or species (i.e. the components of a biotope) to return to a state close to that which existed before the activity or event caused change.

'Sensitivity' is dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery. For example, a "highly sensitive" species or habitat is one that is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover only over a very long period of time, (10 to 25 years: 'low' recoverability). Intolerance and hence sensitivity must be assessed relative to a specified change in a specific environmental factor.

Revised sensitivity scale

The *MarLIN* programme used a *sensu stricto* definition of 'sensitivity' until January 2003 together with a separate assessment of recoverability. The SensMap approach used a more broad (*sensu lato*) definition. The definition of 'sensitivity' used in the Marine Stewardship Report (Defra, 2002) was developed as part of the Review of Marine Nature Conservation and differed from that developed for use in the *MarLIN* programme. The Review of Marine Nature Conservation (see Laffoley *et al.*, 2000) defined 'sensitivity' as follows:

"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 over a very long period or not at all. A sensitive habitat or species is one that is easily affected by a human activity, and is expected to only recover over a long period."

The JNCC Marine Habitats Team also suggested a single ‘sensitivity’ rank (*sensu lato*) as part of JNCC’s advice to OSPAR for the identification of priority species.

While the *MarLIN* definition of sensitivity developed in 1999 was strictly correct, a broader definition conveyed a general level of understanding to a wider audience. In addition, for the practical application of sensitivity information in a map-based system, the *MarLIN* sensitivity and recoverability ranks should be combined, in order to give a single overall assessment of the likely damage to the habitat or species.

Therefore, after January 2003, the *MarLIN* programme developed a broad definition of ‘sensitivity’, in consultation with our Biology & Sensitivity Technical Management Group and a Sensitivity Mapping Advisory Group created to advise of the subject. Both groups are composed of representatives of the statutory conservation agencies and relevant industries as well as marine scientists.

The broad definition required *MarLIN* to combine ‘sensitivity’ (=intolerance) and ‘recoverability’ into a single scale. This would have considerable benefits for those involved in environmental protection that do not want too many steps in their interpretation of likely damage to species or biotopes. The original intolerance, recoverability, and confidence ranks, together with the supporting explanation, remain available.

MarLIN adopted the term ‘intolerance’ for the present assessments of sensitivity *sensu stricto*, and the rationale outlined below to combine ‘intolerance’ and ‘recoverability’ into an overall ‘sensitivity’ *sensu lato* scale. Henceforth, ‘intolerance’ will be used for all prior instances of the term ‘sensitivity’ including prior ‘sensitivity assessments’. The term ‘sensitivity’ now refers to the combination of ‘intolerance’ and ‘recoverability’. The rationale used to derive sensitivity from ‘intolerance’ and ‘recoverability’ assessments is shown in Table A.1.

The rationale shown in Table A.1 takes into account the fact that, while many sensitive habitats and species will be adversely affected, even destroyed, by an activity or event, such effects ‘matter’ to the continued survival of that feature if it does not have the potential to recover. ‘Intolerance’, and hence ‘sensitivity’, are assessed relative to a change in a specified external factor, the benchmark level of effect.

The rationale uses the question ‘does it matter if……?’, together with the definitions of sensitive habitats and species proposed in the RMNC (Laffoley *et al.*, 2000) as touch-stones throughout. In addition, due to the importance of recoverability in assessing the overall survival of a habitat or species population, the sensitivity scale proposed below is intuitively weighted towards recoverability. For instance, if a habitat or species is likely to be adversely affected (damaged or destroyed) by an external factor but unlikely to recover for a very long time (>10 years) then it would be considered to be highly sensitive. The sensitivity scales and definitions must be meaningful in marine environmental management, protection, and conservation.

NB: Where there is insufficient information to assess the recoverability of a habitat or species (‘insufficient information’) the ‘precautionary principle’ will be used and the ‘recovery’ *will be assumed* to take a very long time i.e. ‘low’ recoverability in the derivation of a sensitivity rank.

The above definitions and scenarios give rise to the decision matrix shown in Table A.2. The decision matrix is used to automate the combination of ‘intolerance’ and ‘recoverability’ within the *MarLIN* biology and sensitivity database.

The decision matrix shown in Table A.2 is not symmetrical because the scale represents scenarios in which the potential damage to the species or habitat ‘matters’. The scale is intuitively weighted towards recoverability, although in a few cases intolerances has been given a greater weight rather than under-estimate the potential sensitivity of marine habitats and species.

The combined ‘sensitivity’ scale introduced another step into the *MarLIN* approach to sensitivity assessment previously outlined in Tyler-Walters *et al.* (2001) and on the *MarLIN* Web site. The revised approach to sensitivity assessment developed since January 2003 is not presently available on the *MarLIN* Web site. The revised sensitivity assessment rationale for species and biotopes, as amended in March 2003, is summarized in below together with the relevant definitions of intolerance, recoverability, and sensitivity.

Table A.1. Defining 'sensitivity' *sensu lato* for habitats and species.

Sensitivity scale	Sensitivity definition or scenario
Very High	'Very high' sensitivity is indicated by the following scenario: • The habitat or species is very adversely affected by an external factor arising from human activities or natural events (either killed/destroyed, 'high' intolerance) and is expected to recover only over a prolonged period of time, i.e. >25 years or not at all (recoverability is 'very low' or 'none'). • The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) but is not expected to recover at all (recoverability is 'none').
High	'High' sensitivity is indicated by the following scenarios: • The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover over a very long period of time, i.e. >10 or up to 25 years ('low' recoverability). • The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) and is expected to recover over a very long period of time, i.e. >10 years (recoverability is 'low', or 'very low'). • The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, 'low' intolerance) but is not expected to recover at all (recoverability is 'none'), so that the habitat or species may be vulnerable to subsequent damage.
Moderate	'Moderate' sensitivity is indicated by the following scenarios: • The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) but is expected to take more than 1 year or up to 10 years to recover ('moderate' or 'high' recoverability). • The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) and is expected to recover over a long period of time, i.e. >5 or up to 10 years ('moderate' recoverability). • The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, 'low' intolerance) but is expected to recover over a very long period of time, i.e. >10 years (recoverability is 'low', 'very low'), during which time the habitat or species may be vulnerable to subsequent damage.
Low	'Low' sensitivity is indicated by the following scenarios: • The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) but is expected to recover rapidly, i.e. within 1 year ('very high' recoverability). • The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) but is expected to recover in a short period of time, i.e. within 1 year or up to 5 years ('very high' or 'high' recoverability). • The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, 'low' intolerance) but is expected to take more than 1 year or up to 10 years to recover ('moderate' or 'high' recoverability).
Very low	'Very low' is indicated by the following scenarios: • The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) but is expected to recover rapidly i.e. within a week ('immediate' recoverability). • The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) but is expected to recover rapidly, i.e. within a week ('immediate' recoverability). • The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, 'low' intolerance) but is expected to recover within a year ('very high' recoverability).
Not sensitive	'Not sensitive' is indicated by the following scenarios: • The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, 'low' intolerance) but is expected to recover rapidly, i.e. within a week ('immediate' recoverability). • The habitat or species is tolerant of changes in the external factor.
Not sensitive*	The habitat or species may benefit from the change in an external factor (intolerance has been assessed as 'tolerant*').
Not relevant	The habitat or species is protected from changes in an external factor (i.e. through a burrowing habit or depth), or is able to avoid the external factor.

** 'Reduced viability' includes physiological stress, reduced fecundity, reduced growth, and partial death of a colonial animal or plant.

Table A.2. Combining 'intolerance' and 'recoverability' assessments to determine 'sensitivity'

		Recoverability						
		None	***Very low (>25 yr.)***	***Low (>10–25 yr.)***	***Moderate (>5 -10 yr.)***	***High (1 -5 yr.)***	***Very high (<1 yr.)***	***Immediate (< 1 week)***
Intolerance	***High***	Very high	Very high	High	Moderate	Moderate	Low	Very low
	Intermediate	Very high	High	High	Moderate	Low	Low	Very Low
	Low	High	*Moderate*	*Moderate*	Low	Low	Very Low	Not sensitive
	Tolerant	Not sensitive	Not sensitive	Not sensitive	Not sensitive	Not sensitive	Not sensitive	Not sensitive
	Tolerant*	Not sensitive*	Not sensitive*	Not sensitive*	Not sensitive*	Not sensitive*	Not sensitive*	Not sensitive*
	Not relevant	*Not relevant*	*Not relevant*	*Not relevant*	*Not relevant*	*Not relevant*	*Not relevant*	*Not relevant*

Assessing the sensitivity of species

The assessment process involves judging the intolerance of a species to change in an external factor arising from human activities or natural events. The rationale then assesses the likely recoverability of the species following cessation on the human activity or natural event. Intolerance and recoverability are then combined to provide a meaningful assessment of their overall sensitivity to environmental change.

1. Collate the key information for the species. The best available scientific information required to describe the biology and likely sensitivity of the species is collated using the resources of the National Marine Biological Library (NMBL), the World Wide Web, and the expertise of marine biologists based at the Marine Biological Association of the UK (MBA), Plymouth.

2 Indicate quality of available data. The *MarLIN* programme operates an internal quality assurance procedure, to ensure that only the most accurate available information is provided on-line. The quality of the available evidence and our confidence in our assessments (based on availability of information) is clearly stated (see Table A.3).

Table A.3. Scale used to rank the level of information available to support the assessment of intolerance and recoverability

EVIDENCE / CONFIDENCE The scale indicates an appraisal of the specificity of the information (data) available to support the assessment of intolerance and recoverability.	
Rank	**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.
Note: 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'.	

3. Assess the intolerance of the species to change in environmental factors. The likely intolerance (see Table A.4) of the species is assessed with respect to a specified magnitude and duration of change (the standard benchmark) for 24 separate environmental factors (see Table A.5).

Table A.4. Species intolerance (previously 'sensitivity' and revised April 2003).

SPECIES INTOLERANCE The susceptibility of a species population to damage, or death, from an external factor. Intolerance is assessed relative to change in a specific factor.	
Rank	**Definition**
High	The species population is likely to be killed/destroyed by the factor under consideration.
Intermediate	Some individuals of the species may be killed/destroyed by the factor under consideration and the viability of a species population may be reduced.
Low	The species population will not be killed/destroyed by the factor under consideration. However, the viability of a species population may be reduced.
Tolerant	The factor does not have a detectable effect on survival or viability of a species or structure and functioning of a biotope.
Tolerant*	Population of a species may increase in abundance or biomass as a result of the factor.
Not relevant	This rating applies to species where the factor is not relevant because they are protected from the factor (for instance, through a burrowing habit), or can move away from the factor.

Table A.5. Environmental factors for which intolerance and hence sensitivity is assessed.

Physical factors	
	Substratum loss
	Smothering
	Suspended sediment
	Desiccation
	Changes in emergence regime
	Changes in water flow rate
	Changes in temperature
	Changes in turbidity
	Changes in wave exposure
	Noise
	Visual presence
	Abrasion and physical disturbance
	Displacement
Chemical factors	
	Synthetic compounds
	Heavy metals
	Hydrocarbons
	Radionuclides
	Changes in nutrient levels
	Changes in salinity
	Changes in oxygenation
Biological factors	
	Introduction of microbial pathogens
	Introduction of non-native species and
	Selective extraction of this species
	Selective extraction of other species

Precedence is given to direct evidence of effect or impact. For example, information from targeted studies / experiments that looked at the effect of the specific factor on the species, or targeted work / experiments on the effects of similar factors on similar species or studies of the likely effects of a factor. The assessment of intolerance (see scale) is then made by reference to the reported change in environmental factors and their impact, relative to the magnitude and duration of the standard benchmarks and other relevant key information.

In the absence of direct evidence, the *MarLIN* rationale includes simple decision trees to aid intolerance and recoverability assessment based on the available key information for the species. The decision trees provide a systematic and transparent approach to assessment. The decision trees are described in full by Tyler-Walters *et al.* (2001).

4. Assess the recoverability of the species. The likely recoverability of a species from disturbance or damage is dependent on its ability to regenerate, regrow, recruit or recolonize, depending on the extent of damage incurred and hence its intolerance. The recoverability of a species is assessed against the recoverability scale by reference to direct evidence of recruitment, recolonization or recovery (e.g. after environmental impact or experimental manipulation in the field) and/or key information on the reproductive biology, habitat preferences and distribution of the species (see Table A.6).

Table A.6. Recoverability.

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. Ranks also only refer to the recoverability potential of a species, based on their reproductive biology etc.	
Rank	**Definition (From Hiscock *et al*. 1999)**
None	Recovery is not possible
Very low / none	Partial recovery is only likely to occur after about 10 years and full recovery may take over 25 years or never occur.
Low	Only partial recovery is likely within 10 years and full recovery is likely to take up to 25 years.
Moderate	Only partial recovery is likely within 5 years and full recovery is likely to take up to 10 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 6 months.
Immediate	Recovery immediate or within a few days.
Not relevant	For when intolerance is not relevant or cannot be assessed. Recoverability cannot have a value if there is no intolerance and is thus 'Not relevant'.

5. Assess the sensitivity of the species. The overall sensitivity rank is derived from the combination of intolerance and recoverability using the rationale shown in Tables A.1 and A.2 above.

For example, if a habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover over a very long period of time, i.e. >10 or up to 25 years ('low' recoverability) then it would be considered to be highly sensitive. Similarly, if a habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, 'intermediate' intolerance) but is expected to recover in a short period of time, i.e. within 1 year or up to 5 years ('very high' or 'high' recoverability) then it would be considered to be of low sensitivity. The scenarios used to derive the sensitivity scale are listed in Table 1.

Please note that the intolerance, recoverability and sensitivity ranks should be read in conjunction with the on-line rationale for each assessment, which outline the evidence and key information used and any judgements made in the assessment. The information used and evidence collated is fully referenced throughout.

6. Signing-off. *MarLIN* reviews are checked by the Programme Director for accuracy and clarity and the required changes made before the review goes 'on-line' on the Web site.

7. Referee. As a final stage in the *MarLIN* quality assurance, Key Information reviews are subject to peer review by an external marine biologist where possible.

Assessing the sensitivity of habitats and their associated species (biotopes)

The *MarLIN* approach to the assessment of the sensitivity of biotopes assumes that the sensitivity of a community within a biotope is dependent upon and, therefore, is indicated by the sensitivity of the species within that community. The species that indicate the sensitivity of a biotope are identified as those species that significantly influence the ecology of that component community (see Table A.7). The loss of one or more of these species would result in changes in the population(s) of associated species and their interactions. The criteria used to identify species that indicate biotope sensitivity subdivide species into 'key' and 'important' based on the likely magnitude of the resultant change.

The protocol used to prepare a review of the biology and sensitivity key information for a biotope is given below.

1. Collate key information on the biotope. The best available scientific information required to describe the ecology and likely sensitivity of the biotope is collated using the resources of the National Marine Biological Library (NMBL), the World Wide Web, and the expertise of marine biologists based at the MBA, Plymouth.

2. Select species indicative of biotope sensitivity. Species are selected based on the review of the ecology of habitat and community, where direct evidence of community interaction or dependency is available, or where the species are 'important characterizing' (see Table A.7).

Table A.7. Species that indicate biotope sensitivity.

SELECTION CRITERIA The following criteria are used to decide which species best represent the sensitivity of a biotope or community as a whole.	
Rank	**Criteria**
Key structural species	The species provides a distinct habitat that supports an associated community. Loss/degradation of the population of this species would result in loss/degradation of the biotope.
Key functional species	The species maintains community structure and function through interactions with other members of that community (for example, predation, grazing, competition). Loss/degradation of the population of this species would result in rapid, cascading changes in the biotope.
Important characterizing species	The species is/are characteristic of the biotope and are important for the classification of the biotope. Loss/degradation of the population of these species would result in loss of that biotope.
Important structural species	The species positively interact with the key or characterizing species and is important for their viability. Loss/degradation of populations of these species would result likely reduce the viability of the key or characterizing species. For example, these species may prey on parasites, epiphytes, or disease organisms of the key or characterizing species.
Important functional	The species is/are the dominant source of organic matter or primary production within the ecosystem. Loss/ degradation of these species could result in changes in the community function and structure.
Important other species	Additional species that do not fall under the above criteria but where present knowledge of the ecology of the community suggests they may affect the sensitivity of the community.
Note: All key species will be used in the sensitivity assessment. However, where several important species satisfy the above criteria examples from each rank should be used. Preference should be given to examples where direct evidence of community interaction is available or they are characteristic (highly faithful) of the biotope.	

3. Review key information for the selected species. Key information on the biology and sensitivity of the indicative species is researched.

4. Indicate quality of available data. The *MarLIN* programme operates an internal quality assurance procedure, to ensure that only the most accurate available information is provided on-line. The quality of the available evidence and our confidence in our assessments (based on availability of information) is clearly stated.

5. Assess the intolerance, recoverability, and sensitivity of indicative species to environmental factors. The sensitivity of the indicative species is assessed with respect to change in 24 separate environmental factors (see Table A.5 above). Precedence is given to direct evidence of effect or impact. In the absence of direct evidence, the *MarLIN* rationale includes simple decision trees to aid intolerance and recoverability assessment based on the available information. The decision trees provide a systematic and transparent approach to assessment. The decision trees are described in full by Tyler-Walters *et al.* (2001).

6. Assess overall intolerance and recoverability of the biotope. The intolerance and recoverability of the biotope are derived from the intolerance and recoverability of the species identified as indicative of sensitivity, using a simple procedure shown in Figure A.1 for intolerance and in Figure A.2 for recoverability. The definitions of biotope intolerance (revised in April 2003) are shown in Table A.8.

Knowledge of the biology of other species in the biotope, especially if they have been researched as a part of the *MarLIN* programme, is also taken into account.

Table A.8. Biotope intolerance (previously 'sensitivity' and revised April 2003)

BIOTOPE INTOLERANCE The susceptibility of a habitat, community or species (i.e. the components of a biotope) to damage, or death, from an external factor. Intolerance must be assessed relative to change in a specific factor.	
Rank	**Definition**
High	Species important for the structure and/or function of the biotope, or its identification ('important characterizing' species), are likely to be killed and/or the habitat is likely to be destroyed by the factor under consideration.
Intermediate	The population(s) of species important for the structure and/or function of the biotope, or its identification ('important characterizing' species), may be reduced or 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	Species important for the structure and/or function of the biotope, or its identification ('important characterizing' species), will not be killed or destroyed by the factor under consideration and the habitat is unlikely to be damaged. However, the viability of a species population or the diversity / functionality in a community will be reduced.
Tolerant	The factor does not have a detectable effect on the structure and/or function of a biotope or the survival or viability of species important for the structure and/or function of the biotope or its identification.
Tolerant*	The extent or species richness of a biotope may be increased or enhanced by the factor.
Not relevant	Intolerance 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 affected by increased emergence regime).

Precedence is given to direct evidence of the effects of changes in environmental factors on a habitat, its community and associated species (i.e. the components of a biotope), and its subsequent recovery. The intolerance of a biotope to change in each environmental factor is assessed against a standard 'benchmark' level of effect, which allows the user to compare the recorded sensitivity to the level of effect predicted to be caused by a proposed development or activity. The evidence and key information used to assess intolerance, recoverability, and sensitivity, and any judgements made are explained in the on-line rationale for each assessment. The source of all information used is clearly referenced on-line.

7. Assess sensitivity of the biotope. The overall sensitivity rank is derived from the combination of intolerance and recoverability using the rationale shown in Tables A.1 and A.2 above.

8. Assess the likely effect of the environmental factors on species richness. Change in an environmental factor may not significantly damage key or important species but may still degrade the integrity of the biotope due to loss of species richness. Therefore, the likely effect of the factor on species richness in the biotope is indicated (see Table A.9).

Table A.9. The likely response of species richness to an external factor

SPECIES RICHNESS The number of species in a given habitat, biotope, community or assemblage	
The following scale is used to judge the likely response of species richness to an external factor.	
Rank	**Definition**
Major decline	The number of species in the community is likely to decrease significantly (>75% of species) in response to the factor, probably because of mortality and loss of habitat. For example, a change from very rich to very poor on the NHAP scales (Hiscock, 1996).
Decline	The community is likely to loose some of its species in response to the factor by either direct mortality or emigration.
Minor decline	The community is likely to loose few species (<25% of species) in response to the factor. For example, a decrease of one level on the NHAP scales (Hiscock 1996).
No change	The factor is unlikely to change the species richness of the community
Rise	The number of species in the community may increase in response to the factor. (Note the invasion of the community by aggressive or non-native species may degrade the community).
Not relevant	It is extremely unlikely for a factor to occur (e.g. emergence of a deep water community) or the community is protected from the factor.

9. Signing-off. *MarLIN* reviews are checked by the Programme Director for accuracy and clarity and the required changes made before the review goes ‘on-line’ on the Web site.

10. Referee. As a final stage in the *MarLIN* quality assurance, Key Information reviews are subject to peer review by an external marine biologist where possible.

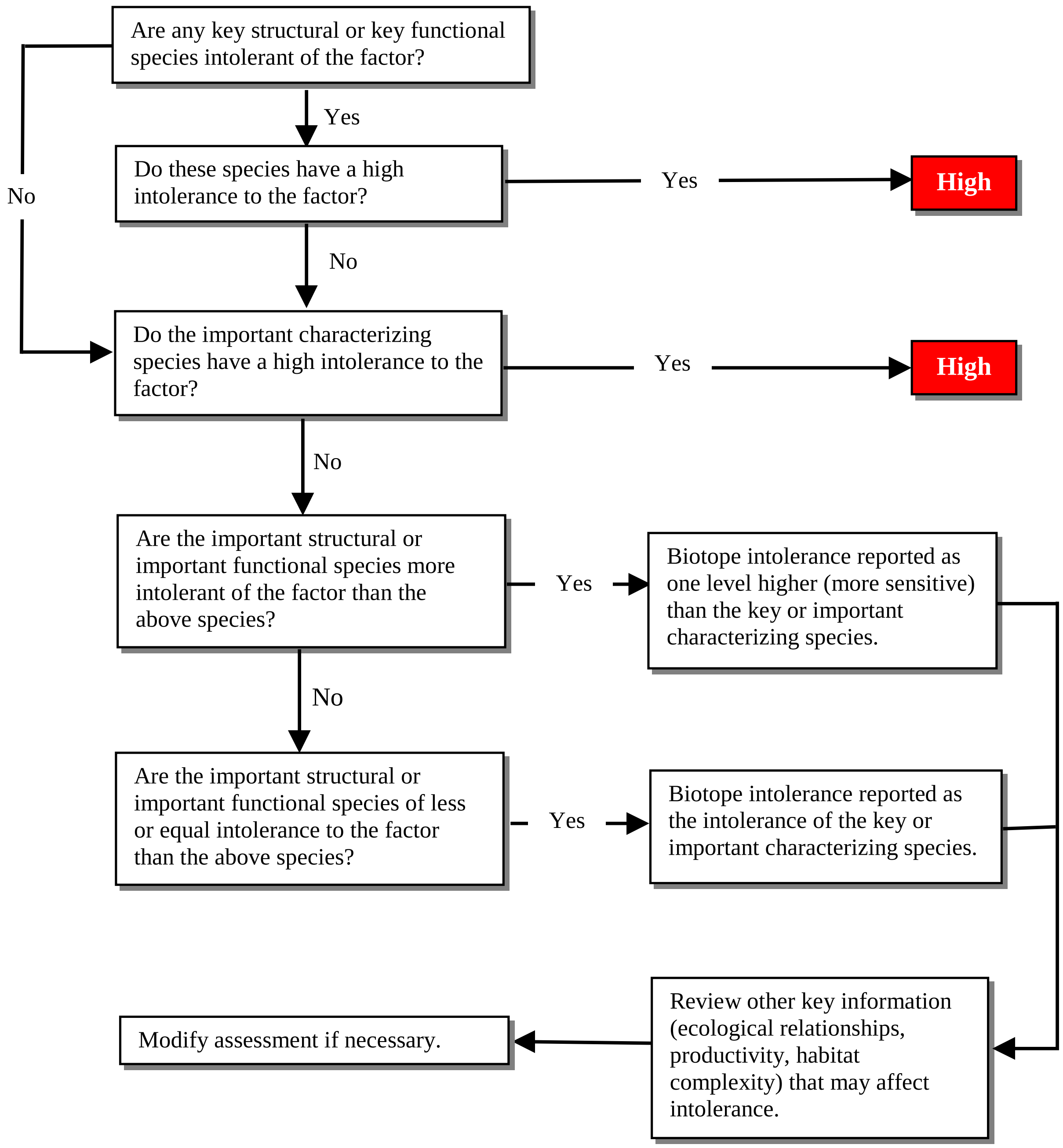

Figure A.1. Biotope 'intolerance' assessment rationale.

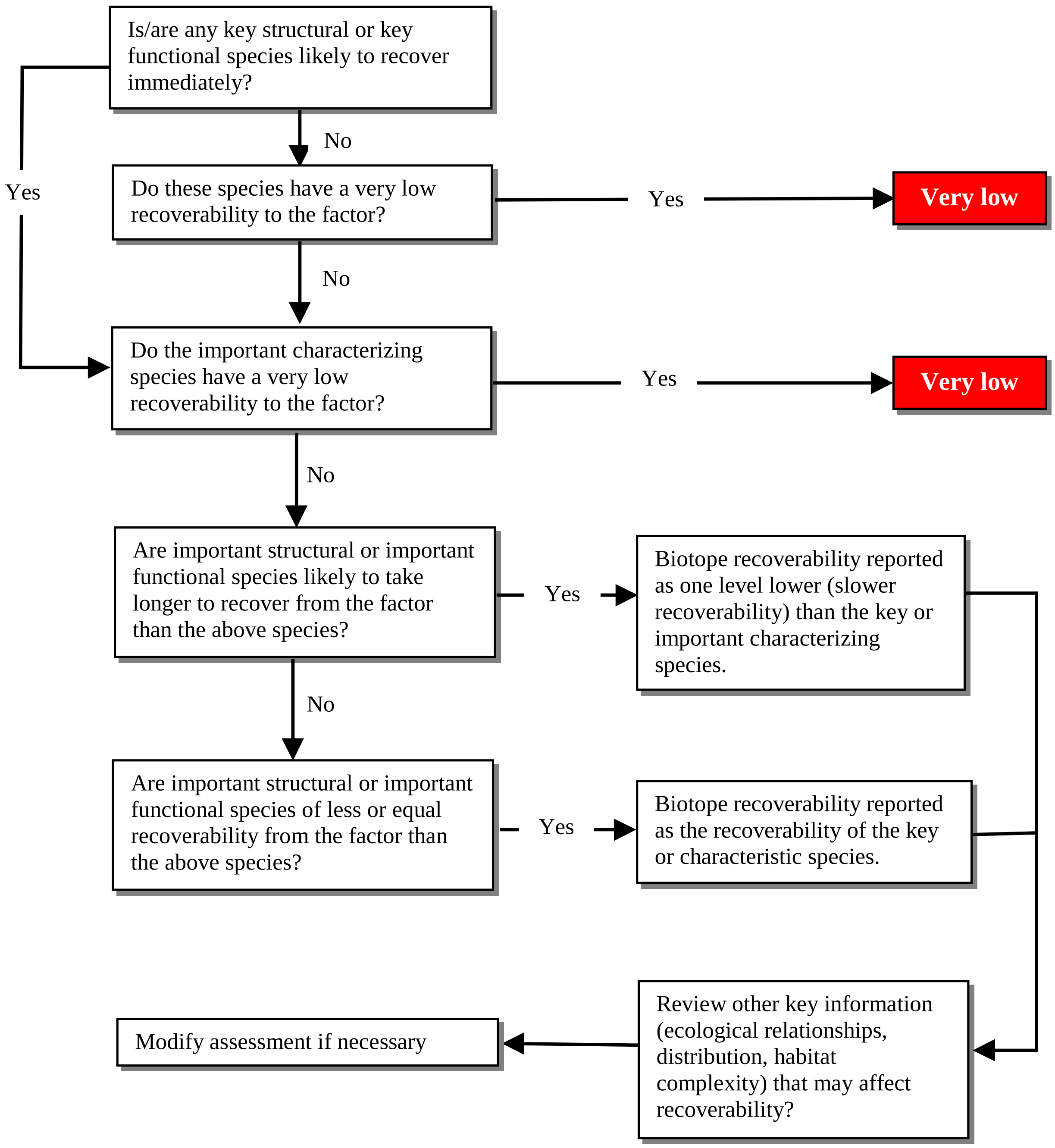

Figure A.2. Biotope recoverability assessment rationale.

Appendix 2. Benchmarks for the Assessment of Sensitivity and Recoverability

The sensitivity of a species (or community) is an estimate of its intolerance to damage from an external factor and is determined by its biological and physical characteristics. Sensitivity must be estimated (assessed) in response to a change in a specific environmental factor and to the magnitude, duration, or frequency of that change.

Marine organisms may be affected by a number of human activities and natural events. The effects of an activity (or event) are dependant on the receiving environment. The same activity (or event) in different locations may have different effects. For example, an activity that markedly increased siltation may have little effect in a turbid estuary whereas it would probably have significant effects in a sheltered embayment. Therefore, the effects of an activity and the resultant change in environmental factors are site specific and cannot be generalised.

Hence, the magnitude, duration, and frequency of change in an environmental factor, are dependant on both the nature and scale of the human activity or natural event, as well as the location or site at which the activity or event occurs. Therefore, it was necessary to set standard 'benchmarks' to enable the assessment of sensitivity relative to a specified change in an environmental factor.

The use of a standard benchmark level of change in an environmental factor ensures that the sensitivity of different species or communities is assessed with respect to the same level of change or perturbation. In addition, standard benchmarks allow the relative sensitivity of different species and communities to be compared.

1. Derivation of benchmarks

The standard benchmarks were derived from a review of relevant literature. In many cases, the available information did not allow 'quantified' benchmarks to be set. Therefore, it was necessary to adopt a mixture of approaches to derive the benchmarks, depending on the environmental factor. The following approaches were used.

- Quantified benchmarks were based on available evidence.
- Qualified benchmarks were derived from interpretation of the available evidence.
- Quantified and qualified benchmarks were derived from standard scales, e.g. the wave exposure scales and biological zone boundaries given in the MNCR Rationale and Methods (Hiscock, 1996).
- Where evidence was lacking or the factor was naturally highly variable (e.g. suspended sediment or nutrient levels), arbitrary benchmark levels were chosen.
- Where evidence was lacking or quantified benchmarks were inappropriate (see 'contaminants') defined levels of evidence were suggested as 'surrogate' benchmarks.

The chosen magnitude and duration of each benchmark reflects the reported or likely change in the factor because of relevant maritime activities or natural events, unless otherwise stated, and represent a hypothetical 'average' level of effect. It was necessary to avoid negligible or extreme levels of effect, as these would under or over estimate sensitivity respectively.

To assess sensitivity or recoverability a hypothetical 'average' population is considered. A hypothetical 'average' population may be thought of as a population in the middle of its habitat preferences with respect to, for instance, its biological zone, temperature or salinity tolerances, wave exposure tolerances, or geographical distribution. Populations at the extremes of their habitat preferences (or range) are likely to be exposed to environmental conditions close to their physiological tolerances limits and are, therefore, likely to be more sensitive. In addition, where appropriate, increases or decreases in an environmental factor are assessed separately.

Note: The benchmarks are intended to:

- be pragmatic guidance values for sensitivity assessment;
- allow comparison of sensitivities between species, and;
- allow comparison with the predicted effects of project proposals.

The chosen benchmark levels of change in environmental factors are likely to affect different marine species to different degrees. Therefore, the benchmarks are considered precautionary in nature (*sensu* 'the precautionary approach').

2. Duration of change

In addition to a magnitude (or level of effect), the benchmarks specify a duration wherever possible. The magnitude or duration of changes in environmental factors include:

- short term acute change;
- repeated (at given frequency) short term, acute change;
- long term, chronic change; and
- long term incremental or steady change.

Where activities are likely to cause more than one type of change, separate benchmarks are given for short term acute or long term chronic changes. Where there was clear evidence on the known sensitivity or effect of activities on a particular factor, representative time frames were used. For example, Crisp ed. (1964) reported mortalities for a wide range of marine species resulting from a drop in temperature of 5-6 ºC.

However, in most cases, 'short-term' was defined arbitrarily as 'one month' and a period of one year was chosen arbitrarily to represent 'long term' change since this period accommodated the life cycle of many marine species.

The interactions between an activity and its effects are extremely complex and the benchmarks should not be considered perfect. The *MarLIN* team would welcome any comments or additional guidance.

3. Interpretation of benchmarks

Short term acute and long term chronic change were chosen because they represented the most likely effects of maritime activities. The benchmarks are only a 'starting point' and sensitivity assessments can be interpolated if the known or predicted change is greater or less than the benchmark. For example:

- if the change in a factor has a greater magnitude than that used in the benchmark, then it is likely that the organism will have a greater sensitivity to this change;
- if the change in a factor has a longer duration than that used in the benchmark, then it is likely that the organism will have a greater sensitivity to this change;
- if the change in a factor is likely to occur at higher frequency than used in the benchmark, then it is also likely that the species or community will exhibit a higher sensitivity.

However, the frequency of change should be compared with the species or communities recoverability. If the species or community is likely to recover between the impacting events then it may not exhibit an increased sensitivity.

Activities that result in incremental long term change, such as climate change, are difficult to assess since the given level of change varies with time. These effects have **NOT** been addressed within the present sensitivity assessments. However, benchmarks could be compared to the predicted level of change at specific time intervals.

PLEASE NOTE Sensitivity assessments are indicative qualitative judgements based on the best available scientific information. They represent the most likely (probable) result of a given change in a factor. *They do not allow quantitative analysis.* The sensitivity assessments should be used in conjunction with the key information provided with each species. In all cases, an 'explanation' behind each sensitivity assessment, the relevant key information and references are highlighted.

The benchmarks that follow were revised in March 2003, based on the experience gained after three years research on the biology and sensitivity of marine species and biotopes. Only the benchmarks relevant to this report are reproduced here. The benchmarks used prior to March 2003 are published in Tyler-Walters *et al.* (2001) and the revised benchmarks are available on the *MarLIN* Web site.

4. Benchmarks for Sensitivity Assessment

Sensitivity and recoverability ranks for species are indicative. Ranks are assessed against the same intensity of change in environmental factor or 'benchmark'. The following table standardises the magnitude of each factor in order for effects to be normalised across species.

Physical factors	
	The level of effect against which sensitivity is rated.
Substratum loss	The physical removal of the substratum inhabited or required by the species or community in question. Newell *et al.* (1998) reviewed the environmental effects of dredging in coastal waters. They reported that trailer suction hopper dredging could result in dredged tracks 2-3 m wide and 0.5 m deep but up to 2 m deep in some cases. In comparison, anchored dredging may result in pits of up to 75 m in diameter and 20 m deep. 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 1year in high currents, 5-10 years in lower currents and up to 15 years on tidal flats (Newell *et al.*, 1998). Hall (1994) reports pits 3.5 m wide and 0.6 m deep due to suction dredging for *Ensis* in a Scottish sea loch. Newell *et al.* (1998) states that removal of 0.5 m of sediment was likely to eliminate benthos from the affected area. The chosen benchmark is representative of localized impacts on a specific area of substratum. This benchmark also includes the removal of other species that provide substrata for the species or community of interest, for example macroalgae. The time taken for the substratum to 'recover' within the habitat preferences of the species or community under consideration is not addressed. **Benchmark.** All of substratum occupied by the species or biotope under consideration is removed. A single event is assumed for sensitivity assessment. Once the activity or event has stopped (or between regular events) suitable substratum remains or is deposited. Species or community recovery assumes that the substratum within the habitat preferences of the original species or community is present.
Smothering	The physical covering of the species or community and its substratum with additional sediment (silt), spoil, detritus, litter, oil or man-made objects. Overgrowth by other species such as encrusting ascidians is also included here. Major storms may deposit a layer of additional material of several centimetres at 20 m depth and several millimetres at 40 m (Hall, 1994). For example, storms were reported to deposit 4-10 cm of sand at 28 m in the Helgoland in German Bight and up to 11 cm of sand off the Schleswig-Holstein coast (Hall, 1994). In a study of the impact of mill tailings, discharged into a Canadian silled fjord, Ellis and Heim (1985) observed layers of tailings of 0.5 cm, 5 cm and greater than 5 cm (up to 60 cm in one location). The chosen benchmark represents the likely level of smothering resulting from natural events and comparable to the effects of maritime activities. [The definition does not include land claim. The habitat and its resident species would be destroyed by land claim. Recovery would not be possible, as the effect is permanent.] **Benchmark.** All of the population of a species or an area of a biotope is smothered by sediment, similar to the existing substratum, to a depth of 5 cm above the substratum for one month. **NB** Spoil that differs from the existing sediments (e.g. in grain size, or porosity), and impermeable materials (e.g. concrete, oil, or tar) are likely to have a greater effect.

	The level of effect against which sensitivity is rated.
Physical disturbance or abrasion	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 (snapped). Physical disturbance due to of mobile fishing gear continues to be a concern in marine conservation. In most cases, the weight of evidence regarding habitat or species sensitivity to physical disturbance concerns the effects of mobile fishing gear, e.g. epifaunal communities or *Modiolus modiolus* beds. The benchmark was chosen to be representative of a potentially damaging marine activity, namely scallop dredging. The benchmark has been set as the magnitude of impact equivalent to that caused by a passing scallop dredge. We believe that a scallop dredge is representative of the impact likely to cause damage to a habitat or species, and to be of concern for marine conservation or environmental management. The intertidal is also susceptible to abrasion and physical impact from trampling, however, no standard units have been identified, although units such as 'number of footsteps per m^2' or 'number of persons per transect' have been reported. Where trampling is relevant, the evidence and trampling intensity will be reported in the rationale. **Benchmark.** Force equivalent to a standard scallop dredge landing on or being dragged across the organism. A single event is assumed for assessment. Where trampling is relevant, the evidence and trampling intensity will be reported in the rationale.

Appendix 3. Maritime and coastal activities to environmental factors matrix

		ENVIRONMENTAL FACTORS																							
		Physical													Chemical							Biological			
Coastal & Maritime Activities / Events	Sub-activities /events	Substratum loss	Smothering	Suspended sediment	Desiccation	Changes in emergence regime	Changes in water flow rate	Changes in temperature	Changes in turbidity	Changes in wave exposure	Noise disturbance	Visual presence	Abrasion / Physical disturbance	Displacement	Synthetic compound contamination	Heavy metal contamination	Hydrocarbon contamination	Radionuclide contamination	Changes in nutrient levels	Changes in salinity	Changes in oxygenation	Introduction of microbial pathogens / parasites	Introduction of non-native species	Selective extraction of target species	Selective extraction of non-target species
Aquaculture	Fin-fish		R	R			R		R		P	P	R		R				R		R	R	R		
	Macro-algae		P	P			P		P		P	P							P		P	R	R	R	R
	Predator control										R	R			P										
	Shellfisheries		R	R			R		R		R	R	R		R				R		R	R	R	R	R
Climate change	Current change						R	R	R										R	P		R	R		
	Sea level change				R	R	R			R										R					
	Temperature change				R			R	R										R		R	R	R		
	Weather pattern change				R			R														R	R		
Coastal defence	Barrage	R	R	R	R	R	R		R	R	R	R	R	R	P	P	P		R	R	R				
	Beach replenishment	P	R	R	R	R	R		R	R	R	R	R	R	P	P	P		R		R				
	Groynes	P	P	R	R		R		R	R		R		P							P				
	Sea walls / breakwaters	P	P	R	R	R	R		R	R		R		P							P				
Collecting	Bait digging	R	R	R	R				R		R	R	R	R										R	
	Bird eggs										R	R	R											R	
	Curios										P	P	R	R										R	R
	Higher plants	R		R			R				R	R	R	R					R					R	R
	Kelp & wrack harvesting	R		R	R		R		R	R	R	R	R	R					R		R			R	R
	Macro-algae	R			R		R				R	R	R	R	P									R	R
	Peelers (boulder turning)		R		R	R	R				R	R	R	R										R	
	Shellfish	R	R	R	R				R		R	R	R	R										R	R
Development	Construction phase	R	R	R	R	R	R	P	R	R	R	R	R	R	P	P	P	P	R	R	R				
	Artificial reefs		P	R			R		R	R					P	P	P		R		R				
	Communication cables		P	R			R		R			R													
	Culverting lagoons			R	R	R	R	R	R	P									R	R	R				
	Dock/port facilities		R	R			R	P	R	R	R	R	R	R	R	P	R	P	R	P	R	R	R		
	Land claim	R	R	R	R	R	R		R	R									R	R	R				
	Marinas		R	R	R	P	R	P	R	R	R	R	R	R	R	P	R		R		R	R	R		
	Oil & gas platforms		R				R		R		R	R	R		R	R	R		R		R				
	Urban			R					R		R	R	R		R	R	R		R	R	R	R			
Dredging	Captial dredging	R	R	R	R	R	R		R	R	R	R	R	R	P	P	P	P	R	P	R				
	Maintenance dredging	R	R	R					R		R	R	R	R	P	P	P	P	R		R				
Energy generation	Nuclear power generation		P	R				R	R		R	R			R	P		P	R	P	R				
	Power stations		P	R				R	R		R	R			R	R	P		R	P	R				
	Renewable (wind/tide/wave)		P	P	P	P	R		P	R	P	P			R		P				P				
Extraction	Maerl	R	R	R			R		R		R	R	R	R					R		R			R	R
	Rock/minerals (coastal quarrying)	R	R	R					R		R	R	R	R	R	R	R		R		R				
	Oil & gas		R								R	R			R	R	R		R		R				
	Sand / gravel (aggregates)	R	R	R			R		R	P	R	R	R	R	P	P	P	P	R		R				
	Water resources (abstraction)				P	P	R												R	R	R				
Fisheries/ Shellfisheries	Benthic trawls (e.g. scallop dredging)	R	R	R					R		R	R	R	R	P	P	P		R		R			R	R
	Netting (e.g. fixed nets)										R	R	R	R										R	R
	Pelagic trawls										P	P												R	R
	Potting / creeling		R								R	R	R	R										R	R
	Suction (hydraulic) dredging	R	R	R					R		R	R	R	R	P	P	P		R		R			R	R
Recreation	Angling										R	R	R	P										R	R
	Boating / yachting								P		R	R	R		R	P	R		R		R	R	R		
	Diving / dive site										R	R	R	R										R	
	Public beach										R	R	R						P						
	Tourist resort			R					R		R	R	R		R	R	R		R		R				
	Water sports										R	R	R		R	P	R								
Uses	Animal sanctuaries										P	P	P						P			P	P		
	Archaeology	R	R	R					R		R	R	R	R	P	P	P		R		R				R
	Coastal farming		R	R					R		R	R	R		R	P	R		R		R	P			
	Coastal forestry		R	R					R		R	R	R		R	P	R		R		R				
	Education/interpretation										R	R	R	R										R	R
	Military										R	R	R		P	P	P	P							
	Mooring / beaching / launching		R	R			R		R		R	R	R	R	R	P	R					P	P		
	Research	P									R	R	R	P	P	P	P		P			P	P	R	P
	Shipping		P	R					R		R	R	R	R	R	R	R	P	R		R	R	R		
Wastes	Fishery & agricultural wastes		R	R					R						R				R		R	R			
	Industrial effluent discharge		R	R					R						R	R	R		R		R				
	Industrial / urban emissions (air)			P					P						R	R	R								
	Inorganic mine and particulate wastes		R	R					R				R		P	R	P	P	R		R				
	Land / waterfront runoff		R	R					R						P	P	P		R	R	R				
	Litter and debris		R										R		P	P	P								
	Nuclear effluent discharge			R					R							R		R							
	Sewage discharge		R	R					R						R	R	R	P	R		R	R			
	Shipping wastes		P	R					R						R	R	R		R		R	R	R		
	Spoil dumping		R	R					R				P		P	P	P	P	R		R				
	Thermal discharges (cooling water)			R				R	R						R	R	P			P	R	P	P		
Other	Removal of substratum	R	R	R	P	P	P		R	P	R	R	R	R	P	P	P		R		R				

PROBABLE EFFECT	-	R

POSSIBLE EFFECT	-	P

Appendix 4a. Sensitivity of representative component biotopes to substratum loss.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	High	High	**Moderate**	High	Removal of the substratum would also remove entire populations of the infauna and sessile epifauna in the biotope. Intolerance is therefore assessed as high and there would be a major decline in species richness.
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	High	High	**Moderate**	Moderate	Most species in the CMS.AbrNucCor biotope are infaunal or epifaunal. Although many are mobile burrowing species, they are not very fast moving and so are likely to be removed along with the substratum. Intolerance of the biotope has been assessed to be high. Recoverability has been assessed to be high, for instance, *Abra alba* recovered to former densities following loss of a population from Keil Bay within 1.5 years, whilst *Lagis koreni* took only one year (Arntz & Rumohr, 1986). However, the recovery of *Echinocardium cordatum* may take longer owing to recruitment that is frequently unsuccessful (Rees & Dare, 1993).
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	High	Moderate	**Moderate**	High	Most species in the CMS.AfilEcor biotope are infaunal or epifaunal and will be lost if the substratum is removed so the overall intolerance 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. The 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.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	High	Moderate	**Moderate**	Low	Most species are infaunal or epifaunal and will be lost if the substratum is removed so the overall intolerance 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.
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	High	Moderate	**Moderate**	High	Species within the CMU.BriAchi biotope are infaunal and will be lost if the substratum is removed so the overall intolerance of the biotope has been recorded as high. Although some species are mobile e.g. *Calocaris macandreae* and *Nephrops norvegicus*, if disturbed they are likely to seek refuge within a burrow within the substratum and so are also likely to be removed. The characterizing species do not reach sexual maturity for several years and recovery has been assessed to be moderate (see additional information below).
CMU.SpMeg	Seapens and burrowing megafauna in circalittoral soft mud	High	Moderate	**Moderate**	High	Most species are infaunal or epifaunal and will be lost if the substratum is removed so the overall intolerance of the biotope is high. Although some of the mobile species in the biotope may be able to escape, most, such as the harbour swimming crab *Liocarcinus depurator* and the starfish *Asterias rubens* are not very fast moving and so are also likely to be removed. Nothing is known about the life cycle and population dynamics of British sea pens, but data from other species suggest that they are likely to be long-lived and slow growing with patchy and intermittent recruitment. The burrowing megafauna in the biotope vary in their longevity and reproductive strategies and some species do not reach sexual maturity for several years. *Calocaris macandreae*, for example, does not reproduce until five years old. Therefore, it seems likely that a community of sea pens and burrowing megafauna may take longer than five years to recover and so a recoverability score of moderate is reported.
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	High	Moderate	**Moderate**	Moderate	Most species are infaunal or epifaunal and will be lost if the substratum is removed so the overall intolerance of the biotope is high. Although there are many mobile species in the biotope that may be able to escape, most, such as *Amphiura* sp. brittlestars and small spider crabs are not very fast moving and so are also likely to be removed. See additional information for recovery.
COS.ForThy	Foraminiferans and *Thyasira*	High	Moderate	**Moderate**	High	The community would be highly sensitive to substratum loss as it is

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
	sp. in deep circalittoral soft mud					dominated by infaunal and epifaunal species. Removal of the substratum would remove these species. Intolerance has been assessed to be high. Recoverability may be only moderate (see additional information below).
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	High	High	**Moderate**	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, intolerance is assessed as high and there would be a major decline in species richness. Recoverability is recorded as high (see additional information).
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	High	High	**Moderate**	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, intolerance has been assessed to be high and there would be a major decline in species richness. Recoverability has been assessed to be high (see additional information below).
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Intermediate	Very high	**Low**	Low	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 because 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, intolerance 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. Intolerance would be expected to be higher because a proportion of the population would die and displaced fauna suffer a reduction in habitat.
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or	High	Moderate	**Moderate**	High	Muddy sand communities are highly sensitive to substratum loss because most species are infaunal and so will be removed and die. A few mobile

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
	shallow sublittoral muddy fine sand.					demersal species like the crab *Liocarcinus depurator* may be able to avoid the factor but even fast moving polychaetes will be removed during substratum loss. Dredging operations, for example, were shown to affect large infaunal and epifaunal species, decrease sessile polychaetes and reduce numbers of burrowing heart urchins. Recovery is dependant on return of suitable sediment and recruitment of individuals. *Echinocardium cordatum* has high fecundity, reproduces every year, and has pelagic larvae so recovery should be good on return to normal conditions. The first re-population of *Echinocardium cordatum* after the *Torrey Canyon* accident was recorded two years after the oil spill (Southward & Southward, 1978). Although recruitment of *Ensis ensis* is sporadic, recovery should be complete within five years. Populations may be skewed towards smaller and younger individuals. However, all invertebrate communities respond to perturbations in a similar way. Initial massive mortality and lowered community diversity is followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993). Oscillations in population numbers slowly dampen over time and diversity slowly increases to original levels. Thus, although the individual key species may recolonize the area within five years, the biotope may take longer to return to original species diversity and abundance and so recovery is assessed as moderate.
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	High	High	**Moderate**	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 intolerance has been assessed to be high. Recoverability has been assessed to be high (see additional information).

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	High	High	**Moderate**	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 unlikely to be recognized until after six months. Recoverability is therefore recorded as high (see additional information below).
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	High	Moderate	**Moderate**	Low	The important characterising species associated with this biotope rank high to substratum loss, as they are infaunal, burrowing species. *Philine aperta* has fast growth and reproductive rates and could recolonize from other areas as the species is common. Very little is known about the population dynamics and longevity of *Virgularia mirabilis* in Britain, however information from other species suggest that this species is likely to be slow growing with patchy and intermittent recruitment. Therefore, full recovery of this biotope and the important characterising species will take many years.
IMX.An	Burrowing anemones in sublittoral muddy gravel	High	Moderate	**Moderate**	Low	The species in the biotope are burrowing and will be lost if the substratum is removed so the overall intolerance of the biotope is high.
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	High	High	**Moderate**	High	Removal of the substratum would remove entire populations of infauna, epifauna and macroalgae. Intolerance is therefore assessed as high and there would be a major decline in species richness. Recoverability is assessed as high (see additional information).
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	High	High	**Moderate**	High	The majority of characterizing and dominant species in this biotope are fixed to the substratum and, therefore, will be removed with the substratum. Intolerance is therefore high. For recoverability, see Additional information below.
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	High	High	**Moderate**	High	The infauna reside in the uppermost layers of the substratum and removal of the substratum would cause a major decline in species richness, as they would be removed with it. Thus, all the biotopes represented by this key information review have been assessed to be highly intolerant of substratum loss at the benchmark level. Recolonization by the important characterizing species is likely following deposition of a sandy substratum, therefore recovery has been assessed to be high. However, extensive areas of intertidal mud and sand flats have been lost through land-claim (Davidson *et al.*, 1991) and should this biotope be covered over it would never recover.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	High	High	**Moderate**	Moderate	Characterizing species within this biotope are infaunal and would therefore be removed along with the substratum. Intolerance has been assessed to be high because the species that characterize the biotope would be lost. Recoverability has been assessed to be high. See additional information below.
LMS.MS	Muddy sand shores	High	High	**Moderate**	High	Newell *et al.* (1998) state that removal of 0.5m depth of sediment is likely to eliminate benthos from the affected area. Dredging activities may result in deep pits or trenches between 0.5m - 20m deep depending on the techniques used (Newell *et al.* 1998). Hall (1994) reported that suction dredging for *Ensis* species in 7 m of water in a Scottish sea loch resulted in pits in the sediment and significant reductions in the abundance of a large proportion of the species at the experimental site. However, no differences in species abundances between the impacted plots and controls were detectable after 40 days. This rapid recovery was probably due to intense wave and storm activity during the experimental period that transported sediment and animals in suspension and in bedload transport (Hall, 1994). In the intertidal, mechanical cockle harvesting resulted in significant losses of common invertebrates in muddy sand and clean sand in the Burry Inlet (Ferns *et al.*, 2000). For example, losses varied from 31% of *Scoloplos armiger* to 83% of *Pygospio elegans* in dense populations. Populations of *Nephtys hombergii*, *Scoloplos armiger* took over 50 days to recover. However, recovery was more rapid in clean sand than in muddy sand. In muddy sand, *Bathyporeia pilos*a took 111 days to recover while *Pygospio elegans* and *Hydrobia ulvae* had not recovered their original abundance after 174 days (Ferns *et al.*, 2000). Storms and intense wave action may move or remove substrata in shallow subtidal or intertidal sedimentary habitats. For example, in shallow subtidal sands and muddy sands in Liverpool Bay, Eagle (1973) reported significant fluctuations in the abundance of dominant species (e.g. *Abra alba*, *Lanice conchilega* and *Lagis koreni*). Recolonization of one of the three dominants occurred rapidly, depending on the availability of larvae and redistribution of juveniles or adults by bedload transport (Eagle, 1975; Hall, 1994). Similar observations were reported for *Lagis koreni* and *Abra alba* in the intertidal muddy sands and mobile offshore sands of Red Wharf Bay, Anglesey, and the surrounding coast (Rees *et al.*, 1977). Muddy sand communities are likely to be highly intolerant of substratum loss as the infauna will be removed and heart urchin, molluscs and crustaceans are likely to be damaged or killed in dredging operations (Elliot

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						et al. 1998). Dredging operations were shown to affect large infaunal and epifaunal species, decrease sessile polychaetes and reduce numbers of burrowing heart urchin.
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	High	High	**Moderate**	High	The majority of the species in the biotope are infaunal and would therefore be removed along with the substratum. This would result in loss of entire populations and therefore intolerance is assessed as high and species richness would experience a major decline. Recoverability is assessed as high (see additional information below).
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	High	Very low	**Very High**	High	Most of the characteristic species in the biotope are permanently attached to the substratum (e.g. the sponges, sea fans and bryozoans) and will not re-attach once displaced. Substratum loss will result in loss of these species and so intolerance of the biotope is high. *Pentapora foliacea* has good reproductive and recolonizing abilities. It has been recorded as recovering in 3.5 years after almost total loss of a local population (Cocito *et al*., 1998b). *Eunicella verrucosa* is long lived, slow growing, and little is known of its reproduction. It is known to colonize wrecks at least several hundred metres from other hard substrata with sea fans, but is thought to have larvae which generally settle near the parent. Little is known of the reproduction and recruitment mechanisms in *Axinella dissimilis* or other sponges but branching sponges have not been observed to colonize wrecks and growth rate of *Axinella dissimilis* at Lundy is extremely slow (less than 1 mm a year) (K. Hiscock, pers. comm.). In monitoring studies at Lundy, branching sponges showed no recruitment, only losses over a 13 year period (K. Hiscock pers. comm.). Recovery of some parts of this community may therefore take a long time or not occur. Other species in the biotope may have long-lived widely dispersing larvae. Mobile species such as the echinoderms and fish should be able to return rapidly.
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate	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 intolerance 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*.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	High	Very low	**Very High**	High	Removal of the substratum would result in the loss of the *Modiolus modiolus* bed and its associated community. Therefore, an intolerance 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 (see additional information). Therefore, a recoverability of very low has been recorded.
MCR.Mus	*Musculus discors* beds on moderately exposed circalittoral rock	High	Moderate	**Moderate**	Low	Removal of the substratum whether the macroalgae to which *Musculus discors* was attached or the rocky substratum itself will result in loss of the community. Therefore, an intolerance of high has been recorded. Recoverability will depend on recruitment from adjacent or nearby populations and may take many years (see additional information below).
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	High	High	**Moderate**	High	Removal of the substratum will include the removal of all the species within the biotope. Therefore, an intolerance of high has been recorded. Although a single good recruitment event may recolonize the substratum within a year, recovery may take up to 5 years, and is some circumstances significantly longer (see additional information below). Therefore, a recoverability of high has been recorded.
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate	*Ophiothrix fragilis* and the other brittlestars that may be present in the biotope are epibenthic animals so substratum loss would result in their removal and hence mortality. Infaunal organisms and sessile species, such as *Alcyonium digitatum* and *Urticina felina*, would also be lost if substratum were removed. Although there are some mobile species in the biotope, such as the starfish *Asterias rubens* and *Crossaster papposus*, they are not very fast moving and so are also likely to be removed. Therefore, most species would be lost if substratum were removed and so the biotope is highly sensitive.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	High	High	**Moderate**	High	The key structural species (*Sabellaria spinulosa*), important functional, and characterizing species (such as *Ophiothrix fragilis*) and other species (*Alcyonium digitatum*) in the biotope are all benthic, some of them permanently attached. Substratum loss would cause destruction of the biotope. *Sabellaria spinulosa* is the most important species in this biotope. *Sabellaria spinulosa* has a long-lived larva with good dispersive ability and can recruit readily although this can be affected by environmental conditions. Other species that may occur in the biotope (e.g. *Urticina felina*) might take longer to return due to poor dispersal (Solé-Cava *et al*., 1994) and slow growth (Chia & Spaulding, 1972). There are few frequent characterising species. The other species present in this biotope probably reflect the species composition of nearby biotopes.
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	High	Moderate	**Moderate**	Moderate	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 intolerance 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*.
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	High	High	**Moderate**	Moderate	Removal of the substratum will result in removal of the entire community with the exception of mobile fish, which can probably avoid the factor. Therefore, a intolerance of high has been recorded. Recoverability has been assessed as high, although species diversity, especially epifauna may take longer to recover.
MIR.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	High	High	**Moderate**	High	The community will be removed with the substratum and so intolerance is high. .

Appendix 4b. Sensitivity of representative component biotopes to smothering.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Low	Very high	**Very low**	Low	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 intolerance 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. The species that will be most affected by smothering are the sessile epifauna, such as *Hydroides norvegica*. The 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.
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	**Not sensitive**	High	The biotope will probably have a low intolerance to smothering by 5 cm of sediment because most species are capable of burrowing through sediment to feed, e.g. *Abra alba* and *Lagis koreni* are capable of upwardly migrating if lightly buried by additional sediment (Schafer, 1972). There may be an energetic cost expended by species 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 reburrow or move up through the sediment within hours or days so recovery has been assessed to be immediate. Intolerance to smothering with sediment atypical for the biotope, viscous or impermeable material would be expected to be higher.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Low	Immediate	**Not sensitive**	High	The biotope will have low intolerance 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 reburrow or move up through the sediment within hours or days so recovery is set at immediate. Intolerance to smothering by other factors such as oil may be higher.
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very Low**	Moderate	The biotope will have low intolerance to smothering by 5cm of sediment because many of the species are burrowing and live within the sediment anyway. The sea pen *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 intolerance of the biotope is recorded as low. Intolerance to other smothering factors, oil for example, may be higher. Recovery should be rapid as species move through the sediment and self clean.
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	Low	Immediate	**Not sensitive**	Moderate	The biotope will probably have a low intolerance to smothering by 5cm of sediment because the characterizing species are all infaunal burrowers. There may be some energetic cost expended to either re-establish burrow openings in the case of *Calocaris macandreae* and *Nephrops norvegicus*, or to self-clean feeding apparatus though this is not likely to be significant. The biotope is likely to be more sensitive to smothering by viscous or impenetrable materials e.g. smothering by sediment of a coarser texture may affect burrowing and feeding. At the benchmark level, recovery of the community from smothering is assessed to be immediate.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CMU.SpMeg	Seapens and burrowing megafauna in circalittoral soft mud	Low	Immediate	**Not sensitive**	High	The biotope will have low intolerance to smothering by 5 cm of sediment because most species are burrowing and live within the sediment anyway. The burrowing thalassindean crustaceans, the echiuran worm *Maxmuelleria lankesteri*, infaunal polychaetes, brittlestars and bivalves are not likely to be affected by smothering by 5cm of sediment. There may be an energetic cost expended either to re-establish burrow openings or to move up through the sediment though this is not likely to be significant. The sea pens *Virgularia mirabilis* and *Pennatula phosphorea* are able to withdraw rapidly into the sediment and appear to be able to recover from smothering. Although the sea pen *Funiculina quadrangularis* is not able to withdraw into the sediment its height, up to 2 m, means that it is unlikely to be affected by smothering of 5 cm of sediment. Most animals will be able to reburrow or move up through the sediment within hours or days so recovery is set at immediate. Intolerance to smothering by other factors such as oil may be higher.
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	Intermediate	High	**Low**	Moderate	Smothering by 5cm of sediment is likely to lead to the death of some of the organisms in the biotope. The populations of tube dwelling polychaete *Ampharete falcata* will probably be unable to feed or respire and will die. Some individuals may be able rise through the sediment but survival is probably dependent on the speed at which new tubes can be built. Some of the burrowing fauna, such as the *Amphiura* spp. brittlestars and *Nephrops norvegicus* and the small bivalve *Parvicardium ovale*, will not be affected by smothering beyond re-establishing burrow openings or moving up through the sediment. However, polychaete dominated communities in deep muddy habitats may be adversely affected. Kukert & Smith (1992) examined the effects of depositing artificial mounds of similar sediment, averaging 5-6 cm thick, on polychaete dominated communities in the Santa Catalina Basin at depths of 1240 m. All trophic groups exhibited a 32% reduction in abundance within the first four days but the macrobenthos reached background levels within 11 months, although community succession continued for 23 months (Kukert & Smith, 1992). Therefore, the overall impact of the factor on the biotope is likely to be the loss of a proportion of the polychaete species and intolerance is reported to be intermediate.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	High	Moderate	**Moderate**	Very low	Burrowing species are likely to be able to burrow through the extra layer of smothering sediment and resume their usual infaunal positions, although this would involve an energetic cost. Epifaunal foraminifera may not be able to burrow to the surface and at least a proportion of the population may be lost. However, little information on foraminiferans biology was found, and so it the absence of information an intolerance of high has been recorded, albeit with very low confidence. The biotope is likely to be more sensitive to smothering by viscous or impenetrable materials e.g. smothering by sediment of a coarser texture may affect burrowing and feeding. Loss of the characterising species of foraminifera would mean that the biotope is no longer COS.ForThy and so intolerance is high. Recoverability may only be moderate.
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Low	Very high	**Very Low**	Low	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 intolerance 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.
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Low	Immediate	**Not sensitive**	Moderate	The tube of *Lanice conchilega* rises several centimetres above the sediment surface. Ziegelmeier (1952) showed that the polychaete increased the height of the tube top with increasing sedimentation. It is therefore, unlikely that silt would smother the worm. For other polychaetes, such as *Magelona mirabilis*, that deposit feeds at the surface by extending contractile palps from its burrow, a layer of sediment would result in a temporary cessation of feeding activity. *Abra alba* and *Fabulina fabula* are shallow burrowers in sandy sediments. These bivalves require their inhalant siphons to be above the sediment surface for feeding and respiration. Smothering with 5 cm of

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						sediment would temporarily halt feeding and respiration and require the species to relocate to its preferred depth. Similarly, infaunal polychaete species would move up through additional sediment without adverse effect. Intolerance has been assessed to be low as relocation would be at energetic cost and feeding activity would be inhibited. Recovery has been assessed to be immediate. Smothering by viscous or impenetrable materials would be expected to have a more severe effect.
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Immediate	**Not sensitive**	Moderate	Smothering by 5 cm of sand is unlikely to adversely affect the important characterizing species, which are able to burrow. At the benchmark level intolerance 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 intolerance 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 if 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 might find conditions favourable for colonization and a transitional community may result and the biotope begin to change to another.
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	Tolerant	NR	Not sensitive	Moderate	The biotope is characterized by mostly burrowing species such as the heart urchin *Echinocardium cordatum*, razor shells *Ensis* sp., polychaete worms and bivalves and is therefore not sensitive to smothering by 5cm sediment as they should be able to burrow upwards. However, smothering by other material, especially oil, would result in the death of most species in the biotope.
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Tolerant	NR	Not sensitive	Low	The biotope is characterized by mostly burrowing bivalve species, polychaete worms, and macrofauna such as the heart urchin *Echinocardium cordatum* and brown shrimp, *Crangon crangon*. The biotope has been assessed not to be sensitive to smothering by 5 cm of additional sediment as the infauna should be able to burrow upwards (Schafer, 1972; Rees & Dare, 1993) or are sufficiently mobile to avoid the factor. However, a higher intolerance would be expected following smothering by other materials that are very viscous or impermeable.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	Low	Very high	**Very low**	Low	Species within the biotope are able to deal with small and temporary increases in silt deposition as they have the ability to self-clean. Depositions of thick silt, however, are likely to smother individuals to an extent where they are unable to self-clean or dig out and may leave the substratum unsuitable for recolonization. However, at the benchmark level an intolerance of low has been recorded. *Philine aperta* exhibits fast growth and reproductive rates. It could recolonize from other areas, as the species is common. Very little is known about the population dynamics and longevity of *Virgularia mirabilis* in Britain, however information from other species suggest that this species is likely to be slow growing with patchy and intermittent recruitment. Therefore, full recovery of this biotope and the important characterising species will take many years and so a score of moderate is reported.
IMX.An	Burrowing anemones in sublittoral muddy gravel	Intermediate	Moderate	**Moderate**	Low	Several species in the biotope, including the anemones, feed at the sediment surface and would be completely smothered by 5cm of sediment. Many of the species are able to move by a limited amount and may be able to rise above the smothering material. For example, *Cereus pedunculatus* can adapt to the accretion of silt by extending the column to maintain the disc at a level above the silt. However, it is also likely that some species may die and so intolerance is reported to be intermediate. See additional information for recovery.
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	Intermediate	High	**Low**	Low	*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 that 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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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 intolerance of the important characterising species, *Venerupis senegalensis*, intolerance 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 (see additional information).
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	Intermediate	High	**Low**	Moderate	The most likely smothering event in this habitat is by other species, for instance, a dense settlement of a colonial ascidian over other species. Some existing species such as barnacles are likely to be killed as access to food and oxygen will be denied. Others, such as erect Bryozoa and Hydrozoa will protrude above the smothering. Since the community will be partially destroyed and the diversity reduced, intolerance is considered intermediate. For recoverability see additional information below.
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	Low	High	**Low**	Low	Smothering by 5cm of sand is unlikely to adversely affect the important characterizing species that are able to burrow. However, it should be noted that biotope sensitivity is likely to be higher if the smothering sediment is atypical for the biotope e.g. fine silt or shingle, 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 the LGS.AEur biotope may start to shift to another community. The biotope would possibly not be recognized and therefore intolerance has been assessed to be high. Recovery has been assessed to be high on return to prior conditions (see additional information below).

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	Intermediate	High	**Low**	High	Although all of the species in the biotope are able to move within the substratum to some extent, some species live at specific depths and/or have to maintain contact with the surface. For instance, Ziegelmeier (1952) showed that *Lanice conchilega* increased the height of its tube top with increasing sedimentation so that it could continue feeding and respire. The bivalve *Cerastoderma edule* has short siphons and needs to keep in contact with the surface of the sediment. It will quickly burrow to the surface if covered by as little as 2 cm of sediment (Richardson *et al.*, 1993b) but Jackson & James (1979) reported that cockles buried under 10 cm of sediment were unable to burrow back to the surface and over a period of six days 83 % mortality was recorded. In the same experiment, most cockles buried to a depth of 5 cm were able to regain contact with the surface. In muddy substrata, all cockles died between three and six days. *Nephtys* species are highly mobile within the sediment. Vader (1964) observed that *Nephtys hombergii* relocated throughout the tidal cycle and is unlikely to be affected by smothering with sediment consistent with that of the habitat. Intolerance has been assessed to be intermediate as mortality of some cockles (especially smaller individuals) and probably other species may occur. At the benchmark level, the composition of the community would probably not alter to the extent that the biotope would not be recognized. In years of good cockle recruitment recovery of the population may occur within a year, however, recruitment tends to be sporadic (see *Cerastoderma edule*, reproduction) and may take longer in 'bad' years.
LMS.MS	Muddy sand shores	Intermediate	High	**Low**	High	Smothering with 5 cm of sediment for a month is unlikely to adversely affect species that can burrow through sediment, although it may clog the feeding apparatus suspension feeding organisms. Maurer (1981 cited by Hall, 1994) reports that mucous tube feeders and labial deposit feeders were most sensitive to burial, whereas epibenthic suspension feeders and boring species which could not tolerate addition of more than 1 cm of sediment. Infaunal non-siphonate suspension feeders escaped 5cm but were sensitive to less than 10 cm, whereas deep burrowing siphonate species could tolerate up to 50 cm. Moralities were higher when the smothering sediment was atypical of that area, e.g. fine silt on coarse sand, which would dramatically change the nature of the substratum and hence the communities present. Smothering by muds would encourage littoral mud communities to develop whereas coarse material would encourage littoral gravel communities, assuming they were not removed by the hydrographic regime. On return to prior conditions, recovery would depend on the surviving species and recruitment as above. *Cerastoderma edule* inhabit the top few cm of

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						sediment in LMS.Pcer and may be more sensitive to smothering that infaunal species.
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	Low	Very high	**Very Low**	Moderate	The important characterising species in the biotope are infaunal and capable of burrowing. Smith (1955) noted that when a population of *Hediste diversicolor* was covered with several inches of sand, the worms burrowed through the additional material and showed no adverse reaction. *Macoma balthica* is also a mobile species and is able to burrow upwards and surface from a depth of 5-6 cm (Brafield & Newell, 1961; Brafield, 1963; Stekoll *et al.*, 1980). It is possible that there would be an energetic cost related to the infauna relocating to their preferred depth and so intolerance is assessed as low. The energetic cost would be short lived so recoverability is assessed as very high. Ephemeral algae in the biotope would be smothered by a 5 cm layer of sediment and therefore, where they were present beforehand there would be a minor decline in biotope species richness.
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	Intermediate	Moderate	**Moderate**	Moderate	Some of the species in the biotope are upright and branching (e.g. *Axinella dissimilis* and *Eunicella verrucosa).* These species project above the substratum to sufficient height not to be covered completely by 5 cm of sediment and consequently may not be killed by smothering. Other more low lying or encrusting species (encrusting sponges, hydroids, bryozoans etc.) are more likely to be completely covered and will probably die. Many of the species are sessile and attached to the substratum so recovery of the population through immigration of adults is not possible. Mobile species such as the echinoderms and fish may be able to return more rapidly. *Pentapora fascialis* has some regenerative ability as well as good reproductive and recolonizing abilities. It has been recorded as recovering in 3.5 years after almost total loss of a local population (Cocito *et al*., 1998b). Some species such as *Nemertesia ramosa* are annuals and recruit readily over short distances. The long-lived slow growing and infrequently recruiting species are likely to survive smothering and the ones that are likely to be lost are also likely to recolonize within a few years. Recovery of the biotope as a whole is, however, likely to take more than five years. Therefore, a recovery score of moderate is suggested.
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Low	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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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. Although the biotope will probably survive smothering at the benchmark level, 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 *Alcyonium 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, an intolerance of intermediate is suggested to reflect the reduced species richness. Recoverability is likely to be high (see additional information). Prolonged smothering, however, is likely to favour biotopes dominated by *Urticina felina* (e.g. MCR.Urt.Urt).
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	Intermediate	Low	**High**	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 (see benchmark). *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 (see below), 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 intolerance of intermediate has been recorded. Hydroids and brittle stars may be more sensitive,

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						therefore, species richness is likely to decline. 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.
MCR.Mus	*Musculus discors beds* on moderately exposed circalittoral rock	High	Moderate	**Moderate**	Low	*Musculus discors* lives in fixed nests of byssus threads on the surface of the substratum. While the nest will protect the bivalve from the direct effects of smothering, they are unlikely to be able to burrow up through deposited spoil or other smothering agent. Smothered individuals will probably succumb to the effects of anoxia. Although, individuals on raised substrata such as the stipe of kelps may escape the effects of smothering, *Musculus discors* was considered highly intolerant. Large epifauna such as *Alcyonium digitatum, Nemertesia antennina,* large branching or globose sponges and anemones (e.g. *Urticina felina)* are unlikely to be adversely affected by smothering with 5 cm of sediment. But smaller or encrusting forms and some ascidians (e.g. *Clavelina lepadiformis)* may be adversely affected. Overall, loss of the *Musculus discors* population would result in loss of the biotope and a biotope intolerance of high has been recorded. Recoverability will depend on recruitment from adjacent or nearby population and may take many years (see additional information below).
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	Intermediate	High	**Low**	Moderate	Intertidal *Mytilus edulis* beds have been reported to suffer mortalities as a result on smothering by large scale movements of sand or sand scour (Holt *et al.*, 1998; Daly & Mathieson, 1977). Similarly, biodeposition within a mussel bed results in suffocation or starvation of individuals that cannot re-surface. Young mussels have been shown to move up through a bed, avoiding smothering, while many others were suffocated (Dare, 1976; Holt *et al.*, 1998). This suggests that a proportion of the population may be able to avoid smothering in subtidal conditions, and, therefore, a intolerance of intermediate has been recorded. Although, *Mytilus edulis* is highly fecund, larval mortality is high. Larval development occurs within the plankton over ca 1 month (or more), therefore, whilst recruitment within the population is possible, it is likely that larval produced within the biotope are swept away from the biotope to settle elsewhere. Therefore, recovery is dependant on recruitment from outside the biotope and a recoverability of high has been reported (see additional information below).

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	High	High	**Moderate**	Moderate	Dense populations of brittlestars do not persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines) and ultimately suffocate them (Schäfer, 1962 cited in Aronson, 1992). Therefore, smothering by 5cm of sediment is likely to result in the death of most individuals. Aronson (1989) refers to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively attributes this to increased sedimentation caused by the localized dumping of construction materials. Other species in the biotope such as the soft coral *Alcyonium digitatum* and the anemone *Metridium senile* project above the substratum so may not be completely covered with sediment but feeding structures may become clogged. Infaunal organisms are not likely to be significantly affected. However, with the loss of brittlestars the biotope no longer exists so intolerance is assessed as high. For recovery, see additional information.
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate	MCR.Urt is characteristic of areas subject to cover by coarse sediment. Holme & Wilson (1985) reported communities that were subject to periodic smothering by thin layers of sand, up to ca 5cm in the central English Channel. *Flustra foliacea*, hydroids such as *Nemertesia spp. and the anemone Urticina felina* were noted in their sand scoured communities which may have included examples of MCR.Urt.Cio. Smothering with a layer of sediment will prevent or reduce feeding and hence growth and reproduction. Although the biotope will probably survive smothering at the benchmark level, the species richness of the biotope will probably decline due to the loss of more sensitive species 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 intolerance of intermediate is suggested to reflect the reduced species richness. Recoverability is likely to be high (see additional information below) as the long-lived, slow growing species (*Ciocalypta penicillus* and *Urticina felina*) will most likely survive).

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	Intermediate	High	**Low**	Low	*Halidrys siliquosa* and laminarians are large and unlikely to be smothered by 5cm of sediment (see benchmark). Similarly, erect turf forming red and brown algae, e.g. *Furcellaria lumbricalis, Ahnfeltia plicata, Chondrus crispus, Dilsea carnosa, Dictyota dichotoma, and Delesseria sanguinea* are probably large enough to be unaffected. For example, *Ahnfeltia plicata* and *Furcellaria lumbricalis* are tolerant of sand cover (Dixon & Irvine, 1977). However, smaller or low lying algae may be adversely affected. Algal spores and propagules are adversely affected by a layer of sediment, which can exclude up to 98% of light (Vadas *et al.*, 1992), although the germlings of *Halidrys siliquosa* can survive darkness for up to 120 days. Germlings and juveniles are likely to be highly intolerant of smothering and any associated scour. A layer of sediment is likely to interfere with settlement and attachment of spores, especially if smothering occurred during winter reproductive maxima for the dominant species. Therefore, it is likely that while adult plants of most species will survive, smaller species and overall recruitment in the community may be adversely affected. Therefore, a intolerance of intermediate has been recorded. Algal recruitment within the community is likely to be rapid, so a recoverability of high has been recorded.
MIR.LsacChoR	*Laminaria saccharina, Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	Intermediate	High	**Low**	Moderate	The time of year at which smothering occurred would be important. Smothering at the time spores of colonizing species were settling might reduce their abundance significantly. However, once grown, the algae would protrude above silt. Other species such as encrusting seaweeds, tubeworms, and barnacles would be likely to survive under silt for the benchmark of three weeks although if de-oxygenation occurred it would cause mortality. For recoverability, see additional information.

Appendix 4c. Sensitivity of representative component biotopes to physical disturbance and abrasion

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	Intermediate	High	**Low**	Moderate	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 bivalves. The same is likely to occur to the venerids in the biotope. The echinoid, *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 intolerance is therefore recorded as intermediate. Recoverability is assessed as high (see additional information below). It is unlikely that any species would be eradicated from the biotope and hence there would be no change in species richness.
CMS.AbrNucC or	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Intermediate	High	**Low**	Moderate	The biotope is probably not generally subject to much human induced physical disturbance of the substratum because it does not support quantities of any infaunal commercial species. However, fishing for demersal species will disturb the surface layer of sediment and any protruding or shallow burrowing species. Shells of *Abra alba*, *Corbula gibba* and *Nucula nitidosa* are probably vulnerable to physical damage (e.g. by otter boards; Rumohr & Krost, 1991), but their small size relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals that pass through. Schafer (1972) noted that adults of *Lagis koreni* were incapable of re-constructing their delicate sand-tubes once removed from them, and that mortality following physical disturbance to the substratum, e.g. from trawl/tickler chain damage, is likely to be significant (de Groot & Apeldoorn, 1971). For other infaunal species that burrow deeper into the sediment, e.g. *Echinocardium cordatum*, immediate effects are dependant on the depth of penetration of an object, e.g. an anchor or fishing gear relative to the distribution of animals in the sediment. Houghton *et al.* (1971), Graham (1955), de Groot & Apeldoorn (1971) and Rauck (1988) refer to significant trawl-induced mortality of *Echinocardium cordatum*. Brittlestars such as *Ophiura albida* may be more tolerant of abrasion. Bergman & Hup (1992)

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						for example, found that beam trawling in the North Sea had no significant direct effect on small brittlestars. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. At the benchmark level of the dropping and dragging of an anchor and chain, intolerance has been assessed to be intermediate as mortality of important characterizing species may occur. However, the community is unlikely to change significantly and recovery is likely to be rapid owing to larval recruitment, e.g. *Abra alba* recovered to former densities following loss of a population from Keil Bay within 1.5 years, whilst *Lagis koreni* took only one year (Arntz & Rumohr, 1986). Such evidence suggests that recoverability of important characterizing species of the biotope would be high. However, the recovery of *Echinocardium cordatum* may take longer owing to recruitment that is frequently unsuccessful (Rees & Dare, 1993).
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Intermediate	High	**Low**	Moderate	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. 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 intolerance 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 may not be relevant to *Callianassa subterranea* because the species rarely leaves its burrows under normal circumstances and burrows are deep enough, sometimes up to 80 cm, 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,

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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 platessoides* 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 intolerance 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.
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	**Very low**	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. Sea pens retract slowly and are likely to be sensitive to abrasion by trawling for instance, that 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 reburrow but those that are damaged are likely to die. *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. 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). However, the densities of *Virgularia mirabilis* were similar in trawled and untrawled sites in Loch Fyne and no changes in sea pen density was observed after experimental trawling over a 18 month period in another loch (Howson & Davies, 1991; Tuck *et al*., 1998; Hughes, 1998). Hughes (1998) concluded that *Virgularia mirabilis* and *Pennatula phosphorea*, which can withdrawn into the sediment, were probably less susceptible to the effects of damage by fishing gear than *Funiculina quadrangularis*, which is unable to withdraw. In an investigation into the effect of shellfish traps on benthic habitats (Eno *et al*., 1996), creels were dropped on sea pens and left for extended periods to simulate the effects of smothering which could occur during commercial operations. The sea pens consistently righted themselves following removal

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						of the pots. 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 intolerance of *Amphiura filiformis* to abrasion and physical disturbance is recorded as low. Similarly, Bradshaw *et al.* (2002) reported that *Ophiura albida*, *Amphiura filiformis*, and *Ophiocomina nigra* increased in abundance in a long term study of the effects of scallop dredging. Therefore, the intolerance of the biotope is also reported to be .low. Recoverability is probably very high (see additional information)
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	Intermediate	High	**Low**	High	The CMU.BriAchi biotope can be affected by fishing activity in areas such as the northern Irish Sea, where the community may also contain *Nephrops norvegicus* (Mackie *et al.*, 1995). Where intense benthic dredge fishing activity occurs populations of *Brissopsis lyrifera* may be reduced. Brittlestars have fragile arms, which are likely to be damaged by abrasion or physical disturbance. *Amphiura chiajei* burrows in the sediment and extends its arms across the sediment surface to feed. Ramsay *et al.*, (1998) suggests that *Amphiura* species may be less susceptible to beam trawl damage than other species of echinoid 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 brittlestars. Brittlestars can tolerate considerable damage to arms and even the disc without suffering mortality and are capable of disc and arm regeneration so their recovery is likely to be rapid. Deeper burrowing crustaceans such as *Calocaris macandreae* may occasionally be displaced from burrow openings by towed gear (Atkinson, 1989). During long term monitoring of fishing disturbance on the Northumberland coast Frid *et al.* (1999) observed a decrease in the numbers of sedentary polychaetes, echinoid echinoderms, and large (> 50 mm) brittlestars. Fishing disturbance is a more intense disturbance than the benchmark level (an anchor) and is likely to affect the species composition of the biotope and so intolerance is assessed to be intermediate. Recovery is likely to be high, as members of the community are likely to remain and be able to repopulate.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
CMU.SpMeg	Seapens and burrowing megafauna in circalittoral soft mud	Intermediate	High	**Low**	Moderate	The biotope is subject to much physical disturbance because it supports a major fishery for one of its characteristic species, *Nephrops norvegicus*. Information on the effects of trawling on the other fauna in the biotope is limited but it is likely that the deep burrowing species such as the crustaceans *Callianassa subterranea* and *Jaxea nocturna* and the echiuran worm *Maxmuelleria lankesteri* and some burrowing fish will be little affected by this type of disturbance. Individual burrowing crustaceans may occasionally be displaced from burrow openings by towed gear (Atkinson, 1989). However, the animals will be able to re-establish burrow openings if these become blocked so recovery would be immediate. Of the three sea pen species, *Funiculina quadrangularis* is likely to be the most sensitive to abrasion and disturbance because it has a long brittle stalk and is unable to retract into the sediment. However, experimental studies have shown that all three species can re-anchor themselves in the sediment if dislodged by fishing gear and Eno *et al*. (1996) found that even if damaged *Funiculina quadrangularis* appeared to remain functional and this could also be true of the other sea pens. However, the apparent absence of *Funiculina* from open-coast *Nephrops* grounds may be a consequence of its susceptibility to trawl damage (D.W. Connor, pers. comm. in Hughes, 1998). In long term experimental trawling Tuck *et al.* (1998) found no effect on *Virgularia mirabilis* populations and Kinnear *et al.* (1996) found that sea pens were quite resilient to being smothered, dragged or uprooted by creels. The investigation by Tuck *et al* (1998) examined the effects of extensive and repeated experimental trawl disturbance on whole benthic communities over an 18 month period in a Scottish loch that had previously been un-fished for 25 years. The subsequent patterns of recovery over a further 18 -month period were also investigated. Trawling disturbance resulted in reduced species diversity and a disproportionate increase in the abundance of a few dominant species, in particular the opportunistic polychaetes *Chaetozone setosa* and *Caulleriella zetlandica*. 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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						fish, *Hippoglossoides platessoides*, 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). Scavenging species such as *Liocarcinus depurator*, *Pagurus bernhardus* and *Asterias rubens* might be expected to benefit from fishing disturbance, through increased food availability. Kaiser & Spencer (1994) found that benthic disturbance by fishing gear caused an increase in the density of epifaunal scavengers, in response to an increase in food availability in the form of damaged and disturbed organisms. The long term effects on infauna were still noticeable after 18 months and short- term effects on epifauna recovered 6 months after fishing ceased. During long term monitoring of fishing disturbance on the Northumberland coast Frid *et al*. (1999) observed a decrease in numbers of sedentary polychaetes, echinoid echinoderms and large (>50mm) brittlestars. Observations of the effects of *Nephrops* trawl fishing in the North Sea led Ball *et al.* (2000) to suggest that the bivalves *Corbula gibba* and *Thyasira flexuosa* were sensitive to fishing disturbance. Thus, it appears that abrasion and physical disturbance, such as that caused by fish trawling, is likely to affect the species composition of the biotope and so intolerance is assessed as intermediate.
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	Intermediate	High	**Low**	Low	Fauna that inhabit or construct tubes, such as *Ampharete falcata* are likely to be particularly vulnerable to damage or disturbance by beam trawls (Kaiser & Spencer, 1996). The biotope is also likely to be sensitive to abrasion at the level of the benchmark, a force equivalent to an anchor being dragged along the bottom. However, it is not expected to remove the whole population of *Ampharete* spp. in the biotope and so intolerance is reported to be intermediate. 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. See additional information for recovery.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	Intermediate	High	**Low**	High	Abrasion is likely to damage or result in death of some individuals of the characteristic species of the biotope. For instance, *Thyasira* sp. are small bivalves, the shells are thin and fragile and abrasion is likely to cause death. Residing 2 cm below the sediment surface means that they are susceptible to abrasive damage. However, some of the impact of physical disturbance will displace individuals without killing them allowing for recovery. Sparks-McConkey & Watling (2001) found that trawler disturbance resulted in a decline of *Thyasira flexuosa* in Penobscot Bay, Maine. However, the population recovered after 3.5 months. Brittlestars have fragile arms which are likely to be damaged by abrasion or physical disturbance. *Amphiura chiajei* burrows in the sediment and extends its arms across the sediment surface to feed. Ramsay *et al.* (1998) suggested that *Amphiura* sp. may be less susceptible to beam trawl damage than other species of echinoid or tube dwelling amphipods and polychaetes. Brittlestars can tolerate considerable damage to arms and even the disc without suffering mortality and are capable of disc and arm regeneration. Whilst a proportion of *Thyasira* sp. and some other species would probably die and other species important within the biotope may be damaged, many individuals would be displaced or suffer damage that can be repaired. Intolerance has been assessed to be intermediate. Recoverability is probably high (see additional information below).
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Intermediate	High	**Low**	Low	Despite their robust body form, bivalves are vulnerable to physical abrasion. For example, due to of dredging activity, mortality and shell damage have been reported in *Mya arenaria* and *Cerastoderma edule* (Cotter *et al.*, 1997). The benchmark level of physical abrasion is less severe; for example, the dragging of an anchor. However, venerid bivalves are generally shallow burrowers and *Fabulina fabula* has a fragile shell (Fish & Fish, 1996). The bivalves, which 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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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 intolerance is assessed as intermediate. Recoverability is recorded as high (see additional information below). Particularly vulnerable forms, such as the epifaunal echinoderms, may be eliminated so there may be a minor decline in species richness in the biotope.
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	Intermediate	High	**Low**	Low	*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, as a result of dredging activity, mortality and shell damage has been reported in *Mya arenaria* and *Cerastoderma edule* (Cotter *et al.*, 1997). However, the benchmark level of physical abrasion is less severe. The most sensitive species identified was *Echinocardium cordatum*, which 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 high fecundity, normally reproduces every year, and has pelagic larvae so recovery would be expected. Intolerance 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 (see additional information below).
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Low	Very high	**Very Low**	Low	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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						physical disturbance can be responsible for the deterioration of infaunal polychaete populations. However, such disturbance is greater than that of the benchmark and intolerance has been assessed to be low with a very high recoverability.
IMS.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore or shallow sublittoral muddy fine sand.	High	Moderate	**Moderate**	Moderate	The two key species in the biotope, *Echinocardium cordatum* and *Ensis ensis*, are very sensitive to abrasion and physical disturbance. Abrasion from dredges for example is likely to damage or kill individuals. For example, Eleftheriou & Robertson (1992) observed large numbers of *Ensis ensis* killed or damaged by dredging operations and a substantial reduction in the numbers of *Echinocardium cordatum* due to physical damage. Gaspar *et al*. (1998) also reports high levels of damage in *Ensis siliqua* from fishing. Some other bivalve and crustacean species are also likely to be killed and damaged by physical disturbance so the intolerance of the biotope as a whole is high. Recovery is likely to be moderate because although the individual key species may recolonize the area within five years several of the species are very long-lived and so the biotope may take longer to return to original age-structure and species diversity.
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	Low	High	**Low**	Moderate	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 per m^2). Therefore intolerance at the benchmark level has been assessed to be low and the biotope would not be changed. Recoverability has been assessed to be high (see additional information). However, the biotope may be subjected to more intense abrasive / physical disturbance from otter and beam trawls used to capture the brown shrimp, *Crangon crangon*. However, 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 that 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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						would have a higher sensitivity to factors causing more intense abrasion / physical disturbance in comparison to the benchmark level.
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	Intermediate	Very high	**Low**	Low	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 passing scallop dredge. Physical disturbance by a passing dredge will also break up the structure of the surface sediment. Biotope intolerance 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 or on-going physical disturbance, intolerance will be more similar to 'substratum removal' above.
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	Low	Very high	**Very Low**	Low	The important characterizing species associated with this biotope can retract into the sediment and displaced individuals that are not damaged will reburrow. *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. 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). However, the densities of *Virgularia mirabilis* were similar in trawled and untrawled sites in Loch Fyne and no changes in sea pen density was observed after experimental trawling over a 18 month period in another loch (Howson & Davies, 1991; Tuck *et al.*, 1998; Hughes, 1998). Hughes (1998) concluded that *Virgularia mirabilis* and *Pennatula phosphorea*, which can withdrawn into the sediment, were probably less susceptible to the effects of damage by fishing gear than *Funiculina quadrangularis*, which is unable to withdraw. In an investigation into the effect of shellfish traps on benthic habitats (Eno *et al.*, 1996), creels were dropped on sea pens and left for extended periods to simulate the effects of smothering which could occur during commercial operations. The sea pens consistently righted themselves following removal of the pots. However, predation may increase and the viability of a population may be reduced whilst regeneration occurs.

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
IMX.An	Burrowing anemones in sublittoral muddy gravel	Low	Immediate	**Not sensitive**	Moderate	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 mitchellii*, within and alongside dredge paths were similar to pre-dredge levels several weeks later. Thus, it seems likely that the biotope will have low intolerance 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.
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	Intermediate	High	**Low**	Low	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, as a result 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 intolerance is recorded as intermediate and species richness may suffer a minor decline. Recoverability is assessed as high (see additional information below).
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	Low	High	**Low**	Moderate	Abrasion is unlikely to affect the infaunal species of this biotope. Species such as amphipods and isopods may be small enough to avoid damage. The tops of polychaete burrows may be damaged and repaired subsequently at energetic cost to their inhabitants In other biotopes represented by this review, the bivalve, *Angulus tenuis*, may be abundant and is an important food source for young plaice. This brittle bivalve may be damaged by abrasion from objects impacting and dragging through the sand, therefore LGS.AP, LGS.AP.P, and LGS.AP.Pon may be more sensitive than the LGS.AEur biotope, but intolerance has been assessed to be low. Recovery has been assessed to be high as a proportion of the tellin population is likely to remain undamaged and it breeds annually.
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	Intermediate	Very high	**Low**	Moderate	*Lanice conchilega* inhabits a permanent tube and is likely to be damaged by any object that penetrates or drags through the sediment, as are all other infaunal polychaetes. For instance, Ferns *et al.* (2000) recorded significant losses of common infaunal polychaetes from areas of muddy sand worked with a tractor-towed cockle harvester; 31% of the polychaete *Scoloplos armiger* (initial density of 120 per m²) and 83% of *Pygospio elegans* (initial

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						density 1850 per m²) were removed. The population of *Pygospio elegans* remained depleted for more than 100 days after harvesting, whilst those of *Nephtys hombergii*, *Scoloplos armiger*, and *Bathyporeia* spp. were depleted for over 50 days. In locations of cleaner sand with lower densities of *Cerastoderma edule* and dense aggregations of *Lanice conchilega*, recovery occurred more rapidly. Cockles are often damaged during mechanical harvesting, e.g. 5-15% were damaged by tractor dredging (Cotter *et al*, 1997) and ca 20% were too damaged to be processed after hydraulic dredging (Pickett, 1973). However, abrasion during harvesting is more extreme than the benchmark level. Abrasion due to a passing scallop dredge is likely to result in less damage to the population and an intolerance of intermediate is reported. Recoverability has been assessed to be very high.
LMS.MS	Muddy sand shores	Low	Very high	**Very Low**	Very low	Abrasion is unlikely to affect infaunal species. Epibenthic species such as amphipods and isopods may be mobile and small enough to avoid damage. The tops of burrows may be damaged and repaired subsequently at energetic cost to their inhabitants. *Cerastoderma edule* lives in the top few centimetres of sediment and cockle beds may be damaged by abrasion, therefore LMS.Pcer may be more sensitive than other LMS.MS biotopes.
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	Intermediate	High	**Low**	Low	The infaunal polychaetes in the biotope, including *Hediste diversicolor*, have a fragile hydrostatic skeleton, and are therefore vulnerable to damage by physical abrasion. An anchor dragging at the sediment surface may damage fragile feeding structures and/or penetrate the soft substratum sufficiently to impact the infauna. The bivalves in the biotope, although more robust, are also vulnerable to physical abrasion. For example, damage caused by mechanical harvesting has been reported in *Cerastoderma edule* (Pickett, 1973; Cotter *et al*., 1997). It is likely that some mortality would occur and therefore intolerance is assessed as intermediate, though species richness would be unlikely to decline. Recoverability is recorded as high (see additional information below).
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	High	Low	**High**	Moderate	The three selected key or important characterising species in this biotope are highly or intermediately sensitive to abrasion. Other species in the biotope that are upright and protrude above the substratum will also be damaged or killed by abrasion (e.g. hydroids, branching and cup sponges etc. also mobile surface species that are not fast movers, *Echinus esculentus* for example. *Pentapora foliacea* has good reproductive and recolonizing abilities. It has been recorded as recovering in 3.5 years after almost total loss of a local population (Cocito *et al*., 1998b). *Eunicella verrucosa* is long lived, slow growing, and little is known of its reproduction. Sponges are

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						often slow growing and long lived. Little is known of the reproduction and recruitment mechanisms in *Axinella dissimilis* or other sponges. Recovery of some parts of this community and biotope may take a long time. Other species are annuals and may have long-lived widely dispersing larvae. Many of the species in the biotope (including the 3 selected characterising species) have permanent attachments to the substratum so immigration of adults into the biotope is not possible. Mobile species such as the echinoderms and fish will be able to return more rapidly.
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate	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 matrices 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 (see above). 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 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)

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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, an intolerance of intermediate has been recorded. Recoverability is likely to be high due to repair and regrowth of hydroids and bryozoans (e.g. *Flustra foliacea*), and recruitment within the community from surviving colonies and individuals (see additional information below).
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	High	Low	**High**	Moderate	*Modiolus modiolus* is large and relatively tough. 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 queen trawling 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 but 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

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						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. Disruption of the clumps or beds may result in loss of horse mussels, and together with the apparent intolerance of epifauna suggested above, an overall intolerance 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 (10-25years) has been recorded.
MCR.Mus	*Musculus discors* beds on moderately exposed circalittoral rock	Intermediate	High	**Low**	Low	*Musculus discors* has a reasonably tough shell but it is likely that physical disturbance at the benchmark level would physically remove some individuals from their substratum and break the shells of some individuals, depending on their size. Disturbance of the cohesive mat of individuals may strip away tracts of the biotope or create gaps or 'edges' that may allow peeling away of the *Musculus discors* mat by tidal streams or wave action. *Musculus discors* may be affected indirectly by physical disturbance that removes macroalgae to which they are attached. Erect epifaunal species are particularly vulnerable to physical disturbance. Hydroids and bryozoans are likely to be uprooted or damaged by bottom trawling or dredging and bryozoans repair damage slowly (Holt *et al.*, 1995). Veale *et al.* (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort. 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* were more sensitive than the horse mussels themselves and reflected early signs of damage. Overall, physical disturbance at the benchmark level may remove or damage a proportion of the *Musculus discors* bed and its associated epifauna. Therefore, a intolerance of intermediate has been recorded. Recovery will probably take up to 5 years (see additional information). Large scale physical disturbance effects (e.g. from mobile fishing gear) may be more

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						akin to substratum removal (see above).
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	Intermediate	High	**Low**	Low	Wave driven logs have been reported to influence *Mytilus edulis* populations, causing the removal of patches from extensive beds that subsequently open the beds to further damage by wave action (Holt *et al*., 1998). A similar effect could be caused by a vessel grounding. Little information on physical disturbance in subtidal *Mytilus* spp. beds was found. Fishing activities, e.g. scallop dredging, are know to physically disturb marine communities. However, benthic trawls tend to avoid rough ground, such as reefs and rocky areas. *Modiolus modiolus* beds have been reported to have declined off the Isle of Man due to scallop dredging, presumably because the scallop dredging activity had damaged the edges of denser beds over time (Jones, 1951; Holt *et al*., 1998). Benthic trawls, where they occur, may affect *Mytilus edulis* beds similarly. Scallop dredging and otter trawls have also been reported to damage *Alcyonium digitatum* (Hartnoll, 1998; Holt *et al*., 1998). Starfish, such as *Asterias rubens* have been reported to be damaged by benthic dredges, but have considerable regenerative capability, and, as scavengers, benefit from the presence of other damaged or killed animals (Emson & Wilkie, 1980; Gubbay & Knapman, 1999). Therefore, it is likely that abrasion or impact at the level of the benchmark (a boat anchor being dragged through or landing on the population) would damage or remove patches of the population and a intolerance of intermediate has been recorded. Recovery is dependant on recruitment of *Mytilus edulis* from outside the biotope and a recoverability of high has been reported (see additional information below).
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	Intermediate	High	**Low**	Moderate	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 biotope. Brittlestars have fragile arms that are likely to be damaged by abrasion. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration (Sköld, 1998). Fishermen tend to avoid brittlestar beds since the animals clog their nets (Jones *et al*., 2000). However, a passing scallop dredge is likely to remove, displace, or damage brittlestars caught in its path. Although several species of brittlestar are reported to increase in abundance in trawled areas, Bradshaw *et al* (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long term in areas subject to scallop dredging. Overall, a proportion of the population is likely to be damaged or

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						removed and an intolerance of intermediate has been recorded. *Asterias rubens* is also able to tolerate the loss of one or more arms. Although individuals can survive loss of one or more arms, the viability of a population with a high index of arm damage may be reduced as nutritional resources are used for repair and growth at the expense of gametogenesis. An average of 36% of individuals in five British brittlestar beds were regenerating arms (Aronson, 1989). Significant impacts in population density would be expected if such physical disturbance were repeated at regular intervals. Other species, particularly sessile fauna such as *Alcyonium digitatum* and *Metridium senile* may be sensitive to physical damage. Recoverability of the biotope will be high as remaining brittlestars re-orientate to fill in spaces and create new patches. However, component species may take some years to recolonize.
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid circalittoral rock	Intermediate	High	**Low**	Low	The key structural species (*Sabellaria spinulosa*) and other selected important or characterizing species (*Urticina felina*, *Ophiothrix fragilis*, *Mytilus edulis*) that may be found in the biotope have intermediate intolerance to this factor. Abrasion may cause damage to or loss of some of the *Sabellaria spinulosa* crust and organisms that live on or in it. *Sabellaria spinulosa* has a long -lived larva with good dispersive ability and can recruit readily although this can be affected by environmental conditions. Recruitment may be aided by the presence of adults and/or empty tubes, which form a preferred substratum (Wilson, 1929).

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Intermediate	High	**Low**	Moderate	The species that characterize this biotope are tolerant of sediment scour but may be damaged by the impact of a hard surface such as an anchor or dredge. 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) whilst the upper surfaces at least of cushion sponges mat be ripped off. Veale *et al.* (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort. Colonies of ross (*Pentapora fascialis*) are likely to be particularly sensitive and will be broken by slight impact from a hard object. Hydroid and bryozoan matrices 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 (see above). 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) and 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. The characterising species will be injured but not, in the main, lost. Therefore, an intolerance of intermediate has been recorded. Recoverability is likely to be high due to repair and regrowth of hydroids and bryozoans (e.g. *Pentapora fascialis*), and recruitment within the community from surviving colonies and individuals or parts of sponges and bryozoans left behind.
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	Intermediate	High	**Low**	Low	This biotope is characterized by species tolerant of sediment abrasion, suggesting a tolerance of abrasion. However, physical disturbance by, e.g., an anchor (see benchmark) is likely to damage fronds and may remove some individuals, especially large macroalgae such as *Laminaria saccharina*. Therefore, an intolerance of intermediate has been recorded. Loss of the distal parts of the plants may entail loss of the epiphytes, resulting in loss of

Biotope code	Biotope name	Intolerance	Recovery	Sensitivity	Confidence	Explanation
						species richness. Recovery may be rapid, especially where the holdfasts or encrusting forms of species remain (e.g. *Chondrus crispus* or *Ahnfeltia plicata*) and has been assessed as high. Large -scale physical disturbance, such as dredging, will have an impact similar to substratum removal (see above).
MIR.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	Intermediate	High	**Low**	Moderate	The biotope exists because of physical disturbance of mobile substrata. The community is likely to be destroyed by severe storms but will regenerate the following spring when conditions of wave action usually settle down. It might be that the biotope develops in a largely undisturbed way until the next severe storm, perhaps after several years. If disturbance occurs 'out-of-season', the biotope will be adversely affected for the remainder of the year. '

Appendix 5. Recoverability information for representative component biotopes.

Biotope code	Biotope name	Recoverability information
CGS.Ven	Venerid bivalves in circalittoral coarse sand or gravel	The venerid bivalves in the biotope reach sexual maturity within 2 years, spawn at least once a year and have a pelagic dispersal phase (Guillou & Sauriau, 1985; Dauvin, 1985). No information was found concerning number of gametes produced but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). Their powers of recoverability are therefore likely to be high and it is expected that, following mortality, the populations would recover within 5 years. The purple heart urchin, *Spatangus purpureus*, is a broadcast spawner and disperses via a pelagic larva (Fish & Fish, 1996). It is likely that recoverability would be similar to another heart urchin, *Echinocardium cordatum*. The first repopulation of *Echinocardium cordatum* following the *Torrey Canyon* oil spill was recorded after two years (Southward & Southward, 1978). However, Buchanan (1967) observed that recruitment was sporadic, occurring in only 3 years out of 10. For all the shallow burrowing infauna, an important factor contributing to recoverability may be bedload sediment transport (Emerson & Grant, 1991). It has been demonstrated to account for changes in densities of the clam, *Mya arenaria*, and suggested that it may affect recruitment in other infaunal bivalves and polychaetes (Emerson & Grant, 1991). Based on the likely recoverability of the venerid bivalves, recoverability of the biotope is assessed as high.
CMS.AbrNucCor	*Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	*Abra alba* and *Macoma balthica* demonstrate an 'r' type life-cycle strategy and are able to rapidly exploit any new or disturbed substratum available for colonization through larval recruitment, secondary settlement of post-metamorphosis juveniles or redistribution of adults. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976 the *Macoma balthica* population had recovered to 51 individuals/m². One year later, there was no detectable difference in the *Macoma balthica* population between the recently dredged area and a reference area elsewhere in the bay. In 1976, 2 generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to 6 generations were identified, giving further evidence of active immigration to the dredged area. *Abra alba* recovered to former densities following loss of a population from Keil Bay owing to deoxygenation within 1.5 years whilst *Lagis koreni* took only one year (Arntz & Rumohr, 1986). However, the recovery of *Echinocardium cordatum* may take longer owing to recruitment that is frequently unsuccessful (Rees & Dare, 1993).
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	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

Biotope code	Biotope name	Recoverability information
		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.
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	No evidence on community development was found. Very little is known about the population dynamics and longevity of *Virgularia mirabilis* in Britain. However, information from other species suggest that this species is likely to be slow growing with patchy and intermittent recruitment and so recovery from loss of this species is likely to longer than five years. The other key species, *Amphiura filiformis* and *Pecten maximums* are also long lived and take a relatively long time to reach reproductive maturity. It takes approximately 5-6 years for *Amphiura filiformis* to grow to maturity so population structure will probably not reach maturity for at least this length of time. In addition, Muus (1981) shows the mortality of new settling *Amphiura filiformis* to be extremely high with less than 5% contributing to the adult population in any given year. *Pecten maximus* reaches sexual maturity within the first two to three years and has a life span of 10-20 years. The suggested life span for *Ophiura ophiura* in the west of Scotland was 5-6 years (Gage, 1990). Many of the other species in the biotope, such as polychaetes and bivalves, are likely to reproduce annually, be shorter lived and reach maturity much more rapidly. However, because the key species in the biotope, *Virgularia mirabilis* and *Amphiura filiformis* are long lived and take several years to reach maturity the time for the overall community to reach maturity is also likely to be several years, possibly in the region of 5-10 years. Thus, a score of moderate is reported for recovery from loss of key species in the biotope.
CMU.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud	The biotope is likely to have a moderate capacity for recovery. The burrowing megafauna that characterise the biotope vary in their reproductive strategies and longevity. *Brissopsis lyrifera* is short lived (4 years) but is fecund and has shown clear evidence of successful and consecutive annual recruitment (Buchanan, 1967). Individuals become sexually mature in their forth year. *Amphiura chiajei* is longer lived than *Brissopsis lyrifera* and reaches sexual maturity in its forth year, thus the population structure of these species will not reach maturity for at least this length of time. Once established, a cohort of *Amphiura chiajei* can dominate a population, even inhibiting its own consecutive recruitment, for up to 10 years. Time to reach sexual maturity is longer in *Nephrops norvegicus,* about 2.5 - 3 years and for the very long-lived *Calocaris macandreae* individuals off the coast of Northumberland did not become sexually mature until five years of age, and produced only two or three batches of eggs in their lifetime. In the biotope, polychaetes account for the vast proportion of the biomass, and these are likely to reproduce annually, be shorter lived and reach maturity much more rapidly. Most of the characterizing species reproduce regularly but recruitment is often sporadic owing to interference competition with established adults of the same and other species. However, owing to the fact that the characterising species take between 3 and 5 years to reach sexual maturity, it is likely that the time for the overall community to reach a fully diverse state will also be several years. It is likely that the low-energy hydrodynamic regime is an important factor in the maintenance of stable benthic populations in this biotope, as larvae are retained in the vicinity of the parent population.
CMU.SpMeg	Sea pens and burrowing megafauna in circalittoral soft mud	Nothing is known about the life cycle and population dynamics of British sea pens. Data from *Ptilosarcus guerneyi* in the USA suggests that sea pens may live up to 15 years, take 5-6 years to reach sexual maturity and produce large numbers of eggs and larvae (up to 200, 000). However, larval settlement was patchy in time and space, with no effective recruitment in some years resulting in a sub-divided population made up of overlapping patches of different size classes (Hughes, 1998). The burrowing megafauna in the biotope vary in their longevity

Biotope code	Biotope name	Recoverability information
		and reproductive strategies and some species do not reach sexual maturity for several years. *Calocaris macandreae*, for example, does not reproduce until five years old. Therefore, it seems likely that a community of sea pens and burrowing megafauna may take longer than five years to recover and so a recoverability score of moderate is reported
COS.AmpPar	*Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy very fine sand near margins of deep stratified seas	If the total population of the polychaete *Ampharete falcata* has been removed, recovery of the biotope will probably be very poor. Populations are often separated by great distances and recruitment from other populations is unlikely because the dispersal potential of larvae is restricted because the larvae are benthic. Thus, if total populations are lost recovery has been recorded as moderate. It is possible that other ampharetid polychaetes such as *Melinna critata* may replace *Ampharete* spp. so a functionally similar biotope could develop in a much shorter period. If some adults remain in the biotope after a perturbation, recovery will be more likely and would be recorded as high because local recruitment from benthic larvae can take place to return populations to previous abundance. The other key species in the biotope, *Parvicardium ovale*, is very widespread and reproduces every year so populations would be more likely to recover from loss. Other species such as the brittlestars are also very widespread and populations should recover within five years.
COS.ForThy	Foraminiferans and *Thyasira* sp. in deep circalittoral soft mud	Little is known about the mode of reproduction, growth rate and recoverability of foraminifera. In the absence of such information, assessment of recovery potential has to be precautionary and may be more than five years. All other characteristic species within the biotope are fecund and species such as polychaetes and brittlestars are likely to recover fairly quickly. However, the larval development of *Thyasira equalis* is lecithotrophic and the pelagic stage is very short or quite suppressed. This agrees with the reproduction of other *Thyasira* sp.. In some cases (*Thyasira gouldi*) no pelagic stage occurs at all (Thorson, 1946). This means that larval dispersal is limited. If mortality of *Thyasira* sp. occurs, there would have to be nearby populations for recovery to occur. Where some individuals survive, because larvae spend little or no time in the water column, post-settlement survival may be higher, and the population may be able to recover. It is also possible that adults could be brought into the area by bedload transport, enabling colonization for example: • after a decline in the abundance of *Thyasira flexuosa* in Penobscot Bay, Maine, after trawler disturbance, populations were reported to recover within 3.5 months (Sparks-McConkey & Watling, 2001); • although deoxygenation of bottom waters between 1979 and 1980, resulted in the depletion of *Thyasira equalis* and *Thyasira sarsi* from 550/m² to almost zero, by 1987 200/m² were present (Dando & Spiro, 1993). Overall and particularly bearing in mind the lack of information on foraminiferans, recovery of the biotope following catastrophic loss may be only moderate or possibly low.
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Niermann *et al.* (1990) studied the recovery of a fine sand *Fabulina fabula* community from the German Bight following a severe hypoxia event. Re-establishment of faunal composition took approximately 8 months, but biomass did not fully recover for approximately 2 years. However, some of the climax species, including *Fabulina fabula*, were the least affected by the hypoxia and therefore did not limit the recovery of the biotope. Diaz-Castaneda *et al.* (1989) studied the colonization of defaunated sediments from a *Venus* community in Dunkerque Harbour, France. The number of species in the experimental substrata increased progressively and reached a stabilized value similar to the number in the surrounding community within 13 to 17 weeks in spring and summer and 16 to 24 weeks in autumn and winter. It was noted

Biotope code	Biotope name	Recoverability information
		that biomass took much longer to recover than species richness, as most colonizers were young and small. Indeed, larval recruitment accounted for 70% of colonizers, suggesting that biotope recoverability is likely to be governed by larval dispersal rather than migration of adults. The last species in the successional sequence to establish themselves were equilibrium species such as *Fabulina fabula, Nephtys hombergii* and venerid bivalves. The life history characteristics of the species that characterize the biotope suggest that the biotope would recover from major perturbations within 5 years. Experimental studies support this conclusion and hence biotope recoverability is assessed as high. As biotope recoverability is largely dependent on larval recruitment, recoverability is not likely to be significantly more rapid in instances of intermediate biotope intolerance versus high intolerance.
IGS.Lcon	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand	The life history characteristics of the polychaete and bivalve species that characterize the biotope suggest that the biotope would recover from major perturbations within five years. For instance; • *Lanice conchilega* spends up to 60 days in the plankton and could disperse over a wide area. Heuers & Jaklin (1999) found that areas with adult worms or artificial tubes were settled and areas without these structures were not. Strasser & Pielouth (2001) reported that larvae were seen to settle in areas where there were no adults but took 3 years to re-establish the population. Recoverability is, therefore, probably quicker in areas that already had a population of *Lanice conchilega* but would occur in suitable substratum within only a few years even in the absence of existing populations. • *Abra alba* demonstrates a considerable capacity for recovery. *Abra alba* spawns at least twice a year over a protracted breeding period, during which time an average sized animal of 11 mm can produce between 15, 000 and 17,000 eggs. Such egg production ensures successful replacement of the population, despite high larval mortality, which is characteristic of planktonic development. Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month (Dauvin & Gentil, 1989), in which time the larvae may be transported over a considerable distance. Whilst some larvae may settle back into the parent population, the planktonic presettlement period is important for dispersal of the species and spatial separation from the adults also reduces the chances of adult induced mortality on the larvae through adult filter feeding (Dame, 1996). In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting (Sigurdsson *et al.*, 1976, see adult distribution) and probably bedload transport (Emerson & Grant, 1991). Niermann *et al.* (1990) studied the recovery of a fine sand *Fabulina fabula* community from the German Bight following a severe hypoxia event. Re-establishment of faunal composition took approximately 8 months, but biomass did not fully recover for approximately 2 years.
IGS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	Subtidal sandbanks are the result of relatively high energy conditions and experience regular episodes of natural disturbance by distruption of the prevailing hydrographic regime. The ability of the community to recover from physical disturbance is likely to be very high or immediate in some instances, because the component species, errant polychaetes and small crustaceans, are highly mobile, tolerant of sediment movement and would accompany the influx/re-settlement of disturbed material. Sherman & Coull (1980) observed that meiofaunal recolonization occurred within a few days owing to recruitment from hyperbenthic populations. The attainment of typical densities of macrofauna would also be dependant to some extent on the timing of disturbance in relation to reproductive period, which for many of the macrobenthos occurs over a discrete period of the year

Biotope code	Biotope name	Recoverability information
IGS.NeoGam	*Neomysis integer* and *Gammarus* spp. in low salinity infralittoral mobile sand	No evidence concerning community development was found. However, it is expected that the community, which consists entirely of swimming species, could establish very rapidly as migration from other populations would occur in addition to any larval recruitment. The length of time for recruitment to occur might be a few hours but 'maturity' would not be expected for several weeks in the case of extensive defaunation of the substratum. Recoverability has therefore been assessed to be very high in general.
IMS.MacAbr	*Macoma balthica* and *Abra alba* in infralittoral muddy sand or mud	The life history characteristics of the species that characterize the biotope suggest that the biotope would recover from major perturbations within 5 years. For instance, *Abra alba* and *Macoma balthica* demonstrate an 'r' type life-cycle strategy and are able to rapidly exploit any new or disturbed substratum available for colonization through larval recruitment, secondary settlement of post-metamorphosis juveniles or re-distribution of adults. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976 the *Macoma balthica* population had recovered to 51 individuals/m². One year later, there was no detectable difference in the *Macoma balthica* population between the recently dredged area and a reference area elsewhere in the bay. In 1976, 2 generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to 6 generations were identified, giving further evidence of active immigration to the dredged area. *Abra alba* recovered to former densities following loss of a population from Keil Bay owing to deoxygenation within 1.5 years as did *Lagis koreni*, taking only one year (Arntz & Rumohr, 1986). Such evidence suggests that recoverability of the key functional and important characterizing species of the IMS.MacAbr biotope would be typically be high. However, the recovery of *Echinocardium cordatum* may take longer owing to recruitment that is frequently unsuccessful (Rees & Dare, 1993).
IMU.AphTub	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud	The biotope typically consists of fast growing opportunistic species so that recoverability is expected to be very high or high. However, recovery to full species richness may take longer than one year. The following information has informed the recoverability assessment. Ferns *et al*. (2000) found that, following significant depletion of *Nephtys hombergii* by cockle dredging recovery took more than 50 days (but not more than 100 days). Hall & Frid (1998) found that colonization by many of the polychaetes associated with this biotope did not vary significantly with season although recruitment of *Tubificoides benedii* and *Ophyrotrocha hartmanni* did vary significantly with season. Also, there may be spawning failure in some years, for instance in *Nephtys hombergii* (Olive *et al.* 1997). Following a hypoxia event in summer 1994 in the southern Baltic, species (some of which occur in the biotope) took at least two years to recolonize but by summer 1996 had returned to pre-event community structure (Powilleit & Kube, 1999).
IMU.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud	No evidence on community development was found. Very little is known about the population dynamics and longevity of *Virgularia mirabilis* in Britain. However, information from other species suggest that this species is likely to be slow growing with patchy and intermittent recruitment and so recovery from loss of this species is likely to longer than five years. *Philine aperta* is thought to live for 3-4 years and spawns egg masses, which release pelagic larvae, for several months between the spring and summer so recovery is likely to rapid. Individuals can also migrate in from outside areas. However, since one the key species, *Virgularia mirabilis* may not recover from loss within a five year period, the recovery score for the biotope is set to moderate.

Biotope code	Biotope name	Recoverability information
IMU.TubeAP	Semi-permanent tube-building amphipods and polychaetes in sublittoral mud or muddy sand	Amphipods have a short life span, mature quickly and may have multiple generations per year (Mills, 1967; Dauvin & Bellan-Santini, 1990) suggesting that they would have strong powers of recoverability. However, fecundity is generally low, there is no larval stage and the embryos are brooded in a marsupium, beneath the thorax. Dispersal is limited to local movements of the sub-juveniles and migration of the adults and hence recruitment is limited by the presence of local, unperturbed source populations (Dauvin, 1998). Poggiale & Dauvin (2001) reported that recovery of an *Ampelisca* population took up to 15 years, but this was following an oil spill, to which amphipods are particularly sensitive, and it is likely that this is an exceptional situation. It is expected that, in situations where there is no residual population, amphipods would normally recover within 5 years and so recoverability is assessed as high. The tube building polychaetes, including *Polydora ciliata,* are moderately fecund, the planktonic larvae are capable of dispersal over long distances, and the reproductive period is of several months duration. In colonization experiments in Helgoland, *Polydora ciliata* settled on panels within one month in the spring (Harms & Anger, 1983). Recovery and establishment of a mature community is likely to occur within 5 years and so recoverability is assessed as high. Based on the recoverability of the characterising species, biotope intolerance is assessed as high.
IMX.An	Burrowing anemones in sublittoral muddy gravel	There is very little known of the community development or recovery of this biotope. In addition very little is known of the life history and population dynamics of British sea anemones. However, many are slow growing and very long lived and it is possible that they have patchy and intermittent recruitment. For example, in many localities burrowing anemones were lost with the disappearance of eel-grass beds in the 1930's have not returned despite the recovery of *Zostera* in some regions (Manuel, 1988). Therefore, it seems likely that a community of burrowing anemones could take many years to develop and recover from environmental perturbations. Many anemones can reproduce asexually and such budding could significantly aid recovery. However, the cues for asexual reproduction are unknown. Some species also brood their young releasing miniature anemones into the water column so recruitment may be more rapid in areas where local adult populations are still present.
IMX.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel	The recoverability of the important characterizing species in this biotope, *Venerupis senegalensis*, is the principal factor in assessing the recoverability of the biotope. *Venerupis senegalensis* is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973b; Perez Camacho, 1980). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. Given these life history features, it is expected that *Venerupis senegalensis* would have strong powers of recoverability. However, recoverability will be influenced by pre and post recruitment processes. The species exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980), which suggests that recruitment is patchy and/or post settlement processes are highly variable. Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, for *Venerupis senegalensis*, an annual predictable population recovery is not certain. However, given the life history characteristics discussed above it is expected that recovery would occur within 5 years and therefore recoverability for *Venerupis*

Biotope code	Biotope name	Recoverability information
		senegalensis is assessed as high. The infaunal deposit feeding polychaetes, such as *Arenicola marina* and *Aphelochaeta marioni* have similar recoverability characteristics. Neither species has a pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles. The dispersal and recoverability of *Arenicola marina* have been well studied. Heavy commercial exploitation in Budle Bay in winter 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m^2. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al*. (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Beukema (1995) noted that the lugworm stock recovered slowly after mechanical dredging, reaching its original level in at least three years. Fowler (1999) pointed out that recovery may take a long time on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid. However, where the affected population is isolated or severely reduced, recovery may be extended. For all the shallow burrowing infauna, an important factor contributing to recoverability may be bedload sediment transport (Emerson & Grant, 1991). It has been demonstrated to account for changes in densities of the clam, *Mya arenaria*, and suggested that it may affect recruitment in other infaunal bivalves and polychaetes (Emerson & Grant, 1991). The grazing gastropods in the biotope are likely to have strong powers of recoverability. *Littorina littorea*, for example, is an iteroparous breeder with high fecundity that lives for up to 4 years. Breeding can occur throughout the year. The planktonic larval stage lasts for up to 6 weeks although larvae do tend to remain in waters close to the shore. Recolonization, recruitment, and recovery rates are therefore likely to be high. Among the macroalgae in the biotope, recovery rates are likely to vary according to life history characteristics. Fast growing species, such as *Fucus serratus* are iteroparous, highly fecund, and survive and breed for protracted periods over 3-4 years. The eggs are broadcast into the water column allowing a potentially large dispersal distance. The majority of guilds in the biotope are likely to have high recoverability. In light of this, and particularly the recoverability of the important characterising species, *Venerupis senegalensis*, recoverability of the biotope as a whole is assessed as high.
IR.AlcByH	*Alcyonium digitatum* with a bryozoan, hydroid and ascidian turf on moderately exposed vertical infralittoral rock	Many of the species in this and similar biotopes are fast colonizing and almost all sessile species have planktonic larvae or propagules. For instance, the likely initial colonizing species *Balanus crenatus* heavily colonized a site that was dredged for gravel within 7 months (Kenny & Rees, 1994). Other species such as erect Bryozoa and Hydrozoa will settle on the barnacles and overgrow them. A 'qualitative climax' community was described as being reached within 26 months in the study of establishment on settlement panels in similar communities described by Castric (1977). Some species might be slower to colonize and grow, such as *Alcyonium digitatum*, but it is expected that close to a full complement of species will have re-settled within five years. However, a minority of species that live in the biotope may be less fast to settle and may be of marine natural heritage importance (for instance, *Hoplangia durotrix*). However, overall recovery is predicted to be high.

Biotope code	Biotope name	Recoverability information
LGS.AEur	Burrowing amphipods and *Eurydice pulchra* in well-drained clean sand shores	The important characterizing species, *Eurydice pulchra* and *Bathyporeia pelagica* both produce a sequence of broods throughout the spring and summer which reach maturity within a year to produce subsequent generations. The meiofaunal community produces several generations within a year. Little evidence concerning community development was found and consequently information on the important characterizing species recruitment processes and longevity has been used to infer a time period of 1 to 2 years for the community to recover.
LGS.Lan	Dense *Lanice conchilega* in tide-swept lower shore sand	In many instances, recoverability of the biotope has been assessed to be high. The time required for the community to recover will be in part determined by the proximity of other source populations and the season during which a disturbance occurs. Recolonization by some groups is likely to be more rapid than others. For instance, diatoms may be transported by resuspension in the water column and by lateral sediment transport. The rapid colonization (within days) by diatoms establishes food resources for other species, usually nematodes that subsequently colonize. Dittmann *et al.* (1999) observed that the number of nematode species returned to pre-impact levels within seven days following a month long disturbance. Polychaetes tend to rapid colonizers, and species recorded by Dittmann *et al*. (1999) within two weeks of disturbance included the polychaetes *Pygospio elegans*, *Polydora* sp., *Nephtys hombergii*, *Capitella capitata*, *Heteromastus filiformis*, *Eteone longa*, *Hediste diversicolor* (as *Nereis diversicolor*) and *Scoloplos armiger*, and the molluscs *Macoma balthica* and *Mytilus edulis*. Next to polychaetes, amphipods e.g. *Urothoe poseidonis*, are also rapid colonizers owing to their mobility. However, species that did not recolonize within the period of subsequent monitoring (14 months) included *Arenicola marina*, *Lanice conchilega,* and its commensal *Malmgreniella lunulata*. Although it is likely that these species would recolonize suitable substrata, settlement of *Lanice conchilega*, for instance, has been reported to be more successful in areas with existant adults than areas without (see full *MarLIN* review; Heuers & Jaklin, 1999). Strasser & Pielouth (2001) reported that establishment of a mature population took three years in the absence of an established population. Thus, the time taken for the community to reach maturity and recover, is likely to be in the order of several years.
LMS.MS	Muddy sand shores	Recovery is dependent on return of suitable sediment and recruitment of individuals. Newell *et al.* (1998) report that dredged pits in the intertidal took 5-10 years to fill in low currents and up to 15 years on tidal flats in the Dutch Wadden Sea. However, intertidal dredging is a rare event. In a study of the effects of dredging for <I>Ensis</I> sp. showed that dredging caused significant changes on the community, but that the community was not detectably significantly different from controls after 40 days (Hall 1994). This rapid recovery was probably due to intense wave and storm activity during the experimental period that transported sediment and animals in suspension and in bedload transport (Hall, 1994). Overall recovery will vary between site location or hydrographic regime and that the community may not recover exactly the same species composition as existed prior to disturbance. Once suitable substratum returns, recolonization is likely to be rapid, especially for rapidly reproducing species such as polychaetes, oligochaetes and some amphipods and bivalves. Recolonization and hence recovery may be aided by bedload transport of juvenile polychaetes and bivalves.
LMU.HedMac	*Hediste diversicolor* and *Macoma balthica* in sandy mud shores	The recoverability of the biotope is largely dependent on the recoverability of the important characterising species. The polychaete *Hediste diversicolor* has high fecundity and the eggs develop lecithotrophically within the burrow, brooded by the female (Fish & Fish, 1996). There is no pelagic larval phase and the juveniles disperse principally by burrowing. Recolonization of disturbed sediments must therefore occur by immigration from local populations of juveniles or adults or by longer distance dispersal of post-larvae in water currents

Biotope code	Biotope name	Recoverability information
		or during periods of bedload transport. For example, Davey & George (1986), found evidence that larvae of *Hediste diversicolor* were tidally dispersed within the Tamar Estuary over a distance of 3 km, as larvae were found on an intertidal mudflat, which previously lacked a resident population of adults. Recovery is therefore likely to be rapid and predictable if local populations exist but slow and sporadic otherwise. It is probable that, in the majority of cases, recovery would occur within 5 years and so species recoverability is assessed as high. Other infaunal deposit feeding polychaetes in the biotope such as *Arenicola marina* and *Aphelochaeta marioni* display similar recoverability characteristics. The life history characteristics of *Macoma balthica* give the species strong powers of recoverability. Adults spawn at least once a year and are highly fecund (Caddy, 1967). There is a planktotrophic larval phase that lasts up to 2 months (Fish & Fish, 1996) and so dispersal over long distances is potentially possible given a suitable hydrographic regime. Following settlement, development is rapid and sexual maturity is attained within 2 years (Gilbert, 1978; Harvey & Vincent, 1989). In addition to larval dispersal, dispersal of juveniles and adults occurs via burrowing (Bonsdorff, 1984; Guenther, 1991), floating (Sörlin, 1988) and probably via bedload transport (Emerson & Grant, 1991). It is expected therefore that recruitment can occur from both local and distant populations. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976 the *Macoma balthica* population had recovered to 51 individuals/m². One year later there was no detectable difference in the *Macoma balthica* population between the recently dredged area and a reference area elsewhere in the bay. In 1976, 2 generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to 6 generations were identified, giving further evidence of active immigration to the dredged area. In light of the life history characteristics of *Macoma balthica* and the evidence of recovery, recoverability of the species is assessed as high. Norkko & Bonsdorff (1996) studied the recoverability of a community in the Baltic Sea very similar to that which occurs in the LMU.HedMac biotope. Artificial algal mats were anchored on the substratum, which resulted in significant declines in infaunal species richness, abundance, and biomass due to induced organic enrichment and hypoxia. They found that recolonization of the impacted area over the 5 days from when the impact source was removed was quickest by the gastropod *Hydrobia* sp., the species which dominated the faunal community of the surrounding area. Short term recoverability, therefore, is likely to be determined by proximity of source populations and species mobility. In view of the recoverability of the characterising species, the overall recoverability of the biotope is assessed as high. However, in situations where the biotope is locally perturbed but unimpacted areas persist, there is the potential for the affected areas to recover very quickly due to immigration of mature individuals.
MCR.ErSEun	Erect sponges, *Eunicella verrucosa* and *Pentapora fascialis* on slightly tide-swept moderately exposed circalittoral rock.	*Pentapora foliacea* has good reproductive and recolonizing abilities. It has been recorded as recovering in 3.5 years after almost total loss of a local population (Cocito *et al*., 1998b). *Eunicella verrucosa* is long lived, slow growing, and little is known of its reproduction. It is known to colonize wrecks at least several hundred metres from other hard substrata with sea fans but is thought to have larvae which generally settle near the parent. Little is known of the reproduction and recruitment mechanisms in *Axinella dissimilis* or other sponges. But branching sponges have not been observed to colonize wrecks and growth rate of *Axinella dissimilis* at Lundy is extremely slow (less than 1mm a year) (K. Hiscock, pers. comm). In monitoring studies at Lundy, branching sponges

Biotope code	Biotope name	Recoverability information
		showed no recruitment, only losses over a 13 year period (K. Hiscock pers. comm.). Recovery of some parts of this community may therefore take a long time or not occur. The recoverability of the other 3 biotopes represented by this review is likely to be similar to MCR.ErSEun.
MCR.Flu	*Flustra foliacea* and other hydroid/bryozoan turf species on slightly scoured circalittoral rock or mixed substrata	Where local populations exist or remain after disturbance recruitment is likely to be rapid for most species, including *Flustra foliacea*. Many species, e.g. hydroids, colonial ascidians, sponges, and *Metridium senile* are capable of asexual reproduction and colonize space rapidly. For example, in studies of subtidal epifaunal communities in New England, Sebens (1985, 1986) reported that cleared areas were colonized by erect hydroids, bryozoans, crustose red algae, and tube worms within 1-4 months in spring, summer and autumn. Tunicates such as *Dendrodoa carnea* and *Aplidium* spp. appeared within a year, *Aplidium* sp., and *Halichondria panicea* achieved pre-clearance cover within >2 years, while only a few individuals of *Metridium senile* and *Alcyonium* sp. colonized within 4 years. *Flustra foliacea* is slow growing, long-lived and new colonies take at least 1 year to develop erect growth and 1-2 years to reach maturity (Stebbing, 1971a; Eggleston, 1972a), depending on environmental conditions. Four years after sinking, the wreck of a small coaster, the M.V. *Robert*, off Lundy was found to be colonized by erect bryozoans and hydroids, including occasional *Flustra foliacea* (Hiscock, 1981). The wreck was several hundreds of metres from any significant hard substrata, and hence a considerable distance from potentially parent colonies (Hiscock, 1981 and pers. comm.). Overall, local recruitment is probably good and a damaged or reduced population of *Flustra foliacea*, other erect bryozoans and hydroids may recover abundance and percentage cover in less than 5 years. Where the populations are removed or destroyed, recolonization will depend on recruitment of larvae from other communities. The majority of species are widespread but have poor dispersal so that recruitment rates will depend on the proximity of nearby communities and the hydrographic regime. Exceptions include, mobile crustacea and echinoderms with long-lived planktonic larvae, and *Nemertesia antennina* and *Alcyonium digitatum* which can probably disperse up to 50m or over 100km respectively (Hughes, 1977; Hartnoll, 1998). However, Sebens (1985) suggested that *Alcyonium* spp and *Metridium senile* would probably not recruit to epifaunal communities unless other populations of the species were nearby. *Flustra foliacea* is evidently capable of dispersing over considerable distance, since it colonized the M.V. *Robert* and achieved 1-5% (occasional) cover within 4 years (Hiscock, 1981). However, it would probably take many years for *Flustra foliacea* to recover its original cover. Many other members of the community would probably occupy space rapidly once they colonize the habitat. Colonization of cleared space from distant populations is probably stochastic, reliant on hydrography and environmental conditions. Overall, encrusting bryozoans, hydroids, and ascidians will probably develop a faunal turf within less than 2 years, and *Flustra foliacea* can evidently colonize and reach an abundance of occasional (1-5% cover) within 4 years. While the biotope may be recognizable in up to five years, *Flustra foliacea* may take at least five years to recover its original dominance. Where habitats are isolated by geography (distance) or hydrography, recovery may take longer.

Biotope code	Biotope name	Recoverability information
MCR.ModT	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata	Few members of the horse mussel assemblage (except the horse mussels themselves) are restricted to the horse mussel bed and many associated species have planktonic propagules, likely to recolonize rapidly. Therefore, the recoverability of the biotope is primarily dependant on the recovery of the horse mussel bed. Recruitment in *Modiolus modiolus* is sporadic and highly variable seasonally, annually, or with location (geographic and depth) (Holt *et al.*, 1998). Some areas may have received little or no recruitment for several years. Even in areas of regular recruitment, such as enclosed areas, recruitment is low in comparison with other mytilids such as *Mytilus edulis*. For example, in Strangford Lough small horse mussels (<10mm) represented <10% of the population, with peaks of 20-30% in good years (Brown & Seed, 1978; Figure 3). In open areas with free water movement larvae are probably swept away from the adult population, and such populations are probably not self-recruiting but dependant on recruitment from other areas, which is in turn dependant on the local hydrographic regime. In addition, surviving recruits take several to many years to reach maturity (3-8 years, see reproduction) (Holt *et al.*, 1998). Holt *et al.*, (1998) point out that where impacts are severe enough to clear extensive areas of a horse mussel bed, recovery would be unlikely even in the medium term. They also noted that both the time required for small breaks in beds to close up due to growth of surrounding clumps, and the survival of clumps torn from the bed is not known. Witman (1984) cleared 115cm^2 patches in a New England *Modiolus modiolus* bed. None of the patches were recolonized by the horse mussel after 2 years, 47% of the area being colonized by laminarian kelps instead (Witman pers. comm. cited in Suchanek, 1985). No details on longer term studies were found. The horse mussel is long-lived and reproduction over an extended life span may compensate for poor annual recruitment. However, any factor that reduces recruitment is likely to adversely affect the population in the long-term. Any chronic environmental impact may not be detected for some time in a population of such a long -lived species. Overall, while some populations are probably self-sustaining it is likely that a population that is reduced in extent or abundance will take many years to recover, and any population destroyed by an impact will require a very long time to re-establish and recover, especially since newly settled larvae and juveniles require the protection of adults to avoid intense predation pressure.
MCR.Mus	*Musculus discors beds* on moderately exposed circalittoral rock	No information concerning recruitment or recovery in *Musculus discors* was found. Brooding in *Musculus discors* probably results in relatively lower levels of juvenile mortality. Therefore, within populations recruitment is likely to be good. Martel & Chia (1991) suggested that in species that brood their offspring (such as *Musculus discors*) bysso-pelagic drifting probably contributed to rapid local dispersal and recruitment, depending on the hydrographic regime. Hence, within a population or between adjacent populations recruitment and recovery of *Musculus discors* is probably rapid, and it is suggested that prior abundance may recover within up to 5 years. However, where recovery is dependent on recruitment from distant populations recruitment may take longer. If a population is removed, recovery will depend on recruitment from nearby populations by drifting, followed by subsequent expansion of the population. The species is widespread so that a ready supply of juveniles will probably be present, albeit in small numbers. Therefore, it is suggested that recovery after removal of a population may take about 5 to 10 years. Holt *et al.* (1995) suggested that many hydroids and bryozoans were rapid colonizers, able to settle rapidly, mature and reproduce quickly. Many species have a short lived planktonic phase, resulting in relatively local recruitment,

Biotope code	Biotope name	Recoverability information
		however, fecundity is high and most species are widespread, so that recruitment is likely to be rapid from surrounding populations. Ascidians have external fertilisation but short lived larvae, so that dispersal is probably limited. Where neighbouring populations are present, recruitment may be rapid but recruitment from distant populations may take a long time. Most sponge species produce short lived, planktonic larvae so that recruitment is localized, depending on the hydrographic regime. Some species (e.g. *Polymastia robusta*) produce benthic crawling larvae that probably settle close to the parent (see Fell, 1989 for review). Growth rate vary between and within species, so that time to reach maturity is also variable and large colonies may take several years to develop. However, little information was found. In strong water flow associated with this biotope, most pelagic larvae are probably transported away form the biotope, so that most recruits of species with pelagic life stages come from outside the community. However, direct development and brooding in *Musculus discors* probably ensures a relatively good, local recruitment. Overall, the community is primarily dependent on *Musculus discors*, which may regain abundance within 5 years, or recover from removal within 5-10 years. The associated epifaunal community will probably develop within less than 5 years, although slow growing sponges may take many years to develop.
MCR.MytHAs	*Mytilus edulis* beds with hydroids and ascidians on tide-swept moderately exposed circalittoral rock	Larval supply and settlement could potentially occur annually, however, settlement is sporadic with unpredictable pulses of recruitment (Lutz & Kennish, 1992; Seed & Suchanek, 1992). *Mytilus edulis* is highly fecund but larval mortality is high. Larval development occurs within the plankton over ca 1 month (or more), therefore, whilst recruitment within the population is possible, it is likely that larval produced within the biotope are swept away from the biotope to settle elsewhere. Therefore, recovery is probably dependant on recruitment from outside the biotope. While good annual recruitment is possible, recovery may take at least 5 years. However, it should be noted that in certain circumstances and under some environmental conditions recovery may take significantly longer. Overall, *Mytilus* spp. populations were considered to have a strong ability to recover from environmental disturbance (Holt *et al.*, 1998; Seed & Suchanek, 1992). The other characterising species are likely to recolonize the substratum rapidly.
MCR.Oph	*Ophiothrix fragilis* and/or *Ophiocomina nigra* beds on slightly tide-swept circalittoral rock or mixed substrata	Breeding of the main bed forming brittlestar *Ophiothrix fragilis* occurs annually and there may be multiple recruitment phases (Davoult *et al*., 1990). Reproductive capability may be reached in 6-10 months depending on time of recruitment (Davoult *et al*., 1990) so recovery is likely to be high. However, lost populations may not always be replaced because settlement of larvae of *Ophiothrix fragilis* is highly dependent on hydrographic conditions and consequently may be unpredictable. In the strong water currents of the English Channel larvae can disperse up to 70-100 km and establish populations elsewhere. Therefore, if conditions change recruitment may fail and lost populations may not be replaced. For example, dense aggregations of *Ophiothrix fragilis* in the Plymouth area have not been seen to have recovered since their decline in the 1970's are it is suggested that cyclical changes in the oceanographic cycle affecting the western Channel resulted in increased predation pressure from *Luida ciliaris* and also recruitment failure of *Ophiothrix fragilis*. If any adults remain, aggregations may re-establish, as individual brittlestars tend to crawl back and forth across water currents until a conspecific is found (Broom, 1975). Other species occurring in the bed recruit mostly from the plankton or are mobile so that their recovery would be rapid.
MCR.Sspi	*Sabellaria spinulosa* crusts on silty turbid	*Sabellaria spinulosa* is the most important species in this biotope. *Sabellaria spinulosa* has a long lived larva with good dispersive ability and can recruit

Biotope code	Biotope name	Recoverability information
	circalittoral rock	readily although this can be affected by environmental conditions. Other species that may occur in the biotope (e.g. *Urticina felina*) might take longer to return due to poor dispersal (Solé-Cava et al., 1994) and slow growth (Chia & Spaulding, 1972). There are few frequent characterising species. The other species present in this biotope probably reflect the species composition of nearby biotopes.
MCR.Urt	*Urticina felina* on sand-affected circalittoral rock	Where local populations exist or remain after disturbance, recruitment is likely to be rapid for many species including regrowth from any remaining fragments of species such as *Ciocalypta penicillus* and *Pentapora fascialis*. Some others, such as *Pomatoceros triqueter* and *Balanus crenatus* are likely to settle rapidly after loss. In studies of subtidal epifaunal communities in New England, Sebens (1985, 1986) reported that cleared areas were colonized by erect hydroids, bryozoans, crustose red algae, and tubeworms within 1-4 months in spring, summer, and autumn. Some species will take longer. For instance, *Alcyonium* sp. colonized within 4 years. *Flustra foliacea* is slow growing, long-lived and new colonies take at least 1 year to develop erect growth and 1-2 years to reach maturity (Stebbing, 1971a; Eggleston, 1972a), depending on environmental conditions. Four years after sinking, the wreck of a small coaster, the M.V. *Robert*, off Lundy was found to be colonized by erect bryozoans and hydroids, including occasional small *Pentapora fascialis* (Hiscock, 1981). The wreck was several hundreds of metres from any significant hard substrata, and hence a considerable distance from potentially parent colonies (Hiscock, 1981 and pers. comm.). *Pentapora fascialis* is noted as having good reproductive and recolonization abilities, quite fast growth rates and gaining reproductive competency at an early stage (Cocito *et al*., 1998). However, no information has been found about the reproduction and recolonization potential of *Ciocalypta penicillus* and other cushion sponges (species of *Polymastia*) which may be slow. In addition, recovery of *Urticina felina* is likely to be slow in populations where nearby individuals do not exist. The large size, slow growth rate, and evidence from aquarium populations suggest that *Urticina felina* is long lived. Although it probably breeds each year there is no information regarding fecundity. Breeding probably does not occur until the anemone is at least 1.5 years old. Dispersal ability is considered to be poor in the similar *Urticina eques* (Solé-Cava et al., 1994). The larva is most likely benthic and, although unlikely to settle for many days after release (based on work on the similar *Tealia crassico*rnis for north-west USA), is unlikely to travel far. Adults can detach from the substratum and relocate but locomotive ability is very limited. In view of the likelihood that two of the main characterising species are unlikely to recover former abundance rapidly following catastrophic loss of the biotope, a recoverability of moderate is identified in those circumstances.
MIR.HalXK	*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment.	*Halidrys dioica* was shown to recruit to cleared areas within 3-4 months in the absence of sea urchins on the California coast (Sousa *et al.*, 1981). Similarly, *Halidrys siliquosa* became a dominant alga in 3 years after the removal of kelps in Norway (summary only, Svendsen, 1972). Several fucoids have been shown to recolonize cleared areas readily, especially in the absence of grazers (Holt *et al.*, 1995, 1997). For example, *Fucus* dominated areas may take 1-3 years to recolonize in British waters (Holt *et al.*, 1995). Kain (1975) reported that *Laminaria saccharina* and *Saccorhiza polyschides* were initial colonizers, colonizing of cleared blocks in the shallow subtidal within 25-28 weeks (ca 6 months). *Saccorhiza polyschides* colonized within the winter months only whereas *Laminaria saccharina* recruited throughout the year (Kain, 1975).

Biotope code	Biotope name	Recoverability information
		Delesseria sanguinea was shown to colonize cleared blocks within 56-59 days or 41 weeks (ca 10 months) depending on depth and time of year. Similarly, *Chondrus crispus* recovered prior biomass after its substratum was denuded by ice scour within 5 years, and if holdfasts remained was able to recover cover within 18 months. However, *Furcellaria lumbricalis* is slow growing, takes 5 year to reach maturity, and has limited dispersal and would probably take between 5 and 10 years to recover. Overall, macroalgal recruitment, and hence recovery is likely to be good within cleared areas in the proximity of reproductive parent plants, depending on season and species. The limited evidence suggests that *Halidrys siliquosa* may recover within 5 years. Similarly, most red algal species appear to be capable of rapid recovery, probably less than 5 years, with the exception of *Furcellaria lumbricalis*. Epiphytic species are also widespread and ubiquitous so that, although their dispersal is limited, they are likely to recruit quickly. However, the most luxuriant epiphytic growth occur on old plants (e.g. *Halidrys siliquosa*) may take many years to recover, perhaps up to 10 years. It is likely that some sort of succession would occur in colonization of bare substratum, with establishment of the balance of species in the biotope taking several years to establish. Nevertheless, it is likely that the biotope will re-establish within 5 years. Isolated population may take longer to recover their macroalgal cover, due to the poor dispersal capabilities of most fucoids or red algae, again dependant of hydrography.
MIR.Ldig.Ldig	*Laminaria digitata* on moderately exposed sublittoral fringe rock	The community is composed of predominantly opportunistic and fast colonizing species. For instance, Kain (1975) recorded that *Laminaria saccharina* was abundant six months after substratum was cleared. Although the community might look very similar one year after loss of species, some species such as encrusting coralline algae that survive winter storms will not reach their previous extent on cobbles for some years. Recoverability from impact is therefore described as high

Annex

Irish Sea Pilot – Mapping Sensitivity within Marine Landscapes

Consultative workshop 22 August 2003

Summary of meeting

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Irish Sea Pilot – Mapping sensitivity within Marine Landscapes

Consultative workshop on 22 August 2003

Summary of meeting

The *MarLIN* team was commissioned by the 'Irish Sea Pilot' (ISP) to trial the assessment of the sensitivity of Marine Landscapes and its application to the production of sensitivity maps for the Irish Sea. A consultative report was prepared in July 2003 and circulated to members of the *MarLIN* Sensitivity Mapping Advisory Group, the *MarLIN* Biology and Sensitivity Technical Management Group and others. A consultative workshop was held on 22 August 2003 to discuss draft report of July 2003. A list of consultees and workshop participants is listed at the end of the Annex.

The first part of the meeting was a briefing of the *MarLIN* approach to assessing sensitivity, to applying sensitivity assessments to the Irish Sea and to mapping survey data and sensitivity information in GIS – basically a summary of what was in the preceding report.

The following notes are a summary of discussion points presented and, where relevant, as actions

1. The *MarLIN* approach to assessing sensitivity.

Biotope sensitivity assessments seek to assess the impact of a change in an environmental factor on the community as a whole. Biotopes are perceived as being characterized by a small number of dominant species [Faithful species where present are also important in characterizing the biotope]. Biotope sensitivity assessment is based on 'species indicative of biotope sensitivity', which include key structural or functional species as well as species of potential importance in community function. However, biotope sensitivity cannot accurately represent loss of species diversity, loss of function, or reduced biomass.

In addition, *MarLIN* sensitivity assessments are based on a hypothetical 'average population' and are not site specific but require interpretation on a site-by-site and activity-by-activity basis. The inherent limitations in sensitivity assessment need to be further clarified in the report.

There is always a risk that sensitivity maps (or any map-based information) will be misinterpreted. It should be remembered that sensitivity maps and the survey data presented need expert interpretation.

2. Benchmarks.

Benchmarks were developed by *MarLIN* to represent the likely magnitude and duration of change in an environmental factor as a result an impact, to provide a 'standard' level of impact against which to assess intolerance. The benchmarks are not fixed and can evolve Three scenarios emerged:

1. If benchmarks are not considered realistic in a management context, they need to be changed.
2. If the benchmarks are relevant under the majority of Marine Landscapes but may give rise to significant under or over-estimates of sensitivity under particular circumstances, then their limitations need to be clarified clarification
3. If there are management-relevant alternative scenarios, more than one benchmark and therefore assessment might be needed.

Concerns were expressed that the benchmarks might significantly underestimate the time taken for the substratum itself to recover to a condition which would enable the species or biotope to start recovery – for example under very sheltered conditions, a 5 cm depth of smothering material may take a long time to be removed or incorporated into the sediment. This is not incorporated into the sensitivity ranking but conditions in which the sensitivity are likely to be higher or lower are outlined in the explanatory text for each assessment. It was agreed that:

- there were a wide range of alternative scenarios but that it is not practical or appropriate to develop and work with large numbers of benchmarks;
- the three benchmarks considered were likely to be broadly appropriate, and that
- the benchmarks should not be changed at this stage.

Additional clarification/caveats should be considered to highlight their limitations eg factors/conditions which may lead to significant under or over-estimation of sensitivity. Where the clarification/caveats are of particular relevance to a species or biotopes it might be possible to refer to it in that sensitivity assessment but also to show how they can be used for comparison with predicted levels of impact.

3. Does it 'matter' if biotopes are lost or damaged?

It was pointed out that, whilst a biotope might no longer exist because characterizing species are lost, it may be replaced by another, and biodiversity be unaffected. In fact, the situation is more complicated and 'Does it matter?' judgements have to be made on whether components in the biotopes are key structural, nationally rare or scarce, BAP species etc. However, from a marine natural heritage importance point-of-view, although a biotope is no longer present, sensitivity might be low because the replacing biotope(s) preserve function and diversity in the area. Also recovery is not generally considered to mean recovery to exactly as a habitat, community or species population was before an event. Overall, it was felt that it is not possible for sensitivity assessments to consider every possible outcome and, in reality, sensitivity assessments should be indicative with interpretation required by experienced marine biologists.

4. 'Marine Landscapes ' and 'physiographic features'.

Clarification was sought regarding these two apparently similar broad types with different names. Offshore, where extensive areas of broadly similar habitat may exist, Marine Landscapes had been determined primarily by geophysical features such as sediment type, bathymetry, slope, generalized bed forms and bed stress. In coastal and estuarine waters, where a much greater complexity of habitat types may exist in relatively small areas e.g. within estuaries and sea lochs, a physiographic classification has been used. These also link to the EC Habitats Directive definitions of Annex 1 types. KH remains unconvinced that an adequate differentiation between / accurate definition of 'Marine Landscapes ' and 'Physiographic features' has been made and, as observed during the meeting, finds the 'photic rock' concept difficult because it seems to have been used for coastal fringing rock, a great deal of which will be aphotic. However, the consultation version of Marine Landscapes paper (Golding *et al.*¸2003) distinguishes between photic reef and aphotic reef, has tried to addresses this point.

5. Levels at which sensitivity can be assessed (marine landscape, biotope complexes, biotopes, nationally important features, species etc).

After discussion of various points, the following points were noted:

1. The Marine Landscape sensitivity assessments undertaken by *MarLIN* are useful in providing an overall assessment across the unit. These need to be linked to records of the actual biotopes present (as and when more data is available) or the predicted biotopes checked against the biotope complex records identified for each unit by the ISP. They might be improved by assessing the proportional occurrence/extent of the different biotopes/biotope complexes.

2. The initial characterization of marine landscape units by the ISP has been carried out at the level of biotope complexes. Further characterization of Marine Landscapes by nationally important features, biotopes and species needs to be given further consideration (recognizing that we may not be able to progress this much further within the resources of the Pilot)

3. Biotopes within complexes (especially on heterogeneous substrata in subtidal areas) are often very different in character and therefore the biotope complex may not adequately represent the range of likely sensitivities of component biotopes. The new biotopes classification (the 2003 version), especially subtidal sediments, would need inspection to see how well biotope complexes represented the range of component biotopes. Care is needed to understand the benefits and dis-benefits of assessments made at the biotope and biotope complex levels, and to use these assessments most appropriately.

4. There may not be enough data in offshore areas to get to the biotope level. However, in offshore areas, management requirements are usually at a broad scale (e.g. fisheries) and broad scale mapping is appropriate. Therefore, while biotopes may be a particularly useful and practical unit for mapping in inshore areas, biotope complexes may be a more appropriate unit offshore.

5. There may be several levels (e.g. Marine Landscape, biotope complex, biotope, nationally important feature, species, at which it is appropriate to make sensitivity assessments, depending on the purpose for which it is intended. It was concluded that all available levels of information should be included in the system adopted. Geographical Information Systems (GIS) provides the facility to examine the data at a variety of levels and scales.

6. Where discrimination from existing survey data is inadequate, targeted survey may be required.
7. It is important that for all sensitivity assessments, a check needs to be made using expert judgment to see whether the sensitivity assessments feel right. If there are significant discrepancies, the methodology may need to be adjusted to ensure that the results do feel right and tie in with field observations.

6. Sensitivity categories

When assessing the sensitivities of the marine landscape units, *MarLIN* identifies some units with an overall low sensitivity but which contained important biotopes of locally high sensitivity. Additional sensitivity categories e.g. low/moderate sensitivity, high in places, were suggested to address this.

It was suggested during discussion that many areas identified as of moderate or low overall sensitivity are likely to have local features that are of high sensitivity – particular biotopes or nationally important features for example. The use of a 'low/moderate sensitivity, high in places' hatched units may be misleading – implying that areas without this caveat do not. The following was proposed:

1. We should not introduce a new overall sensitivity category e.g. 'low/moderate sensitivity, high in places'. This starts to combine data sets rather than building up a more useful picture from the separate layers of data (as proposed at 5.4 above). We should continue to use the original sensitivity categories only, derived using the methodology proposed, but explain the nature of this overall assessment
2. We should use the parallel and complementary mapping of sensitivity at the biotope complex, biotope, species scales to indicate the presence, and potential wider occurrence, of more sensitive interests.
3. We may also be able to map certain highly sensitive biotopes e.g. *Modiolus* beds, fish spawning areas, where more detailed work has been undertaken.
4. When characterizing the sensitivity of Marine Landscapes we should identify whether there are known associations with particularly sensitive interests.

The suggestion was made that any biotope for which no or a >25 yr recovery was predicted should be given a high sensitivity irrespective of their intolerance. *MarLIN* explained that by definition a low intolerance does not result in loss of or decline in species important for the structure/function of the biotope, or of characterizing species but may reduce the viability of species populations and diversity/functionality in a community. It would be un-representative to suggest that a population or community under stress (i.e. low intolerance) but that took a very long time to recover was of equal sensitivity to a population or community partly or completely destroyed by a factor but that took a very long time to recover.

7. Information availability

The Irish Sea Pilot has not had access to all of the seabed biological data likely to be available. It is therefore important that new data and information can be added to the mapping. The GIS layers supplied by *MarLIN* will include look-up sensitivity tables for species/biotopes, so that additional survey data could be plotted for the species/biotopes researched at the end of the contract.

1. The ISP should seek to identify those additional datasets, surveys and other sources of information that need to be incorporated into future work including appropriate databases. This could include biological data from EIAs and SEAs. The Pilot should consider how this might be achieved and make appropriate recommendations. The National Biodiversity Network is an obvious repository.
2. New datasets will need interpreting as biotopes or biotope complexes and there is a clear question of who will do that. It would greatly help to have a survey data to biotope matching programme.
3. Surveys now being undertaken are likely to use cameras rather than grab sampling. It will be important to develop methods to identify biotopes or biotope complexes for matching sensitivity assessments.
4. Multi-beam acoustic surveys will be used to identify areas with different characteristics for more detailed survey.
5. Users of sensitivity information based on biotope complexes, biotopes, nationally important features, species etc need to know how they can and cannot be used. A strength of biotopes is that they allow

comparison of like-with-like to assess quality, to identify variety within an area and can be assessed as rare or scarce. However, they do not identify other important features such as biomass, diversity or functioning of the biology at a location.

6. Identifying the relative proportion of different biotope complexes or biotopes within a marine landscape to suggest the most appropriate complex or biotope(s) to represent the landscape is desirable. But information points (survey data) may be sparse, especially data that has been interpreted as biotope or biotope complexes. The consultation report 'A Marine Landscape classification for the Irish Sea Pilot' (Golding *et al*., 2003) was tabled at the meeting. The report includes tables that match Marine Landscapes to biotope complexes. This new information will need to be reviewed and used where possible to revise the interpretation undertaken by the MarLIN team of which biotopes/biotope complexes characterized the marine landscape units.
7. The assumptions made in assessing sensitivity (e.g. anthropogenic influences, extrapolation to un-sampled features, currency of historical data, time taken for recovery of the substratum itself), must be clearly stated but do not add too many caveats.
8. Sensitivity information should be made available at the full range of scales, from Marine Landscapes to nationally important species. It should be accessible within the GIS.
9. 'Lifeforms' are not being used in the ISP mapping exercise. There are sufficiently strong similarities between lifeforms and biotope complexes to use biotope complexes only.
10. MarLIN will need to continue to update and expand its sensitivity assessments in the light of new information. However, on-going maintenance and updating of the MarLIN sensitivity information requires on-going funding.

8. Application of sensitivity mapping in incident response, emergency planning and environmental management

The sensitivity maps and GIS produced within the project should be useful for incident response (e.g. in the oil industry) and could be useful for Strategic Environmental Assessment (SEA) and Cumulative Environmental Assessment (CEA) at the broad scale and Environmental Assessment (EA) at the local scale.

9. Using the sensitivity maps to assess vulnerability

The report needs to explain very briefly how sensitivity information, combined with information on the exposure (nature, intensity and duration) to human activities, can be used to assess vulnerability. The purpose is simply to set the wider context.

The use of sensitivity maps to assess vulnerability of Marine Landscapes and nationally important features o human activities should be trialled by the Irish Sea Pilot.

Using information on the sensitivities of Marine Landscapes, combined with information on the exposures of these landscapes to factors/human activities, it should be possible to assess the likely vulnerability of these Marine Landscapes to the current changes in factors/levels of human activities. It may be possible to compare these vulnerability assessments with direct scientific observations on environmental change. This would help give a reality check to the assessments that have been made. Attention was drawn to the COST-IMPACT project as relevant, which is identifying the impacts of fishing activities on benthic communities and the wider ocean. Matrices have been developed as part of the European marine site work, which could be used to calculate vulnerability indices. This may work better for more uniform offshore landscapes than complex inshore areas.

10. Use of GIS

Sensitivity mapping requires the use of GIS to display and interpret sensitivity information, which is likely to be available at a range of levels.

It would be useful to access the GIS on-line. The Multi-Agency Geographic Information for the Countryside (MAGIC) and the Interactive Map Services (IMAPS) provided by the UNEP World Conservation Monitoring Centre were suggested as models

It was noted that further development of an on-line GIS system of sensitivity maps would require additional funding, either by a consortium of interested parties or from the European Commission.

11. Specific actions which MarLIN will seek to incorporate into the revised report for JNCC.

- Simplify the report – current report too long and complicated
- Include an Executive Summary.
- Clarify methodology – the draft illustrates how the current methodology has been developed but may lead to confusion because the proposed methodology changes as the report has been developed. Revised report should set out the 'final' methodology with brief explanation as to how this has been arrived at.
- Acquire more data to work with.
- Use polygon-based data system needs to be able to accommodate polygon based data – maps of the extent of biotopes, fish spawning areas etc. These would be viewable as additional map layers in a GIS, or as separate paper maps
- Display appropriate caveats clearly.
- Utilize the proportionality of biotopes or biotope complexes within Marine Landscape units to inform characterization of the units.
- Pursue details of the linkages between biotopes and biotope complexes.
- Make clear the 'fit-for-purpose' ("horses-for-courses" was used) nature of different levels of detail and what can be done with different scales of information.
- Consider and compare the availability of and needs for data and information for near shore and offshore areas:
  - levels of data available;
  - levels of detail of information;
  - levels of data needed to make management decisions.

- Be realistic: for some Marine Landscapes, trying to characterize overall sensitivity may not work (variety of sensitivities of biotopes within a marine landscape may be too great).
- Clarify the limitations in the data and the approach to assessing sensitivity and recoverability.
- Refer to vulnerability.
- Mention how sensitivity assessment is used in the context of (e.g.) planning, accident response, SEA, CEA.
- Design the sensitivity methodology for use in GIS, whilst taking account of the need to be able to output the information as hard copies of maps.
- Ensure that 'hard evidence', i.e. the detailed survey data and sensitivity information is clearly displayed.
- Learn from other Web sites (e.g. IMAP, MAGIC).

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27 August 2003

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