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# ‘DEAD’ MAERL BEDS – A REVIEW OF SENSITIVITY TO THE EFFECTS OF HUMAN ACTIVITIES AND NATURAL EVENTS

A report from:

The Marine Biological Association of the United Kingdom

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## Contents

## List of Appendices

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# ‘DEAD’ MAERL BEDS – A REVIEW OF SENSITIVITY TO THE EFFECTS OF HUMAN ACTIVITIES AND NATURAL EVENTS

## 1 Introduction

Natural England requested a MarLIN sensitivity review of ‘dead’ maerl beds to assist in management planning advice. The MarLIN sensitivity assessment approach was originally designed to rank the sensitivity of marine biotopes to a range of environmental pressures (originally termed ‘factors’). However, ‘dead’ maerl beds are not described specifically as separate biotopes and there is no ‘defined[1]’ characterizing species list for ‘dead’ maerl beds. Therefore, MarLIN’s sensitivity assessment approach required interpretation in order to apply to ‘dead’ maerl beds.

## 2 Live vs. ‘dead’ maerl beds

Maerl beds are highly variable. They range from a thin layer of living maerl on top of a thick deposit of dead maerl, to a layer of live maerl on silty or variable substratum, to a deposit of completely dead maerl or maerl debris of variable thickness. Live maerl beds vary in the depth and proportion of ‘live maerl’ present (Birkett *et al.*, 1998). In areas subject to wave action, they may form wave ripples or mega ripples e.g. in Galway Bay (Keegan, 1974) and in Stravanan Bay (Hall-Spencer & Atkinson, 1999). Maerl beds also show considerable variation in water depth, the depth of the bed, and biodiversity (see Birkett *et al.*, 1998). They also vary in the dominant maerl forming species, with *Phymatolithon calcareum* dominating northern beds while both *P. calcareum* and *Lithothamnion coralloides* occur in the south west of England and Ireland. *L. glaciale* also occurs in northern waters and replaces *L. coralloides* in Scotland (Birkett *et al.*, 1998). Birkett *et al.* (1998) list another eight minor maerl forming species of which five have been recorded in the UK. These were *Lithothamnion lemoineae, L. sonderi, Lithophyllum racemus, Phymatolithon purpureum* and coral weed *Corallina officinalis*.

Relatively few studies have compared live and ‘dead’ maerl beds.

**Hall-Spencer (1998)** examined the molluscan fauna of two maerl beds in the Firth of Clyde, Scotland. Bed 1 was un-impacted by scallop dredging and had 25% live maerl cover, while Bed 2 was subject to scallop dredging for several years prior to the study and historically, and had 98% cover of dead maerl. The vagile epifauna of Bed 2 was impoverished in comparison to bed 1. For example, Bed 1 had a higher abundance of scallops, and mature scallops (*Pecten maximus*) were absent from Bed 2. Similarly, the file shell *Limaria hians* was present in bed 1 but absent from Bed 2, save for dead shells. Bed 1 had a higher biomass per unit area of bivalves than Bed 2 and a higher species diversity (117 species were recorded in Bed 1 compared to 87 species recorded in Bed 2). Nevertheless, the impacted dead maerl bed included a diverse infauna, especially deep burrowing bivalves. The components of the molluscan fauna described by Hall-Spencer (1998) were similar to prior studies by Nunn ((1993)) and early studies summarized by Cabioch (1968). Cabioch (1968) considered maerl faunas to be similar to the *Venus* communities associated with coarse sediments.

**De Grave (1999)** examined the crustacean fauna of four maerl debris sediments (maerl debris, mud-maerl debris, sand-maerl debris and gravel maerl debris) which included ‘very few live maerl fragments’ and four live maerl sediments (maerl banks, seagrass covered maerl banks, shell-gravel maerl banks and mud-live maerl banks) in Mannin Bay, Ireland. The study recorded a total of 69 species of Crustacea, 95% of which were amphipods. De Grave noted that while the dominant species composition varied between the different sediment types

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[1] Where ‘defined’ refers to the UK Marine Habitat Classification; Connor et al. (1997a&b, 2004).

examined, the differences in the crustacean community were relatively minor. However, only live maerl and shell-gravel live maerl banks included decapods (e.g. *Pisidia longicornis* and *Janira maculosa*) in the top ten most dominant species. The high level of amphipod biodiversity was comparable to that seen in kelp holdfasts, rocky subtidal algae and a range of sediments. The amphipod fauna was comparable in composition to that of gravel communities.

**Kamenos *et al.* (2003)** examined the substratum heterogeneity of unimpacted live maerl (from Loch Sween), impacted maerl (from Stravanan Bay), gravel and sand sediments from Stravanan Bay. Impacted maerl came from a bed subject to scallop dredging for ca 20 years, was composed of smaller maerl fragments than unimpacted maerl, and was 'mainly dead'. Kamenos *et al.* (2003) examined the structural heterogeneity in terms of rugosity, internal surface area and volume of each sediment type. Unimpacted maerl had the highest structural heterogeneity, while impacted maerl was lower and similar to that of gravel, while sand had the lowest heterogeneity out of the four sediment types examined.

**Kamenos *et al.* (2004a)** examined the use of maerl by juvenile queen scallops. In mesocosm studies, they found that juvenile queen scallops attached preferentially to pristine live maerl, probably due to contact settlement cues from the living maerl itself, than to impacted dead maerl, gravel or sand. Juvenile queen scallops also used the microhabitat provided by the structure of the live maerl as refuges from predators.

**Kamenos *et al.* (2004c)** surveyed of several sites in the south west Scotland. They found significantly higher densities of the juvenile queen scallop (*Aequipecten opercularis*) on pristine live maerl beds, when compared to gravel, impacted dead maerl or sand habitats. The abundance of the green sea urchin *Psammechinus miliaris,* the edible sea urchin *Echinus esculentus,* the common starfish *Asterias rubens* and the sand gaper *Mya arenaria* was higher in pristine live maerl beds, when compared to gravel, or sand habitats. Live maerl beds are nursery areas for several important and commercially important bivalve species. Hall-Spencer *et al.* (2003) note that maerl beds are feeding areas for juvenile Atlantic cod, and host reserves of brood stock for razor shells *Ensis* spp., the great scallop *Pecten maximus* and the warty venus *Venus verrucosa.* While live maerl attracts settlement by juvenile scallops, dead maerl does not. However, dead maerl beds support a diverse bivalve community (Hall-Spencer, 1998) and, presumably, also provide a reserve of bivalve brood stock.

**Some of the best studied maerl beds in England** occur in the Fal estuary system and Falmouth Bay and include extensive deep deposits of dead (sub-fossil) maerl (Birkett *et al.*, 1998). Rostron (1985) gave detailed lists of epiflora and epifauna for live maerl and other (maerl, mud and maerl gravel combined) . Rostron (1985) recorded 52 epiflora and 53 epifauna from 'live maerl' and 46 epiflora and 58 epifauna from the 'maerl, mud and maerl gravel', suggesting similar species richness at least. Rostron (1985) describe the dead maerl banks off Penarrow Point as 'largely dead', suggesting that some live maerl was present. Rostron (1985) goes on to note that the earlier survey by Hardiman *et al.* (1976) found 85 species in the maerl bed on St Mawes bank (ca 38% of which were found in 1985) but that Hardiman recorded 198 species just outside the Falmouth Bay area where the maerl was 'almost all dead'.

Birkett *et al.* (1998) cited a report by Scott & Moore (1996) that noted that the diversity of species found in maerl beds was not necessarily correlated with the proportion of live maerl within the bed. However, Birkett *et al.* (1998) go on to suggest that Scott & Moore's data required further analysis.

Overall, 'dead' maerl beds have been reported to have a reduced epiflora and vagile epifauna compared to live maerl beds and are less attractive as nursery areas for juvenile scallops and probably other juvenile bivalves. But, 'dead' maerl beds remain areas of high biodiversity compared to the surrounding substrata, with similar biodiversity and communities to those found in live maerl beds. While 'dead' maerl beds may have lower structural heterogeneity than live beds they still exhibit a heterogeneity comparable to that of gravel habitats and provide a unique habitat for a diverse community.

Birkett *et al.* (1998) reported ca 150 macroalgal species and ca 500 benthic faunal species from maerl beds in the British Isles. However, relatively few species are associated uniquely with maerl, and most are found in similar sedimentary habitats. Given the structural heterogeneity of live and 'dead' maerl, and variability in sedimentary composition (shell-gravel, gravel, sand and mud components) maerl beds (live and 'dead') provide a variety of microhabitats and hence support a highly diverse community.

# 3 Approach

Few of the above studies provide an absolute definition of a 'dead maerl' bed. Hall-Spencer (1998) gives the most qualitative definition for 98% dead maerl, while most others refer to dead beds as areas where the majority of the bed is composed of dead maerl but where small amounts of live maerl may be present. Small amounts of live maerl may be transported by storms and human activities from adjacent sites if present. However, for the purpose of this assessment a dead maerl bed is assumed to be one in which no live maerl is present. .

## 3.1 Sensitivity assessment

The MarLIN approach to biotope sensitivity assessment (Hiscock & Tyler-Walters, 2006, Tyler-Walters & Hiscock, 2003, Tyler-Walters & Hiscock, 2005, Tyler-Walters *et al.*, 2001) is summarised in Appendix 1, together with the relevant definitions of intolerance, recoverability, and sensitivity.

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 assessments to consider every possible outcome. Therefore, MarLIN sensitivity assessments are indicative qualitative judgments based on the best available scientific information. *They do not allow quantitative analysis.* The sensitivity assessments represent the most likely (or probable) result of a given change in an environmental pressure (factor) on a species population or biotope.

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**. In all cases, an explanation of each intolerance, recoverability and hence sensitivity assessment is provided, together with a summary of the relevant key information, and references highlighted.

### *3.1.1 Benchmarks*

Marine organisms may be affected by a number of human activities and natural events. The magnitude or scale of the effect of an activity (or event) is dependent 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 pressure s are site specific and cannot be generalized.

In addition, any one activity (or event) may change one or more environmental pressures. 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 Tyler-Walters *et al.,* 2001 and the MarLIN website). The 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 pressures 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 (see Tyler-Walters *et al.,* 2001, MarLIN website). A full list of benchmarks and their definitions is available online at http://www.marlin.ac.uk/sensitivitybenchmarks.php.

### *3.1.2 Assumptions*

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 pressure.
- The effects of an activity or natural event and the resultant change in environmental pressures are site specific and cannot be generalised. Therefore, a series of standard level of effect or change in each environmental pressure are used for assessment (the benchmarks).
- **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 pressure has been removed or stopped and the habitat returned to a state capable of supporting the species or biotope in question.**
- Where the collated key information and other evidence suggest 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.

### *3.1.3 Interpretation of sensitivity assessments*

Sensitivity is based on the assessment of intolerance against a benchmark level of change in an environmental pressure, and the likely recoverability of the species population or biotope.

- The benchmarks are intended to be pragmatic guidance values for sensitivity assessment based on likely levels of effect from a pressure, 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 pressure of greater magnitude and/or longer duration and/or greater frequency than the benchmark. For example:
    - if the predicted change in an environmental pressure has a greater magnitude than that used in the benchmark, then it is likely that the species population / biotope will have a greater sensitivity to this change;
    - if the predicted change in an environmental pressure has a longer duration than that used in the benchmark, then it is likely that the species population / biotope will have a greater sensitivity to this change;

  - if the predicted change in an environmental pressure 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;
  - if the frequency of the predicted change in an environmental pressure is greater than the time required for recovery then the species or community will probably exhibit a higher sensitivity,
  - while if the species or community is likely to recover between the impacting events then it may not exhibit an increased sensitivity.
- Similarly, if a species population is isolated from sources of recruitment, for instance in isolated water bodies (e.g. sea lochs or lagoons) or by hydrography, then recovery may take longer, and hence the population may exhibit a higher sensitivity. Isolation is already factored into the recoverability assessments for relevant biotopes and lagoonal species.

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 are not addressed within the sensitivity assessments**. However, benchmarks could be compared to the predicted level of change at specific time intervals.

## 3.2 Assessment of 'dead' maerl beds

The MarLIN approach to biotope sensitivity assessment is based on the assumption that the sensitivity of a biotope (or habitat) is dependent on the sensitivity of the species within the associated community (see Appendix 1). Obviously, not all species within a community exert the same level of effect on the structure or functioning of that community. Therefore, the MarLIN approach identified key or important characterizing species, whose sensitivities were then used, together with an understanding of the ecology of the biotope (or habitat), to determine the overall sensitivity.

In the assessment of biotope sensitivity, the detailed characterising species lists provided by the UK Habitat Classification (Connor *et al.*, 2004, Connor *et al.*, 1997a, Connor *et al.*, 1997b) provided the starting point for the identification of key or important characterising species. Maerl biotopes are characterised by the abundance of the relevant maerl species, the key structuring biogenic species. Hence, MarLIN maerl biotope sensitivity assessments are weighted to the sensitivity of the relevant maerl species.

**This approach could not be applied to dead maerl beds,** partly as no defined characteristic species list is available, but mainly as the survival of the biogenic maerl is itself no longer of concern in the assessment. The sensitivity of the 'dead' maerl beds is primarily a function of the sensitivity of the resident community. However, given the very large number of species recorded in maerl beds, it was not possible to assess the sensitivity of a large number of species to represent the sensitivity of the resident community.

Therefore, the following 'generic' approach was applied:

- a range of species was examined to represent the major groups of organisms that make up the community;
- sensitivity assessment was based on
  - the general biological characteristics and recoverability characteristics of the representative species or groups, and
  - information from studies on the effects of different pressures on maerl beds.

No defined list of characterizing species was available for 'dead' maerl beds. Therefore, sensitivity assessment was made against a hypothetical 'dead' maerl beds community, based on the deep dead maerl beds in Falmouth Bay (Rostron, 1985, Dyer & Worsfold, 1998) and Scotland (Hall-Spencer, 1998).

## 3.3 Assumptions about 'dead' maerl beds

Although dead maerl itself was not taken into account in the assessment of sensitivity, its presence as a unique substratum, and the habitat requirements for the presence of the bed itself were taken into account. Like many sedimentary communities, pressures that change the sediment characteristics are likely to result in changes in the resident community. In addition, removal of 'dead' maerl is unlikely to be replaced. It was not assumed that 'dead' maerl was solely the result of direct human impact, as sub-fossil 'dead' beds could result from changes in sea levels (Bosence & Wilson, 2003). However, it was assumed that 'dead' maerl was more fragmented than 'live maerl' beds as the action of burrowing sponges and wave erosion alone can result in fragmentation of maerl nodules.

It was assumed that the community within the 'dead' maerl beds was similar to that found on and in live maerl beds, with the exception of those species that graze maerls directly, species that preferentially settle or grow on live maerls, and any species directly dependent on maerl primary productivity.

# DEAD MAERL BEDS

## DESCRIPTION OF HABITAT

Maerls are calcareous red algae that grow as nodules (occasionally crusts) forming dense but relatively open beds of algal gravel. Beds of maerl form in coarse clean sediments of gravels and clean sands, and occur either on the open coast or in tide-swept channels of marine inlets (the latter often stony). In fully marine conditions, the dominant maerl is typically *Phymatolithon calcareum* or *Lithothamnion coralloides* in England. Dead maerl beds may be composed of smaller maerl fragments than live beds resulting in a denser, less heterogeneous structure, and lack the diversity of mobile epifauna and maerl specific epiflora characteristic of live maerl beds. However, they support diverse communities of burrowing infauna, especially bivalves, and interstitial invertebrates; including suspension feeds polychaetes and echinoderms. Thicker maerl beds occur in areas of water movement (wave or current based) while sheltered beds tend to be thinner with more epiphytes. The associated community varies with underlying and surrounding sediment type, water movement, depth of bed and salinity.

## ECOLOGY

### Ecological and functional relationships

The biodiversity and ecological structure of maerl beds is summarised by Birkett *et al.* (1998). Grall *et al.* ((2006)) used carbon and nitrogen isotope analysis to examine the trophic relationships within maerl beds in the Bay of Brest. The biodiversity of maerl beds (and some 'dead' maerl beds) is shown by Birkett *et al.* (1998), Cabioch (1968), Hall-Spencer (1998), Kamenos *et al.* (2004b), Kamenos *et al.* (2004c), Rostron (1985). Live and dead maerl beds can support similar communities (see section 2 above). However, any species or ecological functions likely to be specific to live maerl are omitted.

Dead maerl provides a substratum for the attachment of epiflora and epifauna, and a range of interstices for mobile epifauna, and shallow burrowing infauna. The variable and open structure of the maerl sediment can also provide good oxygenation at depth and allows many species to burrow deeply into the maerl substratum, while other deep burrowing species (e.g. mud shrimp) can also occur.

- Primary productivity is provided by epiphytic macroalgae or microphytobenthos (e.g. benthic diatoms) growing on the maerl thalli at the surface of the bed, together with deposited phytoplankton and particulate organic materials.
- Photosynthetic macroalgal epiphytes are likely to include red algae e.g. *Gracilaria* spp., *Ceramium* spp., *Polyides rotundus, Dictyota dichotoma*, green algae e.g. *Ulva* spp., *Cladophora* spp. and brown algae e.g. *Chorda filum*, although the actual species present will vary between sites.
- Filter feeders can be divided into those that feed from the water column, those that feed within the surface layer of the bed (epifaunal) and those that feed at the interface between the surface of the bed and deep sediments, e.g. the burrowing bivalves.
- The community may be dominated by a large number of filter feeding species including sponges (e.g. *Scypha ciliata, Suberites* spp. and *Halichondria panicea*); hydroids (e.g. *Obelia geniculata*); anemones (e.g. *Metridium senile*); polychaetes (e.g. the fanworm *Sabella pavonica,* the parchment worm *Chaetopterus variopedatus,* and keel worms *Pomatoceros spp.*); decapods (e.g. *Pisidia longicornis,)*; molluscs (e.g. *Pecten maximus, Crepidula fornicata*); bryozoans (e.g. *Bugula* spp., *Scrupocellaria scruposa*); echinoderms, and sea squirts (e.g. *Ascidiella aspersa*, *Botrylloides leachii*).

- Epifaunal and infaunal surface deposit feeders include polychaetes (e.g. *Notomastus latericeus*) and some crustaceans (e.g. *Apseudes latreilli* and *Athanas nitescens*) (Grall *et al.,* 2006). Burrowing polychaetes also feed on organic material in the finer sediments present within the bed.
- Surface grazers include chitons and gastropods (e.g. *Bittium reticulum* and *Gibbula cineraria*) that feed on benthic diatoms, biofilms and young macroalgae and hydroids growing on shells, pebbles and maerl thalli.
- Predators include demersal fish, star fish (e.g. *Asterias rubens*), crabs (e.g. *Liocarcinus* spp. and *Cancer pagurus*), and gastropods (e.g. the common whelk *Buccinum undatum*) as well as infaunal carnivorous polychaetes (e.g. the eunicid polychaetes) where present.
- Omnivores and scavengers include gastropods (e.g. *Nassarius* spp., *Buccinum undatum*), crabs and starfish.

Grall *et al.* (2006) concluded that the majority of the biomass (in Bay of Brest live maerl beds) was represented by interface filter feeders, small carnivores and epifaunal deposit feeders. Nunn (1993) and Hall-spencer (1998) point out that maerl bed can host a diverse number of infaunal bivalve molluscs, which can represent an extremely high biomass (Hall-Spencer *et al.*, 2003).

### Seasonal and longer term change

Birkett *et al.* (1998) note that there is considerable variation in maerl flora and fauna even within the same bay system (e.g. Galway Bay or Baie de Morlaix) and algal abundance changes between winter and summer. In the Mediterranean, the maerl bed epifloral diversity doubled over summer. In Galway Bay, maerl bed algal diversity increased in summer, in part due to greater stability of the bed surface in summer. Comparison of two sites showed that the increase in algal cover was greatest at shallow the shallow site (5 m) than at the deeper site (10m). Prostrate macroalgae may stabilize the maerl beds in summer by the formation of stolons and secondary attachments (Birkett *et al.*, 1998). Where they occur, byssus forming bivalves (e.g. mussels, flame shells) may also stabilize the surface of the bed. Where present, the gravel sea cucumber (*Neopentadactyla mixta*) migrates deeper within the bed in winter months where is remains in a state of torpor until spring (Smith & Keegan, 1985).

In areas exposed to wave action, and especially winter storms, the surface of the bed may be mobilised, and form ripples and mega-ripples (Keegan, 1974; Birkett *et al.* 1998; Hall-Spencer 1998; Hall-Spencer & Atkinson, 1999). Storms and wave action may result in a reduced epiflora and epifauna provide space for more opportunistic epiflora (Birkett *et al.*, 1998), but is unlikely to affect deep burrowing fauna (e.g. some bivalves and mud shrimp) (Hall-Spencer 1998; Hall-Spencer & Atkinson, 1999).

In the long term established maerl beds are known to be extremely old, and carbon dating suggest that some beds may be between 4000 and 6000 years old (Birkett *et al.* 1998). Bosence & Wilson (2003) calculate the maximum age of the St Mawes Bank, Falmouth, to be 4000 years.

### Habitat structure and complexity

Nodules of maerl provide a loose, open structure with numerous interstices of varying size for a wide range of species to dwell and feed within, while also providing a hard substratum for attachment by epiflora and epifauna. Maerl beds usually include dead shell within the maerl matrix that provides additional substratum. However, maerl substratum is highly variable in terms of depth of the maerl bed itself, patches of different substratum (gravels, sands, muds etc.) within the bed, and the nature of the underlying sediment. As shown above, Grall *et al.* (2006) identified a number of different microhabitats and trophic levels.

Overall, it is the loose open and heterogeneous structure of the bed that provides the diversity of microhabitats and hence diversity of the biological community (Birkett *et al.*, 1998; Kamenos *et al.* 2003; Grall *et al.*, 2006). The open structure also allows water flow to penetrate deep into the bed allowing for species to occur at considerable depth within the maerl matrix. While dead maerl does not provide the structural heterogeneity as live maerl, it was similar to gravel habitats, and so more open than other sediments. For examples, in Scottish beds, rayed artemis *Dosinea exoleta* was recorded at a maximum depth of 42 cm, the razor shell *Ensis arcuatus* at 48 cm, and the gaper clam *Mya truncata* at 56 cm (Hall-Spencer, 1998). The mud shrimp *Upogebia deltaura* can form burrows down to 68 cm (Hall-spencer & Atkinson, 1999), while the *Neopentadactyla mixta* can spend winter at depths of 60 cm in maerl (Smith & Keegan, 1985). The structural complexity is augmented by the presence of tube-building species, such as the mud shrimp and burrowing anemones (*Cerianthus lloydii*) and parchment tube worms (*Chaetopterus variopedatus*), whose burrows allow oxygenated water to penetrate the bed and also provide habitats for interstitial and commensal species (e.g. *Mysella bidentata*).

Dead maerl is presumed to be more fragmented, as is impacted (dredged or extracted) 'dead' maerl. Therefore, it is likely to have a lower heterogeneity than pristine maerl beds (Grall *et al.*, 2006) but nevertheless still supports a diverse fauna and flora (Rostron, 1985; Hall-Spencer 199; Birkett *et al.* 1998).

### Dominant trophic groups

- Photoautotrophs (macroalgae, microphytobenthos)
- Filter feeders (suspension feeders)
- Surface deposit feeders
- Predators and scavengers

### Productivity

Dead maerl beds lack the primary productivity of the maerl itself. Grall *et al.* (2006) estimated that macroalgal productivity of epiflora was 135 g/m$^2$ in the Bay of Brest, and recorded 70g (AFDW) or 11000 individuals per m$^2$ for macrofauna (small invertebrates) and 100 individuals per m$^2$ (11.3-34.8 g AFDW/m$^2$) for megafauna (large invertebrates). In Galway Bay, Bosence (1979; cited in Birkett *et al.*, 1998) reported invertebrate abundances ranging from 10 individuals per 0.25m$^2$ of *Hiatella arctica* to 270 individuals per 0.25m$^2$ for *Bittium reticulum*. However, the productivity of individual beds is likely to be variable.

### Major sources of organic carbon

- Photosynthesis (macroalgae, microphytobenthos, phytoplankton)
- Secondary production (zooplankton, particulate organic materials, detritus).

### Recruitment processes

Dead maerl is by definition unable to recruit or replenish. Passive migration of live maerl nodules or dead maerl fragments is possible from adjacent beds (if present) due to storm or wave activity, or via attachment to macroalgae moved by wave and currents (Birkett *et al.*, 1998). A diversity of species groups may be found in maerl beds (live or dead), and recruitment in a number of example species groups and species is given below.

- Vadas *et al.* (1992) reviewed recruitment and mortality of early post settlement stages of benthic algae. Grazing, canopy and turf effects were the most important factors determining recruitment and settlement but that desiccation and water movement may be as important for the early stages. He indicated that recruitment is highly variable and episodic and that mortality of algae at this period is high.

Chance events during the early post settlement stages are therefore likely to play a large part in survival.

- The propagules of most macroalgae tend to settle near the parent plant (Holt *et al.*, 1997, Norton, 1992, Schiel & Foster, 1986). For example, the propagules of fucales are large and sink readily and red algal spores and gametes are immotile. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition (zygotes or spores being thrown against the substratum). For example, spores of *Ulva* sp. have been reported to travel 35 km and *Phycodrys rubens* travel 5 km. The reach of the furthest propagule and useful dispersal range are not the same thing and recruitment usually occurs on a local scale, typically within 10m of the parent plant (Norton, 1992). However, many of macroalgae also have heteromorphic life histories that include a microscopic gametophytic or sporophytic stage that may itself be more tolerant (or less, depending on species) of environmental change and function in part like a 'seed bank'.
- Guillou & Sauriau (1985) investigated reproduction and recruitment in a *Venus striatula* population in the Bay of Douarnenez, Brittany. There were 2 periods of spawning activity, one in the spring and then again in late summer. The larvae undergo planktotrophic development, metamorphosis occurring 3 weeks after fertilization (Ansell, 1961; cited in Guillou & Sauriau, 1985). There were 2 periods of recruitment, one at the end of the spring and the second in autumn. The mean life span was 5 years and the maximum 10 years. No evidence was found to suggest that recruitment patterns for the other venerid bivalves differed significantly.
- Dauvin (1985) reported that the oval venus *Timoclea ovata* (studied as *Venus ovata*) recruitment occurred in July-August in the Bay of Morlaix. However, the population showed considerable pluriannual variations in recruitment, 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, venerid bivalve recruitment is probably unpredictable and sporadic.
- Hydroids are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). Hydroids that lack a medusa stage, release planula larvae which swim or crawl for short periods (e.g. <24hrs) so that dispersal away from the parent colony is probably very limited (Gili & Hughes, 1995). However, sea beard *Nemertesia antennina* releases planulae on mucus threads, that increase potential dispersal to 5 -50m, depending on currents and turbulence (Hughes, 1977). Few species of hydroids have specific substrata requirements and many are generalists capable of growing on a variety of substrata. Hydroids are also capable of asexual reproduction and many species produce dormant, resting stages that are very resistant of environmental perturbation (Gili & Hughes, 1995). However, it has been suggested that rafting on floating debris (or hitch hiking on ships hulls or in ship ballast water) as dormant stages or reproductive adults, together with their potentially long life span, may have allowed hydroids to disperse over a wide area in the long term and explain the near cosmopolitan distributions of many hydroid species (Gili & Hughes, 1995).
- Sponges may proliferate both asexually and sexually. A sponge can regenerate from a broken fragment, produce buds either internally or externally or release clusters of cells known as gemmules which develop into a new sponge, depending on

species. Most sponges are hermaphroditic but cross-fertilization normally occurs. The process may be oviparous, where there is a mass spawning of gametes through the osculum which enter a neighbouring individual in the inhalant current. Fertilized eggs are discharged into the sea where they develop into a planula larva. However, in the majority development is viviparous, whereby the larva develops within the sponge and is then released. Larvae have a short planktonic life of a few hours to a few weeks, so that dispersal is probably limited and asexual reproduction probably results in clusters of individuals.

- Echinoderms are highly fecund; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability. For example, the heart urchin *Echinocardium cordatum* recruitment has been recorded as sporadic, only occurring in 3 years out of a 10 year period ((Buchanan, 1967)).
- The mating system of amphipods is polygynous and several broods of offspring are produced, each potentially fertilized by a different male. There is no larval stage and embryos are brooded in a marsupium, beneath the thorax. Embryos are released as sub-juveniles with incompletely developed eighth thoracopods and certain differences in body proportions and pigmentation. Dispersal is limited to local movements of these sub-juveniles and migration of the adults and hence recruitment is limited by the presence of local, unperturbed source populations (Poggiale & Dauvin, 2001). Dispersal of sub-juveniles may be enhanced by the brooding females leaving their tubes and swimming to un-colonized areas of substratum before the eggs hatch (Mills, 1967). However, amphipods are generally mobile and liable to recruit from the surrounding substratum.
- The tube building polychaetes, e.g. *Pygospio elegans* and the sand mason worm *Lanice conchilega*, generally disperse via a pelagic larval stage (Fish & Fish, 1996) and therefore recruitment may occur from distant populations, aided by bed load transport of juveniles (Boström & Bonsdorff, 2000). However, dispersal of some of the infaunal deposit feeders, such as *Scoloplos armiger*, occurs through burrowing of the benthic larvae and adults (Beukema & de Vlas, 1979, Fish & Fish, 1996). Recruitment must therefore occur from local populations or by longer distance dispersal during periods of bed-load transport. Recruitment is therefore likely to be predictable if local populations exist but patchy and sporadic otherwise.
- *Mya arenaria* demonstrates high fecundity, increasing with female size, with long life and hence high reproductive potential. The high potential population increase is offset by high larval and juvenile mortality. Juvenile mortality reduces rapidly with age (Strasser, 1999). Strasser *et al.* (1999) noted that population densities in the Wadden Sea were patchy and dominated by particular year classes. Therefore, although large numbers of spat may settle annually, successful recruitment and hence recovery may take longer than a year. Recruitment of shallow burrowing infaunal species can depend on adult movement by bed-load sediment transport and not just spat settlement. Emerson & Grant (1991) investigated recruitment in *Mya arenaria* and found that bed-load transport was positively correlated with clam transport. They concluded that clam transport at a high energy site accounted for large changes in clam density. Furthermore, clam transport was not restricted to storm events and the significance is not restricted to *Mya arenaria* recruitment. Many infauna, e.g. polychaetes, gastropods, nematodes and other bivalves, will be susceptible to movement of their substratum.
- Ascidians such as *Ascidiella scabra* have external fertilization but short lived larvae (swimming for only a few hours), so that dispersal is probably limited. *Ascidiella*

> *scabra* has a high fecundity and settles readily, probably for an extended period from spring to autumn. Svane (1988) describes it as 'an annual ascidian' and demonstrated recruitment onto artificial and scraped natural substrata. Eggs and larvae are free-living for only a few hours and so recolonization would have to be from existing individuals no more than a few km away. It is also likely that *Ascidiella scabra* larvae are attracted by existing populations and settle near to adults (Svane *et al.*, 1987). Fast growth means that a dense cover could be established within about 2 months. Where neighbouring populations are present recruitment may be rapid but recruitment from distant populations may take a long time.

Mobile epifaunal species, such as echinoderms, crustaceans, and amphipods are fairly vagile and capable of colonizing the community by migration from the surrounding areas, probably attracted by the refugia and niches supplied by the maerl. In addition, most echinoderms and crustaceans have long-lived planktonic larvae with high dispersal potential, although, recruitment may be sporadic, especially in echinoderms. Many of the burrowing bivalves have planktonic larvae, potential wide dispersal but high larval mortality resulting in sporadic recruitment.

### Time for community to reach maturity

No information was found concerning the time taken for the 'dead' maerl communities to reach maturity, and where recovery has been examined, no distinction between 'live' and 'dead' was made. However, several studies examined undredged, fallow and dredged sites.

De Grave & Whitaker (1999) compared a dredged (extracted) maerl bed with one that been left 'fallow' for six months in Bantry Bay, Ireland. They noted that the dredged bed had significantly fewer molluscs than the fallow bed, but significantly more crustaceans and oligochaetes. Hall-Spencer & Moore ((2000a, 2000b)) examined the recovery of a maerl community after scallop dredging in previously un-dredged and dredged sites in Scotland. In comparison with control plots, mobile epibenthos returned within one month; fleshy macroalgae within six months; the abundance of the tube anemone *Cerianthus lloydii* was not significantly different after 14 months; other epifauna (e.g. *Lanice conchilega* and *Ascidiella aspersa*) returned after 1-2 years; but some of the larger sessile surface species (e.g. sponges, the plumose anemone *Metridium senile*, the horse mussel *Modiolus modiolus* and flame shell *Limaria hians*) exhibited lower abundances on dredged plots after four years. Deep burrowing species (mud shrimp, large bivalves e.g. *Mya truncata* and the gravel sea cucumber *Neopentadactyla mixta*) were not impacted and their abundance changed little over the four year period. Hall-Spencer *et al.* (2003) note that long lived (>10 years) species (e.g. the rayed artemis *Dosinia exoleta*) can occur at high abundances in maerl beds but that the sustainability of stocks are unknown at present. Hall-Spencer (2000a) noted that there was no significant difference between controls and experimentally dredged sites after 1-2 years at the sites previously subject to dredging.

Overall, it appears that most of the maerl related community could develop within five years, although long-lived and/or large sessile species (e.g. bivalves, anemones, and sponges) would take longer.

## HABITAT PREFERENCE AND DISTRIBUTION

### Distribution in Britain and Ireland

Maerl beds (live and dead) have a patchy distribution around the coast of the British Isles. They are widespread around the west coast of Scotland, in the Western Isles, Orkney and Shetland but restricted to Milford Haven, the Pembrokeshire Islands and the Llyn Peninsula in Wales. Beds are rare in England, reported from Dorset, the Isles of Scilly and Lundy but with extensive beds in the Fal Estuary and mouth of the Helford River. Extensive beds occur on the north east coast of Northern Ireland, and along the west coasts of Ireland (e.g. Galway Bay). In

Europe, maerl beds are found in the Mediterranean, and on the Atlantic coast from Norway and Denmark south to Portugal, Morocco and Mauritania on the African coast (Birkett *et al.* 1998). Few of the distributional records distinguish between 'live' and 'dead' beds.

### Habitat preferences

Extensive maerl beds are restricted to areas of moderate to strong currents protected from strong wave action, e.g. in bays and inlets. *Lithothamnion coralloides* is more tolerant of low water flow that *Phymatolithon calcareum,* so that the species composition varies with water flow. The depth at which live maerl can grow depends on light availability (and hence water clarity), and in the British Isles maerl can occur at 30m but larger beds occur at 15m or less. Species composition is also dependant on temperature. While maerl occurs from the tropics to Norway*, Lithothamnion coralloides* is restricted to southern waters while *Lithothamnion glaciale* is particularly abundant in Scotland (Birkett *et al.* 1998). Maerl beds are normally found at full salinity but can tolerate reduced salinities. Live maerls are intolerant of desiccation, so are rarely found or form beds in the intertidal (Birkett *et al.*, 1998, Wilson *et al.*, 2004).

The presence of 'dead' maerl beds is dependent of the prior growth and development of live maerl beds over decades or thousands of years. Therefore, dead maerl beds can only occur in areas that are presently, or were previously suitable for the growth of live maerl.

## SPECIES INDICATIVE OF SENSITIVITY

The key structural species in live maerl beds is the maerl itself. However, in 'dead' maerl beds the maerl provides the substratum alone. While grazers are probably important species that keep live maerl free of overgrowing species, this is not relevant in 'dead' maerl beds. The maerl bed communities are very dependent on the fauna and flora of the surrounding area, and are highly variable. Therefore, it was not possible to identify particular key or important characterizing species. Therefore, the assessment of sensitivity was based on major functional groups of organisms and representative examples where the evidence allowed. For example, epifloral, epifaunal, infaunal and deep burrowing species. Loss of members of these groups would result in an impoverished community rather than loss of the maerl community itself, so that no one group or species (within 'dead' maerl beds) was identified as representative of sensitivity on its own.

### Species found especially in maerl habitats

The red seaweed *Cruoria cruoriaeformis* occurs on maerl beds in particular and was recorded from 'dead' maerl beds by Rostron (1985).

## HABITAT SENSITIVITY

### Physical Pressures

| | Intolerance | Recoverability | Sensitivity | Evidence / Confidence |
|---|---|---|---|---|
| Substratum Loss | High | None | Very High | High |
| Smothering | Intermediate | High | Low | Low |
| Increase in suspended sediment | Intermediate | High | Low | Very low |
| Decrease in suspended sediment | Not relevant | Not relevant | Not relevant | Not relevant |
| Desiccation | Not relevant | Not relevant | Not relevant | Not relevant |
| Increase in emergence regime | Not relevant | Not relevant | Not relevant | Not relevant |
| Decrease in emergence regime | Not relevant | Not relevant | Not relevant | Not relevant |
| Increase in water flow rate | Intermediate | High | Low | Very low |
| Decrease in water flow rate | High | High | Moderate | Very low |
| Increase in temperature | Low | Very high | Very low | Very low |
| Decrease in temperature | Low | Very high | Very low | Very low |
| Increase in turbidity | Low | Very high | Very low | Very low |
| Decrease in turbidity | Low | Very high | Very low | Very low |
| Increase in wave exposure | Intermediate | High | Low | Low |
| Decrease in wave exposure | Tolerant | Not relevant | Not sensitive | Very low |
| Noise | Tolerant | Not relevant | Not sensitive | Low |
| Visual Presence | Tolerant | Not relevant | Not sensitive | Low |
| Abrasion & physical disturbance | High | Moderate | Moderate | Moderate |
| Displacement | Intermediate | High | Low | Very low |

### Chemical Pressures

| | Intolerance | Recoverability | Sensitivity | Evidence / Confidence |
|---|---|---|---|---|
| Synthetic compound contamination | Intermediate | High | Low | Very low |
| Heavy metal contamination | Intermediate | High | Low | Very low |
| Hydrocarbon contamination | Intermediate | High | Low | Very low |
| Radionuclide contamination | Insufficient information | Insufficient information | Insufficient information | Not Relevant |
| Changes in nutrient levels | High | Moderate | Moderate | Moderate |
| Increase in salinity | Low | Very high | Low | Low |
| Decrease in salinity | Intermediate | High | Low | Low |
| Changes in oxygenation | High | Moderate | Moderate | Moderate |

**Biological Pressures**

| | Intolerance | Recoverability | Sensitivity | Evidence / Confidence |
|---|---|---|---|---|
| Introduction of microbial pathogens/parasites | Low | Very high | Low | Very low |
| Introduction of non-native species | High | Very low | Very high | High |
| Extraction (of key or important characterizing species) | High | None | Very High | High |

## EXPLANATION OF SENSITIVITY

**Physical Pressures**

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| Substratum Loss (see benchmark) | Loss of the substratum (dead maerl) e.g. by extraction, channelization etc., would result in loss of the entire habitat and its associated community. Deep maerl beds are several thousands of years old and dead maerl cannot be replenished (effectively a non-renewable resource) so that recovery of a maerl bed is unlikely to occur naturally. Therefore, a high intolerance and 'none' recovery are recorded. Sensitivity is likely to be very high. |
| Smothering (see benchmark) | Smothering results from the rapid deposition of sediment or spoil, which may occur after dredging (suction or scallop), capital dredging (channelization), extreme runoff, spoil dumping etc. The effects depend on the nature of the smothering sediment. For example, live maerl were found to survive burial in coarse sediment ((Wilson *et al.*, 2004)) but to die in fine sediments. In addition, detrimental effects on *Fucus* embryos were reported in fine sediments, presumably as fine sediment restricts water flow. Similarly, fine sediment is likely to prevent settlement of algal propagules, so that the effects are potentially greater during their settlement period. 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. Dow & Wallace (1961) noted that large mortalities in clam beds resulted from smothering by blankets of algae (*Ulva* 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.<br>Smothering by 5cm of sediment (the benchmark) is likely to clog or reduce water flow through the surface of the bed, and directly smother small non-mobile members of the epifauna and epiflora, while larger species e.g. sea squirts, anemones, some sponges and macroalgae would protrude above the smothering sediment. Mobile small burrowing species (e.g. amphipods and polychaetes) would probably burrow to safety. However non-motile epifauna (e.g. encrusting bryozoans and small hydroids) and small or prostrate algal will probably be reduced in abundance. Deep burrowing bivalves may experience some mortality due to loss of water flow through the bed, deoxygenating and lack of food |

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| | depending on their depth. But large burrowing anemones and mud shrimp would probably just burrow through the smothering material. Overall, a proportion of the community may be lost and an intolerance of intermediate is suggested. Recoverability is probably high. |
| Increase in suspended sediment (see benchmark) | Increased suspended sediment levels will increase turbidity (see below), scour and siltation. Scour induces high mortality in early post settlement algal stages and prevents the settlement of propagules owing to accumulation of silt on the substratum (Vadas *et al.*, 1992). But, increased particulates may provide additional food for filter feeders. However, an increase in suspended sediment may increase the fines within the bed, decreasing water flow and oxygenation through the bed, and hence the depth of the surface epifauna. It may result in an increase in burrowing species compared to filter feeding species. However, De Grave (1999) noted that sedimentary heterogeneity within maerl beds (including maerl debris with mud, sand or gravel) resulted in only minor changes in the community of amphipods and crustaceans present. Overall, a proportion of the epifauna and epiflora may be reduced and an intolerance of 'intermediate' is suggested. Recovery is likely to be high. |
| Decrease in suspended sediment (see benchmark) | Maerl beds occur in strong currents in bays and inlets. A further decrease in suspended sediment levels is unlikely. |
| Desiccation (see benchmark) | In the UK, maerl beds do not occur in the intertidal, as maerl itself is highly sensitive to desiccation (Wilson *et al.*, 2004). Therefore, it is very unlikely that a maerl bed would be exposed at low water as a result of human activities or natural events. |
| Increase in emergence regime (see benchmark) | In the UK, maerl beds do not occur in the intertidal, as maerl itself is highly sensitive to desiccation (Wilson *et al.*, 2004). Therefore, it is very unlikely that a maerl bed would be exposed at low water as a result of human activities or natural events. |
| Decrease in emergence regime (see benchmark) | In the UK, maerl beds do not occur in the intertidal, as maerl itself is highly sensitive to desiccation (Wilson *et al.*, 2004). Therefore, it is very unlikely that a maerl bed would be exposed at low water as a result of human activities or natural events. |
| Increase in water flow rate (see benchmark) | Maerl beds are restricted to areas of strong tidal currents or wave oscillation (Birkett *et al.* 1998). For example, Birkett *et al.* (1998) quote a flow rate of 10 cm/s across the maerl bed at spring tides in Greatman's Bay, Galway, while the UK Biotope classification (Connor *et al.*, 2004) reports maerl beds occurring at sites with between moderately strong to very weak tidal streams. As Birkett *et al.* (1998) note, local topography and wave generated oscillation probably result in stronger local currents at the position of the bed.<br>An increase in water flow from moderately strong to very strong is likely to modify the substratum, removing fines and potentially mobilizing the surface of the bed, perhaps even resulting in winnowing away of the bed. Stronger water flow may favour filter feeders and suspension feeders but adversely affect the deposit or surface deposit feeders. Mobilization of the maerl bed surface is also likely to result in a reduced sessile epifauna and epiflora (macroalgae, sponges, and sea anemones). Overall, the |

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| | community composition is likely to change but probably remain characteristic of maerl beds. Therefore, an intolerance of intermediate is suggested with a recoverability of high. |
| Decrease in water flow rate (see benchmark) | Maerl beds are restricted to areas of strong tidal currents or wave oscillation (Birkett *et al.* 1998). A decrease in water flow is likely to be extremely detrimental to the maerl community. The resultant increase in siltation and deposition of fines is likely to significantly reduce the epiflora, and change the epifaunal community in favour of deposit feeders, with the loss of surface filter feeders, especially passive suspension feeders. Fines would fill the open structure of the bed, restricting the depth to with much of the deep burrowing fauna can live, except normally deep burrowing mud shrimp, and large bivalves (e.g. *Mya* sp.). For example, *Neopentadactyla mixta* probably only survives at depth in maerl/gravel beds due to the good oxygenation, and would probably be lost. Overall, the diverse maerl bed community would probably be replaced by a mud and mixed sediment community. Therefore, an intolerance of high has been suggested, while recovery is probably high once water flow returns to its moderately strong or higher. |
| Increase in temperature (see benchmark) | Maerl beds in the north east Atlantic range from Norway to the African coast, although the component maerl species vary in temperature tolerance (Birkett *et al.*, 1998, Wilson *et al.*, 2004). Similarly, the associated communities occur from Shetland to the Isles of Scilly, and represent a diverse sample of species within the local area. Therefore, long-term temperature change may cause a shift in the associated community to more northern or more southern species but the overall community is likely to remain. Short term acute changes (e.g. from thermal discharges) could potentially affect the surface of the bed as it has an open structure, while the deeper species will probably be unaffected. However, many of the species that occur in Scottish waters are also recorded from southern maerl beds, and have a wide geographic range. While subtidal algae are probably intolerant of acute temperature change, a three day exposure (the benchmark) is unlikely to result in death but will adversely affect photosynthesis and growth. Mobile epifauna could also avoid temperature change by retreating further into the bed. However, larval stages of bivalves and other invertebrates are likely to be more sensitive and thermal discharges could adversely affect recruitment depending on the time of year. Overall, an increase in temperature is unlikely to significantly affect the community. Therefore, an intolerance of low is suggested with a recoverability of very high. |
| Decrease in temperature (see benchmark) | See increase in temperature above. |
| Increase in turbidity (see benchmark) | An increase in turbidity (light attenuation) is liable to reduce the growth of the epiflora, especially green and brown algal species but less so for the shade tolerant red algae, depending on the depth of the bed. Also, increased competition for light and overall reduced light is likely to favour ubiquitous species (e.g. *Ceramium* spp. and *Ulva* spp. (Birkett *et al.*, 1998). There may be a decrease in the overall primary productivity of macroalgae and microalgae, as well as reduced phytoplankton productivity. As a result the food supply for some filter feeders and |

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| | grazers may be reduced. However, the effects are unlikely to have significant effects on the community, even after one year, so an intolerance of low has been given. Recoverability is likely to be very high. |
| Decrease in turbidity (see benchmark) | An increase in light (decreased turbidity) is likely to increase benthic microalgae and macroalgal growth, and hence increase available primary productivity. An increase in algal cover was noted due to eutrophication in the Rade de Brest (Grall & Glemarec 1997; cited in Birkett *et al.*, 1998), which resulted in a slight decrease in the diversity of carnivores, detritivores and scavengers. Birkett *et al.*, (1998) note that shading/smothering by other algae is potentially detrimental to live maerl beds, as it impairs the growth of the maerl. In dead maerl beds the growth of maerl itself is not a concern. However, grazing community is likely to increase. Therefore, an intolerance of low with a recoverably of very high is suggested. |
| Increase in wave exposure (see benchmark) | Maerl beds develop in strong currents but are restricted to areas of low wave action. For example, in Mannin Bay dense maerl beds were restricted to less wave exposed parts of the bay (Birkett *et al.*, 1998). Areas of maerl subject to wave action often show mobile areas in the form of ripples or mega-ripples (Hall-Spencer & Atkinson, 1999, Keegan, 1974). In Galway Bay, Keegan (1974) noted the formation of ripples due to wave action and storms, where the ripples were flattened over time by tidal currents. However, he reported that the rippled area (average crest height 20 cm) had a poor faunal diversity with heavy macroalgal settlement on any firm substratum, including the tubes of *Chaetopterus*. However, the infauna was a typical '*Venus*' community, the majority of which was found at depths of more than 20 cm. Hall-Spencer & Atkinson (1999) noted that mega-ripples at their wave exposed site were relatively stable but underwent large shifts due to storms. However, the mixed sediments of the subsurface of the bed (>12 cm) were unaffected so that the burrows of the mud shrimp remained in place. Similarly, Birkett *et al.* (1998) note that in areas where storms affected the maerl at a depth of 10 m, only the coarse upper layer of maerl was moved while the underlying layers were stable. Following storms infaunal species renewed burrow linings within a week. However, the epiflora of maerl beds was severely disturbed by storms in Galway Bay with a marked drop in abundance in winter months. Deep beds are less likely to be affected by storm damage.<br>Overall, therefore, an increase in wave action is likely to mobilise the surface of the bed, reduce the abundance of epiflora, promoting opportunistic epiflora, reduce the abundance of sessile epifauna, but probably have only limited effect on infauna, especially deep burrowing infauna. Therefore, a reduction in the diversity of the bed is likely and an intolerance of intermediate is given. Recoverability is likely to be high. |
| Decrease in wave exposure (see benchmark) | Maerl beds develop in strong currents but are restricted to areas of low wave action. For example, in Mannin Bay dense maerl beds were restricted to less wave exposed parts of the bay (Birkett *et al.*, 1998). Therefore, where beds occur in areas exposed to wave action, a reduction in wave exposure may benefit the diversity of the bed. Otherwise, further reduction in wave action is unlikely to be detrimental. |

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| Noise<br>(see benchmark) | There is little information on the effects of noise on invertebrates and plants. Some invertebrates may react to vibration and stop feeding. Otherwise, noise is unlikely to have any adverse effect. |
| Visual Presence<br>(see benchmark) | None of the resident species are likely to have the visual acuity to respond to 'visual disturbance'. |
| Abrasion & physical disturbance<br>(see benchmark) | Physical disturbance can result from e.g. channelization (capital dredging), suction dredging for bivalves, extraction of maerl, scallop dredging or demersal trawling. The effects of physical disturbance were summarised by Birkett *et al.* (1998) and Hall-Spencer *et al.* (2010), and documented by Hall-Spencer and co-authors (Hall-Spencer, 1998, Hall-Spencer *et al.*, 2003, Hall-Spencer & Moore, 2000a, Hall-Spencer & Moore, 2000b), Hauton *et al.* (2003) and others.<br>For example, in experimental studies, Hall-Spencer & Moore (2000a, c) reported that the passage of a single scallop dredge through a maerl bed could bury and kill 70% of living maerl in its path. The passing dredge also re-suspended sand and silt that settled over a wide area (up to 15 m from the dredged track), and smothered the living maerl. Abrasion may break up maerl nodules into smaller pieces resulting in easier displacement by wave action, resulting in a reduced structural heterogeneity and lower diversity of species (Kamenos *et al.*, 2003). The dredge left a ca 2.5 m track and damaged or removed most megafauna within the top 10 cm of maerl (Hall-Spencer & Moore, 2000a). For example; crabs, *Ensis* species, the bivalve *Laevicardium crassum*, and sea urchins. Deep burrowing species such as the tube anemone *Cerianthus lloydii* and the crustacean *Upogebia deltaura* were protected by depth, although torn tubes of *Cerianthus lloydii* were present in the scallop dredge tracks (Hall-Spencer & Moore, 2000a). *Neopentadactyla mixta* may also escape damage due to the depth of its burrow, especially during winter torpor. Hall-Spencer & Moore (2000a) reported that sessile epifauna or shallow infauna such as *Modiolus modiolus* or *Limaria hians*, sponges and the anemone *Metridium senile* where present, were significantly reduced in abundance in dredged areas for 4 years post-dredging. Other epifaunal species, such as hydroids (e.g. *Nemertesia* species) and red seaweeds are likely to be removed by a passing dredge.<br>The tracks remained visible for up to 2.5 years. In pristine live beds experimental scallop dredging reduced the population densities of epibenthic species for over 4 years. However, in previously dredged maerl beds, the benthic communities recovered in 1-2 years.<br>Hauton *et al.* (2003) undertook experimental suction (hydraulic dredging) in Stravanan Bay, Scotland, a site subject to scallop dredging and recorded as impacted dead maerl by Kamenos *et al.* (2003). The suction dredge removed epiflora (burrowing algae and macroalgae), maerl, slow moving epifauna (e.g. starfish, gastropods and clingfish) and mainly infauna. Large or fragile polychaetes (e.g. *Chaetopterus*) and *Cerianthus lloydii* were removed and damaged, while polychaetes with tough bodies or strong tubes survived. Large infaunal bivalves dominated the catch, including *Dosinia exoleta, Tapes rhomboides, Abra alba*, and *Ensis arcuatus* but, while *Mya truncata and Lutraria angustior* were not caught because of their depth, the catch did include torn siphons from these species; an injury they are unlikely to survive. The |

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| | dredge resulted in a visible track that left numerous damaged megafauna, which in turn attracted scavengers. In addition, the dredging fragmented maerl and resulted in a large plume of fine sediment that settled over the surrounding area. However, recovery was not examined. Hall-Spencer *et al.* (2003) drew attention to the dangers of suction dredging for bivalves in maerl beds, especially as many of the larger infaunal bivalves are long-lived (e.g. *Dosinia exoleta*), suggesting that the population would take a long time to recover.<br>Hall-Spencer *et al.* (2003) also note that certain maerl beds in the Bay of Brest have been dredged from scallops and *Venus verrucosa* for over 40 years, yet remain productive with high levels of live maerl. Although they suggest that this is due to local restrictions that limit the activity to one scallop dredge per boat. Nevertheless, scallop dredging, demersal trawling and extraction have been reported to contribute to declines in the condition of maerl beds in the north east Atlantic and the UK (Barbera *et al.*, 2003, Hall-Spencer *et al.*, 2010, Hall-Spencer *et al.*, 2003).<br>Therefore, physical disturbance is likely to result is drastic changes in and loss of components of the community and an intolerance of high is suggested. Although recoverability is likely to be high, long-lived bivalves may take a longer period to regain their original abundance and population structure, and a precautionary recoverability of moderate is suggested. |
| Displacement (see benchmark) | Mobilization of the surface of the bed is likely to reduce the diversity of epiflora and epifauna. Species displaced due to physical disturbance, especially infauna, may re-burrow or may be damaged and/or subject to increased predation. Therefore, an intolerance of intermediate is suggested. |
| **Chemical Pressures** | |
| Synthetic compound contamination (see benchmark) | Dead maerl beds host a diverse community of epiflora, epifauna and infauna, including many groups of algae and invertebrates and some fish. The different major groups of species will show a wide range of responses to different synthetic chemicals, heavy metals and hydrocarbons. As no specific study has examined the effects of these contaminants on maerl beds, and as the species list is so long, general summaries of the effects of contaminants have be used. For example.<br>• O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. Laboratory studies of the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages (Grandy, 1984; cited in (Holt *et al.*, 1995).<br>• Beaumont *et al.* ((1989)) concluded that bivalves (especially larvae) are particularly intolerant of tri-butyl tin (TBT), the toxic component of many antifouling paints.<br>• Generally, polychaetes (see Bryan, 1984), gastropods and macroalgae (see Strömgren, 1979a, Strömgren, 1979b) are regarded as being tolerant of heavy metal contamination, while |
| Heavy metal contamination (see benchmark) | |
| Hydrocarbon contamination (see benchmark) | |

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| | the larval and embryonic stages of bivalves are particularly intolerant of heavy metal contamination. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes.<br>• Suchanek (1993) reviewed the effects of oil on bivalves. Sublethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates have increased at low concentrations and decreased at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Mortality following oil spills has been recorded in *Mya arenaria*, *Ensis* sp. and *Cerastoderma edule*. Suchanek (1993) reported that infaunal polychaetes were also vulnerable to hydrocarbon contamination.<br>• Echinoderms also seem to be especially sensitive to the toxic effects of oil, probably because of the large amount of exposed epidermis (Suchanek, 1993). The high intolerance of *Echinocardium cordatum* to hydrocarbons was seen by the mass mortality of animals, down to about 20m, shortly after the *Amoco Cadiz* oil spill (Cabioch *et al.*, 1978). Dauvin (1998) reported the effects of the *Amoco Cadiz* oil spill on the fine sand *Abra alba* community in the Bay of Morlaix. Reductions in abundance, biomass and production of the community were very evident through the disappearance of the dominant populations of the amphipods *Ampelisca* sp. which are very sensitive to oil contamination.<br>Overall, numerous components of the maerl bed community are likely to be intolerant of contaminants to varying degrees, depending on the contaminant, its concentration and duration and the species in question. Any effluent discharge or spill is, therefore, likely to result in loss of a proportion of the community, and an intolerance of intermediate is suggested. Recovery is likely to be high once the contaminant or discharge has been removed. |
| Radionuclide contamination (see benchmark) | Insufficient information. |
| Changes in nutrient levels (see benchmark) | Birkett *et al.* (1998) noted that increased turbidity and eutrophication due to agricultural runoff in Brittany presented the establishment of many algal species resulting in domination of ubiquitous species (e.g. *Ceramium* sp. and *Ulva* sp.), while localised eutrophication due to fish and mussel farming (aquaculture) in a sheltered area resulted in a covering fungi and the bacterial mats of *Begetonia*. Hall-Spencer *et al.* (2006) examined maerl beds in the vicinity of fish farms in strongly tidal areas. They noted a build-up of waste organic materials up to 100 m from the farms examined and a 10-100 fold increase in scavenging fauna (e.g. crabs). In the vicinity of the farm cages the biodiversity was reduced, |

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| | particularly of small crustaceans, with significant increases in species tolerant of organic enrichment (e.g. *Capitella*). Again eutrophication resulting from aquaculture is cited as one reason for the decline of some beds in the north east Atlantic (Hall-Spencer *et al.*, 2010).<br>In Brittany, numerous maerl beds were affected by sewage outfalls and urban effluents, resulting in increases in contaminants, suspended solids, microbes and organic matter with resultant deoxygenation (Grall & Hall-Spencer, 2003). This resulted in increased siltation, higher abundance and biomass of opportunistic species, loss of sensitive species and reduction in biodiversity. Grall & Hall-Spencer (2003) note that two maerl beds directly under sewage outfalls were converted from dense deposits of live maerl in the 1950s to heterogeneous mud with maerl fragments buried under several centimetres of fine sediment with species poor communities. These maerl beds were effectively lost.<br>Therefore, increased nutrient levels and eutrophication can lead to major changes in the associated community and an intolerance of high is suggested. Recoverability of the community associated with dead maerl could recover quickly once the nutrient levels return to prior levels, although this assumes that any deposited sediment is winnowed away by currents. Therefore a recoverability of moderate is suggested. |
| Increase in salinity (see benchmark) | The majority of maerl beds occur in full salinity. An increase in salinity above full is unlikely, except via the discharge of hyper-saline effluents from desalination plants, none of which occur in the UK. However, Wilson *et al.* (2004) note that *Phymatolithon calcareum* and *Lithothamnion coralloides* were tolerant up to 40 psu while most subtidal seaweeds can survive up to50 psu. Where the bed was found in areas of reduced or variable salinity, an increase in salinity may result in an increase in biodiversity and a shift in the community to one more representative of full salinity. Therefore, an intolerance of low is suggested with a recoverability of very high. |
| Decrease in salinity (see benchmark) | The majority of maerl beds occur in full salinity although some occur in areas of reduced salinity (Birkett *et al.* 1998). However, where the surface water may be of reduced salinity the bottom water is likely to be full salinity. A short term reduction in salinity from full to low (the benchmark), e.g. from freshwater runoff, will affect the epifauna and epiflora directly, and may cause the temporary loss of mobile species, and death of some members of the community, e.g. echinoderms which are particularly stenohaline. Long term decrease in salinity from 'full' to 'reduced' will probably result in a shift in the community composition towards reduced salinity tolerant species, with a resultant reduction in biodiversity but increase in abundance of tolerant species. In addition, the epiflora /fauna are most likely to be effected while infauna will be protected to a degree by their depth, depending on the depth of the bed. Therefore, an intolerance of intermediate is suggested, while recoverability is likely to be high. |
| Changes in oxygenation (see benchmark) | Deoxygenation can occur as a result of eutrophication (see nutrient levels above), effluents with high BOD/COD or due to the sudden death (and resultant settlement and decay) of algal blooms. The effects of hypoxia on marine benthos has been well documented (Diaz & Rosenberg, 1995, Pearson & Rosenberg, 1978, Rosenberg & Loo, 1988) and species vary in |

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| | their tolerance of low oxygen levels. For example, echinoderms such as *Asterias rubens* and *Echinocardium cordatum* are highly intolerant of anoxic conditions; the barnacle *Balanus crenatus* is considered to be highly intolerant of anoxia; while Crustacea are probably intolerant of hypoxia but mobile species would be able to migrate to more suitable conditions. However, most polychaetes are capable of anaerobic respiration and *Capitella capitata*, *Hediste diversicolor* and were considered to be resistant of moderate hypoxia while *Nephtys hombergii* and *Heteromastus filiformis* were thought to be resistant of severe hypoxia (Diaz & Rosenberg, 1995).<br>The dinoflagellate bloom on the south coast of England in 1978, resulted in hypoxia of the seabed as a result of sudden mortality and decay (Boalch, 1979, Forster, 1979, Griffiths *et al.*, 1979). As a result numerous fish and invertebrate species were reported dead on the seabed. For example, mortality was observed in *Echinus esculentus, Marthasterias glacialis, Echinocardium cordatum, Labidoplax digitata, Cancer pagurus, Ensis siliqua, Lutraria lutraria*, and some polychaetes while bryozoans, soft corals, and *Lutraria* spp. and other species were moribund.<br>Overall, sudden hypoxia is likely to result in immediate mortality, while prolonged hypoxia is likely to shift the community to species tolerant of low oxygen conditions, resulting in a change in the community and loss of biodiversity. However, where deoxygenation is the result of eutrophication and/or sewage effluent intolerance is likely to be high and recoverability moderate (see nutrient levels above). |
| **Biological Pressures** | |
| Introduction of microbial pathogens/parasites (see benchmark) | No evidence of the effects of diseases and pathogens on maerl beds was found. Many of the species that make up the community will be susceptible to disease in the form of viruses or parasites. Overall, diseases are likely to lower the viability of affected populations and an intolerance of low is suggested. Recovery is probably very high. |
| Introduction of non-native species (see benchmark) | No evidence of the effects of non-native species in the UK was found. However, Grall & Hall-spencer (2003) note that beds of invasive slipper limpet *Crepidula fornicata* grew across maerl beds in Brittany. As a result, the maerl thalli were killed, and the bed clogged with silt and pseudo-faeces, so that the associated community was drastically changed. Bivalve fishing was also rendered impossible. A 'dead' maerl bed would also suffer modification of the bed by silt and pseudo-faeces, with resultant changes in the resident community.<br>Removal of the surface layer of *Crepidula* is possible but only with the removal of the surface layer of maerl itself, which would be extremely destructive on live beds. Overall, therefore, an intolerance of high is suggested. Recovery would depend on the removal of the cover of *Crepidula* which is unlikely to occur naturally. |
| Extraction of key or important characterizing species (see benchmark) | Dead maerl beds have been subject to extraction for the coralline maerl itself. The likely impacts are similar to those described under physical disturbance above but remain one of the major threats to maerl beds (Hall-Spencer *et al.*, 2010). |

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| | Birkett *et al.* (1998) noted that although maerl beds subject to extraction in the Fal estuary exhibit a diverse flora and fauna, they were less species-rich than those in Galway Bay, although direct correlation with dredging was unclear. Grall & Glemarec (1997; cited in Birkett *et al.,* 1998) reported few differences in biological composition between exploited and control beds in Brittany.<br>Dyer & Worsfold (1998) showed differences in the communities present in exploited, previously exploited and unexploited areas of maerl bed in the Fal Estuary but it was unclear if the differences were due to extraction or the hydrography and depth of the maerl beds sampled.<br>In Brittany, many of the maerl beds are subject to extraction (Grall & Hall-Spencer, 2003). For example the clean maerl gravel of the Glenan maerl bank described in 1969, was degraded to muddy sand dominated by deposit feeders and omnivores within 30 years. Grall & Hall-Spencer (2003) noted that the bed would be completed removed within 50-100 years at the rates reported in their study. Hall-Spencer *et al.* (2010) note that maerl extraction was banned in the Fal in 2005.<br>The impact of extraction of maerl beds depends on the intensity of the activity, and low level activity may allow the community to recover in the meantime. The 'dead' maerl beds in the Fal have been reported to have a high species richness, even though they are targeted for extraction. Nevertheless, it is clear that extraction could have significantly detrimental effects on maerl habitats (dead or live). Therefore, an intolerance of high has been recorded. Extraction results in the permanent removal of maerl, which in 'dead' beds in never going to be replaced. Continued extraction must ultimately result in loss of the bed. Therefore, a recoverability of 'none' is suggested. |

## RECOVERABILITY INFORMATION

No information was found concerning the time taken for the dead maerl communities to reach maturity, and where recovery has been examined, no distinction between 'live' and 'dead' was made. However, several studies examined undredged, fallow and dredged sites.

De Grave & Whitaker (1999) compared a dredged (extracted) maerl bed with one that been left 'fallow' for six months in Bantry Bay, Ireland. They noted that the dredged bed had significantly fewer molluscs than the fallow bed, but significantly more crustaceans and oligochaetes.

Hall-Spencer & Moore (2000a, 2000b) examined the recovery of maerl community after scallop dredging in previously un-dredged and dredged sites in Scotland. In comparison with control plots, mobile epibenthos returned within one month; fleshy macroalgae within six months; the abundance of *Cerianthus lloydii* was not significantly different after 14 months; other epifauna (e.g. *Lanice conchilega* and *Ascidiella aspersa*) returned after 1-2 years; but some of the larger sessile surface species (e.g. sponges, *Metridium senile*, *Modiolus modiolus* and *Limaria hians*) exhibited lower abundances on dredged plots after four years. Deep burrowing species (mud shrimp, large bivalves e.g. *Mya truncata* and the gravel sea cucumber *Neopentadactyla mixta*) were not impacted and their abundance changed little over the four year period. Hall-Spencer *et al.* (2003) noted that long lived (>10 years) species (e.g. *Dosinia exoleta*) can occur at high abundances in maerl beds but that the sustainability of stocks are unknown at present. Hall-Spencer (2000a) noted that there was no significant difference between controls and experimentally dredged sites after 1-2 years at the sites previously subject to dredging.

Overall, it appears that most of the maerl related community could develop within five years, although long-lived and/or large sessile species (e.g. bivalves, anemones, and sponges) would take longer.

## IMPORTANCE

### Marine natural heritage importance

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| ***Listed under:*** | UK Biodiversity Action Plan<br>EC Habitats Directive |
| ***National importance*** | Uncommon |
| ***Habitat Directive feature (Annex 1)*** | Sandbanks which are slightly covered by sea water all the time<br>Large shallow inlets and bays |
| ***UK Biodiversity Action Plan habitat*** | Maerl |

**Note:** maerl beds are listed or designated. 'Dead' maerl beds are not listed directly but neither is the status of the maerl explicitly stated.

### Exploitation

Maerl is mainly sold dried as a soil additive but is also used in animal feed, water filtration systems, pharmaceuticals, cosmetics and bone surgery. Maerl beds are dredged for scallops (found in high densities compared with other scallop habitats) where extraction efficiency is very high (Birkett *et al.*, 1998). .

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# Appendix 1. Summary of the MarLIN approach to sensitivity assessment

## Assessing the sensitivity of species

The assessment process involves judging the intolerance of a species to change in an external pressure 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 A3.1).

**3. Assess the intolerance of the species to change in environmental pressures.** The likely intolerance (Table A3.2) of the species is assessed with respect to a specified magnitude and duration of change (the standard benchmark[2]) for 24 separate environmental pressures (see Table A3.3).

### Table A3.1 - 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.* |
|---|---|
| **High** | Assessment has been derived from sources that specifically deal with sensitivity and recoverability to a particular pressure. Experimental work has been done investigating the effects of such a pressure. |
| **Moderate** | Assessment has been derived from sources that consider the likely effects of a particular pressure. |
| **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 pressures . |
| **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 pressure. 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'.

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 pressure on the species,

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[2] Benchmarks are defined online at http://www.marlin.ac.uk/sensitivitybenchmarks.php

or targeted work / experiments on the effects of similar pressures on similar species or studies of the likely effects of a pressure. The assessment of intolerance (Table A3.2) is then made by reference to the reported change in environmental pressures and their impact, relative to the magnitude and duration of the standard benchmarks and other relevant key information.

### Table A2.2 - Species intolerance (previously 'sensitivity' and revised April 2003).

**SPECIES INTOLERANCE**
The susceptibility of a species population to damage, or death, from an external pressure. Intolerance is assessed relative to change in a specific pressure.

| Rank | Definition |
|---|---|
| **High** | The species population is likely to be killed/destroyed by the pressure under consideration. |
| **Intermediate** | Some individuals of the species may be killed/destroyed by the pressure under consideration and the viability of a species population may be reduced. |
| **Low** | The species population will not be killed/destroyed by the pressure under consideration. However, the viability of a species population may be reduced. |
| **Tolerant** | The pressure does not have a detectable effect on survival or viability of a species. |
| **Tolerant*** | Population of a species may increase in abundance or biomass as a result of the pressure. |
| **Not relevant** | This rating applies to species where the pressure is not relevant because they are protected from the pressure (for instance, through a burrowing habit), or can move away from the pressure. |

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).

### Table A3.3 - Environmental pressures for which intolerance and hence sensitivity is assessed.

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

**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 (Table A2.4) 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.

**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 A3.5 and A3.6 below.

### Table A3.4. 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 pressure.

Recoverability is only applicable if and when the impacting pressure 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'. |

The sensitivity assessment rationale uses the question 'does it matter if……?', together with the definitions of sensitive habitats and species proposed in the Review of Marine Nature Conservation (Laffoley *et al.*, 2000) as touch-stones throughout. Due to the importance of recoverability in assessing the continued survival of a habitat or species population, the scale is intuitively weighted towards recoverability. However, where recovery is likely to occur in a short period of time, intolerance has been given a greater weight rather than under-estimate the potential sensitivity of marine habitats and species. The sensitivity scales and definitions are designed to be meaningful in marine environmental management, protection, and conservation.

For example, if a habitat or species is very adversely affected by an external pressure 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 pressure 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 A3.5.

**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 A3.6. 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 A3.6 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 intolerance has been given a greater weight rather than under-estimate the potential sensitivity of marine habitats and species.

**Table A3.5. Defining ‘sensitivity’ *sensu lato* for habitats and species. **=‘Reduced viability’ includes physiological stress, reduced fecundity, reduced growth, and partial death of a colonial animal or plant.**

| Rank | Sensitivity definition or scenario |
|---|---|
| Very High | ‘Very high’ sensitivity is indicated by the following scenario:<br>The habitat or species is very adversely affected by an external pressure 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’).<br>The habitat or species is adversely affected by an external pressure 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:<br>The habitat or species is very adversely affected by an external pressure 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).<br>The habitat or species is adversely affected by an external pressure 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’).<br>The habitat or species is affected by an external pressure 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:<br>The habitat or species is very adversely affected by an external pressure 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).<br>The habitat or species is adversely affected by an external pressure 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).<br>The habitat or species is affected by an external pressure 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: |

| Rank | Sensitivity definition or scenario |
|---|---|
| | The habitat or species is very adversely affected by an external pressure 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).<br>The habitat or species is adversely affected by an external pressure 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).<br>The habitat or species is affected by an external pressure 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:<br>The habitat or species is very adversely affected by an external pressure arising from human activities or natural events (killed/destroyed, 'high' intolerance) but is expected to recover rapidly i.e. within a week ('immediate' recoverability).<br>The habitat or species is adversely affected by an external pressure arising from human activities or natural events (damaged, 'intermediate' intolerance) but is expected to recover rapidly, i.e. within a week ('immediate' recoverability).<br>The habitat or species is affected by an external pressure 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:<br>The habitat or species is affected by an external pressure arising from human activities or natural events (reduced viability **, 'low' intolerance) but is expected to recover rapidly, i.e. within a week ('immediate' recoverability).<br>The habitat or species is tolerant of changes in the external pressure. |
| Not sensitive* | The habitat or species may benefit from the change in an external pressure (intolerance has been assessed as 'tolerant*'). |
| Not relevant | The habitat or species is protected from changes in an external pressure (i.e. through a burrowing habit or depth), or is able to avoid the external pressure. |

## Table A3.6. Combining 'intolerance' and 'recoverability' assessments to determine 'sensitivity'. NS = not sensitive, NR = not relevant.

| | | 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 |

**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 A3.7). 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' (Table A3.7).

**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 pressures.** The sensitivity of the indicative species is assessed with respect to change in 24 separate environmental pressures (see Table A3.3 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 1 for intolerance and in Figure 2 for recoverability. The definitions of biotope intolerance (revised in April 2003) are shown in Table A3.8.

### Table A3.7. 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 (e.g. predation, grazing, and 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.

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.

Precedence is given to direct evidence of the effects of changes in environmental pressures 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 A3.5 and A3.6 above.

## Table A3.8. Biotope intolerance

**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). |

## Table A3.9. 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 lose some of its species in response to the factor by either direct mortality or emigration. |
| **Minor decline** | The community is likely to lose 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. |

**8. Assess the likely effect of the environmental pressures 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 A3.9).

**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.

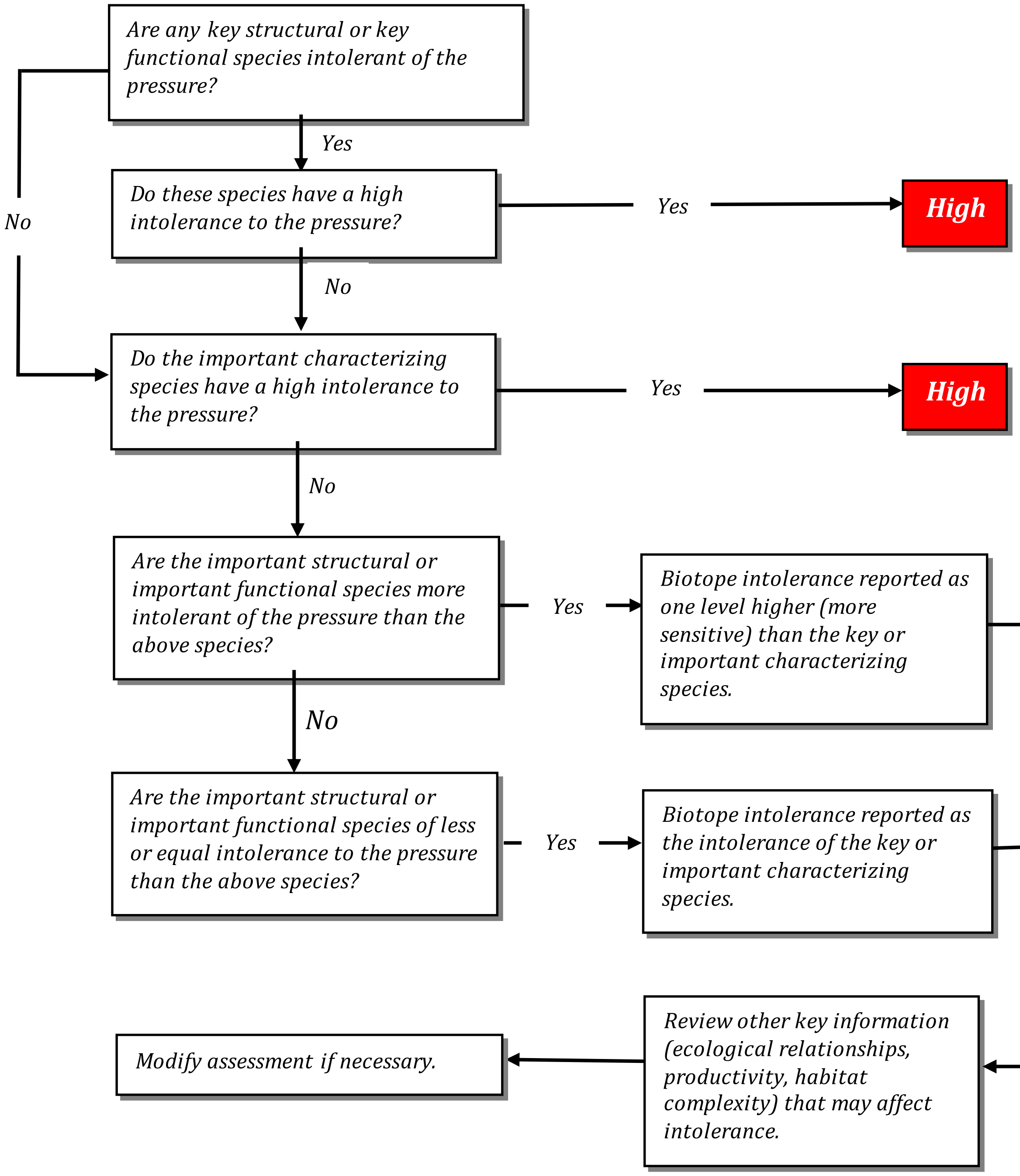

*Figure A3.1. Biotope 'intolerance' assessment rationale.*

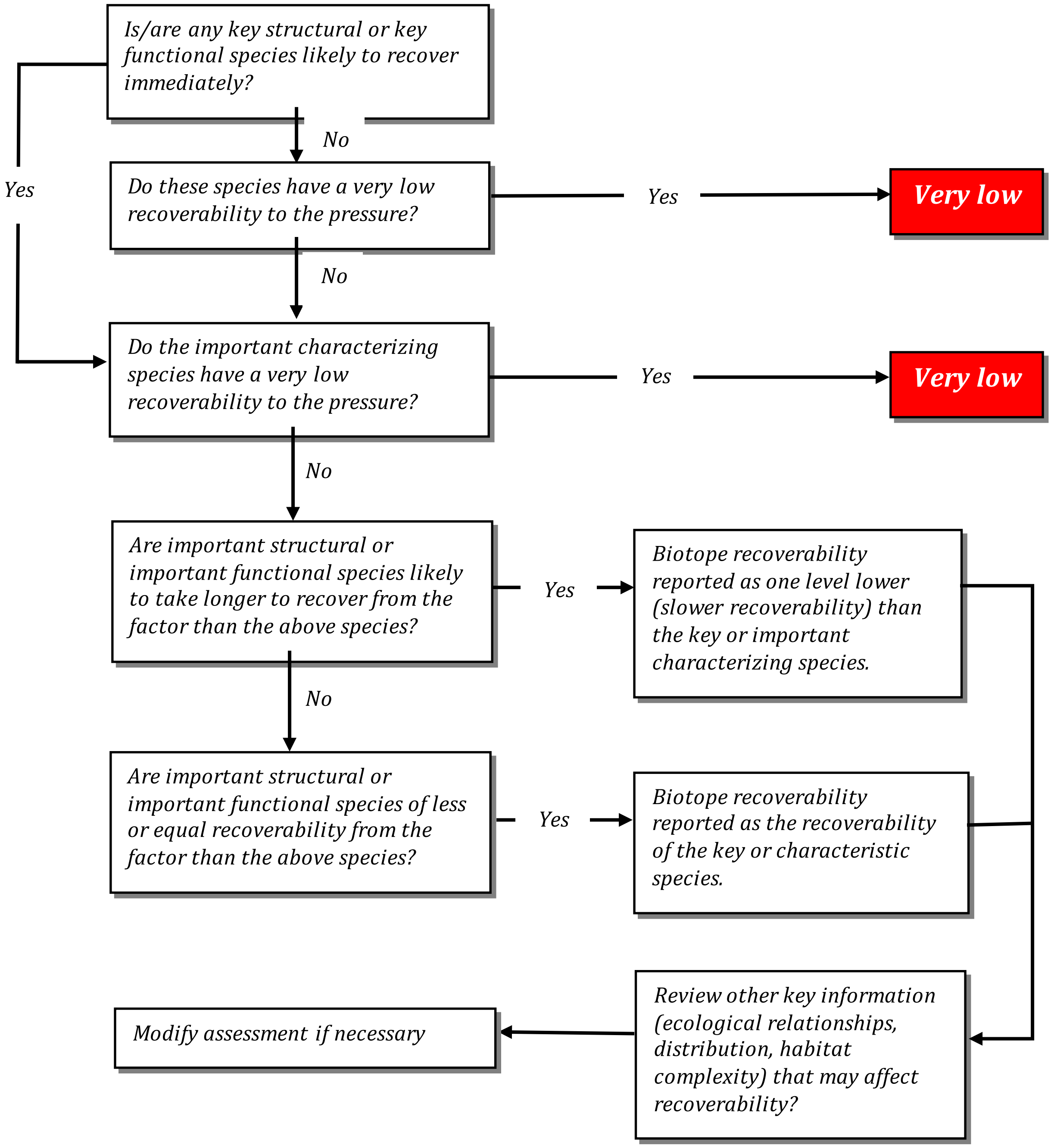

*Figure A3.2. Biotope 'recoverability' assessment rationale.*