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

Assessing seabed species and ecosystems sensitivities. Rationale and user guide.

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Assessing seabed species and ecosystems sensitivities

Rationale and user guide

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Biology and Sensitivity Key Information Sub-programme

Assessing seabed species and ecosystems sensitivities

Rationale and user guide

Harvey Tyler-Walters & Angus Jackson

1. Introduction

This report outlines the rationale under development by the *MarLIN* programme Biology and Sensitivity Key Information Sub-programme to assess the sensitivity and recoverability of marine species and biotopes. The report provides guidance for data researchers on the application of the proposed rationale and is intended to ensure that sensitivity assessments are made in a consistent and systematic manner. The report is designed to provide users with a clear understanding of how sensitivity and recoverability assessments are made, their inherent assumptions or limitations and, therefore, applicability to environmental protection and management. The background and definitions used are explained in *MarLIN* Report No. 1 (Hiscock *et al.* 1999). The objectives and guiding principles of the Sub-programme are given in Appendix 1.

2. Procedure

The procedure uses several scales devised with the Biology and Sensitivity Key Information Sub-programme Management Group (MG) and provides an assessment rather than a score. The term 'score' is avoided since this implies quantitative values whilst the assessments are qualitative in nature. All judgements are based on the best available scientific information and expertise. The scales used throughout the procedures that follow are defined in Appendix 2.

The assessment process involves judging the sensitivity of a species or biotope to change in a

Box 1: Key definitions.

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

‘Factor’ a component of the physical, chemical, ecological or human environment that may be influenced by a natural events or anthropogenic activity. Therefore, activities effect the environment by perturbation of these factors.

‘Recoverability’ is the ability of a habitat, community or species to return to a viable state which is at least close to that which existed before the development, activity or event. Recovery may be because of re growth (in the case of damaged species capable of regrowing from remaining tissue), re-colonization by migration or larval settlement from undamaged populations or may require re-establishment of viability where, for instance, reproductive organs or propagules have been damaged by the event. Recovery can be partial or complete.

‘Sensitivity’ is the intolerance of a habitat, community or individual (or individual colony) of a species to damage, or death, from an external factor. Sensitivity has to be referred to specific environmental perturbations.

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

environmental factor by an external activity. The rationale then assesses the likely recoverability of the species or biotope following cessation of the activity. In addition, the likely effect of a change in a factor on species richness is assessed for biotopes. Key definitions used are given in Box 1 and specific terms are defined in the glossary.

3. Species sensitivity assessment.

The procedure used to assess species sensitivity includes the following stages:

1. a review of relevant available information for the species in question;
2. an assessment of the quality of the data used;
3. the identification of the likely sensitivity of the species to external factors;
4. the identification of the likely recoverability;
5. submission to resultant key information review to referees, and
6. the modification of conclusions to take account of referees comments.

As information is collated, data fields in the *MarLIN* database are completed. The species sensitivity assessment procedure is outlined in Figure 1.

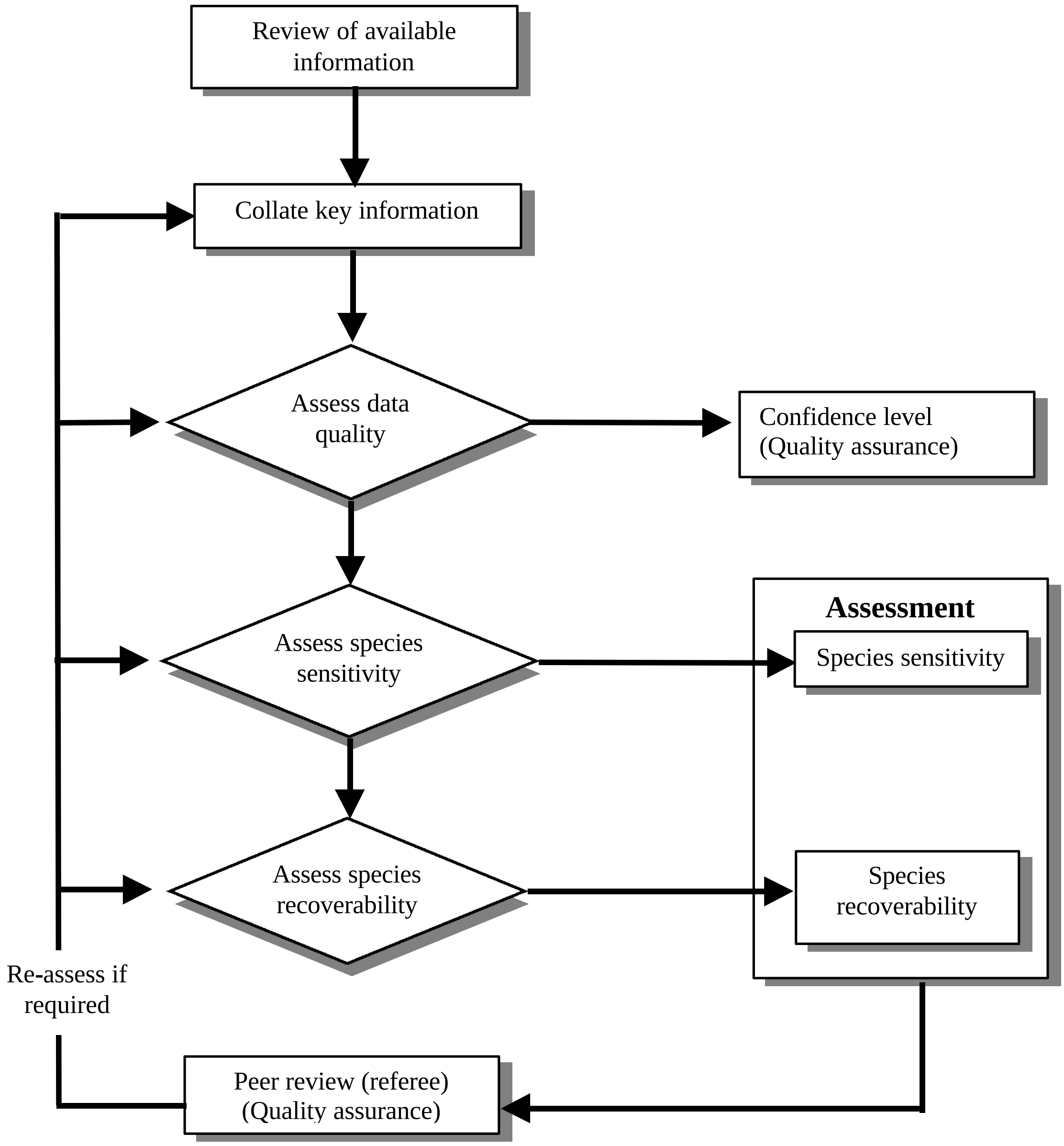

Figure 1. Species sensitivity assessment

3.1. Review key information for the species (Stage 1).

The available data and information on a species are collated and the key information fields completed in the database where possible. If relevant material has been located but it is not sufficiently specific to complete key information fields then 'data deficient' is entered. If the required information has not been found then 'no information found' is entered. Key information fields can be updated as information becomes available. The key information fields used for species are shown in *MarLIN* Report No. 1 (Appendix 6, Hiscock *et al*. 1999)

This information 'mining' typically involves the resources of the National Marine Biology Library (NMBL) and the World Wide Web, together with the experience of resident experts and invited referees.

3.2. Undertake a quality assessment of the available data and information (Stage 2).

The key information and sensitivity assessments are subject to quality assurance by peer review (refereeing) before publication on the Web. However, the researcher must determine the quality and specificity of the data used for assessing sensitivity and recoverability. This is expressed as a 'confidence' level for each assessment of sensitivity or recoverability.

The rationale used to appraise the quality of available data is shown in Figure 2. For example, the effect of tributyl tin (TBT) on *Nucella lapillus* is well documented. Therefore, this species could be assessed as highly sensitive to TBT with a high level of confidence. Conversely, where a species is poorly studied and little information is available the assessments may be based on informed judgement alone. In this case, the assessments would be given a very low confidence.

3.3. Identify the likely sensitivity of the species to external factors (Stage 3).

The sensitivity of each species is assessed as follows:

- address each factor separately using the appropriate rationale for each factor;
- work through each question or module in the decision tree in turn;
- use the standard benchmarks for each factor to inform decisions;
- note the sensitivity assessment from each module or question;
- make an overall sensitivity assessment;
- review overall assessment using additional information;
- record sensitivity value.

3.3.1 Factors and Benchmarks. The major factors affected by maritime activities are listed in Appendix 3. These factors are used to assess sensitivity and recoverability.

The sensitivity of a species (or community) is an estimate of its intolerance to damage from an external activity and is determined by its biological characteristics. However, sensitivity can only be estimated (assessed) in response to a change in an environmental factor. The assessed sensitivity is, therefore, dependent on the magnitude, duration, or frequency of that change. The degree of change to which organisms are 'sensitive' will also vary between species or communities.

The effects of an activity on the environment are likewise dependent on the magnitude and duration of the activity together with the nature of the receiving environment or location. The same activity 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 be significant in a sheltered embayment. Therefore, the environmental effects and the resultant change in factors are site specific and can not be generalised.

Standard benchmarks have been proposed to enable sensitivity to be assessed relative to a specified change in an environmental factor. The use of a standard or 'benchmark' level of change in factors also allows sensitivity assessments to be compared between different species or communities. Examples of these benchmarks are shown in Table 1 and the full list is given in Appendix 3.

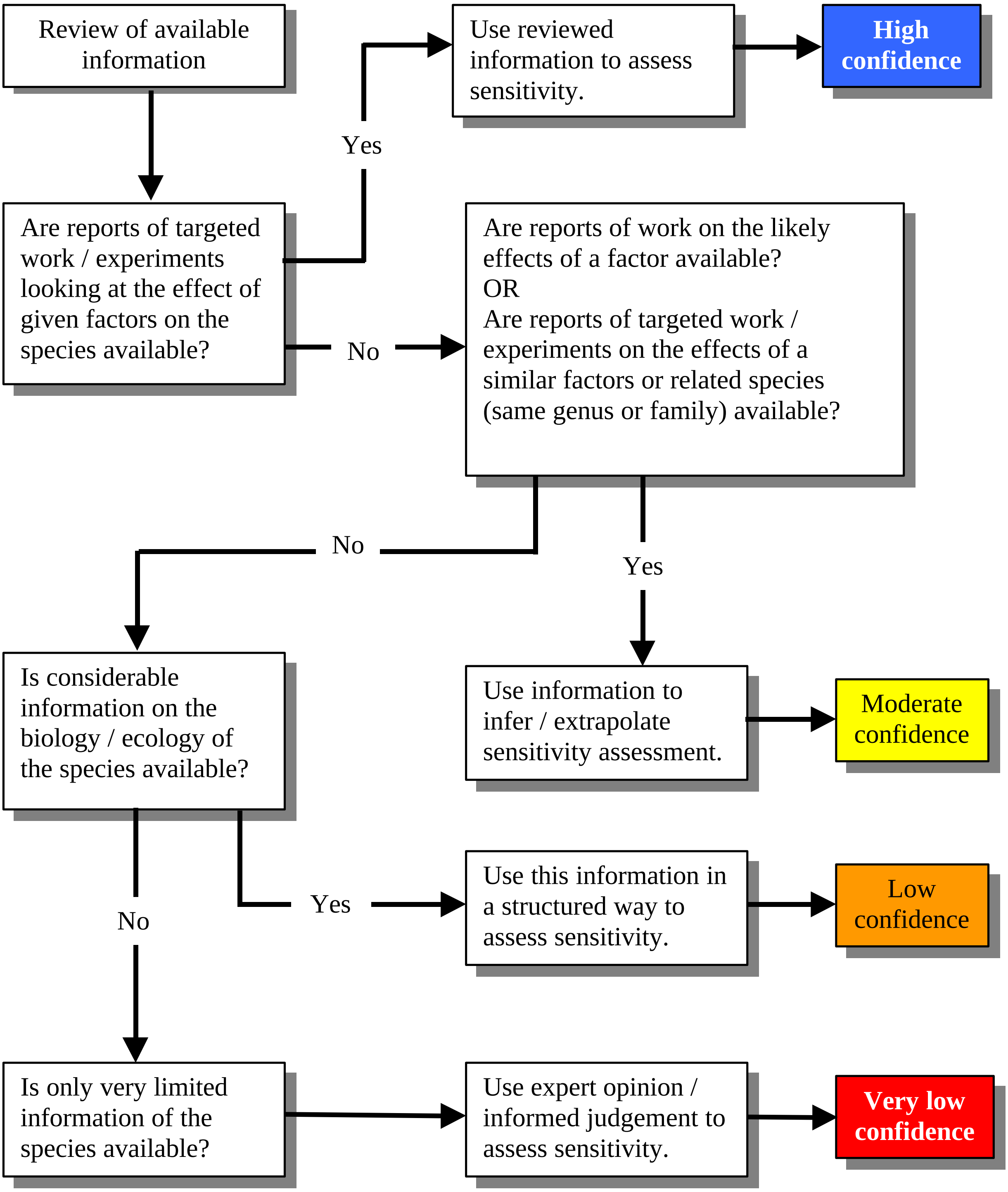

Figure 2. The appraisal of data quality.

The potential changes in an environmental factor, caused by maritime activities or natural events, are summarised in Figure 3. The benchmarks specify a magnitude and duration wherever possible. The chosen magnitude and duration reflect the reported or likely change in the factor as a result of relevant maritime activities or natural events, unless otherwise stated. The benchmarks also enable the change in factors and their sensitivity assessments to be compared with predicted impacts.

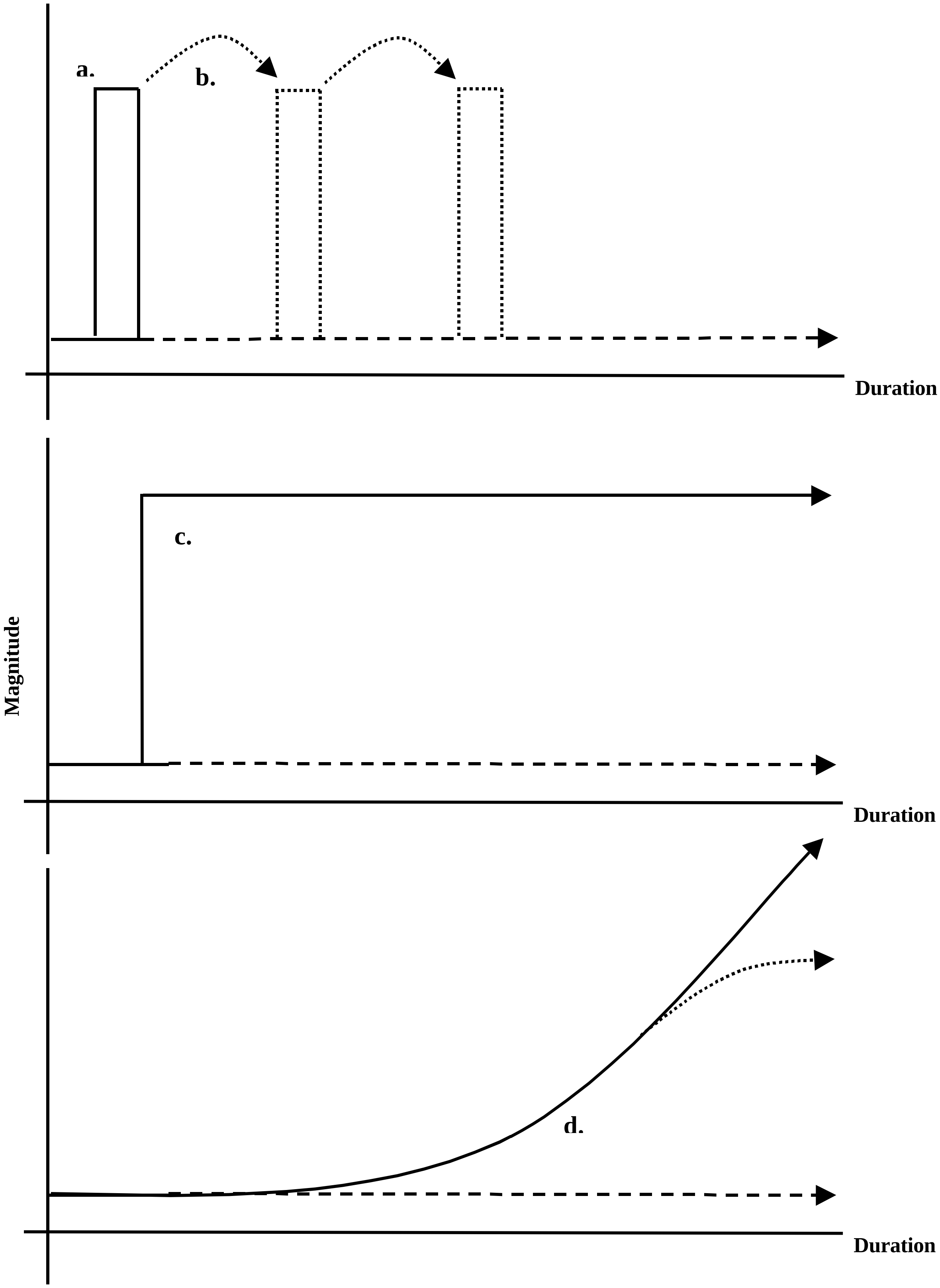

Figure 3. Representative types of change in an environmental factor. For example; a). short term, b). short term repeated at a given frequency, c). long term, d). long term incremental change, which e). may stabilise.

Where activities are likely to cause more than one type of change (Figure 3) separate benchmarks are given for short term acute or long term chronic changes. Short term acute and long term chronic change were chosen because they represented the most likely effects of maritime activities and can be compared with predicted effects. For example:

- if the predicted effect has a greater magnitude than the benchmark, then it is likely that the organism will have a greater sensitivity to this effect;
- if the predicted effect has a longer duration than the benchmark, then it is likely that the organism will have a greater sensitivity to this effect.

Where the predicted effect is comparable to the benchmark but likely to occur at higher frequency, then it is also likely that the species or community will exhibit a higher sensitivity. However, the frequency of change should be compared with the species or communities recoverability. If the species or community is likely to recover between the impacting events then it may not exhibit an increased sensitivity.

Activities that result in incremental long term change, such as climate change, are difficult to assess (Figure 3.d.) since the given level of change varies with time. These effects have not been addressed within the present sensitivity assessments. However, benchmarks could be compared to the predicted level of change at specific time intervals.

The sensitivity of a species population is assessed against the magnitude and duration of change specified in the benchmark. It should be noted that sensitivity assessments are indicative qualitative judgements based on the best available scientific information. They represent the most likely (probable) result of a given change in a factor. They do not allow quantitative analysis. The sensitivity assessments should be used in conjunction with the key information provided with each species. In all cases, the explanation behind each sensitivity assessment, the relevant key information and references are highlighted.

No weighting is given to individual fields, as choice of these weights would be primarily subjective. The order in which fields are considered does not necessarily indicate any order of importance. However, particular values in some fields may automatically cause the factor to be not relevant. For example if a species is found in the supralittoral it is extremely unlikely to be exposed to water flow, hence ‘change in water flow rate’ would be ‘not relevant’.

The fields ‘Typically feeds on’ and ‘Mode of life’ are included for all factors. The species of interest may depend on (e.g., lives on or feeds on) only one species. If this host or prey species is sensitive to the factor in question then the species of interest will be indirectly sensitive to that factor.

The sensitivity of each species to each factor is assessed separately. However, in a few cases the assessment of sensitivity to one factor or more factors may overlap. For example, the assessment of sensitivity to ‘change in emergence regime’ or ‘desiccation’ is likely to involve similar decisions and key information.

3.3.2 Rationale and modules. Specific information on species sensitivity (targeted studies) is used when available. Otherwise, each assessment is made by reference to the key information. However, not all information fields are relevant to the assessment of sensitivity to all factors. For example, sensitivity to smothering may depend on the organisms mobility or preferred feeding method but is unlikely to be affected by its mode of reproduction. The key fields relevant for the assessment of sensitivity to each factor are listed in Table 2.

Table 1. Examples of factors and their benchmarks

Factor	Benchmark	Explanation
Physical factors		
Substratum loss	All of substratum occupied by the species or biotope under consideration is removed. Once the activity or event has stopped (or between regular events) substratum within the habitat preferences of the original species or community remains or is deposited. A single event is assumed for assessment.	
Chemical factors		
Example	**EAL/EQS (for seawater unless otherwise stated)**	**Benchmark** Exposed to the following contaminant concentration
Tributyl tin	0.002 μg/l (Maximum Allowable Concentration)	1). Long term: 0.004 μg/l average in seawater for a 1 year period 2). Short term: 1 μg/l seawater for 2 days (48hrs) Short term value derived from survey of TBT concentrations associated with marinas in the Crouch estuary (Waldock & Miller 1983).
Biological factors.		
Specific targeted extraction of this species	Extraction removes 50% of the species from the area under consideration. The habitat remains intact or recovers rapidly.	

The rationale demonstrates a logical and systematic approach for the assessment of sensitivity to each factor and examines the likely effect of each relevant key information field on the sensitivity of a species. These likely effects are assessed by separate questions or 'modules' of questions. ‘Modules’ represent groups of questions on one or more related key information fields. Figures 4 and 5 show the rationale for substratum loss and smothering respectively.

Each question or 'module' is addressed in turn by reference to the standard benchmarks. The resultant assessment value for that question or 'module' is noted.

The overall sensitivity of the species is best represented by the question or 'module' that results in the highest sensitivity assessment. For example, if the sensitivity of a species to substratum loss is assessed as 'intermediate' because of its mobility but 'low' sensitivity by virtue of its mode of life then the overall sensitivity to substratum loss is reported as 'intermediate'. It follows, therefore, that if any of the key information fields results in a high sensitivity assessment then the overall sensitivity to a particular factor will be reported as high.

3.3.3 Review. Although the rationale and decision trees represent a systematic approach to sensitivity analysis, the biology of each species is unique. Therefore, the remaining key information together with any relevant additional material should be examined and the assessment revised if necessary.

Table 2. Key information to be considered when allocating sensitivity values to a factor in the absence of more detailed information. The key information fields relevant for each factor are shaded.

FACTORS	KEY INFORMATION FIELDS													
	Depth	Size range	Mobility/Attachment	Environmental position	Growth form	Flexibility	Feeding method	Typically feeds on	Depends on	Physiographic type	Biological zone	Wave exposure	Tidal flow rate	Salinity
Substratum loss			■	■				■	■					
Smothering			■	■	■			■	■					
Siltation			■	■			■	■	■		■			
Desiccation		■	■	■	■			■	■		■			
Changes in emergence regime	■		■	■				■	■		■			
Changes in water flow rate		■	■	■	■	■	■	■	■		■		■	
Changes in temperature			■					■	■					
Changes in turbidity	■		■	■			■	■	■		■			
Changes in wave exposure	■	■	■	■	■	■	■	■	■	■		■		
Noise			■					■	■					
Visual presence			■					■	■					
Synthetic compound contamination			■				■	■	■					
Heavy metal contamination			■				■	■	■					
Hydrocarbon contamination			■				■	■	■					
Radionuclide contamination			■				■	■	■					
Changes in nutrient levels			■				■	■	■					
Changes in salinity	■		■					■	■		■			■
Changes in oxygenation			■		■			■	■		■			
Abrasion		■	■	■	■	■		■	■					
Displacement			■					■	■					
Introduction of microbial pathogens / parasites								■	■					
Introduction of non-native species and translocation	Only assessed when a known introduced species has an effect on the species of interest.													
Selective extraction of this species	Automatically assessed as 'intermediate'													
Selective extraction of other species								■	■					

Throughout the above procedure, the key information used to make judgements should be noted together with key references. This information then forms the basis of an explanation for each sensitivity assessment.

Factor: Substratum removal

Description: The physical removal of the substratum inhabited or required by the species or community in question.

Benchmark: All of substratum occupied by the species or biotope under consideration is removed. Once the activity or event has stopped (or between regular events) substratum within the habitat preferences of the original species or community remains or is deposited. A single event is assumed for assessment.

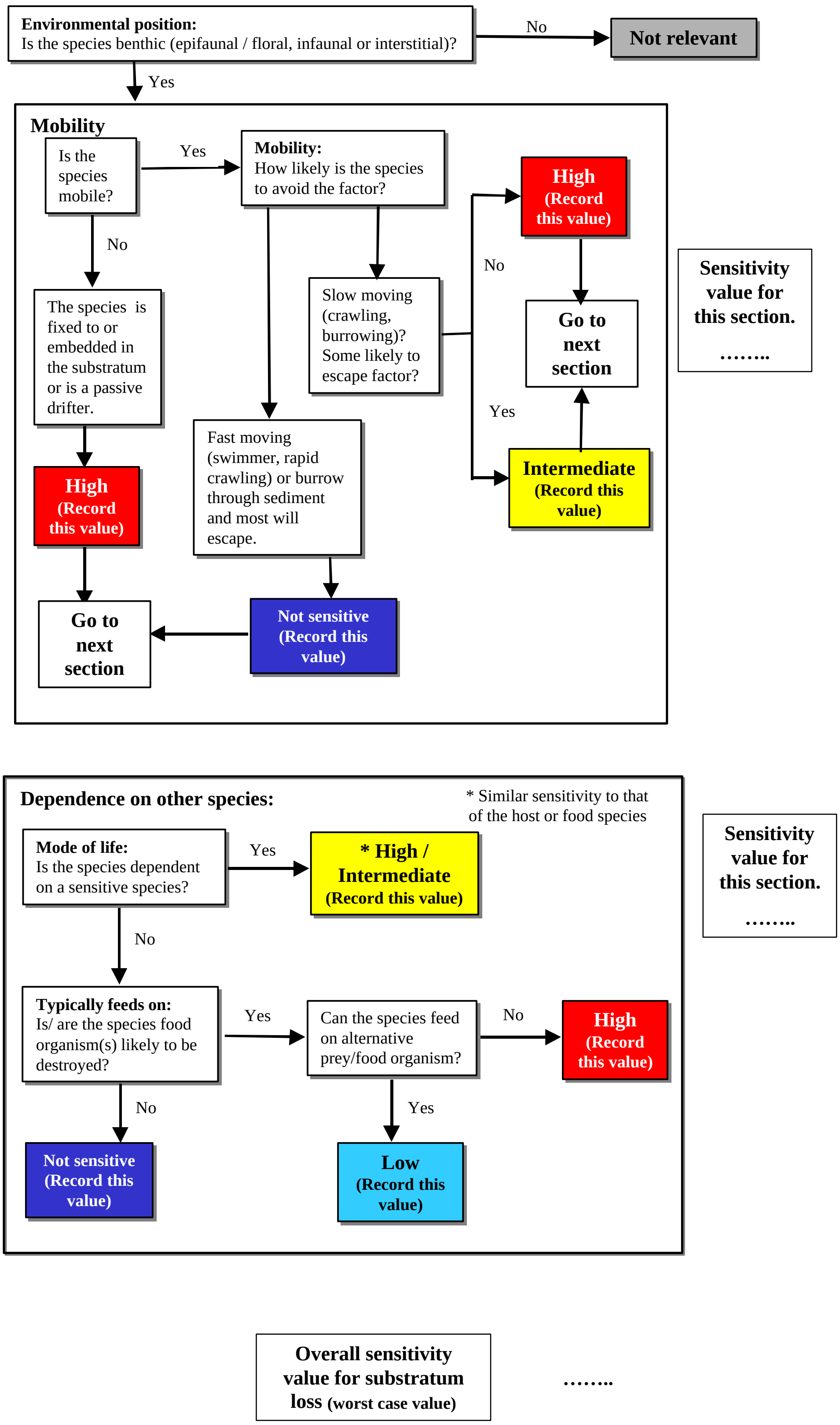

Figure 4. Sensitivity rationale for substratum loss.

Factor: Smothering

Description: The physical covering of the species or community and its substratum with additional sediment (silt), spoil, detritus, litter, oil or man-made objects.

Benchmark: All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month. **Impermeable** materials, such as concrete, oil or tar, are likely to have a greater effect.

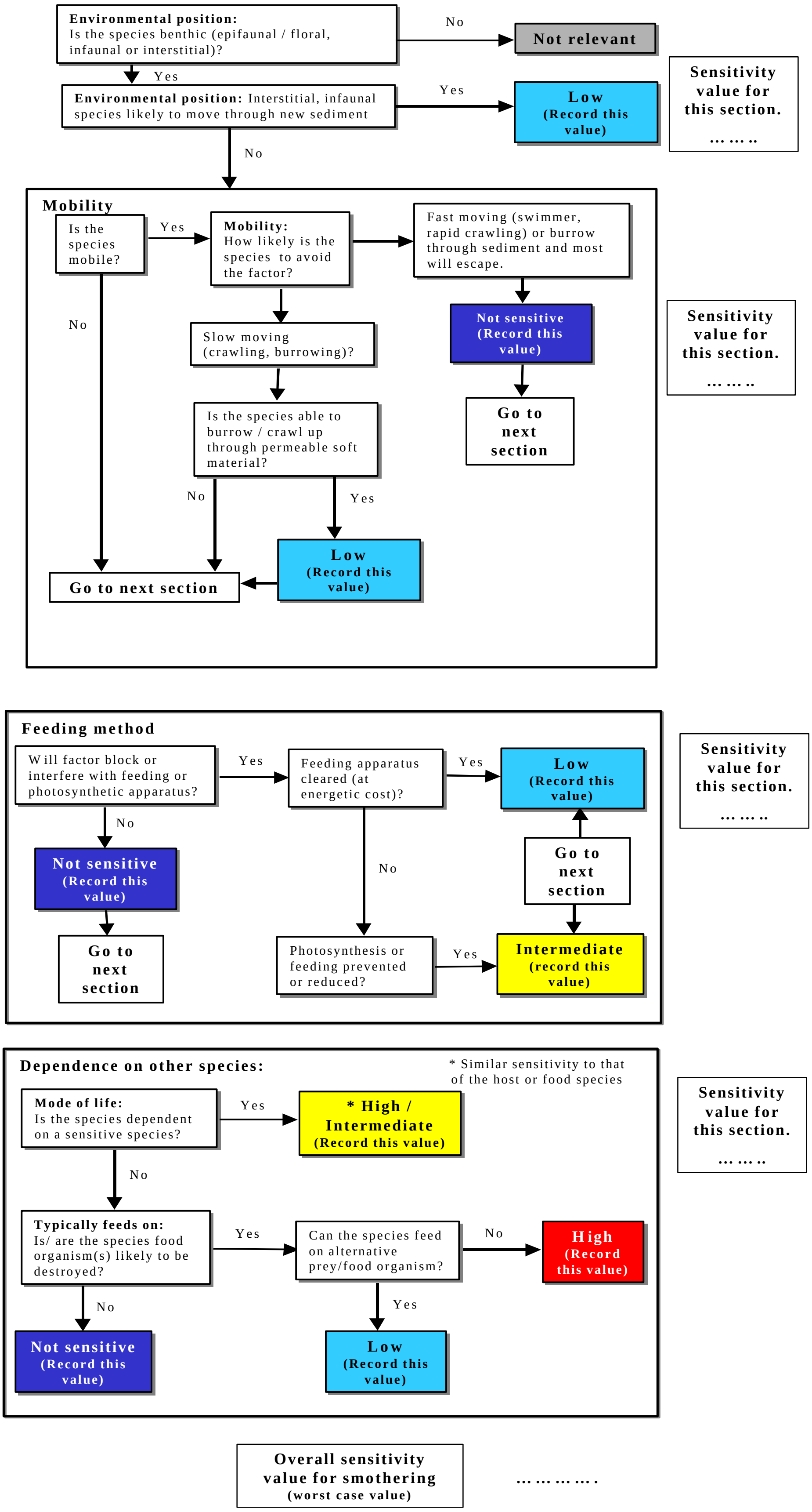

Figure 5. Sensitivity rationale for smothering.

3.4. Identify the likely recoverability of the species to external factors (Stage 4).

The recoverability of any species is dependent upon the species ability to:

- regenerate damage by re-growth;
- re-colonize the habitat by immigration of adults;
- re-colonize the habitat by larvae or juveniles (recruitment);

These criteria will be dependent on the developmental biology, longevity, age at maturity and frequency of reproduction of the adults, together with the biology and sensitivity of the larvae and juvenile stages.

The ability to recover from environmental perturbation is also dependent on the level of population degradation that results from the perturbation. Therefore, recoverability is dependent on the sensitivity of the species to any given factor. For example, a species may recover rapidly from factors that reduce the viability of the population but do not kill any member of the population (defined as 'low sensitivity'). However, a population of a species may take longer to recover from factors that destroy the population (defined as high sensitivity).

It follows, therefore, that recoverability to factors that reduce viability (low sensitivity) is primarily dependent on the species ability to re-grow and regenerate. However, the species ability to recover from destruction of the population is dependent on its ability to recruit and re colonize the habitat. Therefore, more key information fields are required to assess recoverability from factors to which the species is highly sensitive than those to which it has a low sensitivity (Table 3).

Table 3. Fields which are considered to assess recoverability from factors at different levels of sensitivity.

High sensitivity	Intermediate sensitivity	Low sensitivity
Abundance	Abundance	
Size at maturity	Size at maturity	
Growth rate	Growth rate	Growth rate
Mobility	Mobility	
Distribution		
Life span	Life span	Life span
Age at maturity	Age at maturity	Age at maturity
Generation time	Generation time	
Reproductive type	Reproductive type	
Reproductive frequency	Reproductive frequency	
Fecundity	Fecundity	
Larval settling time	Larval settling time	
Dispersal potential	Dispersal potential	

The influence of key information on re-growth, re-colonization and recruitment are assessed. The rationale used to assess recoverability from factors to which the species population has a 'high' or 'intermediate' sensitivity is given in Figures 6 and 7 respectively.

Factors that stress or reduce the viability of species population are assessed as 'low' sensitivity. Subsequent recoverability will depend on the species ability to repair damage, re-grow damaged parts or recover biochemical condition.

The rationale presents the main areas that are addressed, using the key information, to assess recoverability. The assessed ranks depend on the rates of growth and effective migration in the species of interest. The values suggested in Figures 6 and 7 must be treated as guidance values and adjusted in the light of key information research.

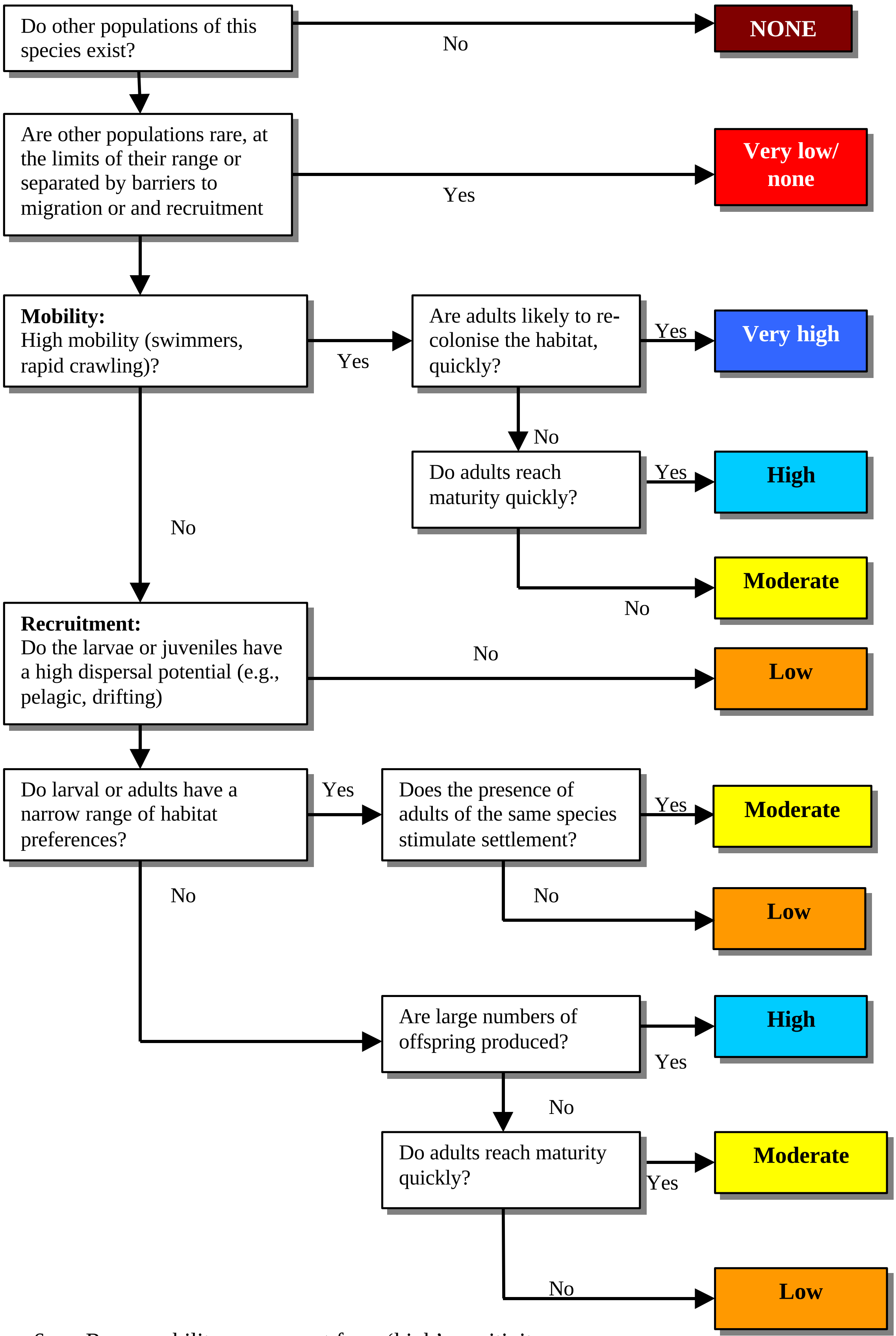

Figure 6. Recoverability assessment from 'high' sensitivity

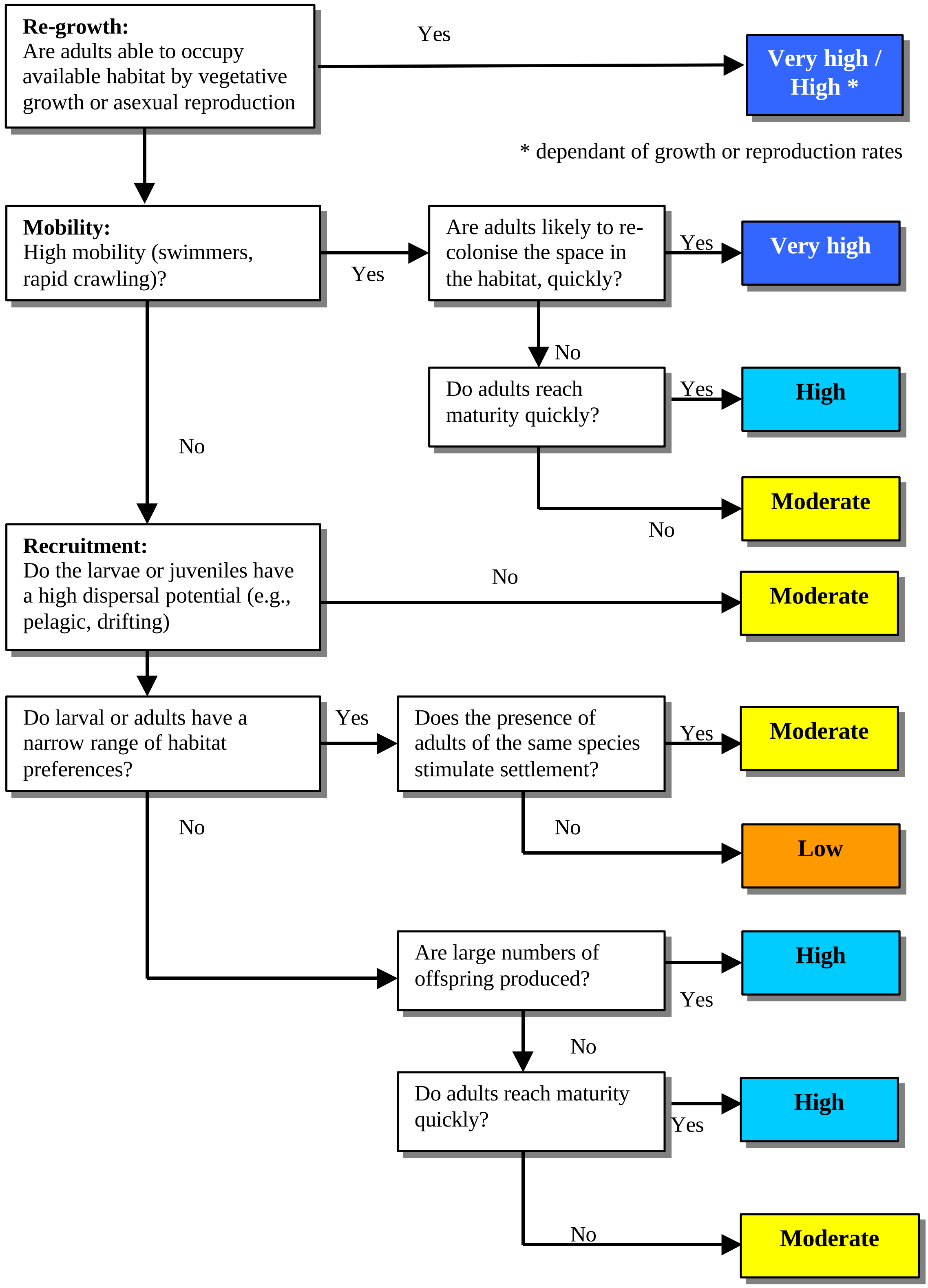

Figure 7. Recoverability assessment from 'intermediate' sensitivity.

Those factors that result in the same sensitivity value will probably have the same recoverability value. However, each should be assessed separately to ensure consistency. Throughout the above procedure, the key information used to make judgements should be noted. This information then forms the basis of an explanation for each recoverability assessment.

3.5. Referee (Stage 5).

The key information, sensitivity and recoverability assessments for each species are subject to peer review prior to publication on the Web.

4. Biotope sensitivity assessment

The procedure used to assess biotope sensitivity includes:

1. review key information for the biotope in question;
2. select species that indicate biotope sensitivity;
3. review key information for these species;
4. indicate quality of available data;
5. assess the sensitivity of species to external factors;
6. assess the recoverability of species in response to external factors;
7. assess overall biotope sensitivity;
8. assess overall biotope recoverability;
9. assess response of species richness to the factors;
10. referee.

The biotope sensitivity assessment procedure is outlined in Figure 8.

4.1. Review of key information (Stage 1).

The available key information fields are collated as for species. The key information fields used for biotopes are listed in *MarLIN* Report No. 1 (Appendix 6, Hiscock *et al.* 1999).

4.2. Select species that indicate sensitivity (Stage 2).

It has been suggested that the sensitivity of a community within a biotope is dependent upon and, therefore, indicated by the sensitivity of the species within that community (Cooke & McMath, 1999). However, not all species within a community affect its sensitivity to environmental change. For example, in the seagrass biotope IMS.Zmar (*Zostera marina / angustifolia* in lower shore or infralittoral muddy sand), the crab *Carcinus maenas* and the neogastropod *Hinia reticulata* are characteristic species (faithful and frequent). However, their loss from the community may not adversely affect the viability, structure or function of the biotope. The abundance, frequency or faithfulness of a species within a biotope are generally not good indicators of the contribution of a species to the sensitivity of the biotope.

The species that indicate the sensitivity of a biotope are identified as those species that significantly influence the ecology of that component community (Table 4). The loss of one or more of these species would result in changes in the population of associated species and their interactions. The criteria used to identify species that indicate biotope sensitivity (Table 4) subdivide species into ‘key’ and ‘important’ based on the likely magnitude of the resultant change.

The loss/degradation of the 'key structural' or 'key functional' species would result in significant and rapid changes in the community and its associated species, for example, loss/degradation of kelp within a kelp forest community. Loss or degradation of ‘important’ species may affect the viability of key species or the community resulting in gradual change or degradation of the biotope.

For example, the loss or degradation of epiphytic grazer populations in seagrass beds may result in increased epiphyte growth, smothering of *Zostera* leaves, reduced viability of the seagrass and lower productivity.

The term 'important characterising' species has been included to aid biotope sensitivity assessment. Important characterising species are species that help to distinguish the biotope. Their loss or degradation would result in the loss of that biotope as an identifiable unit in the field. It is expected that these species would be designated (using the sensitivity indicator species criteria above) as key in most cases. The 'important structural' or 'important functional' species influence the viability of the community or key species.

All species identified as key are used in the sensitivity assessment. However, where several important species can be identified, 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 of the biotope.

Table 4. Selection criteria for species that indicate sensitivity. These criteria are used to decide which species best represent the sensitivity of a biotope or community as a whole.

Rank	Criteria
Key structural	The species provides a distinct habitat that supports an associated community. Loss/degradation of this species population would result in loss/degradation of the associated community.
Key functional	The species maintains community structure and function through interactions with other members of that community (for example, predation, grazing, and competition). Loss/degradation of this species population would result in rapid, cascading changes in the community.
Important characterising	The species is/are characteristic of the biotope (dominant, highly faithful and frequent) and are important for the classification of that biotope. Loss/degradation of these species populations could result in loss of that biotope.
Important structural	The species positively interacts with the key or characteristic species and is important for their viability. Loss/degradation of these species would likely reduce the viability of the key or characteristic species. For example, these species may prey on parasites, epiphytes or disease organisms of the key or characteristic 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	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.

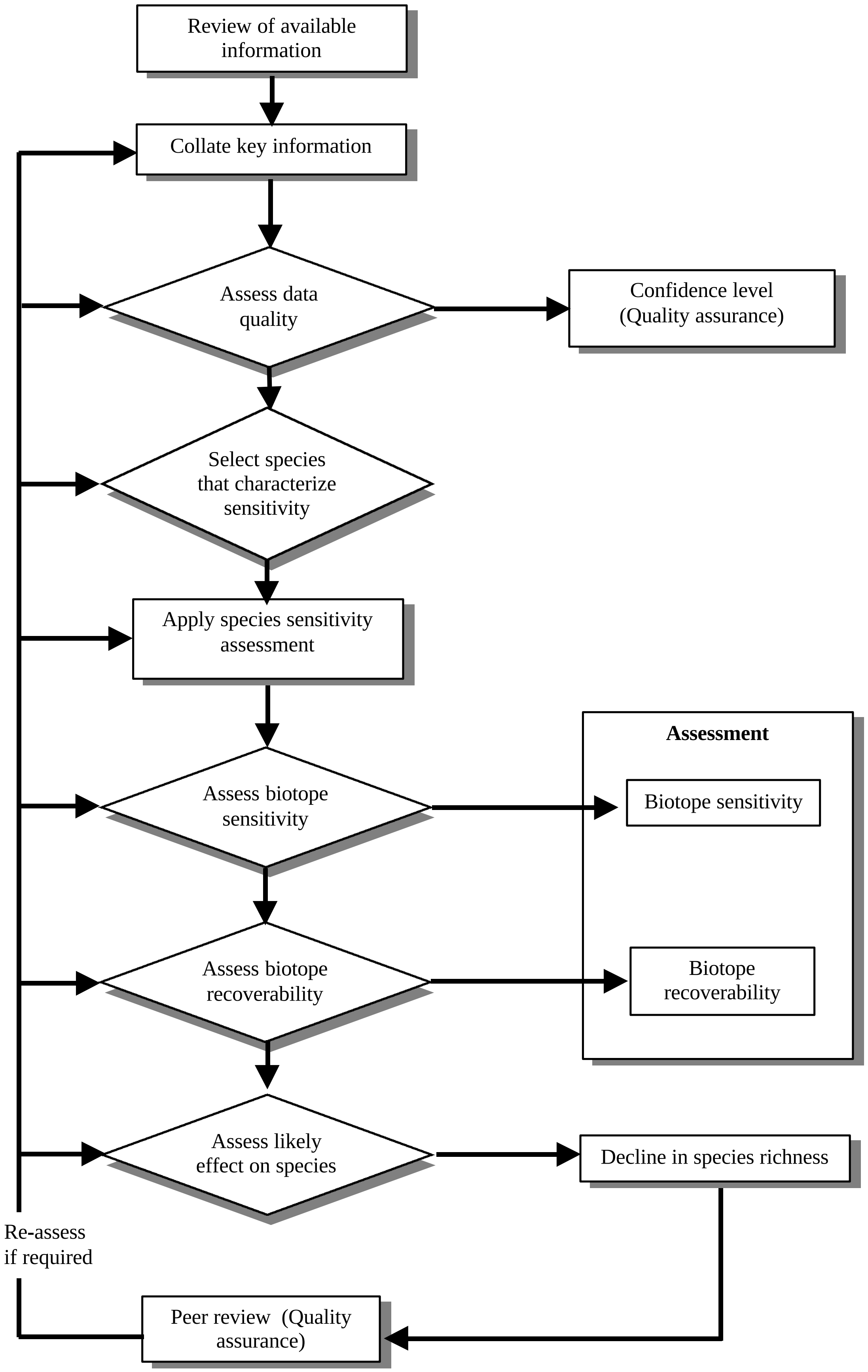

Figure 8. Biotope assessment procedure

4.3. Assess sensitivity and recoverability of the species that characterize community sensitivity (Stages 3-6).

The sensitivity and recoverability of the species selected to characterize community sensitivity are assessed using the species sensitivity rationale (section 3.3 above).

4.4. Assess the overall sensitivity of the biotope (Stage 7).

The sensitivity assessments of the species chosen under stage 3 are used to derive the biotope sensitivity using the rationale shown in Figure 9. A biotope sensitivity assessment is derived for each factor in turn. The evidence, key information and judgements made to derive each assessment is recorded as the explanation attached to each sensitivity assessment.

It is assumed that if any of the key species are highly sensitive then the sensitivity of the biotope as a whole will be high. Similarly, if the ‘important characterising’ species are highly sensitive the overall sensitivity of the biotope is also high. The rationale further assumes that the sensitivity of important species may increase the overall sensitivity of the biotope above that of the key species. For example, if the key species are judged to have an intermediate sensitivity but the important species are highly sensitive to the same factor, then the overall sensitivity of the biotope is reported as high. Further examples are given in Table 5.

Table 5. Examples of biotope sensitivity assessment scales derived from species sensitivitiy assessements. The values shown in the table are for demonstration only.

Species that characterize sensitivity					**Biotope sensitivity**
Key structural	**Key functional**	**Important characterising**	**Important structural**	**Important functional**	
High	High	Intermediate	Intermediate	Low	High
High	Intermediate	Intermediate	Low	Low	High
Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Intermediate	Low	High	Low	Low	High
Low	Low	Intermediate	Low	Low	Intermediate
Low	Intermediate	Low	High	Intermediate	High
Low	Low	Low	Intermediate	Low	Intermediate
Low	Low	Low	Low	Low	Low

The above rationale represents a practical approach to derivation of an overall biotope senstitivity. However, it is important to review the value obtained above using other key information that may affect biotope or community sensitivity. These fields include, ecological relationships, habitat complexity, productivity, and additional information.

4.5. Assess the overall recoverability the biotope (Stage 8).

The recoverability of the biotope is assumed to depend on the recoverabilty of the key species and be modified by the recoverability of the important species. The approach taken to derive biotope recoverability is similar to that taken for biotope sensitivity (Figure 10).

The biotope recoverability assessment is reviewed against relevant key information that may affect the recoverability. These fields include, time to reach maturity, recruitment processes, habitat preferences, distribution, abundance, habitat management and relevant additional information.

4.6. Assess the likely effect of the factor on species richness(Stage 9).

A particular factor may not destroy or significantly damage key or important species within a community but may still result in degradation of the biotope through loss of species richness. Species richness is defined as the number of species present in the community. Therefore, a scale was derived (Table 6) against which to judge changes in species richness. The scale refers to the relative species richness values developed for use in the Natural Heritage Assessment Protocol (NHAP, described in Hiscock 1996 but taking account of subsequent modifications).

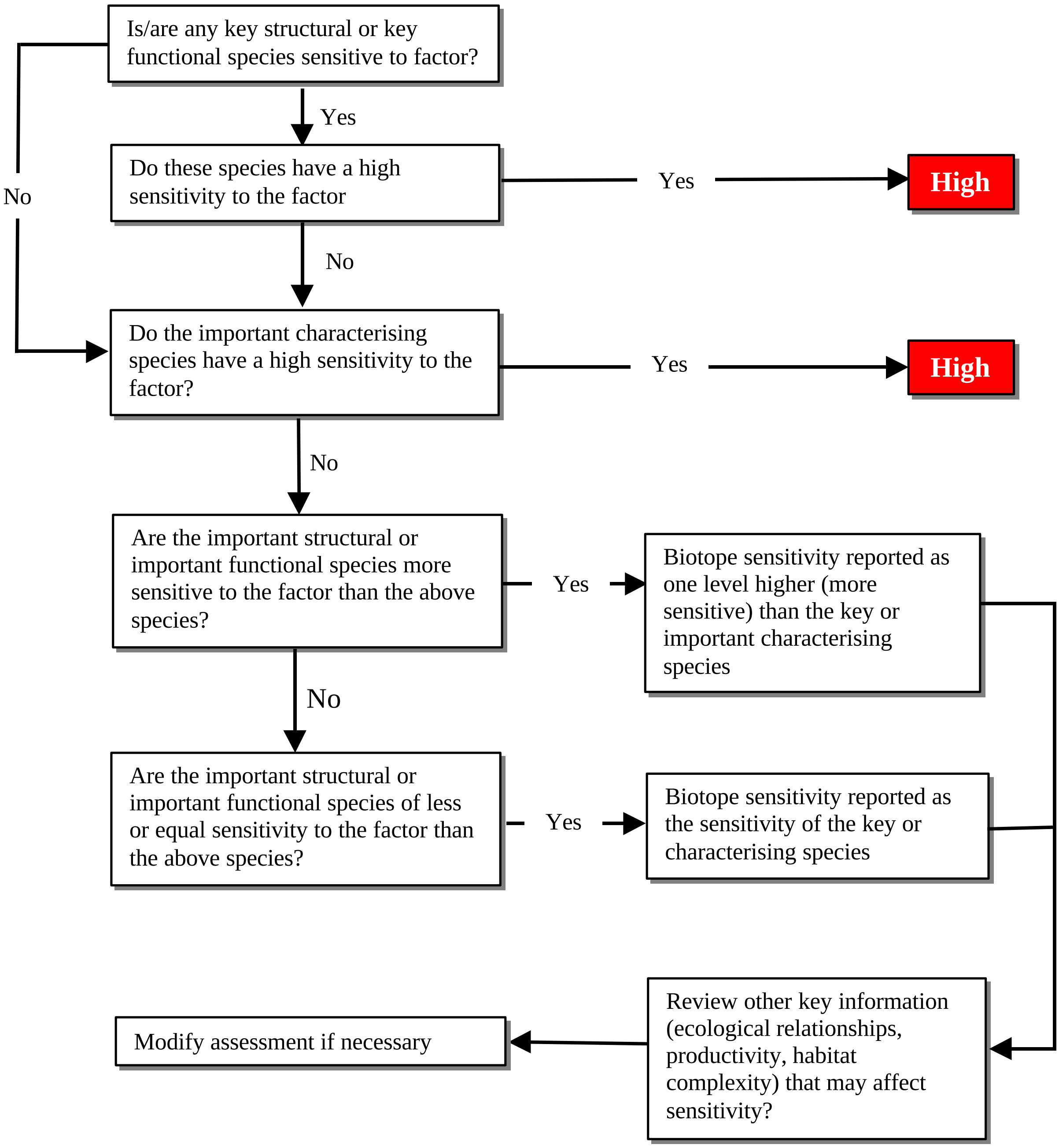

Figure 9. Biotope sensitivity assessment rationale

The change in species richness is dependent on both the sensitivity and recoverability of the biotope. If a biotope is degraded but can recover quickly then the overall species richness may not decline significantly.

The destruction of key or important species within the community (high sensitivity) is likely to result in major decline in species richness. However, if the abundance of a species alone is reduced or degraded (intermediate sensitivity) the species richness is unlikely to change. These principles are demonstrated in Table 7.

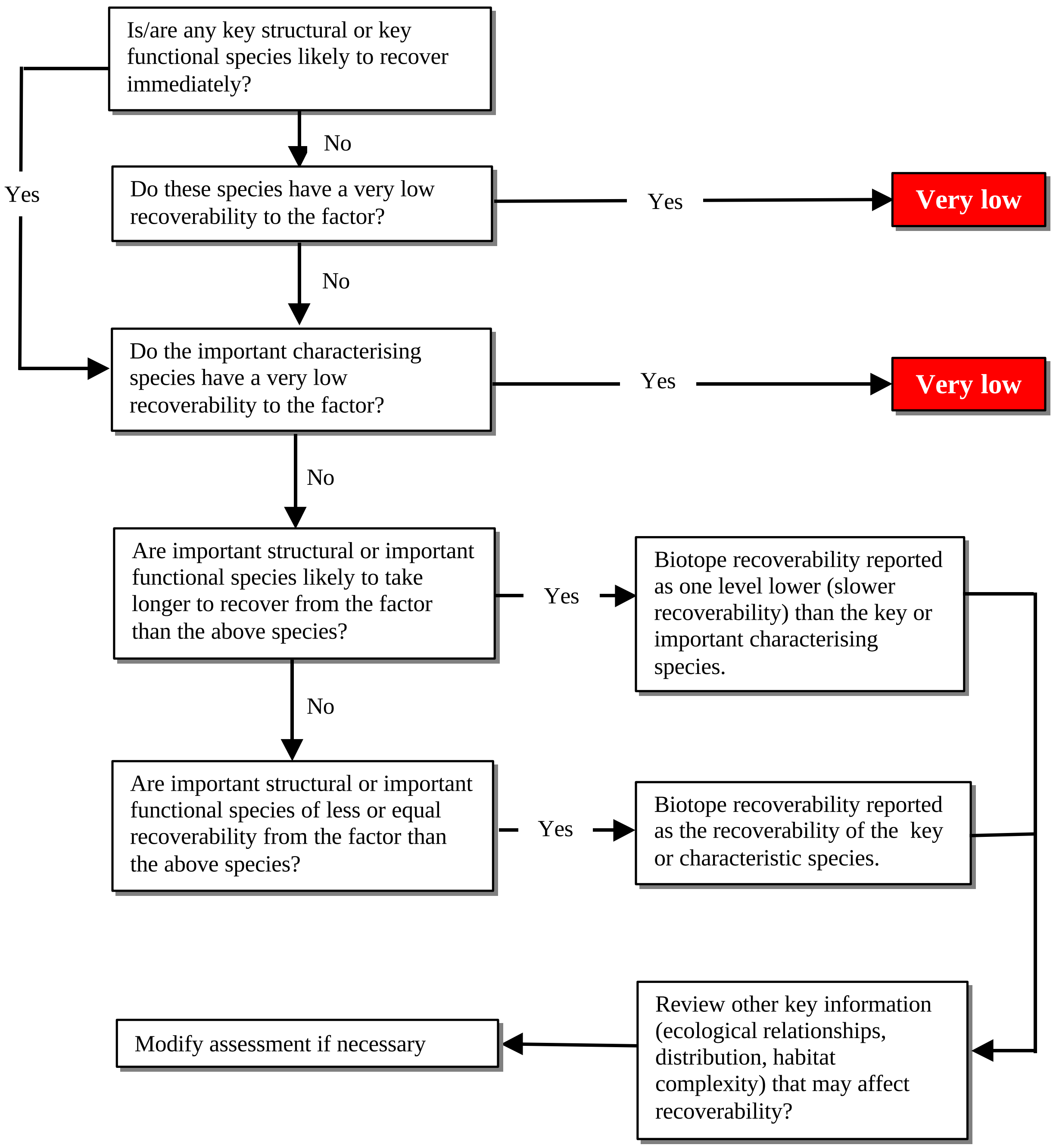

Figure 10. Biotope recoverability assessment rationale

Table 6. The following scale is used to judge the likely response of species richness to an external factor.

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

Table 7. The assesment of the likely change in species richness of a community in response to a factor. The values presented are for demonstration only.

Species that characterize sensitivity		**Change in species richness**
Biotope sensitivity	**Biotope recoverability**	
High	Low or Very low	Major decline
High	Moderate	Decline
High	High	Minor decline
High	Very high	No change
Intermediate	Very low or low	Minor decline
Low	N/A	No change

A decline in species richness is likely when the community is highly sensitive to a factor. A minor decline in species richness may occur if the population of the key or important species is degraded or the habitat reduced and the community recovers slowly. In this case species may be lost due to increased competition for resources or emigration.

The likely change in species richness in response to a given factor is reviewed against relevant key information before a final judgement is made. The relevant key information fields include, adundance, distribution, presence of rare or scarce species, presence of species unique to the community and relevant additional information. The information used and judgement made are recorded to provide the basis of an explanation of how the assessment was derived for each factor.

4.7. Referee (Stage 10).

The key information, sensitivity and recoverability assessments for each biotope are subject to peer review prior to publication on the Web.

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6. Glossary of specific terms

‘Activity’ (maritime) an anthropogenic operation or activity which occurs in the marine or coastal environment (Cooke and McMath 1998).

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

‘Community’ a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and identifiable by means of ecological survey from other groups (from Mills 1969; see Hiscock & Connor 1991 for discussion.)

‘Factor’ a component of the physical, chemical, ecological or human environment that may be influenced by a natural events or anthropogenic activity. Therefore, activities effect the environment by perturbation of these factors.

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

‘Recoverability’ is the ability of a habitat, community or species to return to a viable state which is at least close to that which existed before the development, activity or event. Recovery may be because of re growth (in the case of damaged species capable of re-growing from remaining tissue), re-colonization by migration or larval settlement from undamaged populations or may require re-establishment of viability where, for instance, reproductive organs or propagules have been damaged by the event. Recovery can be partial or complete.

‘Sensitivity’ is the intolerance of a habitat, community or individual (or individual colony) of a species to damage, or death, from an external factor. Sensitivity has to be referred to specific environmental perturbations.

‘Viability’ the quality or state of being viable; capacity for living; ability to live under certain conditions.

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

7. Appendix 1 *MarLIN* Objectives and Guiding Principles

MarLIN OBJECTIVES AND GUIDING PRINCIPLES

THE BIOLOGY AND SENSITIVITY KEY INFORMATION SUB-PROGRAMME

Objective 1
To provide the scientific information required by marine and coastal managers to better understand and describe the sensitivity of key seabed habitats, biotopes and species to natural events and human activities.

Guiding principles to Objective 1

1. The habitats, biotopes and species will be those which are commonly accepted: biotope complexes, biotopes and sub-biotopes from the MNCR biotopes classification (as amended) (Connor *et al.* 1997); species from the MCS/Ulster Museum Species Directory (Howson & Picton 1997) (supplemented for deep water areas within the EEZ.)
2. Any scale developed within *MarLIN* to indicate sensitivity of a habitat biotope or species must:
   1. take account of systems already developed to use their best features;
   2. be assessed against scales developed as a result of expert workshops;
   3. be assigned a confidence rating which also indicates ‘lack of knowledge’;
   4. be disseminated in a form capable of understanding by non-biologists.
3. Acknowledging that preparing full key information and sensitivity assessments for a habitat, biotope or species is a time consuming activity, to adopt an overall two-tiered approach to the development and implementation of the sensitivity work as follows:
   1. Initially, selective information will be entered to the database for all priority habitats, biotopes and species according to the criteria listed below.
   2. Subsequently, further information will be entered for high priority habitats, biotopes or species.

   Priority will be given to habitats, biotopes and species that:

   a. the UK Government has management responsibilities or obligations for under international conventions and directives including protected species and BAP listed species;

   b. have been identified in European workshops as threatened or requiring documentation;

   c. are subject to national regulations;

   d. contribute to national nature conservation initiatives;

   e. are surrogates for the condition of other habitats, biotopes or species;

   f. are indicators of threatening processes;

   g. are at high risk of impact due to their sensitivity or vulnerability;

   h. are nationally rare or scarce;

   i. are ‘keystone’ or characteristic species of a habitat or biotope.

4. Some habitats, biotopes and taxonomic groups that are well documented will also be researched/entered to the database to trial the development of the information fields and database.
5. As habitat, biotope and species pages are completed, they will be refereed by collaborators with experience in the relevant field.
6. Habitat, biotope and species pages will be available on the web and comments will be invited especially on the completed key information and to identify further information sources.

Objective 2
To develop a user-friendly computer-based system that will allow the information thus gathered to be interpreted and used by decision-makers applying the ecosystem approach to environmental management.

Guiding principles to objective 2

1. Demonstration material will be openly accessible on the Internet.
2. Full information will be available through the Internet and CD-ROMs or an Intranet as appropriate to partners / subscribers to *MarLIN*.
3. The system will operate by linking to geo-referenced data sources including MNCR data, accessed under the *MarLIN* seabed data access and acquisition sub-programme.
4. The information will be presented in a format and in a level of detail that will enable organisations or individuals with an interest or responsibility in the marine environment to undertake a preliminary assessment of the likely impact of a human activity or operation on marine habitats, biotopes or species.
5. The information will be accessed using a variety of approaches, including:
    - from an accepted list of potential threatening activities;
    - from the component factors of an activity;
    - from the species or biotope dictionaries.

    Threatening activities will be modified from the Marine Conservation Handbook and JNCC Marine Information Team keywords.

8. Appendix 2. Sensitivity and recoverability assessment scales (ranks and criteria).

SPECIES SENSITIVITY The intolerance of a habitat, community or individual (or individual colony) of a species to damage, or death, from an external factor.	
Rank	**Definition (from Hiscock, Jackson and Lear 1999)**
High	The species population is likely to be killed/destroyed by the factor under consideration.
Intermediate	Some individuals of the species may be killed/destroyed by the factor under consideration and the viability of a species population may be reduced.
Low	The species population is unlikely to be killed/destroyed by the factor under consideration. However, the viability of a species population may be reduced.
Not sensitive	The factor does not have a detectable effect on survival or viability of a species or structure and functioning of a biotope.
Not sensitive*	Population of a species may increase in abundance or biomass as a result of the factor.
Not relevant	This rating applies to species where the factor is not relevant because they are protected from the factor (for instance, through a burrowing habit), or can move away from the factor.

Appendix 2 (continued).

RECOVERABILITY The ability of a habitat, community or individual (or individual colony) of species to redress damage sustained as a result of an external factor.	
Recoverability assumes that the impacting factor has stopped or been removed. The scale also refers only to the recoverability potential of a species, based on its reproductive biology etc.	
Rank	**Definition**
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	If the sensitivity of a species is not relevant then recoverability can not be assessed.

Appendix 2 (continued).

CONFIDENCE A feeling of reliance or certainty	
Confidence level	**Definition**
High	Assessment has been derived from sources that specifically deal with sensitivity and recoverability to a particular factor. Experimental work has been done investigating the effects of such a factor.
Moderate	Assessment has been derived from sources that consider the likely effects of a particular factor.
Low	Assessment has been derived from sources that only cover aspects of the biology of the species or from a general understanding of the species. No information is present regarding the effects of factors.
Very low	Assessment derived by 'informed judgement' where very little information is present at all on the species.
Not relevant	The available information does not support an assessment, the data is deficient or no relevant information has been found.

Appendix 2 (continued).

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

Appendix 2 (continued).

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	The species provides a distinct habitat that supports an associated community. Loss/degradation of this species population would result in loss/degradation of the associated community.
Key functional	The species maintains community structure and function through interactions with other members of that community (for example, predation, grazing, and competition). Loss/degradation of this species population would result in rapid, cascading changes in the community.
Important characterising	The species is/are characteristic of the biotope (dominant, highly faithful and frequent) and are important for the classification of that biotope. Loss/degradation of these species populations could result in loss of that biotope.
Important structural	The species positively interacts with the key or characterising species and is important for their viability. Loss/degradation of these species would likely reduce the viability of the key or characterising species. For example, these species may prey on parasites, epiphytes or disease organisms of the key or characterising 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	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 species identified as key 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.

Appendix 2 (continued).

SPECIES RICHNESS The number of species in a given habitat, biotope, community or assemblage	
The following scale is used to judge the likely response of species richness to an external factor.	
Rank	**Definition**
Major decline	The number of species in the community is likely to decrease significantly (>75% of species) in response to the factor, probably because of mortality and loss of habitat. For example, a change from very rich to very poor on the NHAP scales (Hiscock 1996).
Decline	The community is likely to loose some of its species in response to the factor by either direct mortality or emigration.
Minor decline	The community is likely to loose few species (<25% of species) in response to the factor. For example, a decrease of one level on the NHAP scales (Hiscock 1996).
No change	The factor is unlikely to change the species richness of the community
Rise	The number of species in the community may increase in response to the factor. (Note the invasion of the community by aggressive or non-native species may degrade the community).
Not relevant	It is extremely unlikely for a factor to occur (e.g. emergence of a deep water community) or the community is protected from the factor.
	Hiscock, K. 1996. Interpretation of data. In: *Marine Nature Conservation Review: Rationale and methods*, ed. K. Hiscock, p. 73-84. Peterborough: Joint Nature Conservation Committee.

9. Appendix 3. Factors and their benchmarks.

Benchmarks for the assessment of Sensitivity and Recoverability

The chosen benchmarks reflect the magnitude and/or duration of change in a factor likely to occur as a result of the relevant maritime activity. The benchmark magnitude is set at the 'most likely' level. Where appropriate two benchmarks are given to represent short term acute change and long term chronic change. Should this result in two different assessments of sensitivity for a factor the highest sensitivity will be recorded. In all cases the assessment of recoverability assumes that the causal activity ceases or is removed and the environmental factor returns to its original (pre-effect) level.

Environmental factors.

Physical factors

Substratum loss: The physical removal of the substratum inhabited or required by the species or community in question. Newell *et al.* (1998) reviewed the environmental effects of dredging in coastal waters. They reported that trailer suction hopper dredging could result in dredged tracks 2-3m wide and 0.5m deep but up to 2m deep in some cases. In comparison, anchored dredging may result in pits of up to 75m in diameter and 20m deep. In the Baltic dredged tracks may still be detectable 12 months later. The time taken for pits to fill in the Dutch Wadden Sea was between 1 year in high currents, 5-10 years in lower currents and up to 15 years on tidal flats (Newell *et al.* 1998). Hall (1994) reports pits 3.5m wide and 0.6m deep as a result of suction dredging for *Ensis* in a Scottish sea loch. Newell *et al.* (1998) state that removal of 0.5m of sediment was likely to eliminate benthos from the affected area.

The chosen benchmark is representative of localised impacts on a specific area of substratum. This benchmark also includes the removal of other species that provide substrata for the species or community of interest, for example macroalgae.

	The level of effect against which sensitivity is rated.
Substratum loss	All of substratum occupied by the species or biotope under consideration is removed. Once the activity or event has stopped (or between regular events) substratum within the habitat preferences of the original species or community remains or is deposited. A single event is assumed for assessment.

Smothering: The physical covering of the species or community and its substratum with additional sediment (silt), spoil, detritus, litter, oil or man-made objects. Major storms may deposit a layer of additional material of several centimetres at 20m depth and several millimetres at 40m (Hall 1994). For example, storms were reported to deposit 4-10cm of sand at 28m in the Helgoland in German Bight and up to 11cm of sand off the Schleswig-Holstein coast (Hall 1994). In a study of the impact of mill tailings, discharged into a Canadian silled fjord, Ellis and Heim (1985) observed layers of tailings of 0.5cm, 5cm and greater than 5cm (up to 60cm in one location).

The chosen benchmark represents the likely level of smothering resulting from natural events and comparable to the effects of maritime activities. [The definition does not include land claim. Evidently, the habitat and its resident species would be destroyed by land claim. Recovery would not be possible as the effect is permanent].

	The level of effect against which sensitivity is rated.
Smothering	All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month. **Impermeable** materials, such as concrete, oil or tar, are likely to have a greater effect

Change in siltation rate: The settling out of suspended matter from the water column to the substratum. The rate of siltation is dependent on the availability of suspended sediment, its particle size range and the water flow rate. In estuarine environments siltation is increased by the flocculation of inorganic and organic substances due to mixing of fresh and saltwater. Floods are likely to increase the availability of sediment entering coastal waters from rivers. Storms may re-suspend sediment and transport it to other areas. Coastal erosion is a primary source of sediment. Activities that alter sediment availability (e.g., coastal quarries, de-forestation, coastal forestry, construction and dredging) or that change the water flow rate (e.g., coastal engineering such as channelisation and breakwater construction) are likely to change the siltation rate. Suspended sediment concentration varies around the UK, from 1-327 mg/l around the English coast and 1-227 mg/l around the Welsh coast. However, suspended sediment concentrations in estuaries may be much higher; measured in g/l.

'Siltation' is included as a factor for those species likely to be sensitive to clogging of respiratory or feeding apparatus by silt or species that require a supply of sediment for tube construction such as *Sabellaria sp.* Therefore, an arbitrary benchmark was chosen to represent a change in the availability of suspended sediment.

	The level of effect against which sensitivity is rated.
Changes in siltation rate	A change in suspended sediment concentration of 100mg/1 outside the normal range experienced by the organism or community of interest for 1 year.

Desiccation: the removal of water or drying. Desiccation rate during emersion is dependent on sunlight (and hence temperature), air movement (wind) and humidity. Intertidal organisms exhibit a number of physiological or behavioural adaptations to avoid or reduce desiccation. Two benchmarks are given. The first benchmark represents stranding on the shore or the sudden exposure of an organism or community to desiccation, for example by turning over rocks on the shore to expose undersurface communities. The second benchmark represents changes in the desiccation rate due to changes in exposure to sunlight and air as result of a change in the emergence regime, exposure of the shore or prolonged periods of sunlight and higher temperatures.

	The level of effect against which sensitivity is rated.
Desiccation	1). A normally subtidal, demersal or pelagic species including intertidal migratory or under surface species is continuously exposed to air and sunshine for 1 hour. 2). A normally intertidal species or biotope suffers 25% change in exposure to sunlight or wind for one year.

Change in emergence: the time spent emersed and exposed to air. Intertidal species are regularly emersed with the falling tide, the percentage of time emersed is dependent on their position or height on the shore relative to the tide. There are seven sub-zones recognized in the intertidal. This benchmark also includes organisms in the splash zone (supralittoral) where the wetness regime is also dependent on the wave energy (wave height) reaching the shore.

	The level of effect against which sensitivity is rated.
Changes in emergence	A 1 hour change in the time covered or not covered by the sea for a period of 1 year.

Change in water flow rate: The movement of water associated with the rise and fall of the tide (tidal streams), prevailing winds and ocean currents. Strong tidal streams result in areas where water is forced through or over restrictions (e.g. gullies or narrows) or around offshore rocks. Currents are dependent on the meteorology, oceanography and hydrography of the location.

Maritime activities, for example coastal engineering, are likely to cause changes in water flow rate at least as large as the benchmark level. In addition, many species and biotopes occur under a range of water flow conditions and a change of two categories is more likely to affect a range of species than is a change of one category.

	The level of effect against which sensitivity is rated.
Changes in water flow rate	A change of two categories in water flow rate for one year (see *MarLIN* glossary) for 1 year. For example from moderately strong (1-3 knots) to very weak (negligible).

Changes in temperature: Changes in the intensity of heat of the surrounding environment. The temperature of thermal discharges is likely to be between 2°C and 10°C (UNEP 1984). UNEP (1984) recommend an impact assessment level for thermal discharge plumes of equal to or greater than three degrees centigrade. Crisp *et al.* (1964) reported the effects of the severe winter of 1962/63. Mortalities were recorded for a wide range of marine species as a result of a temperature drop of 5-6°C below the long term average for the south, south west and west coast of England during a two month period. Marine organisms are likely to be more tolerant to slow temperature change than sudden change. For example, species are likely to be more sensitive to a temperature change of 5 °C if it occurs over a period of a few hours rather than a few days.

Benchmark 1) represents single pulse events, such as occasional short term industrial discharges or accidental spillages. However, species are likely to be more sensitive to discharges of longer duration. Benchmark 2) represent continuous discharges of lower level. A year's duration was chosen to represent the probability that the temperature change would impinge on the larval forms and breeding cycle of most marine organisms.

	The level of effect against which sensitivity is rated.
Changes in temperature	1) A change of 5 °C outside normal temperature range for 3 consecutive days. This definition includes short term thermal discharges. 2) A change in temperature of 2 °C outside normal temperature range for a year. This definition includes long term thermal discharges. For intertidal species, the normal range of temperatures includes the normal air temperature regime for that species.

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

The chosen benchmark reflects the likely change in turbidity, expressed as suspended sediment, resulting from maritime activities. For example, Churchill (1989) recorded a 100 - 550 mg/l plume of suspended matter behind a shrimp trawl in Corpus Christie Bay, USA. Newell *et al.* (1998) cite a sediment plume up to 100m behind a dredger in Hong Kong waters of 75-150 mg/l reducing to nearly background levels in 30 min. The benchmark includes light attenuation to represent a change in turbidity due to dissolved substances and assumes that any algal species being considered are at the upper or lower limits of their distribution.

	The level of effect against which sensitivity is rated.
Changes in turbidity	Exposed to 50 mg/l suspended particulate matter or light absorption of 30% for five weeks.

Changes in wave exposure: Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of the winds. Wave exposure is expressed as an eight rank scale of exposure (see glossary). Wave exposure may be altered by coastal engineering developments such as breakwaters and artificial reefs and are likely to be permanent unless positioned to temporarily protect other activities. Many species and biotopes occur under a range of wave exposure conditions. A change of one category might be effective in altering the survival or abundance of a few species, however, placing the benchmark magnitude at two at ranks is more likely to encompass a significant number of species. The benchmark level is also representative of the likely effects of a number of relevant maritime activities, such as, breakwaters.

	The level of effect against which sensitivity is rated.
Changes in wave exposure	A change of two ranks on the wave exposure scale (see glossary) e.g. from Exposed to Extremely exposed for a period of 1 year.

Noise: generally defined as unwanted or disruptive sound**.** Noise can cause sensitivity in three ways:

1). actual discomfort, damage or death;
2). interference with the use of hearing for feeding or communication reducing viability;
3). disturbance of breeding or other behaviours reducing viability.

The units of the benchmark are received sound pressure in decibels (dB) shown as a ratio of received pressure to a fixed reference pressure (re) of 1 Pa at 1 metre. A typical ambient coastal noise level in calm weather would be around 40 – 60 dB (Morris 1995). Various maritime activities produce noise of various frequencies at pressures from 120 to 250 dB (Richardson *et al.* 1999). A distance of 1 metre is not very applicable to the exposure of marine organisms to noise in the environment. A typical decrease in pressure (transmission loss) over 100 metres would be 40 dB (Richardson *et al.* 1999). In setting the benchmark for underwater noise, this loss has been applied to the typical noise pressures resulting from various activities. Different activities tend to produce noise of different pressures at different frequencies. For example:

- drilling noise tends to be up to 160 dB re 1 Pa-m at frequencies below 300 Hz with a peak below 2 Hz;
- dredging tends to be up to 180 dB re 1 Pa-m and below 1kHz;

- boats and small ships produce sound up to 170 dB re 1 Pa-m with frequencies up to 10 kHz (outboards motors have peaks at frequencies above 1kHz and larger vessels peak below 1 kHz);
- sonar sound can be up to 230 dB re 1 Pa-m and range from 500 Hz to several hundred kHz; and
- seismic airguns at 250 dB re 1 Pa-m up to several kHz (strongest below 100Hz)(Richardson *et al.* 1999).

In addition, atmospheric noise can affect marine animals at the water surface or for example, hauled out on sand banks. Conventionally aircraft noise is referred to at a distance of 300 metres from the source. In extreme cases, such as for military jets, noise produced can be up to 130 dB re 1 Pa at 300m

Noise duration varies with activity, ranging from several weeks (dredging) to a fraction of a second repeated regularly for several hours (seismic survey) to a few minutes (a passing ship or plane). The benchmark was set using a duration that could typically result from a variety of activities e.g. continuous daytime boat activity, dredging, construction or proximity to an airport.

This benchmark does not deal with the transmission of atmospheric noise to the water.

	The level of effect against which sensitivity is rated.
Noise	**Underwater noise levels** 130 dB re 1 Pa (for broad spectrum noise 45 – 7070 Hz) at 100 metres from source intermittently over a 24 hour period for 1 month during important feeding or breeding periods. This approximates to the regular passing of a 30 metre trawler at 100 metres or a working cutter-suction transfer dredge at 100 metres. **Atmospheric noise levels** 98 dB re 1 Pa (for broad spectrum noise 45 – 7070 Hz) at 300 metres below the source on and off over a twenty-four hour period for 1 month during important feeding or breeding periods. This approximates to the regular passing of a Boeing 737 passenger jet 300 metres overhead.

Visual presence: This benchmark applies only to species that have sufficient visual acuity to resolve moving objects or at least differentiate between rapid changes in light intensity (as in a moving shadow). Response is likely to be immediate with the species moving out of range of the stimulus. The duration of the factor has been set in line with potential maritime activities (such as disturbance to seals by tourists) and also at a level that could cause a measurable effect on the species.

	The level of effect against which sensitivity is rated.
Visual presence	The continuous presence for one month of moving objects not naturally found in the marine environment (e.g. boats, machinery, and humans) within the visual envelope of the area in which the species under consideration occurs.

Abrasion: the mechanical interference or rubbing of the organism of interest. Protrusive species may be crushed, and delicate organisms with a fragile skeleton or soft bodies may be physically. The chosen benchmark was chosen to be representative of a common maritime activity.

	The level of effect against which sensitivity is rated.
Abrasion	Force equivalent to a standard lobster pot or creel landing on the organism.

Displacement: physical removal or transportation of the species or community of interest. The community, colony or organism may be removed from its natural habitat but remains in the vicinity. For example an individual may be disturbed by a storm, or passing trawl, not killed but thrown into suspension. The definition of the factor used here assumes that a permanently attached species cannot re-attach and is likely to die whilst many burrowing species or sedentary species can re-burrow or re-attach. The benchmark was chosen to represent significant bioturbation as a result of pit digging by large epi-benthic predators such as Rays and Gray Whale (Hall, 1994; Table 2), or removal from hard substrata by wave action. Anthropogenic effects such as of suction dredging or beam trawling are likely to be greater than this level.

	The level of effect against which sensitivity is rated.
Displacement	Removal of the organism from the substratum and displacement from its original position onto a suitable substratum. A single event is assumed for assessment.

Chemical factors

Chemical contaminants: Laboratory or field experiments and observations suggest that species are adversely affected by the sorts of concentrations of any chemical that occur as a result of human activities or in accidents. However, the behaviour of chemicals in the marine environment is extremely complex and it is difficult to quantify the most likely effect of an activity. Similarly, the environmental concentration of any given contaminant may be the result of several activities, including aerial deposition.

A very large number of chemicals might affect marine species. The effects of some, such as TBT, are well known. However, in view of the incomplete or poor state of knowledge for many marine species, it is accepted that considerable extrapolation is required and that our confidence ratings are likely to be low.

It would be impractical to set separate benchmarks for all potential contaminants within the marine environment. Therefore, benchmarks have been set based on available environmental quality standards (EQSs), environmental assessment levels (EALs) (EA, 1997) or World Health Organisation Guidance values (see Cole *et al.* 1999 for review). The Environmental Agency uses the EQSs and EALs to define the upper boundary of concentrations of a substance in the environment that can be considered tolerable. A process should then be considered a priority for control where the predicted environmental concentration resulting from that process is 80% of the EAL. Environmental quality standards (and EALs) are derived by the application of safety factors, often arbitrary, to available toxicity data. Reference should be made to Cole *et al.* 1999 and the references cited therein for further information.

Benchmarks have been suggested for both long term chronic change and short term acute change. Long term chronic change assumes continued exposure to a contaminant that may result in sub-lethal effects. Therefore, the benchmarks assume an exposure to an ambient contaminant concentration level of, due to a discharge or other activity, equal to 2 times (100% increase) of the EAL (or EQS).

Short term acute benchmarks represent local effects in the vicinity of point discharges, accidents or re-suspension and dissolution. The short term acute benchmarks assume a ten fold increase above the EQS or EAL. Sediment quality criteria are included and used to derive long term benchmarks for sediment dwelling species.

Where the benchmark can be based on a known activity then this is stated. The tolerance to contaminants of species of interest will be included when available. The available toxicological information will vary between species and a species may be assessed to have different sensitivities to different chemicals within each class (heavy metals, synthetic chemicals, hydrocarbons, radionuclides) for example Cu, Zn and Hg within heavy metals. In these cases the available information will be clearly stated and the 'worst case' sensitivity reported.

Changes in levels of synthetic chemicals: synthetic chemicals are by definition man-made and include, for example, organotins (tributyl tin, triphenyl tin), pesticides (lindane, atrazine, dichlorvos, DDT), organochlorides, organophosphates, solvents (carbon tetrachloride, chloroform) and poly-chlorinated biphenyls (PCBs).

	The level of effect against which sensitivity is rated.	
Changes in synthetic chemicals		
Example	**EAL/EQS (for seawater unless otherwise stated)**	**Benchmark** Exposed to the following contaminant concentration
Tributyl tin	0.002 µg/l (Maximum Allowable Concentration)	1). Long term: 0.004 µg/l average in seawater for a 1 year period 2). Short term: 1 µg/l seawater for 2 days (48hrs) Short term value derived from survey of TBT concentrations associated with marinas in the Crouch estuary (Waldock & Miller 1983).
DDT (all isomers)	0.025/l annual average	1). Long term: 0.05 µg/l average for 1 year 2). Short term: 0.25 µg/l for 48hrs
Lindane (γ-HCH)	0.02µg/l annual average.	1). Long term: 0.04 µg/l average in seawater for a 1 year period 2). Short term: 0.2 µg/l for 48hrs

Changes in levels of heavy metals: heavy metals include, for example, Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb), Zinc (Zn) and Copper (Cu).

	The level of effect against which sensitivity is rated.	
Changes in levels of heavy metals		
Example	**EAL/EQS (for seawater unless otherwise stated)**	**Benchmark** Exposed to the following contaminant concentration
Copper	5 µg/l annual average	1) Long term: 10 µg/l annual average for 1 year period. 2) Short term: 50 µg/l for 48hrs
Mercury	0.3 µg/l annual average 0.13 mg/kg for sediments	1). Long term: 0.6µg/l annual average for 1 year, or 0.26 mg/kg in sediments for 1 year 2) Short term: 3 µg/l for 48hrs

Changes in levels of hydrocarbons: hydrocarbons include, for example, oils (crude and fuel oils) and poly aromatic hydrocarbons (PAHs).

	The level of effect against which sensitivity is rated.

Changes in levels of hydrocarbons		
Example	**EAL/EQS (for seawater unless otherwise stated)**	**Benchmark** Exposed to the following contaminant concentration
Benzo(a)pyrene	88.8 µg/kg sediment (Cole *et al* 1999)	Exposed to 176 µg/kg in sediment for 1 year. This is consistent with levels detected by the National Marine Monitoring Program (cited in Cole *et al.* 1999).

Changes in levels of radionuclides: isotopes of elements that emit alpha, beta or gamma radiation. Radionuclides in the environment result from nuclear weapons tests, nuclear fuel processing, nuclear power generation and natural sources. The little information known on the biological effects of radionuclides was reviewed by Cole *et al.* 1999. Dose rates of 10 milli-grays per hour (mGy/hr) are considered acceptable for the protection of aquatic populations. Lethal levels in invertebrates range between 0.2 and 500 grays (Gy). The 'gray' is a measure of the absorbed dose of ionizing radiation and of specific energy imparted by radiation (1 Gy = 1 J/kg). However, environmental concentrations of radionuclides are measured in becquerels per litre (Bq/l). Dosage is dependent of the type and energy of the radiation emitted, its transmission through the environmental medium as well as characteristics of the target organism. MAFF (1998) report values of caesium-137 in filtered seawater typically 50-500 mBq/kg in the north eastern Irish Sea and 2-20 mBq/kg in the North Sea. Concentrations of tritium (^{3}H) in the Bristol Channel ranged between 0-12 Bq/kg (MAFF 1998). In the absence of clear guidelines, the benchmark chosen was derived from the average concentration of caesium-137 in Scottish waters and the Irish Sea (MAFF 1998).

	The level of effect against which sensitivity is rated.	
Changes in levels of radionuclides		
Example	**EAL/EQS (for seawater unless otherwise stated)**	**Benchmark** Exposed to the following contaminant concentration
All radionuclides	None	Exposure to concentration of radionuclide equivalent to 100 mBg/l. of caesium-137 (^{137}Cs) for 1 year.

Changes in levels of nutrient: nutrients include substances required for growth, for example, nitrogen, phosphorus, silicon, and micro-nutrients (heavy metals and vitamins). Nutrient availability often limits growth or primary production in the marine environment. Ecosystems may be affected by changes in nutrient availability. Mean nutrient concentrations in English and Welsh coastal waters range from 0.07-1.85 mg/l total inorganic nitrogen (TIN), whereas estuarine concentrations vary between 0.1 to 15 mg/l total inorganic nitrogen (TIN). However, there is considerable variation in response to storms, floods, and seasons. Estuary concentrations peak in autumn/ winter and coastal concentrations in winter. However, man made input from, for example, livestock, fertilisers, and sewage treatment works, may exceed the assimilative capacity of the environment and result in eutrophication. The chosen benchmark represents a marked change in nitrogen concentration, comparable with the difference between the general quality assessment categories for estuaries (Cole *et al*. 1999). The benchmark for phosphorus assumes a total inorganic nitrogen to total reactive phosphorus ration of 10:1.

	The level of effect against which sensitivity is rated.
Changes in levels of nutrient	A change of total nitrogen of 3 mg/l and/or phosphorus of 0.3 mg/l as an annual average. Alternatively, a 50% increase of nutrients as an annual average.

Changes in salinity: Salinity is a measure of the amount of dissolved salts in the water. The salinity scale used by the Marine Nature Conservation Review (Hiscock, 1996) was developed to reflect the occurrence of significantly different species from one category to another. Therefore, a change of one category was chosen as an appropriate benchmark for sensitivity assessment.

	The level of effect against which sensitivity is rated.
Changes in salinity	1) A change of one category from the MNCR salinity scale (see glossary) e.g. from reduced to low for 1 year. 2) A change of two categories from the MNCR salinity scale, e.g. from full to reduced for 1 week.

Changes in oxygenation: Oxygenation is a measure of the amount of dissolved oxygen in water. Oxygen is required by the majority of organisms for respiration; the process by which organic molecules are broken down to provide energy for work and metabolism. Natural events such as plankton blooms may deplete the oxygen levels locally. For example, a planktonic bloom, in the presence of a thermocline (which prevented mixing on the water column), in the North Atlantic Bight resulted in reduction of dissolved oxygen below 2mg/l for several months and the subsequent deaths of fish and benthos. De-oxygenation may also result from the addition of organic material to the water column and subsequent bacterial activity that consumes available dissolved oxygen. The chosen benchmark was based on the general quality assessment levels for estuaries (8 mg/l, 4mg/l and 2mg/l) reported by Cole *et al*. (1999). Gray and Jensen (1993) reported <4 mg/l as the concentration chosen by as likely to affect marine life and therefore to trigger cessation of dredging operations. Anaerobic species would get a 'Not sensitive*' ranking if oxygen levels fall.

	The level of effect against which sensitivity is rated.
Changes in oxygenation	Exposure to dissolved oxygen concentration of 2 mg/l for 1 week.

Biological factors

Introduction of microbial pathogens and parasites: By definition, disease causes a reduction in fitness of the organism so all species automatically score as sensitive to disease.

	The level of effect against which sensitivity is rated.
Introduction of microbial pathogens and parasites	Sensitivity can only be assessed relative to a known, named disease. Likely to cause partial loss of a population and will be assessed of intermediate sensitivity.

Introduction of alien or non-native species: 'sensitivity' is assessed against a specific non-native species that already occurs in Britain and/or Ireland that is most likely to have an adverse effect and indicate the species being considered in the 'notes' section.

	The level of effect against which sensitivity is rated.
Introduction of alien or non-native species	Sensitivity assessed against the likely effect of the introduction of alien or non-native species in Britain or Ireland.

Specific targeted extraction of this species: a species is bound to be sensitive to its removal and will automatically be assessed as 'intermediate'. Potential for recovery after a very efficient extraction has been undertaken can also be assessed using this definition.

	The level of effect against which sensitivity is rated.
Specific targeted extraction of this species	Extraction removes 50% of the species from the area under consideration. The habitat remains intact or recovers rapidly.

Specific targeted extraction of other species: the species will be regarded as sensitive if the targeted species is a host for the species being considered, an obligate food source, or if it creates the habitat required by the species or community under consideration. ('Displacement' is considered under a separate category).

	The level of effect against which sensitivity is rated.
Specific targeted extraction of other species	A species that is a required host or prey for the species under consideration (and assuming that no alternative host exists) or a keystone species in a biotope is removed.

10. Appendix 4: Decision flow charts for the assessment of species sensitivity.

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