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Marine Evidence-based Sensitivity Assessment (MarESA) - Guidance Manual

DATE: February 2023

AUTHOR:
H. Tyler-Walters, H.M. Tillin, E. A.S. d'Avack, Perry, F., Stamp, T.
Marine Life Information Network (MarLIN)

Marine Biological Association

Recommended citation:

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F., Stamp, T., 2023. Marine Evidence-based Sensitivity Assessment (MarESA) – Guidance Manual. *Marine Life Information Network (MarLIN)*. Marine Biological Association of the UK, Plymouth, pp. 170. Available from https://www.marlin.ac.uk/publications

Title of Document: Marine Evidence –based Sensitivity Assessment (MarESA) – Guidance

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Document control

	Originated	Checked	Reviewed	Authorised	Date
Creation	HTW	HMT	EL/LR/JNCC		
Edits	HTW				12/02/2018
Edits	HTW		EL/LR/JNCC		5/3/2018
Published	HTW			HTW	6/3/2018
Amended	HTW			HTW	05/04/2018
Amended	HTW			HTW	05/12/2018
Amended	HTW			HTW	19/03/2019
Amended	HTW			HTW	2020-03-06
Amended	HTW			HTW	2020-05-15
Amended	HTW			HTW	2021-01-08
Amended	HTW			HTW	2021-10-01
Updated	HTW			HTW	2023-02-16
Updated	HTW			HTW	2025-07-30
Notes					

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MARINE EVIDENCE–BASED SENSITIVITY ASSESSMENT (MARESA) – A GUIDE

Executive summary

The Marine Evidence-based Sensitivity Assessment (MarESA) methodology was developed by the Marine Life Information Network (MarLIN) team at the Marine Biological Association of the UK. The following guide details the approach, its assumptions, and its application to sensitivity assessment.

The guide discusses:

- key terms used in sensitivity assessment;
- the definitions and terms used in the MarESA approach;
- its assumptions;
- the definition of resistance, resilience, and sensitivity;
- the definition of pressures and their benchmarks;
- the step-by-step process by which the possible sensitivity of each feature (habitat, biotope, or species) to each pressure is assessed;
- the interpretation and application of evidence to sensitivity assessments on a pressure-by-pressure basis; and
- limitations in the application of sensitivity assessments in management.

The MarESA methodology provides a systematic process to compile and assess the best available scientific evidence to determine each sensitivity assessment. The evidence used is documented throughout the process to provide an audit trail to explain each sensitivity assessment. Unlike other expert-based approaches, this means that the MarESA assessments can be repeated and updated.

The resultant 'evidence-base' is the ultimate source of information for the application of the sensitivity assessments to management and planning decisions. The MarESA dataset and MarLIN website represent the largest review of the potential effects of human activities and natural events on the marine and coastal habitats of the North East Atlantic yet undertaken.

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Contents

List of Tables

List of Figures

List of Appendices

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MARINE EVIDENCE–BASED SENSITIVITY ASSESSMENT (MARESA) – A GUIDE

1 Introduction

The 'concept' of the sensitivity of receptors (such as birds, fish, mammals, and habitats) and, hence, sensitivity assessment, has developed over many decades. Numerous approaches have been developed, applied at a range of spatial scales, and to a variety of management questions (see Roberts *et al.*, 2010). The different approaches fall into three main classes: 1) empirical techniques aimed at specific pressures or activities (e.g. fishing, aggregate dredging), 2) biological traits-based approaches, and 3) evidence–based and/or expert judgement-based approaches that enable broad coverage of both pressures and habitats or species (Roberts *et al.,* 2010). The Marine Evidence-based Sensitivity Assessment (MarESA) is an evidence-based expert judgement approach.

The sensitivity assessment of UK marine habitats developed from the initial concepts of Holling (1973) and oil spill sensitivity mapping (Gundlach & Hayes, 1978), through seminal work by Holt *et al.* (1995, 1997), MacDonald *et al.* (1996) and Hiscock *et al.* (1999, 1999). Sensitivity assessment was developed further by MarLIN (The Marine Life Information Network) in liaison with the UK Statutory Nature Conservation Bodies (SNCBs[1]) and Government departments and agencies[2], and was applied to numerous marine species and habitats (as biotopes), in particular features of marine Special Areas of Conservation , between 1999 and 2010 (Hiscock *et al.*, 1999, Tyler-Walters *et al.*, 2001, Tyler-Walters & Hiscock, 2003, Tyler-Walters, 2004, Tyler-Walters & Hiscock, 2005, Hiscock & Tyler-Walters, 2006).

The UK approach to sensitivity assessments was revised by the UK SNCBs and Defra in response to the need to identify and assess Marine Protected Areas (under the MB0102 project) (Tillin *et al.*, 2010). Tillin & Hull (Tillin & Hull, 2012-2013) expanded the MB0102

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[1] The Joint Nature Conservation Committee (JNCC), English Nature (EN), Scottish Natural Heritage (SNH), and Countryside Council for Wales (CCW)

[2] Dept Environment, Transport and the Regions (DETR), and Dept. For Environment, Food and Rural Affairs (Defra) and Centre for Environment, Fisheries and Aquaculture Science (CEFAS)

approach and incorporated an auditable evidence base, similar to the MarLIN approach. Recent work to examine the sensitivity of ecological groups and specified designated habitats (d'Avack *et al.*, 2014, Gibb *et al.*, 2014, Mainwaring *et al.*, 2014, Tillin & Tyler-Walters, 2014b, a) incorporated the defined list of pressures resulting from human activities that was produced by the OSPAR[3] Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR, 2011).

Minor revision of the pressures and their benchmarks by the SNCBs[4], Defra, Marine Scotland, and MarLIN resulted in the current approach to sensitivity assessments; the Marine Evidence-based Sensitivity Assessment (MarESA) approach.

The MarESA methodology provides a systematic process to compile and assess the best available scientific evidence to determine each sensitivity assessment. The evidence used is documented throughout the process to provide an audit trail to explain each sensitivity assessment. Unlike other expert-based approaches, this means that the MarESA assessments can be repeated and updated.

The guidance that follows outlines the MarESA approach to sensitivity assessment. The MarESA approach has been applied to both benthic species and habitats (biotopes). Therefore, the guidance focuses on benthic species and habitats (biotopes), except where stated. The MarESA approach has now been applied to most of the biotopes[5] in the Marine Habitat Classification for Britain and Ireland (Connor *et al.*, 2004; JNCC, 2022) for littoral and sublittoral habitats and a selection of deep-sea biotopes (Parry *et al.*, 2015, JNCC, 2022) (Tyler-Walters & Hiscock *et al.,* 2023).

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3 OSPAR (Oslo and Paris Commission)

4 The Joint Nature Conservation Committee (JNCC), Natural England (NE), Scottish Natural Heritage (SNH), and Natural Resources Wales (NRW)

5 Note that, to date, the MarESA approach has been applied to biotopes, however, in theory the approach could also be applied to habitats defined under different classification systems.

2 Common terms and definitions

Holt *et al.* (1995) defined **sensitivity** as 'the innate capacity of an organism to suffer damage or death from an external factor beyond the range of environmental parameters normally experienced'. This definition was widely accepted (McLeod, 1996, Tyler-Walters *et al.,* 2001; Zacharias & Gregr, 2005), and was extended beyond the focus on single organisms to include 'the habitat, community, or species' (McLeod, 1996).

Sensitivity assessments encompass a measure of the effect of a pressure (sometimes referred to as disturbance, perturbations, or stress) on a receptor. The UK Review of Marine Nature Conservation (Defra, 2004) defined sensitivity as 'dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery.' Intolerance was defined as the 'susceptibility of a habitat, community, or species to damage, or death, from an external factor', and recoverability as the 'ability of a habitat, community, or species to return to a state close to that which existed before the activity or event caused change' (Hiscock *et al.*, 1999; Hiscock & Tyler-Walters, 2006).

Most sensitivity assessment approaches define **'sensitivity'** as a product of:

- the likelihood of damage (termed resistance, tolerance, or intolerance) due to a pressure; and
- the rate of (or time taken for) recovery (termed resilience, or recoverability) once the pressure has abated or been removed.

In other words, "a species (population) is defined as **very sensitive** when it is easily adversely affected by human activity (e.g. low resistance) and recovery is only achieved after a prolonged period, if at all (e.g. low resilience or recoverability)" (OSPAR, 2003; Laffoley *et al.,* 2000).

The concepts of **resistance** and **resilience** (or equivalent terms) have been widely used to assess sensitivity. The OSPAR commission, for example, used these concepts to evaluate sensitivity as part of the criteria used to identify 'threatened and/or declining' species and habitats within the OSPAR region; the Texel-Faial criteria (OSPAR, 2003). Similarly, the sensitivity methodology used within MarLIN (Hiscock & Tyler-Walters, 2006); project MB0102 (Tillin *et al.,* 2010), and subsequently adopted for MarESA, uses a combined measure of resistance (or intolerance) and resilience (or recoverability).

Activities in the marine environment result in a number of **pressures**, which may result in an **impact** on environmental components that are sensitive to the pressure. Pressures have been defined as ‘the mechanism through which an activity has an effect on any part of the ecosystem’ (Robinson *et al.,* 2008). Pressures can be physical, chemical, or biological. The same pressure can be caused by a number of different activities. For example, fishing using bottom gears and aggregate dredging both cause abrasion; a physical damage pressure (Robinson *et al.*, 2008). Impacts are defined as the consequences of these pressures on components of an ecosystem where a change occurs that is different to that expected under natural conditions. Different pressures can result in the same impact, for example, habitat loss and habitat structure changes can both result in the mortality of benthic invertebrates (Robinson *et al.,* 2008).

Vulnerability is a measure of the likelihood of exposure of a feature to a pressure to which it is sensitive. For example, a species may be sensitive to a given pressure, but it is only **‘vulnerable’** if it is exposed to that pressure. It is usually expressed as a combination of the likelihood or degree of exposure and the likely sensitivity to the pressure of interest (Hiscock *et al.,* 1999; Oakwood Environmental Ltd., 2002). Vulnerability has close similarities with the concept of **risk,** that is a combination of hazard (a probability of exposure) and consequence (a likely effect or sensitivity).

‘Feature’ is a generic term. Features can be single species, groups of species, single biotopes, or ‘habitats’ composed of (or defined by) a number of biotopes and/or component species, for example Scottish Priority Marine Features (PMFs).

Terms and definitions used in the MarESA assessment and application of sensitivity assessments are listed in Table 1.

Table 1. Common terms and definitions

Term	Definition	Sources
Sensitivity	The likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience)	Tillin *et al.* (2010), Tillin & Hull (2012-13), Tillin & Tyler-Walters (2014)
Resistance	Resistance characteristics indicate whether a receptor can absorb disturbance or stress without changing character	Holling (1973)
Resilience	The ability of a receptor to recover from disturbance or stress	Holling (1973)
Pressure	The mechanism through which an activity has an effect on any part of the ecosystem. The nature of the pressure is determined by activity type, intensity, and distribution	Robinson *et al.* (2008)
Pressure benchmark	A standard descriptor of the pressure defined in terms of the magnitude, extent, duration, and frequency of the effect. Benchmarks may be quantitative or qualitative	Tyler-Walters *et al.* (2001)
Exposure	The action of a pressure on a receptor, with regard to the extent, magnitude, and duration of the pressure	Robinson *et al.* (2008)
Vulnerability	Vulnerability is a measure of the degree of exposure of a receptor to a pressure to which it is sensitive	Hiscock *et al.* (1999); Oakwood Environmental Ltd (2002)

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3 Application

Resistance, resilience and, hence, sensitivity are inherent characteristics determined by the biology/ecology of the feature (species or habitat) in question. In addition, they are 'relative' concepts that depend on the degree of the effect on the feature (expressed as magnitude, extent, frequency, or duration).

Therefore, sensitivity assessment approaches use a variety of standardized thresholds, categories, and ranks to ensure that the assessments of ‘relative’ sensitivity can be applied usefully and that they compare ‘like with like.’ These are:

- standard categories of human activities and natural events, and their resultant ‘pressures’ on the environment;
- descriptors of the nature of the pressure (i.e. type of pressure, e.g. temperature change, physical disturbance, or oxygen depletion);
- standard descriptors of the pressure (e.g. magnitude, extent, duration, and frequency of the effect), termed the pressure benchmark;
- categories or ranks of resultant change / damage, the ‘resistance’ (e.g. proportion of species population lost, area of habitat lost/damaged);
- categories or ranks of recovery, the ‘resilience’ thought to be significant; and
- resultant ranks of sensitivity and/or vulnerability.

Note. The term ‘resilience’ is used to describe the ability of a feature (species/habitat) to return to a state that existed prior to damage, while the terms ‘recovery’ and or ‘recovery rate’ are used to denote the process.

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4 MarESA sensitivity assessment process

MarESA sensitivity assessment involves a systematic process to examine the biology or ecology of a **feature**[6], compile the evidence of the effect of a given pressure on the feature (species or habitat) in question, assess the likely sensitivity of the feature to the pressure against standard scales, and to document the evidence used and justify assessments made.

MarESA sensitivity assessment involves the following steps (Figure 1).

Step 1. Literature/evidence review
Step 2. Define the key elements of the feature (in terms of life history, and ecology of the key and characterizing species);
Step 3. Assess the feature's resistance to a defined intensity of pressure (the pressure benchmark);
Step 4. Assess the feature's resilience based on its ecology;
Step 5. Combine resistance and resilience to derive an overall sensitivity score;
Step 6. Assess the confidence in the sensitivity assessments;
Step 7. Document the evidence used and any considerations around application; and
Step 8. Undertake quality assurance and peer review.

Some of the steps may overlap but for clarity, they are discussed separately.

4.1 Step 1. Literature review strategy

The evidence review uses a simplified Rapid Evidence Assessment (REA) approach. A systematic approach is used based on a defined list of key words and search terms shown in Appendix 1. The search records form a useful audit trail allowing the review to be updated in the future, or repeated, and increase the transparency of the review process.

The ‘literature review’ and the ‘definition of key elements of the feature’ are undertaken simultaneously. Therefore, prior expertise on the feature and a preliminary literature review of the species/habitat is undertaken.

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[6] ‘Feature’ is a generic term. Features can be single species, groups of species, single biotopes, or ‘habitats’ composed of (or defined by) a number of biotopes and/or component species, for example Scottish Priority Marine Features (PMFs).

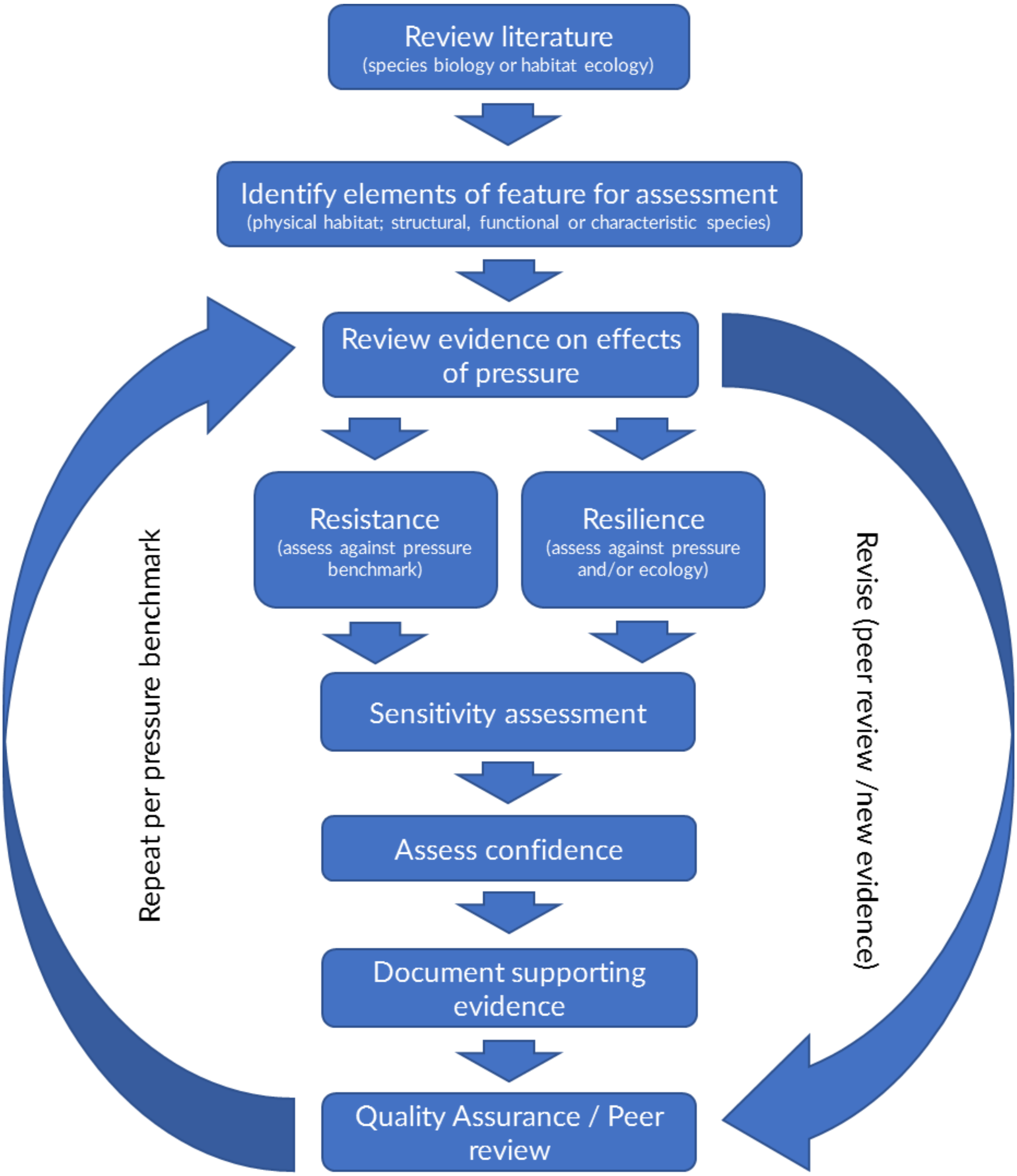

Figure 1. Overview of the sensitivity assessment process

4.1.1 Preliminary review

A short preliminary review of the literature is undertaken to focus the full literature review and to contribute to the 'definition of the key elements of the feature.'

Therefore, in the context of MarESA the terms are used as follows. The term **'feature'** is used to denote habitats, biotopes, or species. The term **'habitat'** is used to denote a single biotope or a number of biotopes that share similar characteristics of substratum, location, and assemblage. In this report, it is used as a generic term for biotopes or groups of similar biotopes. For example, 'horse mussel beds' or 'kelp beds' refer to a habitat even though they a composed of a number of separate biotopes. The term **'biotope'** refers to a community and its associated habitat as defined by the Marine Habitat Classification for Britain and Ireland (Connor *et al.*, 2004; JNCC, 2022). The term **'species** used in its strict sense.

The preliminary review includes:

- consultation with experts – to identify key evidence or literature sources;
- reference to existing sensitivity reviews on similar habitats (by MarLIN and others);
- the MarLIN in-house reference library (in Endnote) and, in the case of habitats (biotopes);
- the Marine Habitat Classification for Britain and Ireland (Connor et al., 2004; JNCC, 2022), including the characterizing species list and comparative tables.

The physical habitat, the characteristic species, and their relative contribution to similarity and/or ecological structure and function are considered in the 'definition of the key elements of the feature' for habitats or biotopes. Where the habitat is defined as one or more biotopes then it is essential to understand the physical or community characteristics of the habitat (biotope) that structure and, hence, define the biotope. Particular attention should be paid to the factors that distinguish between similar biotopes (e.g. species composition, salinity, physical disturbance, turbidity, scour, or grazing pressure).

4.1.2 Full literature review

Once defined, the 'key elements of the feature' (that is, 'species that contribute to sensitivity', and / or physical characteristics that determine the habitats), provide the focus of the literature review.

The following resources are used by MarLIN to search for relevant literature.

- The National Marine Biological Library catalogue (http://www.mba.ac.uk/nmbl) - the NMBL is the specialist library for marine biology and includes recent academic journal but also grey literature and expedition reports dating back to the 1880s;
- Web of Science / Web of Knowledge – indexes articles from highly respected journals (1900 to the present) - recommended as a resource for interdisciplinary topics but it is a science citation index and not as extensive as an abstracting journal;
- Science Direct (www.sciencedirect.com) - Elsevier's journal portal provides subscription based full-text scientific and medical research journal articles and e-

books back to 1995, and indexes pre-1995 articles back to the first issue of each journal; and

- Google Scholar (and general Google) searches (https://scholar.google.co.uk/) – Google Scholar catalogues papers and reports held online in a variety of formats on specialist library portals and institutional or personal websites.

Particular species groups may also have specialist databases dedicated to their taxonomy. Most such databases focus on taxonomy but may also include information relevant to their biology, habitat preferences, or life-history (e.g., AlgalBase (www.algalbase.org), FishBase (www. fishbase.org), Hexacorallians of the World (http://hercules.kgs.ku.edu/hexacoral/anemone2/index.cfm).

4.1.3 Guidance notes

The sensitivity reviews and assessments aim to 'support marine environmental management, protection and education'. Therefore, they target the information required to achieve that aim.

- The literature review should target evidence that allows the authors to:
  - assess the key elements of the habitat– i.e. biological interactions in the habitat or similar habitats, factors that affect habitat structure, functional groups, productivity etc.;
  - assess autecology (if a species) e.g. habitat requirements, growth rates, distribution, feeding type etc.;
  - assess the resilience – e.g. life history of key or important species, population dynamics, direct evidence of response to change and/or recover from disturbance;
  - assess the direct evidence of damage from human activities, natural events, and/or their pressures; and
  - assess the indirect evidence of the potential effects of pressures, e.g. from similar species, taxonomic or functional groups, or via proxies for habitat preferences (see below).
- As above, biotope literature reviews should focus on general material on the relevant dominant functional groups (e.g. fucoids, sponges, burrowing infauna, etc.) and intertidal or subtidal ecology, as well as the species that contribute to sensitivity.
- The literature review is time limited (to ca 1-2 days depending on the habitat/species) and, therefore, must be kept focused.

- An exception is made for well-studied species (e.g. Mytilus edulis) or habitats (cold-water coral reefs) where timed review would not adequately cover the subject and could, therefore, invalidate the assessments.
- The literature review process should be organized so that similar habitats, or habitats that share characterizing species, are addressed one after the other so that the general information on the habitats, or the characteristic species, and other evidence can contribute to more than one review.
- An initial screening, based on abstracts or summaries, where available, should be used to reject evidence that is clearly not relevant.
- Review articles are extremely useful and can circumvent the need to review the literature too far into the past.
- Old reviews or papers should be used if needed, as many species are poorly studied, and descriptions and information from the early 1900s may be still valid and may not have been superseded.
- Search terms should include the relevant species names, common names, and recent (post 1950) synonyms e.g. search for *Z. noltei* (accepted) as well as *Z. noltii* (unaccepted).

All literature collated should be managed through relevant reference management software. Citations (and ideally abstracts) should be downloaded from journal providers, or the abstracting journals directly and then checked for consistency (as not all journal export routines work exactly the same way) against the in-house citations style (see writing style guidelines, Appendix 2).

4.2 Step 2. Defining the key elements of the feature

To assess sensitivity, ‘key elements of the feature’ are selected as the basis of the assessment.

4.2.1 Species

Where the feature under assessment is a single species, that species is assessed. Holt *et al*. (1995) noted that organisms near the limits of their range are more sensitive to change. Therefore, a **theoretical population of the species in the middle of its environmental range** is used as the basis of the assessment.

For example. The shore crab *Carcinus maenas* occurs in a range of habitats from fully marine to brackish. At some point, salinity levels will limit its penetration into estuaries, but it should not be classed as a species that is sensitive to salinity. However, a southern species that reaches its northerly range limit in British waters will be sensitive to small decreases in temperature, although in their more typical southerly habitats, such species would not be considered sensitive to temperature. Hence, the assessment of sensitivity to temperature change in British waters should consider the species as sensitive.

4.2.2 Habitats

The sensitivity of a biological assemblage e.g. the full complement of organisms at a location is a function of the sensitivities of the constituent species populations. Therefore, habitat (biotope) sensitivity assessment assumes that the sensitivity of a habitat (biotope) is dependent on the sensitivity of the species that make up the community, together with the hydrographic, physical, or chemical (e.g. hypoxia) nature of the habitat.

4.2.2.1 Species that contribute to sensitivity

Seabed habitats can be highly diverse, and the species present may vary even between the same type of habitat (or biotope). It is not possible to assess the sensitivity of every species that makes up a biotope in a sensible time frame, as that number can range from a few to several hundred species. Therefore, sensitivity assessment focuses on those species that contribute most to the sensitivity of the habitat (biotope).

Sensitivity assessment assumes that key structural, key functional and important characterizing species, contribute most to sensitivity (as defined in Table 2).

The loss or degradation of key and characterizing species is considered to represent a severe impact to the condition of the habitat (biotope) as these species are important to define the character of the habitat (or define the biotope) and their loss would result in disproportionate changes such as a loss of the habitat or a redefinition of the habitat as another biotope (effectively loss of the biotope).

Species that are considered to contribute to the sensitivity of the biotope are identified based on *a priori* expertise, an understanding of the biotope and, if needed, a preliminary literature review (see section 4.2.1). However, the species considered to contribute to sensitivity may change because of the full literature review.

Table 2. Types of species identified for habitat (biotope) assessment.

Category	Description
Key structural species	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 species	Species that maintain community structure and function through interactions with other members of that community (for example, through predation, or grazing). Loss/degradation of this species population would result in rapid, cascading changes in the community
Important characteristic species	Species characteristic of the biotope (dominant and frequent) and important for the classification of the habitat. Loss/degradation of these species populations may result in changes in habitat classification

For example. Biogenic habitats are created by aggregations of the biogenic species, which represent the key structural and important characterizing species for that habitat (biotope). The loss of horse mussels (*Modiolus modiolus*) from biotopes characterized as 'horse mussel beds' would result in loss of the associated community that depends on this structural species. Furthermore, the loss of the *Modiolus modiolus* characterizing species would mean the resultant habitat would be reclassified as another biotope (i.e. loss of the biotope).

For example. Loss of important characteristic species results in loss of the biotope as defined by Connor *et al.*, 2004; JNCC, 2022). If *Cerastoderma edule* was removed from a cockle bed, then the majority of the underlying infauna would remain, but the resultant biotope would no longer be that of *C. edule* and would be described as a different muddy sand biotope instead.

Therefore, the species identified as important for the structure and functioning of the community or characteristic of the habitat are used to focus the assessment. However, wherever possible, all component species of the habitat are considered in the sensitivity assessment.

In other cases, a single species may not be the most suitable 'important characterizing' species, or there may be several 'important characterizing species' groups. For example, suspension feeders or passive predators (e.g. hydroids, bryozoans, anthozoans, and ascidians) dominate faunal turfs. In this instance, the sensitivity assessment may focus on:

- species named within the biotope descriptions as an example of the taxonomic group; or
- the characteristics of the taxonomic group (e.g. hydroids, bryozoans); or
- a mixture of the two approaches depending on the evidence available.

For example, the 'bryozoan turf and erect sponges' (ByErSp) biotope sensitivity assessment is based on the characteristics of each taxonomic group (bryozoans, sponges) and specific examples of species present (e.g. *Bugula*[7] spp.) are discussed where the evidence allows.

Note. Authors should resist the temptation to include as many species as possible. Sensitivity reviews are focused documents (see literature review and writing style) and there is neither the time nor the necessity to cover every species that occurs within a habitat (biotope). Other species associated with the biotope are commonly found on many different shore types and are either mobile or rapid colonizers. Although these species contribute to the structure and function of the biotope, they are not considered 'key' or 'important' species and are not assessed specifically.

4.2.2.2 Physical, chemical, and hydrographic habitat factors

For habitats that are defined by key habitat variables such as substratum, e.g. peat and clay exposures, intertidal under boulder communities, and littoral chalk communities, the nature of the physical habitat is more relevant to a sensitivity assessment. For example, loss of peat/clay is irreversible, and the feature cannot recover from pressures that remove the substratum. In other cases, the level of wave exposure or shelter is a key structuring factor and is mentioned as a characteristic of the biotope.

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7 Note the recent molecular taxonomy of the genus Bugula identified several clear genera (clades), *Bugula* sensu stricto (30 species), *Bugulina* (24 species), *Crisularia* (23 species) and the monotypic *Virididentulagen*.

4.2.3 Sensitivity characteristics of the habitat and relevant characteristic species

The 'key elements of the feature' selected as the basis of the assessment and the reason for their selection are documented in the 'sensitivity characteristics' section of the review. The characterizing species and any physical and chemical characteristics that structure the biological community are discussed. For benthic habitats, the sediment, or substratum are important drivers structuring the assemblage? The biotope is, therefore, sensitive to pressures that alter these, and this must be stated. Those species or groups of species that are not considered in the sensitivity assessment (for example, those species that are commonly found on many different shore types and are either mobile or rapid colonizers) are also identified in the text.

4.3 Step 3. Resistance assessment

The resistance of the feature is assessed against a standard list of pressures, pressure descriptions, and 'benchmark' levels of each pressure. Resistance is assessed for each pressure (see section 4.6) in turn using the available evidence collated in the literature review. The assessment scale used for resistance is given in Table 3.

The definitions of resistance incorporate both a 'quantitative' and a 'qualitative' term. For instance, 'Low' resistance is defined as either 'significant damage' or a 'significant decline of 25-75% of the extent, density, or abundance' of the selected species or habitat component'. This approach allows us to compare the scale against a variety of evidence from quantified experimental and comparative studies to observational studies and to inferences based on expert judgement. The relative quality of the evidence is assessed under 'confidence' below.

Resistance assessment is based on the evidence collated in the literature review on the effects of each pressure (or activity that results in each pressure) on the key elements of the feature (physical habitat and species that contribute to sensitivity). Resistance assessment considers the following for each pressure in turn:

- reported evidence on the direct effect of a given pressure on the key elements of the feature, compared to the benchmark level of pressure;
- the resultant levels of damage on the key elements, e.g. extent of damage to habitat, loss of population size or abundance, changes in diversity, loss, or reduction in abundance of one of more species groups;

- reported evidence on the direct effect of a given pressure on similar habitats, species, or functional groups, and/or
- in the absence of direct evidence, ‘proxies’ are used to inform the assessment of the likely effect of a pressure on the key elements of the feature.

Table 3. Assessment scale for resistance to a defined intensity of pressure

Resistance	Description
None	Key functional, structural, characterizing species severely decline and/or the physico-chemical parameters are also affected e.g. removal of habitats causing change in habitats type. A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat component e.g. loss of 75% substratum (where this can be sensibly applied)
Low	Significant mortality of key and characterizing species with some effects on physico-chemical character of habitat. A significant decline/reduction relates to the loss of 25-75% of the extent, density, or abundance of the selected species or habitat component e.g. loss of 25-75% of the substratum
Medium	Some mortality of species (can be significant where these are not keystone structural/functional and characterizing species) without change to habitats relates to the loss <25% of the species or habitat component
High	No significant effects to the physico-chemical character of habitat and no effect on population viability of key/characterizing species but may affect feeding, respiration, and reproduction rates

Wherever possible, direct evidence of the effect of a given pressure on the ‘key elements of the feature’ (habitat and/or the species) is used as the basis of the assessment of resistance. Where the evidence quantifies the magnitude, extent, or frequency of the pressure then the evidence can be compared directly with the benchmark. Similarly, if the pressure is qualified in the evidence, then it can be compared with the relevant benchmark. The quality of the evidence and its applicability to each pressure assessment is described under ‘confidence assessment’ below (section 4.9).

In some cases, where evidence is lacking, it is possible to use 'proxies' against which a resistance assessment can be made. For example, the geographic distribution of a species may be used as a 'proxy' for the effect of temperature change. We assume that a species whose natural range extends from the Arctic Circle to the Mediterranean is probably not affected by local, chronic changes in temperature in UK waters, while a species that is reported to be at its most northern or southern extent in the UK is likely to be affected. Any evidence of localised adaption is also considered.

4.4 Step 4. Resilience assessment

Resilience assessment assumes that the pressure is removed or stopped, and that the habitat (biotope) or species experiences the conditions that existed prior to impact. The assessment scale for resilience is shown in Table 4. However, the 'physical loss' pressures ('physical loss of habitat', 'physical change in seabed type' and 'physical change in sediment type') are defined as permanent change so that no recovery from an impact is possible, and resilience is scored as '**Very low**'. In addition, the climate change pressures (except marine heatwaves) represent ongoing (long-term) pressures where recovery is not possible as the pressure is irreversible, in which case resilience is assessed as **'Very low'** by default.

'Full recovery' is envisaged as a return to the state of the habitat or species population that existed prior to impact. However, in the case of habitats, this does not necessarily mean that every component species has returned to its prior condition, abundance, or extent but that the relevant functional components are present, and the habitat is structurally and functionally recognizable as the initial habitat of interest.

Table 4. Assessment scale for resilience (recovery)

Resilience	Description
Very low	Negligible or prolonged recovery possible; at least 25 years to recover structure and function
Low	Full recovery within 10-25 years
Medium	Full recovery within 2-10 years
High	Full recovery within 2 years

Particular attention should be paid to:

- factors affecting reproductive success and larval mortality;
- information on population dynamics, dispersal, and recruitment (by adults and different life-stages);
- information on community succession (where available);
- habitat-specific factors that influence recovery, for example, where pressures affect sediments or substratum, habitat recovery is required before the biological assemblage can recover; and
- any pressure or pressure benchmark specifications that may affect recovery, for example, colonization of habitats by invasive non-indigenous species may prevent recovery unless these are removed.

Resilience is assessed (and documented) independently of resistance and is applicable to all pressure assessments as it refers to recovery potential and recovery rates. However, the time taken for the species population or community to recover (resilience) is dependent on the scale of the change to the population or community (resistance). Therefore, a separate resilience assessment is made based on the possible range of resistances. For example, an assessment should be made for resilience after severe damage (resistance is 'None'), significant damage (resistance is 'Low'), some damage (resistance is 'Medium') and insignificant damage (resistance is 'High'). If resistance is assessed as 'High', then the resilience is assessed as 'High' by default as a resistance of 'High' suggests that there is no impact to from which to recover. Any assumptions are documented in the explanatory text.

4.5 Step 5. Overall sensitivity assessment

The resistance and resilience scores are combined to give an overall sensitivity score as shown in Table 5.

Not sensitive - is recorded where the habitat or species has a 'High' resistance (and hence is likely to recover quickly i.e. a 'High' resilience) at the benchmark level of pressure. In the text, this is denoted by the phrase 'Not sensitive at the benchmark level'. It should be noted that the species or habitat might be sensitive at pressure levels higher than the benchmark (i.e. where the pressure is of greater intensity, magnitude, or duration).

Table 5. The combination of resistance and resilience scores to categorise sensitivity

	Resistance			
Resilience	**None**	**Low**	**Medium**	**High**
Very low	High	High	Medium	Low
Low	High	High	Medium	Low
Medium	Medium	Medium	Medium	Low
High	Medium	Low	Low	Not sensitive

The following terms are used to explain if a sensitivity assessment is not possible.

No evidence (NEv) – is recorded where there is **no evidence** on which to base an assessment of the sensitivity of the specific feature/pressure combination, there is no suitable proxy information regarding the habitat (biotope) or species on which to base decisions, and expert judgement alone does not allow an assessment to be made with any confidence. For example, some species have a limited distribution (e.g. a few or only one location) so that even basic physical, chemical, or biological tolerances cannot be inferred.

Insufficient evidence (IEv) – is recorded where there is not enough evidence to assess the sensitivity of the specific feature/pressure combination, there is no suitable proxy information regarding the habitat (biotope) or species on which to base decisions, and expert judgement alone does not allow an assessment to be made with any confidence. An assessment of **'Insufficient evidence'** means that, while there may be evidence of the effect of the pressure on the specific or similar features, it is incomplete, inconsistent, or otherwise not adequate to make an assessment with any confidence.

In addition, **'Insufficient evidence'** is recorded when the evidence allows a species or habitat to be assessed as 'Not sensitive' to one or more sources (or pathways) of the pressure, the evidence does not allow an assessment of known additional sources (or pathways) of the pressure. Further evidence is required to make an inclusive assessment. For example, a habitat may be 'Not sensitive' to one or more known invasive species, but it would be misleading to conclude that it was 'not sensitive' to one or more other invasive species where the evidence is not conclusive. **Note,** that if the species or habitat is assessed as ‘sensitive’ to one or more pressure sources the ‘worst-case’ scenario is presented.

Not relevant (NR) – is recorded where the evidence suggests that there is no direct interaction between the pressure and the habitat (biotope) or species. ‘Not relevant’ is also used to denote interactions that are unlikely to occur at present or in future and to denote interactions that are literally ‘not relevant’, for example, deep mud habitats are not exposed to changes in emersion. In addition, ‘Not relevant’ is used to denote ‘default’ assessments that result from the definition of the pressure (see section 5.2.23 below).

Not assessed (NA) – is recorded where the available evidence is extremely limited, poorly understood, or completely absent, and no assessment is attempted. For example, the likely effects of the pressure ‘Marine litter’ (pre-2014) on marine species was poorly understood and little studied so it was not possible to set a sensible ‘benchmark’. ‘Not assessed’ was also recorded for the ‘pollutant’ pressures because it was felt that the 2014 pressure benchmark (compliance with all relevant environmental standards’ could be misleading. The ‘pollutant’ pressure assessments are currently under review (see Tyler-Walters *et al*., 2022).

4.6 Step 6. Confidence assessment

Project MB0102 (Tillin *et al.,* 2010) provided a single confidence score based on the robustness of the underlying evidence and it was developed for assessments based on expert judgement. The approach developed by Tillin & Hull (2012-2013) was adapted for subsequent use for the MarESA pressure-sensitivity assessments by the project team for JNCC (Tillin & Tyler-Walters, 2014, d’Avack *et al.* 2014).

The MarESA approach assesses confidence in the evidence using three categories (Table 6):

- the quality of the evidence or information used;
- the degree to which evidence is applicable to the assessment; and
- the degree of concordance (agreement) between evidence types.

The confidence assessments are based on the evidence used in the assessment of resistance and resilience. Therefore, the quality, applicability, and concordance of the evidence are scored independently for both resistance and resilience.

The confidence assessment categories for resistance and resilience are then combined to give an overall confidence score for each confidence category (i.e. quality of information sources, applicability of evidence and degree of concordance) for each individual feature/pressure sensitivity assessment, as shown in Table 7.

Guidance notes

- If resistance is assessed as 'High', then the resilience is assessed as 'High' by default as a resistance of 'High' suggests that there is no impact from which to recover. Hence, in this instance, the confidence in resilience is assessed as 'High', across all categories (quality, applicability, and concordance).
- If expert judgement is used to make either the resistance or recovery assessment then: confidence in the quality of supporting evidence is assessed as 'Low', but confidence in the applicability and degree of concordance are 'Not relevant'' as these categories are not relevant when assessments are based on expert judgement.

Table 6. Confidence assessment categories for evidence.

Confidence level	Quality of evidence (information sources)	Applicability of evidence	Degree of concordance (agreement between studies)
High (H)	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature (habitat, its component species, or species of interest)	Assessment based on the same pressures acting on the same type of feature (habitat, its component species, or species of interest) in the UK	Agree on the direction and magnitude (of impact or recovery)
Medium (M)	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature (habitat, its component species, or species of interest) or similar features	Assessment based on similar pressures on the feature (habitat, its component species, or species of interest) in other areas	Agree on direction but not magnitude (of impact or recovery)

Confidence level	Quality of evidence (information sources)	Applicability of evidence	Degree of concordance (agreement between studies)
Low (L)	Based on expert judgement	Assessment based on proxies for pressures e.g. natural disturbance events	Do not agree on direction or magnitude (of impact or recovery)

- Confidence in applicability is assessed as 'Low' where a proxy has been used e.g. distribution records or habitat information. Confidence in the quality of evidence is based on the source of evidence.
- Confidence in the degree of concordance is 'Not relevant' where the evidence is based on a single source.
- Where assessments are based on AMBI[8] scores as a 'proxy', confidence in the quality of evidence is assessed as 'Medium'. This is because the type of evidence supporting the AMBI score is unclear, but AMBI scores are reported in peer-reviewed literature, are widely used, and are considered credible. However, confidence in applicability and concordance is 'Low' since the underlying evidence and assumptions are unknown.

Table 7. Example of combined confidence assessments.

	Resistance confidence score		
Resilience confidence score	Low	Medium	High
Low	Low	Low	Low
Medium	Low	Medium	Medium

[8] AMBI = AZTI Marine Biotic Index (Borja *et al.,* 2000).

High	Low	Medium	High

4.7 Step 7. Documenting the 'evidence'

A complete and accurate account of the evidence used to make the assessments is recorded so that the basis of the sensitivity assessment is transparent and can be repeated or updated. **The resultant review of 'evidence' is the ultimate source of information for the application of the sensitivity assessments to management and planning decisions**.

Therefore, the sensitivity assessment reviews present the evidence base used for each pressure- specific sensitivity assessment in the form of explanatory text. The explanatory text documents the evidence base and justifies the sensitivity assessments made based on the evidence provided. The evidence base is the most important output for the MarESA sensitivity assessment process. Hence, care is taken to present the evidence clearly.

- All relevant ‘evidence’ is summarised in the explanatory text and the original sources cited;
- All cited sources are included in the bibliography for the review.
- The explanatory text is concise and uses plain English wherever possible.
- Particular attention is given to details (e.g. measured temperature ranges, Median Lethal Temperature (MLT), mortality rates) that allow the user to compare the evidence to the pressure benchmarks, sensitivity assessment scales, or site-specific circumstances.
- Where relevant, information demonstrating effect and information demonstrating no effect is presented.
- The explanatory text is written as ‘stand-alone’ text because the user may only read the explanation for the pressure of interest. Therefore, it is often necessary to repeat evidence in the explanatory text provided for one or more pressures.

The ‘evidence’ for each pressure is compiled in the explanatory text and a final justification (or conclusion) for the assessments given at the end of the text. The justification given in the sensitivity assessment must be transparent, balanced, and impartial. The justification summarises the key evidence used in the assessment in a few sentences, and presents the resistance, resilience, and sensitivity assessment scores (in bold) at the end of the text. The assessment scores should also be included in the text, for example, “…therefore, a resistance of 'Low' has been recorded." A similar statement should be made for resilience and, finally, sensitivity.

4.8 Step 8. Quality assurance and peer review

The resultant sensitivity reviews are subject to internal quality assurance by the MarLIN Editor(s) and, wherever possible, subject to peer review by one or more independent experts.

4.8.1 Quality assurance

The MarLIN Editor checks each of the reviews before they are placed online, to ensure that:

- the evidence collated is adequate to support sensitivity assessment;
- the assessments made are consistent with the MarESA methodology;
- the explanatory text that supports each assessment is a clear and concise précis of the relevant evidence;
- the judgment behind each pressure-sensitivity assessment is clearly stated; and that
- the evidence supports the resistance, resilience, and sensitivity assessments made in the reviews.

The Editor(s) also checks that the reviews comply with house-style guidelines, and that the bibliography is complete.

4.8.2 Peer review

The reviews are subject to peer review wherever possible. Referees are drawn from relevant experts identified during the literature review, experts at the MBA, or experts recommended by the MarLIN Steering Committee.

The referees are asked to check the accuracy of the information presented in the MarESA reviews and identify any omissions or ambiguities, with particular attention to the assessment of resistance, resilience and hence sensitivity. In addition, they are asked to indicate any missing information that would be important to the management, protection, and conservation of the species or biotope under review.

Referees are provided with a PDF copy of the review, notes on the peer review process requested of them, a summary of the MarESA approach, and a standard report form for comments (see Appendix 3). On receipt of comments, the MarLIN Editor(s) and/or original author, address the comments as follows:

- if any errors or ambiguities are identified by the referee – the original evidence is revisited, double-checked, and the review amended as required;
- if any new evidence is highlighted by the referee – the evidence is sourced, reviewed, and added to the review and bibliography, and the review amended as required; and
- if the referee disagrees with a statement, conclusion, or sensitivity assessment – the relevant evidence is revisited or new evidence added, and the review and assessment amended as required.

Please note:

- new evidence provided by the referee may result in a change in the conclusions and the sensitivity assessments; or
- the referee may disagree with conclusions or sensitivity assessments made.

In either case, the revision to the review and the sensitivity assessments is dependent on the evidence provided by the referee. This 'new' evidence may be material omitted from the original literature review, may be evidence that has become known after completion of the review; or may result from a prior misinterpretation of the evidence reviewed. The 'new' evidence is then considered in the MarESA approach and any resultant changes to the review and assessments made. All changes are recorded.

'New' evidence may also take the form of 'expert judgement' on behalf of the expert referee. In this case, the evidence will be clearly attributed to the referee as '*pers. comm.*'.

In some instances, a disagreement with the conclusions or sensitivity assessments made results from a misunderstanding of the sensitivity assessment approach, its terms, and definitions. The MarLIN Editor will engage in dialog with the referee to explain and resolve such misunderstanding. However, in the event of a difference of opinion between the MarLIN Editor and the referee, a second independent referee will be approached.

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5 Assessment guidance

The response of habitats (biotope) and species to each pressure varies, depending on the pathway(s) by which the pressure affects the receptor. Therefore, the aspects of habitat (biotope) or species ecology that are considered in the assessment also vary between pressures. For example, abrasion can directly affect species and the substratum so both these aspects of a habitat are considered in the sensitivity assessment. However, noise may affect species but not substratum so only species responses are considered in noise assessments.

Therefore, guidance on the application of evidence to the assessment of resistance, resilience, and sensitivity, and any assumptions used in the assessment, are discussed below on a pressure-by-pressure basis.

5.1 General considerations

The following points are considered throughout the assessment:

- the sensitivity assessments are generic and NOT site-specific; assessments are based on the likely effects of a pressure on a 'hypothetical' population in the middle of its 'environmental range'; or
- a typical habitat (biotope) in the middle of its 'environmental range'; and
- where the assessment results in one or more possible sensitivity assessment then the '**worst-case' sensitivity** is reported, and explanation provided in the explanatory text.

For example, sensitivity may depend on substratum, e.g. mussel beds on coarse sediment are probably more resistant of increases in water flow than mussel beds on muds, or stalked jellyfish on hard substrata may be more resistant of physical disturbance that stalked jellyfish on seagrass. In each case, both scenarios are discussed in the explanatory text but only the worst-case sensitivity is presented.

Each pressure-species/habitat combination is assessed unless they are clearly 'Not relevant' (i.e. there is no direct interaction between the pressure and the species/habitat). However, the assessments should consider 'what if'. That is, the assessment is undertaken if the pressure could affect the feature (habitat/biotope/species) in UK waters or has in the past (and hence may again). Current mitigation, management, or regulation does not guarantee that an activity will remain under management or regulation in the future. For example, we are not aware of any activities in the UK at present that result in hypersaline effluent, however, it is assessed where possible as desalination plants to generate freshwater could be introduced.

5.2 Pressures and benchmarks

The benchmarks are designed to provide a ‘standard’ level of pressure against which to assess resistance, and hence sensitivity. The pressure definitions and an associated benchmark were developed in liaison with the SNCBs, Defra, and Marine Scotland. The pressure definitions are based on the Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR, 2011). The benchmarks are based on those developed by MarLIN and MB0102 (Tillin *et al.,* 2010; Tillin & Tyler-Walters, 2014a&b) (see Appendix 4). The pressure themes and pressures assessed in MarLIN are presented in Table 8.

Table 8. Summary table of pressures and their benchmarks

Pressure Theme	Pressure	Benchmark
Climate change	Global warming (sea and air temperature)	**Middle emission scenario (A1B) (by the end of this century 2081-2100) benchmark of**: • A 3°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf. • A 2°C rise in surface air temperature in intertidal habitats exclusive to Scotland. **High emission scenario (RCP8.5) (by the end of this century 2081-2100) benchmark of:** • A 4°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf, and

Pressure Theme	Pressure	Benchmark
		• A 3°C rise in surface air temperature in intertidal habitats exclusive to Scotland. **Extreme scenario (RCP8.5 upper range) (by the end of this century 2081-2100) benchmark of**: • A 5°C rise in SST and NBT (coastal to the shelf seas); • A 6°C rise in surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf, and • A 5°C rise in surface air temperature in intertidal habitats exclusive to Scotland.
	Marine heatwaves	Middle emission scenario benchmark: a marine heatwave occurring every three years, with a mean duration of 80 days, with a maximum intensity of 2^{O}C. High emission scenario benchmark: a marine heatwave occurring every two years, with a mean duration of 120 days, and a maximum intensity of 3.5^{O}C.
	Ocean acidification	Middle emission scenario benchmark: a further decrease in pH of 0.15 (annual mean) and corresponding 35% increase in H+ ions with no coastal aragonite undersaturation and the aragonite saturation horizon in the NE Atlantic, off the continental shelf, at a depth of 800 m by the end of this century (2081-2100) High emission scenario benchmark: a further decrease in pH of 0.35 (annual mean) and corresponding 120% increase in H+ ions, seasonal aragonite saturation of 20% of UK coastal waters and North Sea bottom waters, and the aragonite saturation horizon in the NE Atlantic,

Pressure Theme	Pressure	Benchmark
		off the continental shelf, occurring at a depth of 400 m by the end of this century (2081-2100)
	Sea-level rise	Middle emission scenario benchmark: a 50 cm rise in average UK sea-level rise by the end of this century (2081-2100). High emission scenario benchmark: a 70 cm rise in average UK by the end of this century (2018-2100). Extreme scenario benchmark: a 107 cm rise in average UK by the end of this century (2018-2100).
Hydrological changes (inshore/ local)	Emergence regime changes - local, including tidal level change considerations	A change in the time covered or not covered by the sea for a period of ≥ 1 year OR An increase in relative sea level or decrease in high water level for ≥ 1 year
	Salinity changes – local, increase	An increase in one MNCR salinity category above the usual range of the biotope/habitat
	Salinity changes – local, decrease	A decrease in one MNCR salinity category below the usual range of the biotope/habitat
	Temperature changes – local, increase	A 5°C increase in temperature for one month period, or 2°C for one year
	Temperature changes- local, decrease	A 5°C decrease in temperature for one month period, or 2°C for one year
	Water flow (tidal current) changes - local, including	A change in peak mean spring bed flow velocity of between 0.1 m/s to 0.2 m/s for more than 1 year

Pressure Theme	Pressure	Benchmark
	sediment transport considerations	
	Wave exposure changes - local	A change in nearshore significant wave height >3% but <5% for one year
Physical loss (Permanent Change)	Physical loss (to land or freshwater habitat)	Permanent loss of existing saline habitat within site
	Physical change (to another seabed/sediment type)	Change in 1 Folk class (based on UK SeaMap simplified classification).
		Change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa
Physical damage (Reversible Change)	Changes in suspended solids (water clarity)	A change in one rank on the WFD (Water Framework Directive) scale e.g. from clear to intermediate for one year
	Habitat structure changes - removal of substratum (extraction)	Extraction of substratum to 30cm (where substratum includes sediments and soft rocks but excludes hard bedrock)
	Abrasion/disturbance of the substratum on the surface of the seabed	Damage to seabed surface features (species and habitats)
	Penetration and/or disturbance of the	Damage to sub-surface seabed

Pressure Theme	Pressure	Benchmark
	substratum below the surface of the seabed, including abrasion	
	Smothering and siltation changes (depth of vertical sediment overburden)	‘Light’ deposition of up to 5 cm of fine material added to the seabed in a single, discrete event
		‘Heavy’ deposition of up to 30 cm of fine material added to the seabed in a single discrete event
Physical pressure (other)	Barrier to species movement	Permanent or temporary barrier to species movement ≥50% of water body width or a 10% change in tidal excursion
	Electromagnetic changes	Local electric field of 1 V/m. Local magnetic field of 10 µT
	Death or injury by collision	Benthic species: 0.1% of tidal volume on average tide, passing through artificial structure
	Introduction of light or shading	Change in incident light via anthropogenic means
	Litter	Introduction of human-made objects able to cause physical harm (surface, water column, sea floor and/or strandline)
	Noise changes	Underwater noise: MSFD indicator levels (SEL or peak SPL) exceeded for 20% of days in calendar year

Pressure Theme	Pressure	Benchmark
	Vibration	Fish/Birds/Mammals: Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features
	Visual disturbance	Benthic species/Fish/Birds: daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature
Pollution and other chemical changes	Hydrocarbon & PAH contamination.	The introduction of relevant contaminant into the local environment e.g. via spills, approved and incidental discharges[9].
	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals).	The introduction of relevant contaminant into the local environment e.g. via spills, approved and incidental discharges[8].
	Transition elements & organo-metal (e.g. TBT) contamination.	The introduction of relevant contaminant into the local environment e.g. via spills, approved and incidental discharges[8].
	Introduction of other substances (solid, liquid or gas)	The introduction of relevant contaminant into the local environment e.g. via spills, approved and incidental discharges[8].
	Radionuclide contamination	An increase in 10 µGy/h above background levels

9 The sensitivity assessment is based on a Rapid Evidence Assessment (REA) of the relevant contaminant on the species or taxonomic group of interest.

Pressure Theme	Pressure	Benchmark
	De-oxygenation	Benthic species/habitat: exposure to dissolved oxygen concentration of less than or equal to 2 mg/l for 1 week (a change from WFD poor status to bad status).
	Nutrient enrichment	A decrease in the one rank of nutrient status of a water body (as defined by WFD), that is, from High to Good, Good to Moderate, Moderate to Poor for a period of a year.
	Organic enrichment	A deposit of 100 gC/m2/yr.
Biological pressures	Genetic modification & translocation of indigenous species	Translocation of indigenous species and/or introduction of genetically modified or genetically different populations of indigenous species that may result in changes in genetic structure of local populations, hybridization, or change in community structure
	Introduction of microbial pathogens	The introduction of relevant microbial pathogens or metazoan disease vectors to an area where they are currently not present (e.g. *Martelia refringens* and *Bonamia*, Avian influenza virus, viral Haemorrhagic Septicaemia virus).
	Introduction or spread of non-indigenous species (INIS)	The introduction of one of more invasive non-indigenous species (INIS)
	Removal of non-target species	Removal of features or incidental non-targeted catch (by-catch) through targeted fishery, shellfishery or harvesting at a commercial or recreational scale

Pressure Theme	Pressure	Benchmark
	Removal of target species	Benthic species and habitats: removal of species targeted by fishery, shellfishery or harvesting at a commercial or recreational scale.

The ‘pollution’ or ‘contaminant’ pressures were revised in 2022 in consultation with SNCB staff and relevant experts. The revised pressure definitions and benchmarks are shown in Appendix 5. However, the revised approach to the sensitivity assessment of ‘contaminant’ pressures is too detailed to be included here, and the user should refer to Tyler-Walters et al. (2022) for detail.

Additional pressure definitions and benchmarks for climate change related pressures were developed in consultation with statutory agencies and relevant experts (Garrard & Tyler-Walters, 2020). The detailed pressure descriptions are shown in Appendix 6 and discussed in detail by Garrard & Tyler-Walters (2020). The terms, scales and diagrams referred to in the benchmark text are shown in Appendix 7

5.2.1 Benchmarks

Benchmarks provide a standard level of pressure against which to assess resistance. Benchmarks are either quantitative or qualitative. The quantitative benchmarks describe a value for magnitude, extent and in some cases duration. These values are derived from a literature review of the effects of activities that result in the pressure under consideration. In the sensitivity assessment process, these values can be compared with values in the evidence. Examples of quantitative benchmarks used in the MarESA methodology are temperature, salinity, and oxygen level tolerances.

Many benchmarks remain **qualitative**, that is, they describe a pressure or process, e.g., ‘removal of non-target species’ and ‘introduction of non-indigenous species, where the level of resistance is determined by the levels of damage or disturbance documented in the evidence. In these cases, there is the danger that the sensitivity assessments do not compare ‘like’ with ‘like’ and care should be taken to record the evidence used in detail.

For **qualitative benchmarks,** resistance is assessed against the available evidence for the effects of the pressure on the species or community of interest. This is referred to as a 'weight of evidence' approach. For example:

- evidence of severe[10] (mass, >75%) mortality of a population of the species or community of interest (either short or long term) in response to a pressure benchmark will be ranked as 'None' resistance;
- evidence of a significant (ca 25-75%) reduction in the abundance, or extent of a population of the species or community of interest (either short or long term) in response to a pressure benchmark will be ranked as 'Low' resistance;
- evidence of some (minor, <25%) reduction in the abundance, or extent of a population of the species or community of interest (either short or long term) in response to a pressure benchmark will be ranked as 'Medium' resistance; or
- evidence of sub-lethal effects or reduced reproductive potential of a population of the species or community of interest will be assessed as 'High' resistance.

Where otherwise sublethal effects, result in reproductive or recruitment failure, resistance is assessed against any evidence for resultant population decline. For example, Tributyltin (TBT) resulted in severe declines in dog whelk (*Nucella lapillus*) populations, and dog whelk would be assessed as having no (None) resistance to the effects of TBT.

In addition:

- it is assumed that 'change' refers to an increase and decrease in pressure, unless otherwise stated or assessed separately;
- the physical pressures assume a single event, unless otherwise specified;
- the 'physical loss' and 'physical change' pressures assume a permanent change so that recovery is not possible, and resilience is assessed as 'Very low' by default; and
- the climate change pressures (except marine heatwaves) represent ongoing (long-term) pressures where recovery is not possible as the pressure is irreversible, in which case resilience is assessed as 'Very low' by default.

[10] The terms 'severe', 'significant' and 'some' refer to the terms used to qualify resistance in the 'resistance' scale above'

5.2.2 Emergence regime changes - local, including tidal level change considerations

The pressure benchmark is relevant only to littoral and shallow sublittoral fringe biotopes. The marine habitat classification biotope descriptions (Connor *et al.*, 2004; JNCC 2022) provide information on the depth/height ranges of biotopes.

All biotopes in the eulittoral will be affected and their resistance will depend on:

- their position on the shore;
- their dependence on emersion; and
- their susceptibility to desiccation.

Note, even supralittoral biotopes are influenced by emergence (splash and spray). It is assumed that any biotopes occurring below 5 metres will be unaffected[11]. Some sublittoral fringe habitats are assessed e.g. if the vertical range of the biotope is between 0-5 m. Otherwise, 'Not relevant' is recorded.

5.2.3 Salinity changes – local, increase

There is little empirical evidence available to assess sensitivity of marine species or habitats to the increase benchmark (>40 psu), except some data extrapolated from the impacts of desalination plants abroad and inferences from exposure to natural increases where enclosed water bodies are exposed to high levels of evaporation. Therefore, in most cases, the assessment is recorded as 'No evidence'.

Species resistance is assessed against their published salinity tolerances, e.g. Median Lethal Time at a range of salinities. In the absence of direct evidence, the reported distribution in different salinity regimes may be used as a proxy. Reported information on distribution in

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[11] Major earthquakes are an exception and may raise the shore height significantly (e.g. as in Alaska, and Canterbury, New Zealand) but are unlikely in the UK.

taxonomic texts, papers, and the MNCR[12] dataset, NBN Atlas[13] or OBIS[14] consulted for information.

Local populations may acclimatize to the prevailing salinity regime and may exhibit different tolerances to other populations subject to different salinity conditions. Therefore, caution should be used when inferring tolerances from populations in different regions.

5.2.4 Salinity changes – local, decrease

Refer to the Marine Habitat Classification (Connor *et al.,* 2004; JNCC, 2022) for the typical salinity range that defines the biotope. Salinity may also structure biotopes, with changes in diversity or dominant species occurring with decreasing salinity. Therefore, if the benchmark level of decrease in salinity lies outside the biotope's normal range, the biotope is likely to be degraded or changed to another biotope (and is effectively lost). Assess resistance accordingly. Refer to evidence on the salinity tolerances of species that contribute to sensitivity but note that their tolerance range may be larger than the range of salinities in which the biotope (habitat and its associated species) occurs.

Species resistance is assessed against their published salinity tolerances if these exist. In the absence of direct evidence, the reported distribution in different salinity regimes may be used as a proxy. Reported information on distribution in taxonomic texts, papers, and the MNCR dataset, NBN Atlas or OBIS are consulted for information.

Local populations may acclimatize to the prevailing salinity regime and may exhibit different tolerances to other populations subject to different salinity conditions. Therefore, caution should be used when inferring tolerances from populations in different regions.

5.2.5 Temperature changes – local, increase and decrease

Refer to evidence on the temperature tolerances of species that contribute to sensitivity. Species resistance is assessed against their published temperature tolerances, if any exist,

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[12] MNCR – Marine Nature Conservation Review

[13] National Biodiversity Network (NBN) Atlas (https://nbnatlas.org/)

[14] OBIS – Oceanographic Biogeography Information System (www.iobis.org).

e.g. MLT[15]. In the absence of direct evidence, the reported geographic distribution of the species that contribute to sensitivity may be used as a proxy (see reported information on distribution in taxonomic texts, papers, the MNCR dataset, or OBIS for information).

For example, species that are distributed from the Arctic Circle to the coast of Africa are probably likely to be resistant to long-term chronic (2°C) and even acute changes (5°C) in temperature given in the benchmark. However, species with a restricted distribution, those that only occur in isolated areas or thermally stable environments (e.g. deep water), or those that are at their southern or northern limits in UK waters, are not likely to resist changes in temperature at the benchmark level.

The effects of temperature on spawning, reproduction, larval development, larval settlement, and recruitment are also considered. If changes in temperature prevent reproduction or larval development, then a population may be lost through recruitment failure.

Local populations may acclimatize to the prevailing temperature regime and may exhibit different tolerances to other populations subject to different temperature conditions. Therefore, caution should be used when inferring tolerances from populations in different regions.

5.2.6 Water flow (tidal current) changes - local

There are few studies on the water flow tolerances of species. Most evidence on water flow is based on habitat preferences, that is, the tidal stream regime where the habitat (biotope) or species is recorded. Therefore, information on the tidal stream preferences of the habitat (biotope) or species from the MNCR database and habitat classification (especially the relevant habitat matrices) (Connor *et al.*, 2004; JNCC, 2022) is used as a proxy indicator of sensitivity. Both a decrease and an increase in water flow are considered. For example:

- where biotopes occur in high water flow rates (e.g. moderate to very strong tidal streams >0.5 m/s), a change of 0.1-0.2 m/s is probably not significant, so the biotope is considered ‘Not sensitive at the benchmark level’;

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[15] MLT (Median Lethal Temperature) or LT50

- where a biotope occurs in two MNCR categories and the natural variability in tidal stream experienced is a greater magnitude than the pressure benchmark, the biotope is considered ‘Not sensitive at the benchmark level’; and
- where a biotope occurs only in weak –negligible tidal streams it is considered potentially sensitive as the categories refer to a restricted range of flow speeds.

Evidence on the effects of change in water flow on the physical habitat (e.g. the erosion / accretion rates associated with sediments) is considered by reference to the Hjulström-Sundborg diagram (see A5.2). For example, we can say that medium sand (0.25 - 0.50 mm) will be suspended by currents about 0.20-0.25 m/s and it will stay in suspension until flow drops below 0.15-0.18 m/s. Therefore, in sedimentary habitats, a change in water flow may result in change in sediment type.

Wave mediated water flow is also considered. Habitats structured by wave action rather than water flow are considered ‘Not sensitive at the benchmark level’. Information on the relative influence of tidal streams or wave action on water flow and definition of habitats (biotopes) is outlined in the habitat classification (Connor *et al.*, 2004; JNCC, 2022).

5.2.7 Wave exposure changes - local

This benchmark was selected by MB102 on the basis that it was relevant to impact assessments, where permitting and licensing were informed by modelled predictions of changes in hydrography (Tillin *et al.,* 2010). It is a process or activity-based benchmark. The difficulty for sensitivity assessment is that the Marine Habitat Classification provides the range of wave exposures for most of the biotopes (and characteristic species) in the classification. However, evidence in literature on changes of communities to wave exposure is rarely expressed against the same MNCR scale. Similarly, wave height correlates with shore profile (reflective vs. dissipative) and sediment types on beaches, but little evidence relates changes in significant wave height to changes in communities, especially on hard substrata. The MNCR wave exposure scale and measures of significant wave height are not directly comparable.

Therefore, habitats that only occur in wave exposed habitats are considered ‘Not sensitive at the benchmark level’. Similarly, species that prefer wave exposed habitats are likely to be ‘Not sensitive at the benchmark level’. However, habitats (biotopes) or species that require sheltered conditions or substrata that depend on sheltered conditions may be sensitive.

5.2.8 Changes in suspended solids (water clarity)

This pressure addresses changes in suspended sediments and resultant light attenuation (turbidity). Information on natural turbidity levels experienced by many habitats (except estuarine habitats) varies. Therefore, unless evidence suggests otherwise, assume that coastal and estuarine biotopes experience 'Intermediate' turbidity so that an increase at the pressure benchmark is a change to 'Medium' turbidity and a decrease is to 'Clear', based on the UKTAG scale (Appendix 7).

For example:

- assess the resistance of light dependent algae depending on their habitat and depth preferences;
- assess the resistance of suspension feeding organisms to clogging by suspended sediment based on limited experimental studies or habitat preferences;
- examine evidence on the effects of sediment plumes or sediment loaded runoff; and
- consider the likely change in scour resultant from increases or decrease in suspended sediments, e.g. on larval or algal propagule settlement.

Habitats (biotopes) that are defined by turbid conditions are likely to be sensitive to a decrease in turbidity.

Appendix 7 includes additional information on the interpretation of turbidity. Note, turbidity due to chemical means (e.g. Gelbstoff) or algal blooms is not addressed.

5.2.9 Habitat structure changes - removal of substratum (extraction)

The pressure benchmark describes a process by which the sediment is removed, and the sensitivity assessment is made by reference to documented evidence of the effects of extraction or similar activities on the habitat

It is possible for soft rocks (clays, peats, chalks) to be removed by extractive activities. However, it is very unlikely that hard bedrock would be removed or subject to extraction to a depth of 30 cm. Coastal quarries tend to be coastal rather than truly marine, and 'quarrying' is not included in the pressure description. Therefore, this pressure is considered 'Not relevant' to hard substratum habitats.

5.2.10 Abrasion/disturbance of the substrate on the surface of the seabed

The pressure describes the physical disturbance or abrasion of the surface of the substratum in sedimentary or rocky habitats. The effects are relevant to epiflora and epifauna living on or at the surface of the substratum. The benchmark is qualitative, and the sensitivity assessment is based on the likely level of damage determined by the evidence. For example, in intertidal and sublittoral fringe habitats, abrasion is likely to result from recreational access and trampling (including climbing) by humans or livestock, vehicular access, moorings (ropes, chains), activities that increase scour, and grounding of vessels (deliberate or accidental). In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g. kelps) or epifaunal species (e.g. oysters). In sublittoral habitats, passing bottom gear (e.g. rock hopper gear) may also cause abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with abrasion can cover relatively large spatial areas e.g. bottom trawls or bioprospecting, or be relatively localized activities e.g. seaweed harvesting, recreation, potting, and aquaculture.

Many activities that can cause abrasion are also penetrative (e.g. trawls and dredges) and it is important to distinguish between surface effects and the sub-surface penetrative effects, which are addressed in the next pressure.

5.2.11 Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion

The majority of the evidence on which to base sensitivity assessment comes from literature on the effects of fishing (finfish and shellfish). The depth of penetration also determines which species are affected, e.g. some species live in deep rather than shallow burrows.

In general, the macrofauna and near-surface infauna of subtidal muds are susceptible to physical disturbance from bottom fishing gears (i.e. beam trawls, scallop dredges, otter trawls, seine netting, hydraulic suction dredges) (Hall *et al.*, 2008 and references therein; see also reviews by Johnson, 2002, Kaiser *et al.*, 2002, Kaiser *et al.*, 2006; and Thrush & Dayton, 2002).

For example, otter boards plough a groove in the seabed, which can vary from a few cm to 30 cm deep (Jones, 1992). The trawl may remove or damage sedentary organisms and displace stones. Bobbins and chains can also leave tracks (Krost *et al.*, 1990) and remove surface sediment. The disturbance depth depends on board weight, angle of tow and the nature of the substratum (Jones, 1992). Sediment recovery time and infilling will depend on local hydrodynamics and the substratum. Beam trawls leave detectable marks on the seabed. The duration that the beam trawl marks remain visible depends on the upper sediment layer and on the hydrographic conditions. On a seabed consisting of medium to coarse sand, tracks have been observed to remain visible for up to 6 days. On sediments of mainly finer particles, a corresponding figure of 37 hours was observed.

The degree of damage from penetrative activities described in the evidence is used to determine the sensitivity assessment. The depth of macrofauna within the sediment, and the type of sediment are considered. The time taken for the sediment itself to recover (e.g. tracks or pits to infill) is considered in the resilience assessment.

Loss, removal, or modification of the substratum is not included within this pressure (see the 'physical loss' pressure theme). Penetration and damage to the soft rock substrata are considered, however the penetration into hard bedrock is deemed unlikely. 'Not relevant' is recorded for hard substratum habitats, but the abrasion to any epifaunal or epifloral communities are addressed under 'abrasion' and the reader it directed to that section. Also, communities that occur on a pebble, cobble or coarse sediment overlay on hard substrata (bedrock) are considered 'Not relevant', and disturbance to the coarse sediment overlay is addressed under 'abrasion'.

5.2.12 Smothering and siltation changes (depth of vertical sediment overburden)

The benchmark refers to a single event and it is assumed, therefore, that the siltation event is a discrete, pulse event where fine sediments are added in a short period so that the receiving habitat experiences burial to a depth of 5 cm (low) or 30 cm (high). This contrasts with low levels of chronic siltation from activities, where accumulation is prevented by removal over tidal cycles, or the rate of accretion is so low that animals can continually reposition within sediments.

Dredged spoil may contain contaminants but this effect is not considered in this pressure. Similarly, sediments removed by dredging and subsequently deposited may be anoxic, but this effect is also not considered here. Only the effect of smothering is assessed, not sediment change, which is addressed by the physical change pressure.

There is reasonable evidence to support an assessment. Last *et al.* (2011) has augmented the evidence. Duration is a vital component but is related to the hydrography of the site. Therefore, the energy of the habitat (wave and tidal regimes) is considered. It is assumed that smothering is removed rapidly in areas of high energy but is retained for significant periods in areas of low energy. For example, we assume that a 30 cm deposit in a tide-swept or wave exposed habitat will not be retained long enough to have a significant effect. In low energy, sedimentary habitats, the deposit will remain for many tidal cycles and sensitivity is dependent on the ability of the infauna to burrow to the surface and/or resist hypoxic conditions.

5.2.13 Physical change (to another sediment type)

The benchmark for this pressure refers to a change in one Folk class in sediment type (Long, 2006; Appendix 7).

The change in one Folk class is considered a change in classification only to adjacent categories in the modified Folk triangle. For habitats classified as mixed sediments or sand and muddy sand, a change in one Folk class may therefore refer to a change to any of the sediment categories. However, for coarse sediment habitats resistance is assessed based on a change to either mixed sediments or sand and muddy sands, but not mud and sandy muds. Similarly, muds and sandy muds are assessed based on either a change to mixed sediments or sand and muddy sand, but not coarse sediment.

For example, for biotopes described as ‘muddy’, (e.g. A5.325 ‘[*Capitella capitata*] and [*Tubificoides*] spp. in reduced salinity infralittoral muddy sediment’) the benchmark was interpreted as referring to a change to mixed sediments and / or ‘sand and muddy sand’, but not to coarse sediments.

While the pressure assessment considers sensitivity to a change in sediment type, it does not consider sensitivity to the pathways by which this change may occur. For example, due to penetration and disturbance of the sediment and extraction that can remove relatively soft substratum such as chalk, peat or clay, lead to re-suspension of fine sediments that are removed by water currents resulting in coarser sediments or expose different types of substrata. Siltation may alter the character of the sediment or substratum through the addition of fine sediments.

The assessment is based on the likely effect of the change in sediment type. As a specific sediment type defines sedimentary habitats (biotopes), a change in sediment type will result in change in the biotope classification and the loss of the biotope under assessment. Information on the habitat preferences of the sedimentary biotopes is shown in the Marine Habitat Classification and relevant sediment habitat matrices (Connor *et al.,* 2004; JNCC, 2022).

Note that the pressure refers to a 'permanent change' so that no recovery is possible (resilience is 'Very low'). Also, this pressure is 'Not relevant' in hard substratum habitats but the potential change in clay, peats and 'mud-rock' habitats are considered.

5.2.14 Physical change (to another seabed type)

This pressure examines the effect of a change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa. It is included to cover the introduction of artificial substrata e.g. the overlaying of sedimentary habitats by concrete, gabions, boulders etc. This pressure is considered to affect all types of substrata, and all habitats are assessed, as highly sensitive as resistance is likely to be 'None' and, it is a permanent change so that resilience is 'Very low'.

Species sensitivity is dependent on the species requirement for a particular sediment or substratum type. Species that occur on particular substrata (e.g. due to need for attachment) are likely to have a low resistance, while species that colonize a range of substrata may exhibit a high resistance. This pressure is 'Not relevant' for most highly mobile and pelagic species, although benthic and demersal fish, such as, sand eels are an obvious exception.

Note, short term smothering of substrata with sediment is addressed under smothering (siltation).

5.2.15 Physical loss (to land or freshwater habitat)

This pressure is defined as the 'permanent loss of existing saline habitat within a site' (see Appendix 4). Therefore, all marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is therefore, 'High'. Although no specific evidence is described, confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Similarly, most benthic species will be sensitive and their resistance dependent on their ability to relocate (e.g. mobility). In the case of 'mobile species' this pressure is also interpreted as ‘exclusion from existing saline habitat’, for example if the habitat becomes no longer suitable for the species in question or is no longer accessible.

5.2.16 Barrier to species movement

Tidal excursion referred to in the pressure benchmark is the distance travelled by a water particle during a single tidal cycle (ebb and flow tide). Barrages may reduce the degree of tidal excursion.

The pressure is clearly relevant to mobile species such as fish, birds, reptiles, and mammals. However, it should also be considered relevant to macrofauna such as crabs, which undertake migrations to over-winter or to breed, and where populations are dependent on larval or other propagule supply from outside the area. Otherwise, the pressure is considered ‘Not relevant’.

5.2.17 Electromagnetic changes

Species sensitivity depends on the ability of the species to sense the electromagnetic field (EMF) and the degree to which this affects the species. Most work to date has concentrated on fish species although the evidence to assess likely impacts is limited and effects are therefore poorly understood (Gill & Bartlett, 2010). Arthropods are considered to demonstrate sensitivity to magnetic fields. Spiny lobsters (*Palinurus argus*) have been shown experimentally to orient by the Earth’s magnetic field when relocated from home habitat (Boles & Lohmann, 2003). No magneto or electro reception has so far been demonstrated in cephalopods (Williamson, 1995). In talitrids, different populations show different magnetic sensitivities, with Atlantic and Equatorial populations showing evidence of magnetic orientation but Mediterranean ones showing either weak or no response (Scapini & Quochi, 1992). In molluscs, magnetic orientation has been demonstrated for the opisthobranch *Tritonia diomedea* (Lohmann & Willows, 1987)

In general, sessile species or those with low mobility may not have evolved sensitive electro or magneto receptors and may be unaffected by changes in these fields in terms of navigation and prey location. However, these fields may have some physiological effects and some life stages, e.g. larvae, may be more sensitive than adults. Deleterious effects of super-high and low frequency electromagnetic radiation have been recorded for sea urchins (Shkuratov *et al.*, 1998, Ravera *et al.*, 2006). Ravera *et al.* (2006) found that the threshold for formation of anomalous embryos was about 0.75 ± 0.01mT, which is lower than the pressure benchmark. Other physiological effects in animals exposed to magnetic fields include the induction of heat shock proteins in mussels (Malagoli *et al.*, 2004), and altered limb regeneration rates in fiddler crabs (Lee & Weis, 1980).

Nevertheless, the evidence to assess these effects against the pressure benchmark is limited and the impact of this pressure cannot be assessed for most benthic species or habitats. Therefore, 'No evidence' is recorded in most cases.

5.2.18 Death or injury by collision

The benchmark relates to passage through an artificial structure and is, therefore, only relevant to mobile species and the mobile stages of benthic species, such as, larvae. Therefore, in assessment reference is made to evidence on the effects of know barrage or turbine installations (e.g. Oosterschelde estuary).

Nevertheless, it is considered 'Not relevant' to seabed habitats and most benthic species. Collision with hard substrata caused by the grounding (accidental or deliberate) of vessels is assessed under physical damage (abrasion).

5.2.19 Introduction of light or shading

The introduction of artificial light is unlikely to be relevant for most benthic invertebrates, except where it is possible to interfere with spawning cues, although there is thought to be no evidence to that effect. The introduction of light could potentially be beneficial for immersed plants, but again there is not thought to be any relevant evidence of this effect. Similarly, artificial lighting may alter the depth to which algae penetrate caves, but it is assumed that this is unlikely to occur in coastal caves.

Shading by artificial structures (e.g. pontoons or shipping) may affect the depth range of sublittoral algae already at the lower extent of their depth, depending on the habitat (e.g. kelp beds, seagrass beds), due to the amount of incident light. Shading may also alter the dominant algal type in some intertidal communities where incident light affects temperature and desiccation, as well as photosynthesis.

The benchmark is qualitative, and the assessment is based on expert judgement supported by available evidence.

5.2.20 Litter

Litter is clearly relevant for large macrofauna such as fish, birds, and mammals. However, we are not aware of any evidence on the effects of 'litter' on benthic marine species. While there is documented evidence on the accumulation of microplastics in some species and habitats, no ecological effects have been shown to date. The only exception is the effect of ghost fishing on large crustaceans (crabs etc.) (Bullimore *et al.*, 2001). Therefore, no assessment was made and 'Not assessed' is recorded throughout. These assessments can be revised as more evidence becomes available.

5.2.21 Underwater noise changes

The pressure and benchmark are relevant to mobile species, in particular, fish, marine reptiles, and mammals that respond to sound and/or use sound for echolocation, communication, or hunting. The evidence on the effects of underwater noise on marine benthic species is limited. The majority of benthic invertebrates (and, hence their communities) have limited or no known response to noise, although vibrations in the water column, at close proximity, may result in an avoidance response.

Therefore, this pressure is considered to be 'Not relevant' to benthic species and habitats, unless specific evidence to the contrary is found. If evidence on any effect of noise (or vibration) on the component species is found, then it is documented, and the potential for the pressure to result in mortality is assessed.

5.2.22 Visual disturbance

Visual disturbance is only relevant to species that respond to visual cues, for hunting, behavioural responses, or predator avoidance, and that have the visual range to perceive cues at distance. It is particularly relevant to fish, birds, reptiles, and mammals that depend on sight but less relevant to benthic invertebrates. The cephalopods are an exception, but they are only likely to response to visual disturbance at close range (from e.g. divers). Sea horses are disturbed by photographic flash units, but again at close range.

Therefore, this pressure is considered to be 'Not relevant' to benthic species and habitats, unless specific evidence to the contrary is found. If evidence on any effect of visual disturbance on the component species is found, then it is documented, and the potential for the pressure to result in mortality is assessed.

5.2.23 Pollutants

The 'pollutant' or 'contaminant' pressures are assessed using a 'weight of evidence' approach (see benchmarks above) following detailed Rapid Evidence Assessment (REA).

The approach and its application to sensitivity assessment are detailed by Tyler-Walters et al. (2022).

5.2.24 Radionuclide contamination

Evidence on the effects of radionuclide contamination is limited. A few species are used as indictors due to their ability to accumulate radionuclides (e.g. laver), and radionuclides may be reported in the tissues of invertebrates (e.g. bivalves). However, little information on their effect at the population level has been found. Therefore, the limited evidence is recorded where available but an assessment of ‘No evidence’ is recorded.

5.2.25 De-oxygenation

There is considerable evidence on the effects of de-oxygenation in the marine environment due to ongoing work and reviews (Diaz & Rosenberg, 1995, Gray *et al.*, 2002, Riedel *et al.*, 2012). The evidence is based on the observed effects of hypoxic/anoxic episodes, and laboratory and field experiments on many invertebrate groups. Therefore, direct evidence of population mortality can be compared against the benchmark. Where evidence for the species that contribute to sensitivity is not directly available, evidence from similar species within the same taxonomic group is often available instead.

Please note that de-oxygenation can result from nutrient or organic enrichment, and the death of algal blooms, but also can result from smothering, and thermoclines or haloclines in coastal waters. Therefore, de-oxygenation is assessed separately from ‘nutrient or organic enrichment’.

5.2.26 Nutrient enrichment

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014).

Therefore, a habitat (biotope) or species assessed as ‘Not sensitive at the pressure benchmark’ assumes compliance with good status as defined by the WFD.

Please note, although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no effects on the features, the accidental introduction of large quantities of nutrients on a particular area could result in severe eutrophication and have indirect effects on features. Therefore, where evidence on the effect of nutrient enrichment is available the evidence is recorded for reference.

5.2.27 Organic enrichment

Organic enrichment encourages the productivity of suspension and deposit feeding detritivores and allows other species to colonize the affected area to take advantage of the enhanced food supply.

Organic pollution occurs when the rate of input of organic matter exceeds the capacity of the environment to process it and leads to other pressures being exerted on the habitat. Commonly, there is an accumulation of organic matter on the sediment surface that smothers organisms, depletes the oxygen concentrations in the sediment and sometimes the overlying water, which in turn changes the sediment geochemistry and increases the exposure of organisms to toxic substances associated with organic matter. The benthic invertebrate community response is characterized by decreasing numbers of species, total number of individuals and total biomass and dominance by a few pollution tolerant annelids (Pearson & Rosenberg, 1978, Gray *et al.*, 2002).

It is not clear how the pressure benchmark compares to natural levels of sedimentation and thresholds for effect. The impact of adding organic matter will depend on the state of enrichment or pollution of the receiving environment, and whether the additional loading leads to a tipping point. The results reported in Cromey *et al.* (2002) and Eleftheriou *et al.* (1982) suggest that the addition of organic matter at the pressure benchmark may lead to slight enrichment effects, rather than gross organic pollution.

The majority of evidence relates to sedimentary habitats from past activities (e.g. sewage sludge dumping, gross estuarine pollution) but remains relevant. However, it is often difficult to compare the reported effects of organic pollution from those of nutrient enrichment, and difficult to compare the reported effect to the benchmark. Nevertheless, wherever possible, direct evidence of the effect of organic enrichment on the habitat or species is used in the assessment.

In the absence of direct evidence, the AMBI index of pollution disturbance effects, developed by Borja *et al.* (2000) and revised by Gittenberger & Loon (2011) can be used as the basis for the assessment. The AMBI index classifies species depending on their likely response (sensitivity) to organic pollution. However, the evidence underlying the AMBI assessment is not clear and, therefore, less confidence is given to sensitivity assessments based on the AMBI index indicating intolerance to organic enrichment at the pressure benchmark.

Please note that organic enrichment can also result in de-oxygenation and nutrient enrichment but that the sensitivity to the latter pressures is assessed separately.

5.2.28 Genetic modification & translocation of indigenous species

Previously, when developing sensitivity assessments (Tillin *et al.,* 2010, Tillin & Tyler-Walters, 2014a, b), this pressure was considered relevant only to biotopes that are characterized by species which may be translocated or transplanted either for aquaculture or onward growing e.g. *Mytilus edulis*, *Ostrea edulis*, or for habitat creation e.g. seagrass and chord grass (*Spartina* spp.). The impact pathway considers the potential for genetic modification leading to changes in genetic structure of a population, or hybridization. The pressure description also refers to aquaculture escapees and, hence, is relevant to fish species that are currently farmed, and which occur naturally in the wild.

The term genetic modification is slightly misleading. In current use, the term often refers to deliberate alteration of the genetic code of an individual using molecular genetic techniques. However, genetic modification of a species population has been achieved via selective breeding programmes in agriculture. Also, the genetic structure[16] of local populations may be altered by immigration from neighbouring populations or the deliberate translocation of individuals from another population of the same species with a different genetic structure.

Translocation or introduction of similar species that had not previously come into contact could provide the opportunity for hybridization (e.g. *Spartina*). Translocation could also potentially result in competition between the local species, and the introduced species can change the community composition or structure of the receiving habitat.

Introduction of non-native species (whether genetically modified or not) is expressly considered under a separate pressure. Should the introduction of GM non-indigenous species become an identifiable problem then the pressure benchmarks for the two relevant pressures may need to be revisited. This pressure is not relevant to birds or mammals as aquaculture and agriculture are the only recognised activity.

Reintroductions for conservation purposes may be considered as a translocation of indigenous species. Species of conservation interest may be reintroduced into habitats as a

[16] Genetic structure defined in terms of the most common and least common alleles for any particular gene.

conservation measure, however, where there is no natural population, interbreeding effects will not arise, although these may be a consideration in the future. There is no known reintroductions of birds and mammals into the marine environment.

Crustaceans that are reared in hatcheries are not considered in assessments as these do not characterize biotopes and no negative ecological effects have been identified. The pressure description refers to mutations associated with radionuclide contamination, but any evidence would be considered under the radionuclide pollution pressure theme. Currently no genetically modified organisms are licensed for aquaculture in the UK and therefore genetic modification from this source is not considered.

Overall, the assessment is based on evidence of genetic modification, translocation, or introduction of species from otherwise genetically isolated populations, or on the reported effect of escapes from cultivated (and bred) populations. However, except for the specific cases above, most of the species that contribute to sensitivity in habitat (biotopes) are not cultivated or translocated, so the pressure is considered ‘Not relevant’.

5.2.29 Introduction of microbial pathogens

Technically all species host parasites or microbial pathogens and are hence sensitive to disease causing organisms. Therefore, sensitivity assessment is focused on ‘relevant’ microbial pathogens or metazoan parasites that are ‘relevant’ because they are; a) spread or introduced by human activities or humans themselves (e.g. via faeces); b) controllable by management; and c) reported to cause a decline in the affected species population.

Therefore, any significant pathogens or disease vectors relevant to the species or the species contributing to sensitivity of the habitat (biotope), as identified during the evidence review phase, is noted in the text. Evidence on the effect of the pathogens or disease is assessed against the resistance scales. For example, the mass dieback of *Zostera marina* during the 1920s and mid-1930s due to the wasting disease caused by Labyrnthula, or the Phocine distemper virus (PDV) that resulted in the deaths of 21,700 seals, estimated to be 51% of the population along the North Sea, would indicate a resistance of ‘None’ and ‘Low’ respectively. However, where pathogens or disease are present but only result in limited sub-lethal effects on individuals within the population or community, then the species or habitat (biotope) is considered to have a ‘High’ resistance and, hence ‘High’ resilience, and to be ‘Not sensitive’.

5.2.30 Introduction or spread of non-indigenous species (NIS)

The assessment is based on the reported effects of the introduction of one or more non-indigenous species (NIS) on the species or habitat (biotope) under assessment, in the UK or similar habitats overseas. A recommended list of non-indigenous species that may affect marine habitats is given in Appendix 7. However, evidence on the effects on any non-indigenous species is included in the assessment.

The species population or habitat (biotope) will only recover if the NIS is removed, through either active management or natural processes. Hence, resilience is assessed as ‘Very Low’, to recognise that recovery may be prolonged.

Please note the potential for a NIS to invade a habitat (biotope) or species population does not itself mean that the habitat (biotope) or species is sensitive. Where there is no evidence in the literature to assess potential damage, then an assessment of ‘No evidence’ is recorded.

5.2.31 Removal of non-target species

The definition used for the pressure ‘removal of non-target species’ is problematic. The pressure addresses only the biological effects of removal of species and not the effects of the removal process on the species, community, or habitat itself, which results in confusion. In other words, the assessment examines the likely effect on the community or species population if one or more species that contribute to sensitivity are removed, but not the effects of the ‘act of removal’.

In general, the removal of species may result in changes to the biological structure (species richness and diversity) and, where extreme, may lead to a change to another biotope. The direct impact is captured through the physical damage pressures, as those assessments are based on the likelihood of characterizing species being killed or damaged within the direct footprint of the pressure. To avoid direct duplication of the physical damage assessments, the pressure benchmark for the ‘removal of non-target species’ is interpreted as specifically referring to the ecological effects arising from the removal of species that are not directly targeted by fisheries or other harvesting. The basis of the assessment is intended to provide a meaningful risk assessment of an aspect of human activities that is not captured through other pressures.

Therefore, the assessment firstly considers whether the species present in the biotope are likely to be removed based on their environmental position (rather than potential exposure to the activity). Secondly, the assessment considers whether this removal is likely to result in measurable effects on the biotope structure and function.

Biotopes that are sensitive to this pressure include those where the key elements of the feature (i.e. species that contribute to sensitivity) are likely to be removed as ‘by-catch’. For example:

- biogenic habitats that are created by species that may be removed by fishing activities, e.g. maerl beds and *Sabellaria* reefs;
- habitats where the physical structure is created by plants and animals, e.g. hard substrata that are dominated by plant and animal assemblages such as macroalgae, sea fans and erect sponges, and the biotope is considered sensitive to their removal due to changes in biological structure (species richness and diversity) and physical structure (degree of habitat complexity); and
- benthic biotopes where ecosystem engineers may strongly determine the rate of some ecological processes e.g. dense aggregations of Arenicola marina alter sediment properties and influence the species assemblage, and removal of A. marina is considered likely to alter biotope function.

Where species are key characterizing species, for example named in the biotope description or identified as important by the biotope description and have been identified as likely to be removed or displaced as by-catch, this is also noted and the biotope assessed as sensitive. In many instances, species that are likely to be removed as by-catch are epifauna or epiflora that also create much of the physical structure of benthic biotopes e.g. macroalgae, sea fans and erect sponges.

An assessment of ‘Not relevant’ does not mean that the species present are unimportant in terms of ecosystem processes and functions. Nor does ‘Not relevant’ mean that commercial harvesting activities will not remove or damage species that are present within the biotope. The MarESA sensitivity assessments have used ‘Not relevant’ where biotopes are characterized by the absence of a biological assemblage or where communities are unlikely to be targeted by any commercial or recreational fishery or harvest. These two criteria frequently overlap. For example, biotopes for which this pressure has been assessed as ‘Not relevant’ include ‘Barren and/or boulder-scoured littoral cave walls and floors’, and ‘Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock’.

It is strongly advised that the physical damage pressures should be consulted alongside the removal of non-target species pressure to identify the sensitivity of biotopes to physical damage resulting from these activities.

5.2.32 Removal of target species

As above, this pressure addresses the direct effect of removal of characterizing species on biotope classification and the ecological effects of removal of target species. The assessment does not consider the direct physical pressures resulting from the removal process (such as abrasion and penetration of the sediment) on the species, community, or habitat itself, which results in confusion. For example, the removal of sea urchin predators from kelp beds may impact kelp bed dynamics by allowing a proliferation of grazing urchins; and removal of limpets or other gastropod grazers may facilitate habitat conversion to fucoid and barnacle dominated communities.

The removal of a target species may result in biotope reclassification where the biotope would not be recognised without the targeted species. For example, the targeted harvesting and removal of cockles from the biotope *Cerastoderma edule* and polychaetes in littoral muddy sand biotope by targeted harvesting would alter the character of the biotope and result in reclassification. Similarly, the removal of mussels from mussel beds and kelp from kelp beds would lead to the loss of the biotope. Therefore, if commercial harvesting (or intensive recreational harvesting) targets a species that contributes to the sensitivity of the habitat (biotope), the habitat (biotope) is judged sensitive to this pressure (Tillin & Tyler-Walters, 2014a, b; Gibb *et al.*, 2014; Mainwaring *et al.*, 2014; and d'Avack *et al.*, 2014).

In the absence of direct evidence, and where no species traits suggest otherwise, resistance of the species population to removal when targeted should be 'Low' by default. Resistance of populations that are harvested in entirety, e.g. clear cutting of seaweeds, is considered 'None'. Where a species is cryptic, highly mobile, or difficult to catch for other reasons then adjust the resistance accordingly.

Where the species targeted by fisheries does not characterize the biotope the ecological effects of removal may be limited, but the physical damage from the fishing/harvesting may have significant consequences. For example, a targeted fishery that removes scallops from a horse mussel bed or maerl bed is unlikely to affect the ecological structure or function of the bed, but the resultant physical damage may be significant. The beds are sensitive to the physical damage. The user is made aware of the likelihood of physical damage and directed to the relevant pressure assessment.

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6 Limitations and assumptions

The systematic assessment of sensitivity requires a set of standard terms and definitions, and makes a number of assumptions, as explained in section 2. It is not possible to address every possible site-specific pressure / feature combination in the process. Therefore, the assumptions and limitations inherent in the process need to be considered when the resultant resistance, resilience, and sensitivity assessments are applied in site management or marine planning.

- The sensitivity assessments are generic and NOT site-specific. They are based on the likely effects of a pressure on a ‘hypothetical’ population in the middle of its ‘environmental range’.
- Sensitivity assessments are NOT absolute values but are relative to the magnitude, extent, duration, and frequency of the pressure effecting the species or community and habitat in question; thus, the assessment scores are very dependent on the pressure benchmark levels used.
- Sensitivity assessments presented are general assessments that indicate the likely effects of a given pressure (likely to arise from one or more activities) on species or habitats of conservation interest;
- The assessments are based on the magnitude and duration of pressures (where specified) but do not take account of spatial or temporal scale;
- There are limitations in the scientific evidence for the biology of features and their responses to environmental pressures, on which the sensitivity assessments have been based;
- The sensitivity assessment methodology takes account of both resistance and resilience (recovery). Recovery pre-supposes that the pressure has been alleviated, but this will generally only be the case where management measures are implemented;
- Recovery is assumed to have occurred if a species population and/or habitat returns to a state that existed prior to the impact of a given pressure, not to some hypothetical pristine condition;
- Furthermore, sensitivity assessments assume recovery to a ‘recognisable’ habitat or similar population of species, rather than presuming recovery of all species in the community and/or total recovery to prior biodiversity;

- Generally, where resistance is ‘Low’, the need for management measures should be considered, irrespective of the overall sensitivity assessment (for example, even where resilience is assumed to be ‘High); and
- A rank of ‘Not sensitive’ does not mean that no impact is possible from a particular ‘pressure vs. feature’ combination, only that a limited impact was judged to be likely at the specified level of the benchmark.

In line with the precautionary principle, a lack of scientific certainty should not, on its own, be a sufficient reason for not implementing management measures or other action.

Nevertheless, **the resultant 'evidence' is the ultimate source of information for the application of the sensitivity assessments to management and planning decisions**. The significance of impacts arising from pressures also needs to take account of the scale of the features. Users must always consult the evidence provided to determine the applicability of the sensitivity assessments to the site-specific effects or management issues in question.

Where necessary, expert judgement and marine expertise should be used to interpret the evidence relevant to the activities and, hence, pressures present in the site, protected area, or region.

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Zacharias, M.A. & Gregr, E.J., 2005. Sensitivity and vulnerability in marine environments: an approach to identifying vulnerable marine areas. *Conservation Biology*, **19** (1), 86-97. DOI 10.1111/j.1523-1739.2005.00148.x

Appendix 1. Summary table of search terms for each pressure

Note - where species information is very limited, just species name searches are required. Otherwise, 'Xx' refers to the species, habitat, or feature name.

Pressure theme	Pressure	Revised benchmark	Search terms
Hydrological changes (inshore/local)	Emergence regime changes - local, including tidal level change considerations	A change in the time covered or not covered by the sea for a period of ≥ 1 year. OR An increase in relative sea level or decrease in high water level for ≥ 1 year.	Xx + aerial exposure Xx + desiccation Xx + sea level change
	Salinity changes – local, increase	An increase in one MNCR salinity category above the usual range of the biotope/habitat.	Xx + salinity Xx + barrages (e.g. Oosterschelde), Xx + desalination, Xx + run-off Xx + brine discharge
	Salinity changes – local, decrease	A decrease in one MNCR salinity category below the usual range of the biotope/habitat.	Xx + floods/ flood runoff

Pressure theme	Pressure	Revised benchmark	Search terms
	Temperature changes - local	A 5°C increase or decrease in temperature for one month period, or 2°C for one year	Xx + thermal Xx + temperature Xx + Thermal effluents, Xx + thermal tolerances, Xx + biogeography Xx + climate Xx + species range limit
	Water flow (tidal current) changes - local, including sediment transport considerations	A change in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than 1 year	Xx + channelization Xx + channelization Xx + transport Xx + flow Xx + flow/current velocity
	Wave exposure changes - local	A change in nearshore significant wave height >3% but <5%	Barrages (e.g. Oosterschelde), channelization, artificial structures Xx + wave height Xx + wave action

Pressure theme	Pressure	Revised benchmark	Search terms
Physical damage (Reversible Change)	Changes in suspended solids (water clarity)	A change in one rank on the WFD (Water Framework Directive) scale e.g. from clear to intermediate for one year.	Xx + turbidity, Xx + clarity, Xx + suspended solids/sediments, Xx + seston Xx + light attenuation Xx + shading
	Habitat structure changes - removal of substratum (extraction)	Extraction of substratum to 30cm (where substratum includes sediments and soft rocks but excludes hard bedrock)	Aggregate extraction, capital dredging, ports & harbours, coastal defences, marine renewables, offshore infrastructure (oil, gas etc.), spoil dumping, capital/maintenance dredging. Search for depth of burial etc. for characterizing species.
	Abrasion/disturbance of the substratum on the surface of the seabed	Damage to seabed surface features (species and habitats)	Fisheries, shellfisheries, aggregate extraction, capital, and maintenance dredging. Also, key word

Pressure theme	Pressure	Revised benchmark	Search terms
	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	Damage to sub-surface seabed.	searches for species/ecological groups: 'Xx' + abrasion, 'Xx' + fishing, 'Xx' + trawling, 'Xx' + disturbance, 'Xx' + by-catch Suction dredging Dragging Anchoring, mooring Trampling
	Smothering and siltation changes (depth of vertical sediment overburden)	'Light' deposition of up to 5 cm of fine material added to the seabed in a single, discrete event	Severe weather, flood runoff, aggregate dredging, coastal quarrying (tailings), spoil dumping (waste), capital/maintenance dredging, fishing (hydraulic dredging), Also, key word searches for species/ecological groups: 'Xx' + siltation, 'Xx' + burial, 'Xx' + overburden, + smothering

Pressure theme	Pressure	Revised benchmark	Search terms
		'Heavy' deposition of up to 30 cm of fine material added to the seabed in a single discrete event	Xx + siltation, Xx + burial, Xx + overburden, Xx + dredge Xx + spoil Xx + deposition
Physical loss (Permanent Change)	Physical change (to another seabed type)	Change in 1 Folk class (based on UK SeaMap simplified classification)	
		Change from sedimentary or soft rock substrata to hard rock or artificial substrata	
	Physical loss (to land or freshwater habitat)	Permanent loss of existing saline habitat within site	
Physical pressure (other)	Barrier to species movement	Permanent or temporary barrier to species movement ≥50% of water body width or a 10% change in tidal excursion	Relevant to planktonic larvae/seeds/ etc.
	Electromagnetic changes	Local electric field of 1V m-1. Local magnetic field of 10µT	Xx + magnetic Xx + electromagnetic Xx + electric

Pressure theme	Pressure	Revised benchmark	Search terms
			Xx + emf
	Death or injury by collision	Benthic species: 0.1% of tidal volume on average tide, passing through artificial structure	Relevant to mobile or migratory species. E.g., Xx + migration Xx + nursery Xx + feeding grounds
	Introduction of light	Change in incident light via anthropogenic means	Xx +light Xx + photosynthesis Xx +shade
	Litter	Introduction of human-made objects able to cause physical harm (surface, water column, sea floor and/or strandline)	
	Noise changes	Underwater noise: MSFD indicator levels (SEL or peak SPL) exceeded for 20% of days in calendar year	
	Vibration	Fish/Birds/Mammals: Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features	
	Visual disturbance	Benthic species/Fish/Birds: daily duration of transient visual cues exceeds 10% of	

Pressure theme	Pressure	Revised benchmark	Search terms
		the period of site occupancy by the feature	
Pollution and other chemical changes	Organic enrichment	A deposit of 100gC/m2/yr.	XX + enrichment Xx + organic Xx + sewage Xx +aquaculture Xx +AMBI Xx +BOD
	De-oxygenation	Benthic species/habitat: Exposure to dissolved oxygen concentration of less than or equal to 2mg/l for 1 week (a change from WFD poor status to bad status)	Xx + Deoxygenation, Xx + hypoxia Xx + anoxia Xx + sewage XX + agricultural effluents,
	Introduction of other substances (solid, liquid or gas)	None proposed	Xx + Barium /barite

Pressure theme	Pressure	Revised benchmark	Search terms
	Nutrient enrichment	A decrease in the one rank of nutrient status of a water body (as defined by WFD), that is, from High to Good, Good to Moderate, Moderate to Poor for a period of a year	Xx + nutrient load
	Hydrocarbon & PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Based on 'weight of evidence' assessment	Subject to REA
	Radionuclide contamination	An increase in 10µGy/h above background levels	Xx + radiation Xx + radionuclides Xx + radioactivity Xx + mutation
	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Based on 'weight of evidence' assessment	Subject to REA

Pressure theme	Pressure	Revised benchmark	Search terms
	Transition elements & organo-metal (e.g. TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Based on ‘weight of evidence’ assessment	Subject to REA
Biological pressures	Genetic modification & translocation of indigenous species	Translocation of indigenous species and/or introduction of genetically modified or genetically different populations of indigenous species that may result in changes in genetic structure of local populations, hybridization, or change in community structure.	Xx + genetic diversity Xx + genetic variation
	Introduction of microbial pathogens	The introduction of relevant microbial pathogens or metazoan disease vectors to an area where they are currently not present (e.g. Martelia refringens and Bonamia, Avian influenza virus, viral Haemorrhagic Septicaemia virus)	Xx + pathogens Xx + disease Xx + mortality

Pressure theme	Pressure	Revised benchmark	Search terms
	Introduction or spread of non-indigenous species (INIS)	The introduction of one of more invasive non-indigenous species (INIS)	For each biotope, search 'characterizing species' + non-native species listed in Appendix 5. Xx + alien Xx + non-native Xx + invasive
	Removal of non-target species	Removal of features or incidental non-targeted catch (by-catch) through targeted fishery, shellfishery or harvesting at a commercial or recreational scale	Pressure benchmark largely relates to ecological effects ramifying from removal of host/keystone/ecosystem engineer species, relevant information found through general ecology searches for each ecological group
	Removal of target species	Benthic species and habitats: removal of species targeted by fishery, shellfishery or harvesting at a commercial or recreational scale	Pressure relates to target species- any commercially harvested species in ecological groups will be identified

Appendix 2. Guidance on MarLIN writing style, format, and syntax

The MarLIN website and sensitivity reviews (MarESA reviews) form a consistent body of text. Therefore, the following guidelines are followed to ensure consistency in use of terms and their syntax throughout the site.

The sensitivity assessments aim to 'support marine environmental management, protection and education'. Therefore, they target the information required to achieve that aim. The reviews are designed to be read by a wide audience, from environmental managers and statutory agency staff to marine scientists and members of the public. Therefore, the writing style should be concise, yet accurate and the text kept to a minimum.

It should be remembered that many environmental and coastal managers who may use this information are not marine biologists, may know little about the species or biotopes, and may not understand the pressures and pressure benchmarks. Therefore, technical jargon where unavoidable must be explained. Spell out the basis of the assessments outlining any caveats, assumptions etc. Sensitivity reviews will, once refereed and updated, be cited as peer reviewed publications.

Detailed aspects are covered under the house-style guidelines (below).

A2.1. Time constraints for sensitivity reviews

The following timescale is relevant to the 'short reviews' that aimed to update existing MarLIN sensitivities using MarESA. The biotope group reviews have been allocated four days (from literature review (LR)) to completed sensitivity assessment) with 0.5 day allocated for Quality Assessment (QA). However, the level of information that needs to be collated and read varies between biotope groups. Some groups comprise more biotopes than others and the level of new information available will vary. Therefore, the following guidelines are given to minimize data research time.

Short	2 days LR, 3 days update/assessment, 0.5d QA, 0.5-day revisions
Medium	3 days LR, 3 days update/assessment, 0.5d QA, 0.5-day revisions
Long	6 days LR, 6 days update/assessments, 1 d QA, 1-day revisions

A2.2. Writing style

MarLIN species and habitat (biotope) information reviews should be written in the style of scientific reports or reviews.

- Text should be concise and as short as possible without losing detail. Aim to guide the reader through the evidence and assessments i.e. do not provide dense blocks of evidence with no structure or conclusions.
- Use plain English wherever possible and keep technical terminology and jargon to a minimum, although some technical terms are unavoidable.
- Use terms that we can reasonably expect users with some training in the environmental science to understand but explain particularly specialist terms e.g. those that refer only to some taxonomic groups, or disciplines.
- Where necessary scientific terms should be added to the relevant glossary or MarLIN glossary.
- Write in the 'past tense', that is, 'experiment X was done' or 'species Y was found to be affected by pressure B'.
- Where a biotope or species has been poorly studied, only readily available information should be used. Information that cannot be obtained within <3 days should be ignored in the draft review and not subject to further research. Our referees or outside experts may add relevant material in due course.

A2.3. Guidance on writing style, scientific terminology, and correct English

Standard scientific terms are listed in our on-line glossary of terms and the references cited therein. The following key texts are used for standard scientific terms:

Lincoln, R., Boxshall, G. & Clark, P., 1998. *A dictionary of ecology, evolution, and systematics* (2nd ed.). Cambridge: Cambridge University of Press.

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

Stachowitsch, M., 1992. *The invertebrates: an illustrated glossary.* Chichester: John Wiley & Sons, Inc.

The following standard texts are used texts provide guidance on correct English Usage, grammar, and spelling:

Ritter, R.M., 2014. *New Oxford Dictionary for Writers and Editors*: Oxford University Press.

Isaacs, A., Daintith, J. & Martin, E. (ed.), **1991.** *The Oxford Dictionary for Scientific Writers and Editors*. Oxford: Clarendon Press.

The Economist, 2010. *The Economist Style Guide*, 10^{th} edn. London: Profile books Ltd.

OED (Oxford English Dictionary), 1990. *The Shorter Oxford English Dictionary.* Oxford: Clarendon Press.

Note: Do not refer to Webster's dictionary for English spelling or grammar; it is American. The ‘Collins’ is abridged, more colloquial and to be avoided.

A3.4. Species names

We use WoRMS (www.marinespecies.org) as the definitive taxonomic list. The current website is linked to WoRMS for its taxonomy. Therefore, please use the current accepted taxonomic name in the text.

However, occasionally it is necessary to indicate the species described or examined in the study referred to in the text. This is especially true where the taxonomy has changed, species split or combined, or the taxonomy is still confused. Therefore, you would write:

“*Saccharina latissima* (studied as *Laminaria saccharina*) was found to…”

Where the species taxonomy is confused, it is sometimes easier to refer to “sp. (spp. plural)” or ‘agg.’, e.g., ‘*Capitella* spp.’ or ‘*Capitella* agg.’

Syntax rules for species names

All species names are written in full, italicized, and are converted to hyperlinks in the first instance **within a field**. This is an automated process, run by the web developer at intervals. Species names should appear as follow:

- species names are used in full, e.g. Littorina littorea NOT L. littorea, although Littorina spp. is acceptable where relevant;
- species are referred to in the singular unless specifically referring to groups of individuals i.e. Echinus esculentus is…rather than are…;

- note that all scientific names are italicized (they vary between Latin and Greek in origin) to make them stand out from the text, however, if the text is italicized (e.g. in a heading) then the scientific name is not italicized;
- note also that the 'genus', 'species' and 'subspecies' names are italicized but not the taxonomic units, nor are terms like 'var.', 'ecad.', 'indet.', 'sp.', and 'spp.' etc.; and
- for taxonomic units – the proper name takes a capital, but the colloquial version does not. For example, 'Bryozoa' vs. 'bryozoans'; 'Phylum Amphibia' vs. 'amphibians', and so on. Equally the terms 'Phylum', 'Class' and 'Order' etc. are proper nouns in this context.

A2.5. Common (vernacular) names

Species and habitats have a variety of colloquial or 'common' or 'vernacular' names. We on only use common names that are or have been in use in the British Isles. We do not include Gaelic or Welsh counterparts as we do not have the expertise to do so. We try not to use common names from overseas, e.g., the Americas or Europe, but we may include them on the website for information.

Common names **are only included** if listed in published sources that can be cited. Most information on common names comes from the ID guides or taxonomic guides (printed or online). In recent years (2010 onwards) there have been several attempts to create 'common' names to raise awareness of species in need of conservation. In addition, several authors of ID guides have created new 'common' names based on the species specific 'Latin' names (in most cases). Recent 'common' names are acceptable if they are in print in a cited source and 'make sense' from the Latin name.

We can include multiple common names in the database but label species on the website using a 'preferred' name. Preference is given to names presently in use in the British Isles wherever possible. In addition, we try not to use the same common name from more than one species so may 'prefer' to use an alternative common name on the website to distinguish the species, unless no alternative exists.

Published sources for common or vernacular names include:

Bunker, F., Brodie, J., Maggs, C. & Bunker, A., 2017. *Seasearch Guide to Seaweeds of Britain and Ireland (Second edition).* Marine Conservation Society, Ross-on-Wye.

Campbell, A., 1994. *Seashores and shallow seas of Britain and Europe*. London: Hamlyn.

FishBase, 2000. *FishBase. A global information system on fishes*. [On-line] http://www.fishbase.org, 2001-05-03

Guiry, M.D. & Guiry, G.M. 2015. AlgaeBase [Online], *National University of Ireland, Galway* [cited 30/6/2015]. Available from: http://www.algaebase.org/

Hayward, P., Nelson-Smith, T. & Shields, C. 1996. *Collins pocket guide. Sea shore of Britain and northern Europe.* London: HarperCollins.

OBIS (Ocean Biogeographic Information System), 2021. Global map of species distribution using gridded data. Available from: *Ocean Biogeographic Information System*. www.iobis.org. Accessed: 2021-09-30

Porter, J., 2012. *Seasearch Guide to Bryozoans and Hydroids of Britain and Ireland.* Ross-on-Wye: Marine Conservation Society.

Tebble, N., 1976. *British Bivalve Seashells. A Handbook for Identification, 2nd ed*. Edinburgh: British Museum (Natural History), Her Majesty's Stationary Office.

Wood, C., 2005. *Seasearch Guide to Sea Anemones and Corals of Britain and Ireland.* Marine Conservation Society, Ross-on-Wye.

Wood, C., 2009. *Seasearch Observer's Guide to Marine Life of Britain and Ireland*. Ross-on-Wye: Seasearch.

WoRMS, 2015. *World Register of Marine Species*. (11/04/2007). http://www.marinespecies.org

Note on use of WoRMS. WoRMS collates a range of vernacular names from various sources. Ideally the source of the vernacular name should be checked for relevance to British and Irish waters and the original source cited.

Note that common names ‘do not take a capital’ unless they are at the beginning of a sentence OR the common name includes a proper noun. For example, ‘oarweed’, ‘dabberlocks’, or ‘Montagu’s blenny’.

However, many groups of organisms, e.g., hydroids, sea anemones, brittlestars etc. have colloquial terms. Many of these terms are written slightly differently, depending on the editorial style in use.

The list that follows details how to express these terms consistently. For example, we write ‘brittlestar’, not ‘brittle star’ or ‘brittle-star’.

- An acorn barnacle

- An amphipod
- A bivalve mollusc
- A brachiopod
- A branching sponge
- A bristleworm
- A brittlestar
- A brown seaweed
- A burrowing mud shrimp
- A burrowing sea anemone
- A catworm
- A chiton
- A cockle
- A cold-water coral
- A colonial sea squirt
- A crab
- A cushion star
- A fanworm
- An encrusting bryozoan
- An erect bryozoan
- An encrusting coralline alga
- A gammarid shrimp
- A gastropod
- A green seaweed
- A green seaweed
- A heart urchin
- A hermit crab
- A horseshoe worm
- A hydroid
- An isopod
- A kelp
- A lichen
- A mantis shrimp
- An oligochaete
- A nut crab

- A nut shell
- A pseudoscorpion
- A razor shell
- A red seaweed
- A sand hopper
- A sand shrimp
- A sea anemone
- A sea fan
- Seagrass
- A sea mat
- A sea pen
- A sea slater
- A sea slug
- A sea squirt
- A sludge-worm
- A sponge
- A spoon worm
- A starfish
- A tube anemone
- A tubeworm

A2.6. Common spelling and syntax errors

The use of '-ize' over '-ise' is equivocal. Some words take either while others take only one form. US English uses more ‘ize’ than British English. But British English uses ‘ise’ for some words and ‘ize’ for others. For example, 'character**istic**', 'character**ize**' and 'character**izing**', 'colon**ize**', 'colon**ization**', are correct. Util**ize**, mobil**ize**, ferti**lize** and ferti**lization** are correct, while recog**nize** and recog**nise** are both correct. If in doubt, check the ‘Oxford English Dictionary’, the ‘New Oxford Dictionary for Writers and Editors’, ‘the Oxford Dictionary for Writers and Editors’, or the ‘Economist Style guide’.

For consistency, use the following spelling:

- characterize;
- characterization;
- colonization;

- colonize;
- fertilization;
- fertilize;
- mobilize;
- recognize; and
- utilize.

As a rule of thumb use ‘ize’ for the technical terms where they are correct but default to ‘ise’ for plain English, with the exceptions above.

Words that must always be ‘ise’ include:

- advise;
- comprise;
- compromise;
- revise, etc.

Common typos and syntax

The following words and phrases are commonly mis-spelt or mis-typed or can be written in several forms depending on local editorial guidelines. The following corrections follow OED and/or ‘Economist style’ writing guidance.

Short term = **short-term**
Long term = **long-term**
One off = **one-off**
Compass points written as ‘**south-east**’, ‘**south-eastern**’.
Sea water, sea-water = **seawater**
Fresh water, fresh-water = **freshwater**
Free living =**free-living**
Out compete, outcompete = **out-compete**
Life span, life-span = **lifespan**
Life time, life-time = **lifetime**
Back wash, back-wash = **backwash**
Where as = **whereas**
Wide spread and widespread = **wide-spread**
Macro algae, macro-algae = **macroalgae**
Shore bird, shore-bird = **shorebird**

Other issues

The names of ships and other sea going vessels should be italicised, e.g*. Torrey Canyon, Sea Empress, Exxon Valdez*.

Compound vowels should be used (**ae, oe**), e.g. **foetus, amoeba, aeon** etc. The simplified form is American.

Other British/American-English differences – we use British:

- defence (Brit.) / defense (Amer.)
- a licence (Brit.) / license (Amer.) – but note 'to license' i.e. 'to provide a licence' is correct.
- analogue (Brit.) /analog (Amer.)
- catalogue (Brit.) / catalog (Amer)
- and we use 'ou' not 'o' as in 'colour', behaviour', flavour, etc.

Abbreviations are followed by a stop ('.') while contractions are not. Therefore '*et alii'* becomes 'et al.', '*exampli gratia'* becomes e.g., and 'circa' becomes 'ca'.

As above, all Latin terms are italicized, for example '*et al.*', and species names, except where the Latin term is commonplace, for example 'e.g.', 'etc.'. The Economist Style Guide lists the exceptions. Lincoln *et al.* (1998) lists Latin terms and their abbreviations.

One exception is where the surrounding text is italicised in which case the Latin term is not. The reason for italicization is to make their names stand out from the text.

The names of metals are common nouns and do not take a capital except at the beginning of a sentence, for example copper, zinc (NOT Copper, Zinc). Their abbreviations use a mixture of capitals and lower-case letters, e.g. Cu, Zn, Pb etc. Consult the periodic table for correct abbreviations as they are not always based on the English names, e.g. lead and Pb (*plumbum*) and tungsten and W (*wolfram*).

The names of chemical compounds are complex and often have several synonyms. They should be used as common nouns and only capitalized at the start of a sentence. Wherever possible use the shortest version of their name if it is accurate. We use PubChem (https://pubchem.ncbi.nlm.nih.gov/) as our definitive source of chemical names.

Chemical propriety names are often simpler to use in the text, especially online. They are proper names and take a capital. But use them with care as the same propriety name may be given for more than one chemical compound or chemical formulation. If in doubt, use the same name as the original paper quoted and put the full chemical name in brackets if space allows.

Ecotoxicology and physiological experiments often quote 'endpoints' such as 'LC_{XX}– Lethal concentration at XX percentile'. These are correctly written with the percentile as a subscript as so 'LC_{50}'. However, we do not use the subscript in this case as it affects the line spacing online and may be confusing for users with reading difficulties. Use 'LC50', 'LT50', 'EC90' etc.

A2.7. Syntax rules for units

- The correct syntax for degrees Centigrade is ‘10°C’ not ’10 °C’.
- The correct syntax for 'per litre' or 'per min' or 'per year' are '/l' or '/min' or '/year'. While 'l-1' is technically correct, the readership may not easily understand the term and the prior syntax is easier to use and to read online.
- The correct syntax for units is ‘10 mm’ not ‘10mm’, i.e. there should be a space between the numerical value and the unit abbreviation. If talking about units in the text, the unit should be spelled out, e.g. "Jones (1999) measured the length in millimetres".

A2.8. References (citation)

All material and all sources used are cited in the text and referenced in the final review. MarLIN biology and sensitivity key information reviews use the Harvard (Author-Date) System as amended by the Journal of the Marine Biological Association house-style. A detailed description of the Harvard (Author-Date) System is provided by the Oxford Dictionary for Scientific Writers and Editors (Isaacs *et al.,* 1991).

In text citations - references are cited in the text in short form:

- single author (Jones, 1999);
- two authors (Jones & Smith, 2000);
- multiple authors (Jones et al., 2001); or
- multiple works by the same author in the same year Moore (1973a) or Moore (1973a, b);

Exceptions

- Please note the use of et al. (italicised), ampersand instead of ‘and’ and the comma followed by space between last author and date.
- Where the authors name occurs naturally in the sentence only the year is in brackets, e.g. ‘as Jones (1998) suggested…’
- When including a list of references, place them in chronological order and separate each by a semicolon, for example (Moore, 1973a, b; Jacobs, 1985; Callow et al., 1990; Jones & Smith, 2000).
- When citing a report/document produced by an organization, where no author is given, use the abbreviated form of the organisation name e.g. (UNEP, 1995) but

include the full name in the full reference e.g. 'UNEP (United Nations Environment Programme), 1995'.

- When referring to what was done, the experimental evidence, methodology and findings in a paper, use the past tense e.g.,
  Tyler & Young (1999) concluded……
  Jones (2000) demonstrated…….
- When referring to affirmations and statements use the present tense e.g.,
  Jones (2000) states……

A2.9. References styles

The following MarLIN reference styles were based on the Journal of the Marine Biological Association of the UK style (pre-2010), with slight modifications and have evolved slightly since. The MarLIN house-style is available for Endnote. Guidance on Endnote data entry and the MarLIN CMS Import tool is included in Annex 1 to this report.

Book

Barnes, R.D., 1987. *Invertebrate Zoology*, 5th edition. Philadelphia: Saunders College Publishing.

Steers, J.A., 1969. *The coastline of England and Wales*. Cambridge: Cambridge University Press.

Book chapters

Hall-Spencer, J.M. & Moore, P.G., 2000. Impact of scallop dredging on maerl grounds. In Kaiser, M.J. and De Groot, S.J. (eds.). *Effects of fishing on non-target species and habitats*. Oxford: Blackwell Science Limited, pp. 105-117.

Hiscock, K., 1985. Aspects of the ecology of rocky sublittoral areas. In Moore, P.G. and Seed, R. (eds.). *The ecology of rocky coasts: essays presented to J.R. Lewis D.Sc*, London: Hodder and Stoughton, pp. 290-328.

Conferences proceedings

Blunden, G., Farnham, W.F., Jephson, N., Barwell, C.J., Fenn, R.H. & Plunkett, B.A., 1981. The composition of maerl beds of economic interest in northern Brittany, Cornwall, and Ireland. In Gruyter, W.d, *Proceedings of the Xth International Seaweed Symposium*, Goteborg, 11-15 August 1980, pp. 651-656.

Pauly, D., 2002. Growth and mortality of the basking shark *Cetorhinus maximus* and their implications for management of the whale shark *Rhicodon typus*. *Elasmobranch biodiversity, conservation, and management: Proceedings of the international seminar and workshop*, *IUCN SSC Shark Specialist Group Gland*, *Switzerland & Cambridge UK.*, Sabah, Malaysia, 1997, pp. 199-208.

Journal

Rees, S.E., Attrill, M.J., Austen, M.C., Mangi, S.C., Richards, J.P. & Rodwell, L.D., 2010a. Is there a win-win scenario for marine nature conservation? A case study of Lyme Bay, England. *Ocean and Coastal Management*, **53** (3), 135-145. DOI https://doi.org/10.1016/j.ocecoaman.2010.01.011

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Calosi, P., Rastrick, S.P.S., Lombardi, C., de Guzman, H.J., Davidson, L., Jahnke, M., Giangrande, A., Hardege, J.D., Schulze, A., Spicer, J.I. & Gambi, M.-C., 2013. Adaptation and acclimatization to ocean acidification in marine ectotherms: an in situ transplant experiment with polychaetes at a shallow CO2 vent system. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **368** (1627), 20120444. DOI https://doi.org/10.1098/rstb.2012.0444

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Note - the DOI should be included using the 'https://doi.org/....' prefix, which may need to be added in Endnote.

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d'Avack, E.A.S., Tillin, H., Jackson, E.L. & Tyler-Walters, H., 2014. Assessing the sensitivity of seagrass bed biotopes to pressures associated with marine activities. *Joint Nature Conservation Committee, Peterborough, JNCC Report No. 505,* 83 pp. Available from https://www.marlin.ac.uk/assets/pdf/Report_505_web.pdf

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Note – where possible include an URL to an online location; usually the publisher/organization of origin, and preferably persistent.

Electronic report – a variation of the 'report' template

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Dataset

This format is based on the GBIF (Global Biodiversity Information Facility) (international) citation format. There are no entries for datasets in our Endnote library yet. The Author is usually an organization, although some individuals release datasets.

Dorset Environmental Records Centre, 2018. Bryophyte Survey of the Poole Basin Mires - NBN South West Pilot Project Case Studies. Occurrence dataset: https://doi.org/10.15468/eklhxs accessed via GBIF.org on 2018-09-25.

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A2.10. Dutch Names

Dutch surnames in citations should be entered as:

- 'Van der Hoek' NOT 'van der Hoek' or 'Hoek, van der' and NOT 'Van Der Hoek'; or
- Den Hartog - NOT 'Hartog den' NOR 'den Hartog'

The only exception is in text when the first name precedes the surname - e.g., Thomas van der Hoek, but as full names are rarely used in text this is not an issue.

This should prevent the occurrence of duplicate references e.g., when ‘Den Hartog’ is listed under ‘den Hartog’ and ‘Hartog den’ in the bibliography.

Appendix 3. Notes for referees

Referees are asked to check the accuracy of the information presented in the Marine Evidence –based Sensitivity Assessment (MarESA) reviews and identify any omissions or ambiguities. Please pay particular attention to the assessment of resistance, resilience and hence sensitivity. The MarESA sensitivity assessments contribute to the current advice package developed by UK Statutory Nature Conservation Bodies (SCNBs). In addition, please indicate any missing information that would be important to the management, protection, and conservation of the species or biotope under review.

Please annotate the copy of the review provided with your changes and comments. Feel free to either comment on the PDF version or hard copy (printout). Please complete the relevant sections of the enclosed ‘referees report’ form.

From time-to-time, new information may become available, and we may update text or adjust sensitivity or recoverability ratings. If those changes are substantial or significant, we will consult you. Please let us know if you wish to be consulted whenever changes are made.

Sensitivity assessment

The MarESA reviews are designed to assess the potential effect of environmental disturbance from human activities or natural events on marine species and habitats (as biotopes). A summary of the methodology is available online (http://www.marlin.ac.uk/species/sensitivity_rationale) and attached for reference.

In short, sensitivity assessments examine the likely resistance (likelihood of damage) of a marine habitat or species population to a defined, standardised, change (the benchmark) in a defined range of pressures (likely to result from human activities or natural events) and their resilience or ability to recover from ‘damage’ resultant from that change. Resistance and resilience are combined to rank the habitat or species population by ‘sensitivity’ for each pressure. The full list of pressures is available online (http://www.marlin.ac.uk/habitats/SNCB-benchmarks) and attached for reference.

The confidence in each assessment is given in each case. Most importantly, the evidence used to make the assessment (of resistance, resilience and hence sensitivity) is provided, referenced, and the rationale for the final assessment explained in the supporting text.

Please note that the sensitivity assessments are not ‘absolute’ but relative to the benchmark level of change for each pressure. They are also generic, not site-specific and are based on a 'hypothetical' population in the middle of its range. The assumptions adopted, and limitations, are outlined in the methodology.

General notes

The following notes outline the Biology and Sensitivity Key Information programme of MarLIN and the resultant Biology and Sensitivity Key Information reviews of species and biotopes.

- The Key Information reviews are designed to support marine conservation, management, and planning;
- The reviews are NOT designed to be complete scientific monographs on the species or biotope concerned.
- The reviews are based on available scientific information, collated by the MarLIN team using the resources of the National Marine Biological Library at Plymouth.
- The reviews target the key information required to assess the sensitivity (resistance and resilience) of a species or biotope to environmental disturbance.
- The reviews use defined categories (key words or traits with associated on-line glossaries) to produce concise, targeted information.
- 'Additional information' is added where aspects of a species or biotope's ecology do not fit neatly within the defined categories. 'Additional information' is also used to clarify ambiguous material or to add key information that would be otherwise omitted.
- Although concise and key worded, the quality and accuracy of the information is paramount.
- All references used are cited in the text (using Harvard-Author date style) and listed in the associated bibliography at the bottom of each page. Note the bibliography may include general interest literature not specified in the text;
- Please note that the reviews are designed to be viewed on the website (www.marlin.ac.uk) rather than in print form.
- All specific terms used in the Key Information reviews are defined in pop-up glossaries. Additional scientific terms are defined in the MarLIN on-line general glossary. Copies of the glossaries can be provided in the absence of Internet access.

Page specific notes (presentation and syntax)

1. Spellings are consistent with the Oxford English Dictionary v2.0.

2. Species names are derived from the World Register of Marine Species (WoRMS). Note that due to a few recent taxonomic changes, the dataset text is in the process of being updated.
3. The UK Marine Habitat classification (Connor *et al.*, 1997; 2004; JNCC, 2015, 2022) and the European Nature Information System (EUNIS) codes are presented. Biotopes are referred to in the text by the UK classification code.
4. Habitat preferences are based on the UK Marine Habitat classification and MNCR database (Connor *et al.,* 1997; 2004). The distribution maps are based on a query supplied by the Seabed Habitats programme of EMODnet (http://www.emodnet-seabedhabitats.eu/) in liaison with the Joint Nature Conservation Committee (JNCC).

If there are any queries that are not addressed above, please do not hesitate to contact the Acting Editor (Dr Harvey Tyler-Walters; h.tylerwalters@mba.ac.uk).

Tel. +44 (0)1752 633355

Harvey Tyler-Walters - July 2017.

BIOLOGY AND SENSITIVITY KEY INFORMATION

Referees report

Referee: Date:

Species / biotope:

Please annotate the PDF or paper copy of the web pages with your changes. Please attach further comments on additional sheets if necessary.

Overall assessment

	Yes	No	Notes
1. Is the information as accurate as possible (acceptable)?	☐	☐	
2. Is the information acceptable with your changes?	☐	☐	
3. Does the research need to be undertaken again? (name required areas for re-assessment)	☐	☐	
4. Is there insufficient information (in your opinion) to complete this biotope or species research?	☐	☐	

If the research needs to be undertaken again (option 3), please indicate the specific areas that require attention and, if possible, suggest sources of further information.

Appendix 4. Pressure benchmarks for hydrographic, physical, chemical, and biological pressures agreed in 2014 (for information the MB0102 benchmarks and ICG-C descriptions are presented).

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
Hydrological changes (inshore/ local)	Emergence regime changes - local, including tidal level change considerations	*1) Intertidal species* and habitats not uniquely defined by intertidal zone): A 1 hour change in the time covered or not covered by the sea for a period of 1 year. *2) Habitats and landscapes defined by intertidal zone:* An increase in relative sea level or decrease in high water level of 1mm for one year over a	Changes in water levels reducing the intertidal zone (and the associated/dependant habitats). The pressure relates to changes in both the spatial area and duration that intertidal species are immersed and exposed during tidal cycles (the percentage of immersion is dependent on the position or height on the shore relative to the tide). The spatial and temporal extent of the pressure will be dependent on the causal activities but can be delineated. This relates to anthropogenic causes that may directly influence the temporal and spatial extent of tidal immersion, e.g. upstream and downstream of a tidal barrage the emergence would be respectively reduced and increased, beach re-profiling could change gradients and therefore exposure times, capital dredging may change the natural tidal range, managed realignment, salt marsh creation. Such alteration may be of importance in estuaries because of their influence on tidal flushing and potential wave propagation. Changes in tidal flushing can change the sediment dynamics and may lead to changing patterns of deposition and erosion. Changes in tidal levels will only affect the emergence regime in areas that are

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		shoreline length >1km.	inundated for only part of the time. The effects that tidal level changes may have on sediment transport are not restricted to these areas, so a large construction could significantly affect the tidal level at a deep site without changing the emergence regime. Such a change could still have a serious impact. This excludes pressure from sea level rise.
		Revised benchmark	**MBA Comment**
		A change in the time covered or not covered by the sea for a period of ≥ 1 year. OR An increase in relative sea level or decrease in high water level for ≥ 1 year.	The benchmark is only considered relevant to intertidal habitats when applied in sensitivity assessments and habitats restricted to below Chart Datum (CD) are considered ‘Not Sensitive’. The pressure benchmark does not expressly identify the role of ‘desiccation’ but sensitivity to desiccation will be discussed where known or relevant. In application, many intertidal communities are sensitive to changes in emergence, whether it is for one or more hours, or a due to changes in sea level and coastal squeeze. Therefore, the duration of the pressure is set a one year, based on the assumption that the effects on most communities would probably take a year to become apparent.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
Hydrological changes (inshore/ local)	Salinity changes - local	Increase from 35 to 38 units for one year. OR Decrease in Salinity by 4-10 units a year	Events or activities increasing or decreasing local salinity. This relates to anthropogenic sources/causes that have the potential to be controlled, e.g. freshwater discharges from pipelines that reduce salinity, or brine discharges from salt caverns washings that may increase salinity. This could also include hydromorphological modification, e.g. capital navigation dredging if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates. The pressure may be temporally and spatially delineated derived from the causal event/activity and local environment.
		Revised benchmark	MBA Comment
		A decrease / increase in one MNCR salinity category outside the usual range of the biotope/habitat for one year.	Assess increase and decrease in salinity separately.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
Hydrological changes (inshore/ local)	Temperature changes – local,	A 5°C change in temperature for one month period, or 2°C for one year	Events or activities increasing or decreasing local water temperature. This is most likely from thermal discharges, e.g. the release of cooling waters from power stations. This could also relate to temperature changes in the vicinity of operational subsea power cables. This pressure only applies within the thermal plume generated by the pressure source. It excludes temperature changes from global warming which will be at a regional scale (and as such are addressed under the climate change pressures).
		Revised benchmark	MBA Comment
		A 5°C change in temperature for one month period, or 2°C for one year	Assess increase and decrease separately.
Hydrological changes (inshore/ local)	Water flow (tidal current) changes - local, including sediment transport considerations	A change in peak mean spring tide flow speed of between 0.1m/s to 0.2m/s over an area > 1km2 or 50% if width of water body for	Changes in water movement associated with tidal streams (the rise and fall of the tide, riverine flows), prevailing winds and ocean currents. The pressure is therefore associated with activities that have the potential to modify hydrological energy flows, e.g. tidal energy generation devices remove (convert) energy and such pressures could be manifested leeward of the device, capital dredging may deepen and widen a channel and therefore decrease the water flow,

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		more than 1 year.	canalisation &/or structures may alter flow speed and direction; managed realignment (e.g. Wallasea, England). The pressure will be spatially delineated. The pressure extremes are a shift from a high to a low energy environment (or vice versa). The biota associated with these extremes will be markedly different as will the substratum, sediment supply/transport and associated seabed/ground elevation changes. The potential exists for profound changes (e.g. coastal erosion/deposition) to occur at long distances from the construction itself if an important sediment transport pathway was disrupted. As such these pressures could have multiple and complex impacts associated with them.
		Revised benchmark	**MBA Comment**
		A change in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than 1 year	Adopted SNCB amendment (removal of specified impact footprint).

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
Hydrological changes (inshore/ local)	Wave exposure changes - local	A change in near shore significant wave height >3% but <5%	Local changes in wavelength, height, and frequency. 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 winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages, wrecks that can directly influence wave action or activities that may locally affect the incidence of winds, e.g. a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline.
		Revised benchmark	MBA Comment
		A change in near shore significant wave height >3% but <5% for more than 1 year	Retain existing benchmark. Research correlation between significant wave height and wave exposure scales.
Physical damage (Reversible Change)	Changes in suspended solids (water clarity)	A change in one rank on the WFD (Water Framework Directive) scale e.g. from	Changes in water clarity from sediment & organic particulate matter concentrations. It is related to activities disturbing sediment and/or organic particulate matter and mobilising it into the water column. Could be 'natural' land run-off and riverine discharges or from anthropogenic activities such as all

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		clear to turbid for one year	forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed & direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. This pressure also relates to changes in turbidity from suspended solids of organic origin (as such it excludes sediments - see the "changes in suspended sediment" pressure type). Salinity, turbulence, pH, and temperature may result in flocculation of suspended organic matter. Anthropogenic sources mostly short lived and over relatively small spatial extents.
		Revised benchmark	**MBA Comment**
		A change in one rank on the WFD (Water Framework Directive) scale e.g. from clear to intermediate for one year	Changes in suspended sediment loads can also alter the scour experienced by species and habitats. Therefore, the effects of scour are also assessed as part of this pressure.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
Physical damage (Reversible Change)	Habitat structure changes - removal of substratum (extraction)	Extraction of sediment to 30 cm	Unlike the "physical change" pressure type where there is a permanent change in sea bed type (e.g. sand to gravel, sediment to a hard artificial substratum) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonize; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.
		Revised benchmark	MBA Comment
		Extraction of substratum to 30 cm (where substratum includes sediments and soft rocks but excludes hard bedrock)	Adopted SCNB benchmark revision, with amendment
Physical damage	Abrasion/	Damage to seabed	The disturbance of sediments where there is limited or no loss of substrata from the system. This pressure is associated with

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
(Reversible Change)	disturbance at the surface of the substratum	surface features	activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g. scallop dredging, beam trawling. Agitation dredging where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g. from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50cm depth). Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bioprospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonization remain suitable or relatively localized activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrata would adversely affect herring spawning grounds.
		Revised benchmark	**MBA Comment**
		Damage to surface	Physical disturbance or abrasion at the surface of the substratum in sedimentary or

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		features (e.g. species and physical structures within the habitat)	rocky habitats. The effects are relevant to epiflora and epifauna living on the surface of the substratum. In intertidal and sublittoral fringe habitats, surface abrasion is likely to result from recreational access and trampling (inc. climbing) by human or livestock, vehicular access, moorings (ropes, chains), activities that increase scour and grounding of vessels (deliberate or accidental). In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g. kelps) or other intertidal species (trampling) or of epifaunal species (e.g. oysters). In sublittoral habitats, passing bottom gear (e.g. rock hopper gear) may also cause surface abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with surface abrasion can cover relatively large spatial areas e.g. bottom trawls or bioprospecting or be relatively localized activities e.g. seaweed harvesting, recreation, potting, and aquaculture.
Physical damage	Penetration and/or disturbance of the substratum	MB0102 subdivided this pressure and used the	The disturbance of sediments where there is limited or no loss of substratum from the system. This pressure is associated with activities such as anchoring, taking of

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
(Reversible Change)	below the surface, including abrasion	following benchmarks. Damage to seabed surface and penetration ≤25mm Structural damage to seabed >25mm	sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g. scallop dredging, beam trawling. Agitation dredging, where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g. from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50cm depth). Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bioprospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonization remain suitable or relatively localized activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrata would adversely affect herring spawning grounds.
		Revised benchmark	**MBA Comment**
		Damage to sub-surface features (e.g.	Loss, removal, or modification of the substratum is not included within this pressure (see the physical loss pressure

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		species and physical structures within the habitat)	theme). Penetration and damage to the soft rock substrata are considered, however, the penetration into hard bedrock is deemed unlikely.
Physical damage (Reversible Change)	Smothering and siltation rate changes (depth of vertical sediment overburden)	Light - 5cm of fine material added to the seabed in a single event Heavy -up to 30cm of fine material added to the seabed in a single event	When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. This accumulation of sediments is synonymous with "light" smothering, which relates to the depth of vertical overburden. “Light” smothering relates to the deposition of layers of sediment on the seabed. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. For “light” smothering most benthic biota may be able to adapt, i.e. vertically migrate through the deposited sediment. “Heavy” smothering also relates to the deposition of layers of sediment on the

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. This accumulation of sediments relates to the depth of vertical overburden where the sediment type of the existing and deposited sediment has similar physical characteristics because, although most species of marine biota are unable to adapt, e.g. sessile organisms unable to make their way to the surface, a similar biota could, with time, re-establish. If the sediments were physically different this would fall under L2.
		Revised benchmark	MBA Comment
		'Light' deposition of up to 5 cm of fine material added to the habitat in a single, discrete event 'Heavy' deposition of up to 30 cm of fine material added to the habitat in a	'Light' and 'Heavy' deposition assessed separately

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		single discrete event	
Physical loss (Permanent Change)	Physical change (to another substratum type)	Change in 1 folk class for 2 years	The permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including to artificial (e.g. concrete). This therefore involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substratum habitats, removal of coarse substrata (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture i.e. mussel beds. Protection of pipes and cables using rock dumping and mattressing techniques. Placement of cuttings piles from oil & gas activities could fit this pressure type, however, there may be an additional pressure, e.g. "pollution and other chemical changes" theme. This pressure excludes navigation dredging where the depth of

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			sediment is changes locally but the sediment typology is not changed.
		Revised benchmark	**MBA Comment**
		Change in sediment type by 1 Folk class (based on UK SeaMap simplified classification). Change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa.	Tillin & Tyler-Walters (2014) did not consider the change in one Folk class benchmark applicable to hard rock biotopes but did assess the sensitivity of biotopes occurring on softer substrata, including chalk, peat, mud rock, and clay. The simplified Folk class referred to in the benchmark is based on the simplified classification used for UK SeaMap as described by Long (2006). The new benchmark (change from sediment to hard rock or vice versa) would affect all types of substrata, and all habitats would be assessed as highly sensitive. This pressure assumes a permanent change, while short term smothering of substrata with sediment is addressed under smothering (siltation).
Physical loss (Permanent Change)	Physical loss (to land or freshwater habitat)	Permanent loss of existing saline habitat	The permanent loss of marine habitats. Associated activities are land claim, new coastal defences that encroach on and move the Mean High Water Springs mark seawards, the footprint of a wind turbine on the seabed, dredging if it alters the position of the halocline. This excludes changes from

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			one marine habitat type to another marine habitat type.
		Revised benchmark	MBA Comment
		Permanent loss of existing saline habitat	No change.
Physical pressure (other)	Barrier to species movement	10% change in tidal excursion, or temporary barrier to species movement over ≥50% of water body width	The physical obstruction of species movements and including local movements (within & between roosting, breeding, feeding areas) and regional/global migrations (e.g. birds, eels, salmon, and whales). Both include up-river movements (where tidal barrages & devices or dams could obstruct movements) or movements across open waters (offshore wind farm, wave or tidal device arrays, mariculture infrastructure or fixed fishing gears). Species affected are mostly highly mobile birds, fish, and mammals.
		Revised benchmark	MBA Comment
		Permanent or temporary barrier to species movement ≥50% of water body width or	The pressure is clearly relevant to mobile species such as fish, birds, reptiles, and mammals. However, it should also be considered relevant to species or macrofauna such as crabs that undertake migrations to over-winter or to breed, and where populations are dependent on larval

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		a 10% change in tidal excursion	or other propagule supply from outside the site.
Physical pressure (other)	Electromagnetic changes	Local electric field of 1V m-1. Local magnetic field of 10µT	Localized electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). Such cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (e.g. sharks and rays).
		Revised benchmark	MBA Comment
		Local electric field of 1V m-1. Local magnetic field of 10µT	The evidence to assess these effects against the pressure benchmark is limited and the impact of this pressure could not be assessed for benthic species or habitats (Tillin & Tyler-Walters, 2014).
Physical pressure (other)	Death or injury by collision	0.1% of tidal volume on average tide, passing through artificial structure	Injury or mortality from collisions of biota with both static &/or moving structures. Examples include collision with rigs (e.g. birds) or screens in intake pipes (e.g. fish at power stations) (static) or collisions with wind turbine blades, fish & mammal collisions with tidal devices and shipping (moving). Activities increasing number of vessels transiting areas, e.g. new port development

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			or construction works will influence the scale and intensity of this pressure.
		Revised benchmark	MBA Comment
		0.1% of tidal volume on average tide, passing through artificial structure	The benthic species benchmark is only relevant to larvae. Collison with benthic habitats due to grounding by vessels is addressed under 'abrasion'.
Physical pressure (other)	Introduction of light	None proposed	Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24-hour working; new tourist facilities, e.g. promenade or pier lighting, lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth.
		Revised benchmark	MBA Comment
		Change in incident light via	The introduction of light is unlikely to be relevant for most benthic invertebrates, except where it is possible to interfere with spawning cues. But we are not aware of evidence to that effect. The introduction of

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		anthropogenic means.	light could potentially be beneficial for immersed plants, but again, we are not aware of any relevant evidence. Alternatively, shading (e.g. due to overgrowth, construction of jetties or other artificial structures) could adversely affect shallow sublittoral macroalgae, seagrass, and pondweeds.
Physical pressure (other)	Litter	None proposed	Marine litter is any manufactured or processed solid material from anthropogenic activities discarded, disposed, or abandoned (excluding legitimate disposal) once it enters the marine and coastal environment including plastics, metals, timber, rope, fishing gear etc. and their degraded components, e.g. microplastic particles. Ecological effects can be physical (smothering), biological (ingestion, including uptake of microplastics; entangling; physical damage; accumulation of chemicals) and/or chemical (leaching, contamination).
		Revised benchmark	MBA Comment
		Introduction of humman-made objects able to cause physical harm (surface, water column,	We are not aware of any evidence on the effects of 'litter' on benthic marine species. While there is documented evidence of the accumulation of micro-plastics in some species, no ecological effects have been shown to date. The only exception is the effect of ghost fishing on large crustaceans

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		sea floor and/or strandline)	(crabs etc.). Therefore, the sensitivity to litter was not assessed for habitats and was scored 'No evidence' by Tillin & Tyler-Walters (2014). It is relevant for large macrofauna such as fish, birds, and mammals.
Physical pressure (other)	Noise changes	Above water noise: None Underwater noise: MSFD indicator levels (SEL or peak SPL) exceeded for 20% of days in calendar year	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental human-made/anthropogenic noise (apparent)) at a particular location. Species known to be affected are marine mammals and fish. The theoretical zones of noise influence (Richardson *et al.* 1995) are temporary or permanent hearing loss, discomfort & injury; response; masking and detection. In extreme cases, noise pressures may lead to death. The physical or behavioural effects are dependent on a number of variables, including the sound pressure, loudness, sound exposure level, and frequency. High amplitude low and mid-frequency impulsive sounds and low frequency continuous sounds are of greatest concern for effects on marine mammals and fish. Some species may be responsive to the associated particle motion rather than the usual concept of noise. Noise propagation can be over large distances (tens of kilometres), but transmission losses can be attributable to factors such as water depth and seabed topography. Noise levels associated with

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			construction activities, such as pile-driving, are typically significantly greater than operational phases (i.e. shipping, operation of a wind farm).
		Revised benchmark	MBA Comment
		Above water noise: None Underwater noise: MSFD indicator levels (SEL or peak SPL) exceeded for 20% of days in calendar year	Underwater noise – description and benchmarks remain the same. NB: MSFD indicator (2010) states “the proportion of days within a calendar year, over areas of 15’N x 15’E/W in which anthropogenic sound sources exceed either of two levels, 183 dB re 1μPa2.s (i.e. measured as Sound Exposure Level, SEL) or 224 dB re 1μPa peak (i.e. measured as peak sound pressure level) when extrapolated to one metre, measured over the frequency band 10 Hz to 10 kHz”
Physical pressure (other)	Visual disturbance	None proposed	The disturbance of biota by anthropogenic activities, e.g. increased vessel movements, such as during construction phases for new infrastructure (bridges, cranes, port buildings etc.), increased personnel movements, increased tourism, increased vehicular movements on shore etc. disturbing bird roosting areas, seal haul out areas etc.
		Revised benchmark	MBA Comment

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		Daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature	Visual disturbance is only relevant to species that respond to visual cues, for hunting, behavioural responses, or predator avoidance, and that have the visual range to perceive cues at distance. It is particularly relevant to fish, birds, reptiles, and mammals that depend on sight but less relevant to benthic invertebrates. The cephalopods are an exception, but they are only likely to response to visual disturbance at close range (from e.g. divers). Sea horses are disturbed by photographic flash units but again at close range. It is unlikely to be relevant to habitat sensitivity assessments.
Pollution and other chemical changes	Organic enrichment	A deposit of $100gC/m^2/yr$	Resulting from the degraded remains of dead biota & microbiota (land & sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture, or terrestrial/agricultural runoff. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication (see also nutrient enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		Revised benchmark	MBA Comment
		A deposit of 100gC/m2/yr	Direct evidence on the effect of organic enrichment was used to make sensitivity assessments by Tillin & Tyler-Walters (2014). In the absence of direct evidence, reference was made to the AMBI index, supplemented by any other relevant evidence on the effects of organic enrichment on habitats.
Pollution and other chemical changes	De-oxygenation	MB0102 benchmark: compliance with WFD criteria for good status	Any deoxygenation that is not directly associated with nutrient or organic enrichment. The lowering, temporarily or more permanently, of oxygen levels in the water or substratum due to anthropogenic causes (some areas may naturally be deoxygenated due to stagnation of water masses, e.g. inner basins of fjords). This is typically associated with nutrient and organic enrichment, but it can also derive from the release of ballast water or other stagnant waters (where organic or nutrient enrichment may be absent). Ballast waters may be deliberately deoxygenated via treatment with inert gases to kill non-indigenous species.
		Revised benchmark	MBA Comment

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		Exposure to dissolved oxygen concentration of less than or equal to 2mg/l for 1 week (a change from WFD poor status to bad status).	There is considerable evidence on the effects on de-oxygenation in the marine environment due to ongoing work and reviews by Diaz & Rosenberg, among others. Therefore, adopt the MarLIN benchmark of a reduction in oxygen to ≤2mg/l for one week. The proposed benchmark would be based on the WFD status of 'poor' to 'bad' in marine waters and the 'action levels' for transitional waters (UKTAG, 2014).
Pollution and other chemical changes	Introduction of other substances (solid, liquid or gas)	Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls	The 'systematic or intentional release of liquids, gases …' (from MSFD Annex III Table 2) is being considered e.g. in relation to produced water from the oil industry. It should therefore be considered in parallel with P1, P2 and P3.
	Nutrient enrichment	Compliance with WFD criteria for good status	Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct, and atmospheric inputs) or anthropogenic sources (e.g. wastewater runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
	Hydrocarbon & PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls	Increases in the levels of these compounds compared with background concentrations. Naturally occurring compounds, complex mixtures of two basic molecular structures: - straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation) - multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation) These fall into three categories based on source (includes both aliphatics and polyaromatic hydrocarbons): - petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off) - pyrogenic hydrocarbons (from combustion of coal, woods and petroleum) - biogenic hydrocarbons (from plants & animals) Ecological consequences include tainting, some are acutely toxic, carcinomas, growth defects.
	Radionuclide contamination	An increase in 10µGy/h above	Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea-

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		background levels	based operations (e.g. oil platforms, medical sources). The disposal of radioactive material at sea is prohibited unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA), namely that both the following radiological criteria are satisfied: (i) the effective dose expected to be incurred by any member of the public or ship's crew is 10 μSv or less in a year; (ii) the collective effective dose to the public or ship's crew is not more than 1 man Sv per annum, then the material is deemed to contain de minimis levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 μSv/a. Ports and coastal sediments can be affected by the authorised discharge of both current and historical low-level radioactive wastes from coastal nuclear establishments.
	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed	Compliance with all AA EQS, conformance with PELs, EACs, ER-Ls	Increases in the levels of these compounds compared with background concentrations. Synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds include polychlorinated biphenols (PCBs), dichlor-diphenyl-trichloroethane (DDT) & 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD) are persistent and often very toxic.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
	in Annex II of Directive 2008/105/EC.		Pesticides vary in structure, composition, environmental persistence, and toxicity to non-target organisms. Includes: insecticides, herbicides, rodenticides & fungicides. Pharmaceuticals and Personal Care Products originate from veterinary and human applications compiling a variety of products including, Over the counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones. Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments they have become an emerging concern. Ecological consequences include physiological changes (e.g. growth defects, carcinomas).
	Transition elements & organo-metal (e.g. TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC	Compliance with all AA EQS, conformance with PELs, EACs, ER-Ls	The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments, the main elements of concern are arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc organo-metallic compounds such as the butyl tins (tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		Revised benchmark	Steering Group Comment
		Pollutant pressure benchmark: No change.	For all pollution pressures use the MB0102 benchmarks and do not use the MarLIN benchmarks. Where evidence about specific thresholds is available this should be presented in the evidence/justification section of the sensitivity assessments.
Biological pressures	Genetic modification & translocation of indigenous species	Translocation outside of a geographic area; introduction of hatchery – reared juveniles outside of geographic area from which adult stick derives	Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated with radionuclide contamination). Former related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, scallops if GM practices employed. Scale of pressure compounded if GM species "captured" and translocated in ballast water. Mutated organisms from the latter could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration.
		Revised benchmark	MBA Comment
		Translocation of indigenous species and/or introduction of	Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		genetically modified or genetically different populations of indigenous species that may result in changes in genetic structure of local populations, hybridization, or change in community structure.	with radionuclide contamination). The former is related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, and scallops if GM practices, or breeding programmes are employed. The scale of pressure is compounded if GM species "captured" and translocated in ballast water. GM species could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration. The pressure also relates to the translocation of indigenous species which may compete with local populations of species, alter the community of the receiving habitat, or provide the opportunity for hybridization between similar species (e.g. *Spartina* spp. and *Mytilus* spp.).
Biological pressures	Introduction of microbial pathogens	SNCB Revised Benchmark: the introduction of microbial pathogens *Bonamia* and *Martelia refringens* to an area where they are	Untreated or insufficiently treated effluent discharges & run-off from terrestrial sources & vessels. It may also be a consequence of ballast water releases. In mussel or shellfisheries where seed stock is imported, 'infected' seed could be introduced, or it could be from accidental releases of effluvia. Escapees, e.g. farmed salmon could be infected and spread pathogens in the indigenous populations. Aquaculture could

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		currently not present.	release contaminated faecal matter, from which pathogens could enter the food chain.
		Revised benchmark	MBA Comment
		The introduction of relevant microbial pathogens or metazoan disease vectors to an area where they are currently not present (e.g. *Martelia refringens* and *Bonamia*, Avian influenza virus, viral Haemorrhagic Septicaemia virus).	Any significant pathogens or disease vectors relevant to species or the species that characterize biotopes/ habitats identified during the evidence review phase will be noted in the review text.
Biological pressures	Introduction or spread of invasive non-	MB0102 benchmark: A significant pathway exists for	The direct or indirect introduction of non-indigenous species, e.g. Chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spreading and out-competing of native species. Ballast water,

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
	indigenous species (INIS)	introduction of one or more invasive non-indigenous species (INIS) (e.g. aquaculture of NIS, untreated ballast water exchange, local port, terminal harbour, or marina); creation of new colonisation space >1ha. One or more NIS in Table C3 (Technical report) has been recorded in the relevant habitat. SNCB revised benchmark: the introduction of one of more invasive non-	hull fouling, stepping stone effects (e.g. offshore wind farms) may facilitate the spread of such species. This pressure could be associated with aquaculture, mussel, or shellfishery activities due to imported seed stock or from accidental releases.

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		indigenous species (NIS)	
		Revised benchmark	MBA Comment
		The introduction of one of more invasive non-indigenous species (IINIS)	Adopt SNCB revision. Sensitivity assessment will be made against a prescribed list of invasive non-indigenous species (INIS) based on the GBNNSIP list of potential invasive species.
Biological pressures	Removal of non-target species	Removal of features through pursuit of a target fishery at a commercial scale	By-catch associated with all fishing activities. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type (D2) so B6 addresses the direct removal of individuals associated with fishing/ harvesting. Ecological consequences include food web dependencies, population dynamics of fish, marine mammals, turtles, and sea birds (including survival threats in extreme cases, e.g. Harbour Porpoise in Central and Eastern Baltic).
		Revised benchmark	MBA Comment
		Removal of features or incidental non-targeted catch (by-catch)	Defining this pressure has proven to be problematic for sensitivity assessment. It is considered that the pressure addresses only the biological effects of removal of species and not the effects of the removal process

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		through targeted fishery, shellfishery or harvesting at a commercial or recreational scale.	on the species, community, or habitat itself, which results in confusion. Food-web impacts are only relevant to higher trophic levels (birds, fish, mammals, and turtles): for benthic habitats and associated species the pressure has been interpreted as specifically referring to the risk of ecological effects arising from the removal of species that are not directly targeted by fisheries. The assessment considers whether species present in the biotope are likely to be damaged or removed by relevant activities and whether this removal is likely to result in measurable effects on biotope classification, structure (in terms of both biological structures e.g. species richness and diversity and the physical structure, sometimes referred to as habitat complexity) and function. Examples of biotopes that are sensitive to this pressure are therefore i) biogenic habitats that are created by species which may be removed by fishing activities, e.g. maerl beds and hard substrata that are dominated by plant and animal assemblages, ii) biotopes characterized by ecosystem engineers or keystone species that strongly determine the rate of some ecological processes, e.g. beds of suspension feeders that cycle nutrients between the water column and substratum and iii) biotopes with key characterizing species, (e.g. those named in the biotope

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			description or identified as important by the biotope description) that are likely to be removed or displaced as by-catch.
Biological pressures	Removal of target species	MB0102 pressure benchmark: Removal of target species that are features of conservation importance or sub-features of habitats of conservation importance at a commercial scale.	The commercial exploitation of fish & shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type D2, so B5 addresses the direct removal / harvesting of biota. Ecological consequences include the sustainability of stocks, impacting energy flows through food webs and the size and age composition within fish stocks.
		Suggested benchmark	MBA Comment
		Benthic species and habitats: removal of species targeted by fishery, shellfishery or harvesting at a commercial or	Defining this pressure has proven to be problematic for sensitivity assessment. It is considered that the pressure addresses only the biological effects of removal of species and not the effects of the removal process on the species, community, or habitat itself, which results in confusion. Food-web impacts are only relevant to higher trophic levels (birds, fish, mammals, and turtles): for benthic habitats and associated species the

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
		recreational scale	pressure has been interpreted as specifically referring to the risk of ecological effects arising from the removal of species that are directly targeted. The assessment considers whether species present in the biotope are likely to be directly targeted and whether this removal is likely to result in measurable effects on biotope classification, structure (in terms of both biological structures e.g. species richness and diversity and the physical structure, sometimes referred to as habitat complexity) and function. Examples of biotopes that are sensitive to this pressure are therefore i) biogenic habitats that are created by species which may be directly targeted, e.g. bivalve beds, kelp beds, *Ostrea edulis* reefs ii) biotopes characterized by ecosystem engineers or keystone species that strongly determine the rate of some ecological processes and that are directly targeted, e.g. *Echinus esculentus* as keystone grazers maintaining urchin barrens, and *Arenicola marina* which are key bioturbators that may be collected for bait, and iii) biotopes with key characterizing species, (e.g. those named in the biotope description or identified as important by the biotope description) that are likely to be removed as target species, e.g. collection of piddocks for bait or food

Pressure theme	ICG-C Pressure	MB0102 benchmark	ICG-C description
			from biotopes defined on the presence of piddocks.

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Appendix 5. Revised pollution or 'contaminant' pressure definitions (see Tyler-Walters et al., 2022 for details).

The 2014 pressure definitions (see Appendix 4) were revised to reflect the proposed scope of the 'contaminants' literature review and Rapid Evidence Assessment protocol.

Most organic molecules have a hydrocarbon backbone. Therefore, some chemicals may fit into the 'hydrocarbons' pressure or the 'synthetic chemical' pressure. At present, biogenic and petroleum-based hydrocarbons and their direct products are included under 'hydrocarbons and PAHs' while chemicals that have been 'manufactured' from other components for use in industry have been included under 'synthetics'.

Organometals (e.g. TBT) are technically 'synthetic' but are routinely returned in the preliminary literature searches for 'metals. Therefore, they are retained under 'metals' on the presumption that the 'metal' ion is the active, toxic, component, made more biologically available by its organic component.

Pressure theme	Pollution and other chemical changes
Pressure	Revised pressure definition
Hydrocarbon & PAH contamination.	The existing pressure definition has been revised to separate physical and chemical effects. Increases in the levels of these compounds compared with background concentrations. Naturally occurring compounds, or complex mixtures of two basic molecular structures: • straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation), and • multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation). These fall into three categories based on source (includes both aliphatic and polyaromatic hydrocarbons): • biogenic hydrocarbons (from plants & animals); • petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off); and

Pressure theme	Pollution and other chemical changes
	• pyrogenic hydrocarbons (from combustion of coal, woods, and petroleum). Ecological 'chemical' consequences include taint, acutely toxicity, carcinomas, and/or growth defects. In addition, hydrocarbons may have 'physical' as well as 'chemical' (toxic) effects on marine species. Physical effects include smothering, suffocation, and clogging of feathers, breathing apparatus, or the digestive tracts of species at the air/water boundary, on rocks or in the sediment, they inhabit. Dispersants are included here as they are designed to break up oil spills. Dispersants (used to disperse oils spills) are 'synthetic mixtures' often mixtures of distillates, surfactants, and other ingredients but their effects are linked to the oil spills or other oily waters (e.g. bilge water) they are designed to disperse. **Guidance notes** Petroleum-based and vegetable-based (e.g. sunflower, palm) oils and other 'persistent floaters' can spread out over the surface of the water, smother, suffocate and clog feathers, breathing apparatus or the digestive tracts of species (e.g. mobile species) that cross or inhabit the air/water boundary. In addition, petroleum-based and vegetable-based oils may smother rock surfaces and/or bind and smother sediment, including the resident species, if they come ashore. Petroleum-based and vegetable-based oils may also release potentially toxic chemicals (Cunha *et al.,* 2015). Therefore, we assess and score the physical effects separately from the chemical or toxicological effects, where possible, with an emphasis on petroleum-based and vegetable-based oils, that is, 'persistent floaters'.

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Pressure theme	Pollution and other chemical changes
Pressure	Revised pressure definition
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals).	The existing pressure definition has been revised to outline the different groups of chemicals included under this pressure. Increases in the levels of these compounds compared with background concentrations. Synthetic compounds are manufactured for a variety of industrial processes and commercial applications. Chlorinated compounds and other organohalogens are often persistent and often toxic; includes: • Polychlorinated biphenols (PCBs); • Brominated flame-retardants; • Chemical precursors, and solvents. Pesticides vary in structure, composition, environmental persistence, and toxicity to non-target organisms, many of which are also organohalogens or organophosphates; includes: • insecticides • herbicides • rodenticides • fungicides • parasiticides • antifoulants Pharmaceuticals and ‘Personal Care Products’ (PPCPs) originate from veterinary and human applications and include a variety of products: • over the counter medications • fungicides • chemotherapy drugs and animal (e.g. finfish) therapeutics, such as growth hormones and oestrogens • UV-filters e.g. from sun screens

Pressure theme	Pollution and other chemical changes
	Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments, pharmaceuticals have become an emerging concern. Ecological consequences include physiological changes (e.g. growth defects, carcinomas). This category also includes: • Other synthetic and organic esters, • Phthalate esters, and • Synthetic musks; which may also be PBT17s. **Guidance notes** At present, this category includes a number of alcohols such as ethanol and methanol that are transported in bulk as well as some such as 1-Dodecanol and Isononanol that are PBTs. A number of synthetic chemicals that do not fit into other categories are also included as 'synthetic (others'). Exposure to most of these synthetic compounds will probably be via the water column or adsorbed onto particulates. Some may be 'floaters' but further research is required to determine if we need to identify 'physical' and 'chemical' effects separately.
Pressure	**Revised pressure definition**
Transitional elements & organometal (e.g. TBT) contamination	The existing pressure definition has been revised to outline the different groups of chemicals included under this pressure. The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments, the main elements of concern are: • Arsenic, • Cadmium,

[17] PBTs – Persistent, Bioaccumulative, or Toxic substances

Pressure theme	Pollution and other chemical changes
	• Chromium, • Copper, • Mercury and organic mercury compounds, • Nickel and its compounds, • Lead and organic lead compounds, and • Zinc. However, the following may also be released into the marine environment: • Aluminium • Barium • Cobalt • Iron • Molybdenum • Selenium • Tin • Tungsten, and • Vanadium. Organo-metallic compounds such as the butyl tins (tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs. The use of other organo-metalloids, such as organo-copper and organo-zinc compounds, has increased due to the ban on organo-tins. Nanoparticulate metals such a zinc oxide (ZnO), iron oxide (FeO), copper oxide (CuO), titanium (n-TiO_2), gold, and silver nanoparticulate metals are included. **Guidance notes** Although the organometalloids are synthetic, they are included here on the presumption that the metal ion is the active toxic component of the

Pressure theme	Pollution and other chemical changes
	compound. Note, mercury, and lead form organic compounds naturally in the environment. Engineered Nanomaterials (ENMs) include nanoparticulate metals (e.g. ZnO, FeO, CuO, n-TiO_2, Ag, and Au), other inorganic nanomaterials (e.g. Quantum Dots, SiO_2), and organic nanomaterials such as fullerenes and carbon nanotubes (Rocha *et al.*, 2015). Nanoparticulate metals are included here while non-metallic nanomaterials may be considered under the 'Introduction of other substances' pressure below.
Pressure	**Revised pressure definition**

Introduction of other substances (solid, liquid or gas)	The existing pressure definition has been revised to outline the different groups of chemicals included under this pressure.
	
	The 'systematic or intentional release of solids, liquids, or gases …' (from MSFD Annex III Table 2) is considered e.g. in relation to produced water from the oil industry. It should therefore be considered in parallel with the other contaminants' pressures (P1, P2, and P3).
	
	This pressure includes compounds released as operational discharges, produced waters or spills from maritime (offshore/ inshore) installations (e.g. oil & gas, renewables), mariculture, shipping, and harbours etc. that are not assessed elsewhere. This pressure includes:
	• Inorganic chemicals that vary in their physical or chemical effects, e.g.
	    • Chemicals transported in bulk that may be spilt e.g. acetic acid, phosphoric acid, sulphuric acid, sodium hydroxide;
	    • Chemicals in drilling waste or produced waters e.g. barite, calcium carbonate, potash, zinc oxide;
	• Natural products with varied uses, e.g. molasses (transported in bulk) but also glycerins, formalin etc.
	• Fin-fish food supplements – e.g. carotenoids, copper sulphate
	• Releases from munitions dumps

Pressure theme	Pollution and other chemical changes
	• Chemical warfare agents • Explosives/propellants **Guidance notes** This pressure can include a large list of chemicals of mixed ecological effect or none. At present, chemical warfare agents and explosives are included, based on legacy munitions dumps. However, their effects are varied and localized to the vicinity of the dump (hopefully) and may not be a significant concern. Also, the list of 'natural products' may be reduced to focus on only those with localized toxicity. Several of the natural products are manufactured from natural occurring compounds or synthesized commercially and may need to be placed under the 'synthetics' pressure. Chromium trioxide and copper thiocyanate are inorganic chemicals used as antifoulants but are included under the 'Transitional metals' pressure. Cunha *et al.* (2015) also highlighted spills of non-toxic sinkers, such as coal, wheat, rice, sugar cane, copra, and cocoa beans. Spills of such items are likely to smother benthos and/or cause localized nutrient enrichment. They are not included under 'contaminants' as they are non-toxic, and 'smothering' and 'nutrient' and 'organic enrichment' are addressed under other pressures.
Pressure	**Revised pressure definition**
Nutrient enrichment	The existing pressure definition was retained but the benchmark was amended. Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct, and atmospheric inputs) or

Pressure theme	Pollution and other chemical changes
	anthropogenic sources (e.g. wastewater runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes. "**A decrease in the one rank of nutrient status of a water body (as defined by WFD), that is, from High to Good, Good to Moderate, Moderate to Poor for a period of a year.**" Where habitats are defined by eutrophic or nutrient enriched status (e.g. the *Beggiatoa* biotope) then sensitivity will be assessed against an increase in nutrient status.

Appendix 6. Climate change pressure definitions and benchmarks

The proposed pressures and benchmarks are summarized below (see Garrard & Tyler-Walters, 2020 for details).

Pressure theme	Climate change
Pressure	**Proposed benchmark(s)**
Global warming (sea and air temperature)	**Middle emission scenario** (A1B) (by the end of this century 2081-2100) benchmark of: • A 3°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf. • A 2°C rise in surface air temperature in intertidal habitats exclusive to Scotland. **High emission scenario** (RCP8.5) (by the end of this century 2081-2100) benchmark of: • A 4°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf, and • A 3°C rise in surface air temperature in intertidal habitats exclusive to Scotland. **Extreme scenario** (RCP8.5 upper range) (by the end of this century 2081-2100) benchmark of: • A 5°C rise in SST and NBT (coastal to the shelf seas); • A 6°C rise in surface air temperature (in eulittoral and supralittoral habitats); • A 1°C rise in deep-sea habitats (>200 m) off the continental shelf, and • A 5°C rise in surface air temperature in intertidal habitats exclusive to Scotland.

	Pressure description
	Global warming results from the retention of thermal energy within the atmosphere and hence the ocean by ‘greenhouse’ gases, such as CO_2 and CH_4 (amongst others). Since the industrial revolution (in 1800s) the average temperature of the globe has risen by 1°C and the CO_2 concentration in the atmosphere is currently the highest it has been in the last 800,000 years (at over 400 ppm) (Palmer *et al.,* 2018; IPCC, 2019). Since the 1970s, the ocean has absorbed ca 93% of the extra heat (Laffoley & Baxter, 2016). As a result, models predict varying increases in average air and sea surface temperature, depending on the greenhouse gas emission scenario used, well beyond the end of this century (Palmer *et al.*, 2018; IPCC, 2019). Air temperature is included for marine species/habitats in the eulittoral and supralittoral that will be exposed to air when emersed.
Pressure	Proposed benchmark(s)
Marine heatwaves	**Middle emission scenario benchmark**: a marine heatwave occurring every three years, with a mean duration of 80 days, with a maximum intensity of 2^{O}C. **High emission scenario benchmark**: a marine heatwave occurring every two years, with a mean duration of 120 days, and a maximum intensity of 3.5^{O}C.
	Pressure description
	A marine heatwave can be defined as a period when SSTs exceeds its local 99th percentile, based on daily observations of satellite data (Frölicher *et al.*, 2018), and occurs when air temperatures exceed the seasonal average (Garrabou *et al.*, 2009). Marine heatwaves have already doubled in frequency since the 1860 - 1880 baseline, and it is very likely that 84-90% of marine heatwaves occurring 2005-2016 are attributable to anthropogenic temperature rises (Frölicher *et al.*, 2018). Marine heatwaves are expected to increase in frequency, duration, extent, and intensity, with climate models predicting that the frequency of marine heatwaves will increase 50-fold for RCP 8.5 and 20-

	fold for RCP 2.6 by 2081-2100 relative to 1850-1900 (IPCC, 2019). Marine heatwaves can be caused by a range of factors, such as: • air-sea heat flux when surface temperature reaches anomalously high temperatures such as the heatwave experienced in the Mediterranean in the summer of 2003 (Smale *et al.*, 2019), • a decrease in heat loss and a reduction in cold advection which caused a persistent (2013-2016) warm heat anomaly 'the Blob' in the NE Pacific (Bond *et al.*, 2015), and • El Nińo events in the tropical pacific (Holbrook *et al.*, 2019). For example, the Mediterranean heatwave of 2003 saw air temperatures soar to 3-6^{O}C above mean seasonal temperatures, lasting from early June until mid-August, and led to occurrence of a marine heatwave where mean and maximum SSTs were between 1 and 3^{O}C higher than average which saw widespread mortality on rocky reefs (Garrabou *et al.*, 2009). Heatwaves caused by increased air-sea heat flux due to significantly warmer summer temperatures are the most likely heatwaves that the UK will face in the future (D. Smale, *pers. comms.*). These heatwaves generally only impact shallow waters habitats (≤ 50 m).
Pressure	Proposed benchmark(s)
Ocean acidification	**Middle emission scenario benchmark:** a further decrease in pH of 0.15 (annual mean) and corresponding 35% increase in H+ ions with no coastal aragonite undersaturation and the aragonite saturation horizon in the NE Atlantic, off the continental shelf, at a depth of 800 m by the end of this century (2081-2100) **High emission scenario benchmark**: a further decrease in pH of 0.35 (annual mean) and corresponding 120% increase in H+ ions , seasonal aragonite saturation of 20% of UK coastal waters and North Sea bottom waters, and the aragonite saturation horizon in the NE Atlantic, off the continental shelf, occurring at a depth of 400 m by the end of this century (2081-2100)

	Pressure description
	Increased CO_2 concentrations in the atmosphere are absorbed by the ocean. Increased CO_2 concentrations affect the carbonate chemistry of seawater, and result in a reduction in pH, changes in the carbonate saturation and, potentially, hypercapnia (CO_2 poisoning) in marine organisms. Increasing levels of CO_2 in the atmosphere have led to the average pH of sea surface waters dropping from 8.25 in the 1700s to 8.14 in the 1990s, leading to a 25% increase in H^+ ions (Jacobson, 2005). However, the pH of surface waters is highly variable over time (Fig. 5), which reflects seasonal cycles in photosynthesis, respiration and water mixing (Ostle *et al.*, 2016). Marine calcifiers may be particularly at risk, especially as waters suffer from seasonal aragonite undersaturation, leading to dissolution of calcium carbonate. Aragonite saturation state is influenced by dissolved inorganic carbon (DIC) concentration, pressure, and temperature so that deep waters, which have high levels of DIC, high pressure and low temperatures, will be the first habitats to face undersaturation (C. Ostle *pers. comm.*).
Pressure	Proposed benchmark(s)
Sea-level rise	**Middle emission scenario benchmark:** a 50 cm rise in average UK sea-level rise by the end of this century (2081-2100). **High emission scenario benchmark:** a 70 cm rise in average UK by the end of this century (2018-2100). **Extreme scenario benchmark:** a 107 cm rise in average UK by the end of this century (2018-2100).
	Pressure description
	Sea-level rise results from a combination of the thermal expansion of seawater and ice melt (e.g. ice sheets and glaciers). Sea-levels have risen 1-3 mm/yr in the last century (Cazenave & Nerem, 2004, Church *et al.*, 2004, Church & White, 2006). The global mean sea-level has risen by 0.16 m (a range of 0.12-0.21 m) between 1902 and 2015 (IPCC, 2019). The rate of rise in 2006-2015 is unprecedented compared to the last century, during which

	period sea-level rise has been dominated by melting ice sheets and glaciers (IPCC, 2019). A rise in sea-level increases the water depth at the shore and results in increased wave and tidal energy along the shore, due to the increase in fetch and reduction in wave attenuation (Pethick, 2001; Crooks, 2004; Fujii, 2012). As a result, coastal landforms (e.g. subtidal bedforms, intertidal flats, saltmarshes, shingle banks, sand dunes, cliffs, and coastal lowlands) migrate along and parallel to the shore to maintain their position with the coastal energy gradient (Crooks, 2004; Fujii, 2012). Sedimentary habitats are dynamic and liable to adapt to sea-level rise, except where hard structures (e.g. cliffs and artificial structures) prevent their natural movement, where existing intertidal areas are likely to be submerged, eroded, or moved (coastal squeeze).

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Appendix 7. Scales and figures referred to in pressure definitions and benchmarks

The following scales and figures are used in the assessment of evidence against the pressure benchmarks. Additional notes are present as required.

A7.1. MNCR Salinity Scale

Salinity is a measure of the concentration of dissolved salts in seawater. Salinity is defined as the ratio of the mass of dissolved material in sea water to the mass of sea water (UNESCO, 1985; TEOS-10, 2010 http://www.teos-10.org/). The term 'Absolute Salinity' (S_A), measured as g/kg (mass fraction of salt in seawater), has been adopted as the standard SI unit for salinity, for use in calculations of the thermodynamic properties of seawater, by the International Oceanographic Commission (see TEOS-10, 2010). The term 'Practical Salinity (S_P)', based on conductivity, is being phased out.

Unfortunately, salinity has been reported in numerous ways in the past, for example, as parts per thousand (ppt or ‰), as the 'practical salinity unit' (psu) or as 'salinity' without any units. Therefore, for the sake of accuracy when referring to salinity in MarLIN reviews, the units used by the original authors are quoted in the text.

Term	Definition
Full salinity	30-40
Variable salinity	18-40
Reduced salinity	18-30
Low salinity	< 18
Unknown salinity	NA

(adapted from Hiscock, 1996)

A7.2. Water flow (Tidal streams)

The horizontal movement of water associated with the meteorologic, oceanographic, and topographic factors. High water flow rates result in areas where water is forced through or over restrictions for example narrows or around protruding offshore rocks. Tidal streams are associated with the rise and fall of the tide whereas currents are defined as residual flow after the tidal element is removed (McLeod, 1996).

Term	Definition
Very strong	>6 knots (>3 m/sec.)
Strong	3 to 6 knots (1.5-3 m/sec.)
Moderately strong	1 to 3knots (0.5-1.5 m/sec.)
Weak	<1 knot (<0.5 m/sec.)
Very weak	Negligible

Based on the Hjulstrom-Sundborg diagram (Figure A2.1) medium sand (0.25 - 0.50 mm) will be suspended by currents about 0.20-0.25 m/s; it will stay in suspension until flow drops below 0.15-0.18 m/s.

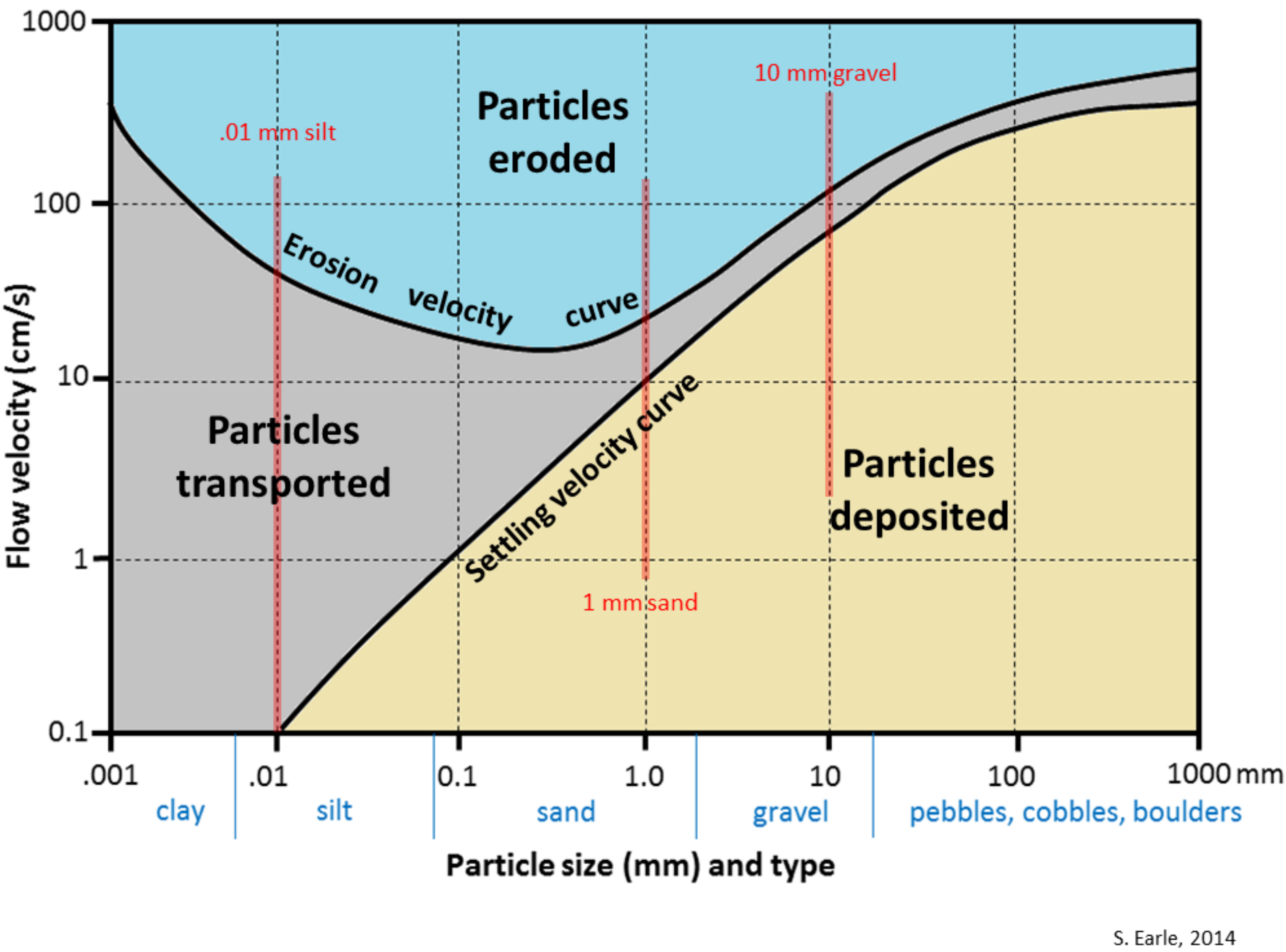


Figure A5.1. The Hjulstrom-Sundborg diagram (Earle, 2014).

In wave dominated environments, with the shore face at a depth of 10 meters, sand suspension can be initiated by waves only one meter high with a period of 4-5 seconds.

A7.3. The MNCR wave exposure scale (Hiscock, 1990).

Rank	Definition
Extremely exposed	Open coastlines which face into the prevailing wind and receive both wind-driven waves and oceanic swell without any offshore obstructions such as islands or shallows for several thousand kilometres and where deep water is close to the shore (50 m depth contour within about 300 m).
Very exposed	1) Open coasts which face into prevailing winds, and which receive wind-driven waves and oceanic swell without any offshore obstructions for several hundred kilometres, but where deep water is not close to the shore (50 m depth contour further than about 300 m). 2) Open coasts adjacent to extremely exposed sites but which face away from prevailing winds.
Exposed	1) Coasts which face the prevailing wind, but which have a degree of shelter because of extensive shallow areas offshore, offshore obstructions, or a restricted (less than 90°) window to open water. These sites are not generally exposed to large waves or regular swell. 2) Open coasts facing away from prevailing winds but with a long fetch, and where strong winds are frequent.
Moderately exposed	Generally, coasts facing away from prevailing winds and without a long fetch, but where strong winds can be frequent.
Sheltered	Coasts with a restricted fetch and/or open water window. Coasts can face prevailing winds but with a short fetch (< 20 km) or extensive shallow area offshore or may face away from prevailing winds.
Very sheltered	Coasts with a fetch less than about 3 km where they face prevailing winds or about 20 km where they face away from prevailing winds, or which have offshore obstructions such as reefs or a narrow (< 30°) open water window

Extremely sheltered	Fully enclosed coasts with a fetch of no more than about 3 km.
Ultra-sheltered	Fully enclosed coasts with a fetch measured in tens or at most a few hundred metres.

Also refer to the relevant habitat matrices that distinguish biotopes based on the energy (wave exposure and tidal streams) (Connor *et al.,* 2004).

A7.4. UK TAG (Technical Advisory Group) (2014) turbidity/suspended solid table

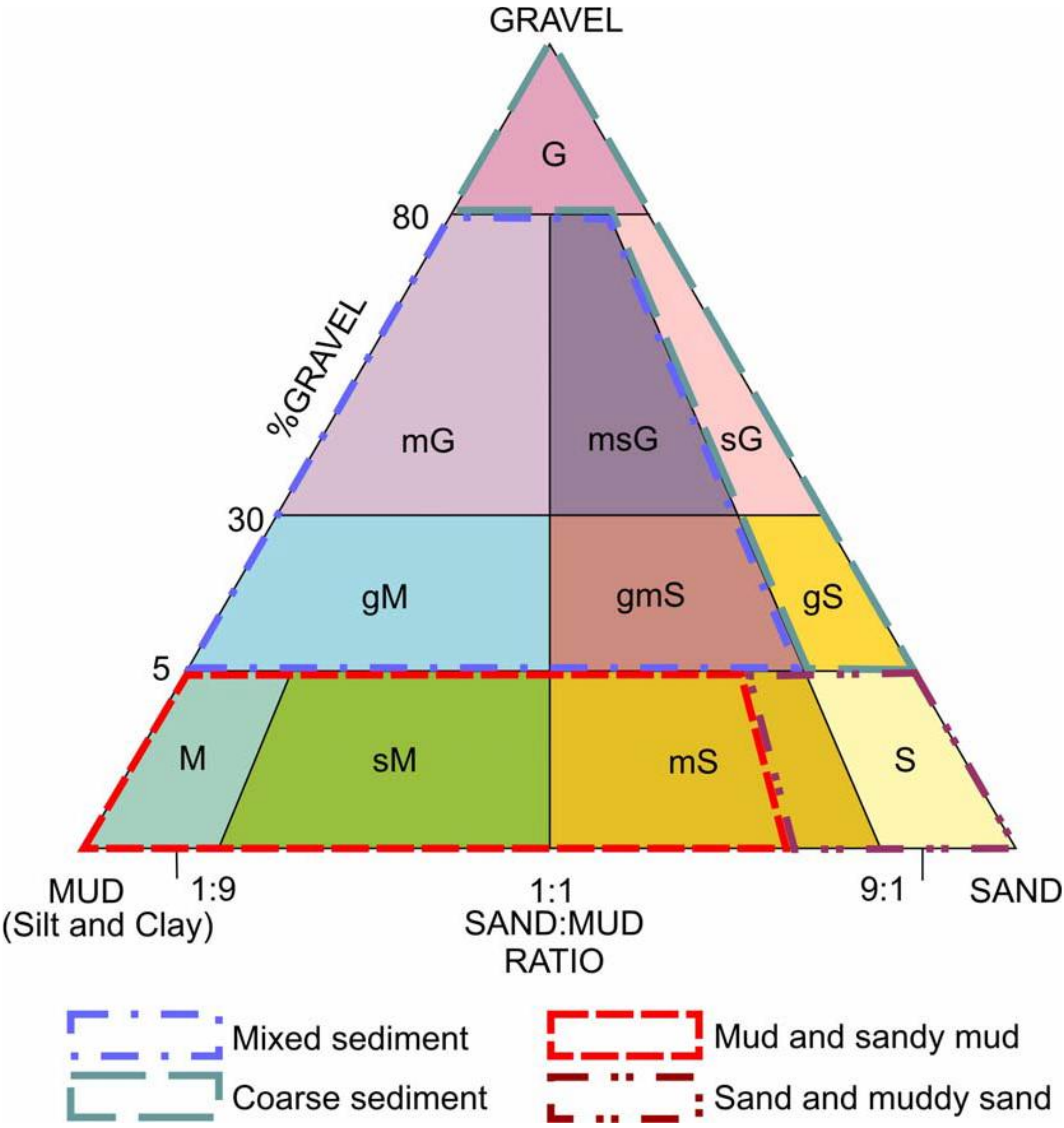
Water turbidity ranks UKTAG (2014) are based on mean concentration of suspended particulate matter mg/l.

Water Turbidity	Definition	Kd (/m)
>300 mg/l	Very turbid	>20
100-300 mg/l	Medium turbidity	6.7 - 20
10-100 mg/l	Intermediate	0.67 - 6.7
<10 mg/l	Clear	

Coastal waters are likely to absorb 10-60% of incident light per metre at a wavelength of 500 nm (Kinne, 1970). If 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. Devlin *et al.* (2008) suggest that coastal waters are typically 3-24.1 mg/l, estuarine (or transitional) waters, 8.2-73.8 mg/l and offshore waters 9.3 mg/l.

Kd (sub-surface light attenuation) values calculated from Devlin *et al.* (2008; equation 9) for coastal waters. It is unclear how this value should be used in practice, but Kd relates to the attenuation per metre, that is, increasing depth. It should be considered as an indicator rather than a precise value.

A7.5. Long (2006) diagram for assessing physical change in sediment type pressure



The benchmark for this pressure refers to a change in one Folk class. The pressure benchmark originally developed by Tillin *et al*. (2010) used the modified Folk triangle developed by Long (2006) that simplified sediment types into four categories: mud and sandy mud, sand and muddy sand, mixed sediments, and coarse sediments. The change referred to is therefore a change in sediment classification rather than a change in the finer-scale original Folk categories (Folk, 1954). The change in one Folk class is considered to relate to a change in classification to adjacent categories in the modified Folk triangle. For mixed sediments and sand and muddy sand habitats a change in one Folk class may refer to a change to any of the sediment categories. However, for coarse sediments resistance is assessed based on a change to either mixed sediments or sand and muddy sands but not mud and sandy muds. Similarly, muds and sandy muds are assessed based on a change to either mixed sediments or sand and muddy sand but not coarse sediment.

Where biotopes were described as 'muddy', for example, EUNIS biotope A5.325 '[*Capitella capitata*] and [*Tubificoides*] spp. in reduced salinity infralittoral muddy sediment' this was interpreted as being applicable to mixed, mud and sandy mud and sand and muddy sand. As a change to coarse sediments is not assessed this biotope would be considered to be 'Not sensitive' at the pressure benchmark.

The pressure assessment considers sensitivity to a change in sediment type. The pressure assessment does not consider sensitivity to the pathways by which this change may occur. Changes in sediment or substratum type may occur through physical damage e.g. penetration and disturbance of the sediment and extraction that can remove relatively soft substratum such as chalk, peat, or clay; lead to re-suspension of fine sediments which are removed by water currents resulting in coarser sediments; or expose different types of substrata. Siltation may alter the character of the sediment or substratum through the addition of fine sediments.

It should be noted that the pressure benchmark is not considered applicable to rock biotopes. However, the sensitivity of biotopes occurring on softer substrata, including chalk, peat, and clay are assessed.

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A7.6. Types of environmental quality standards for contaminants benchmark and relevant directives or programmes.

Pollution targets	Description	Relevant directives / programmes
AA	Annual Average- protects against chronic (long-term effects). It is derived by analysing data from chronic (long term) toxicity tests and, in some cases, from field data.	EQSD, WFD
EAC	Environmental assessment criteria (EACs) are assessment tools used by OSPAR that are intended to represent the contaminant concentration in sediment and biota below which no chronic effects are expected to occur in marine species, including the most sensitive species.	OSPAR
EQS	Environmental Quality Standards- provide high levels of protection for all living organisms. EQS derived for the WFD may refer to long-term values- Annual Averages and short-term standards-Maximum Allowable Concentrations The short-term standard aims to protect against intermittent or short-lived periods of exposure and are often used in the assessments associated with particular incidents. They are not normally used in the context of routine monitoring and compliance assessment because, for most chemicals, the short-term risk is managed sufficiently through the achievement of the Annual Average.	EQSD
ER-L	Effects range low (ER-L), and effects range median (ERM) are concentrations derived from compiled biological toxicity assays and synoptic sampling of marine sediment. These values are used as sediment quality guidelines to help categorize the range of	N/A

Pollution targets	Description	Relevant directives / programmes
	concentrations in sediment which effects are scarcely observed or predicted (below the ER-L)	
MAC	Maximum Allowable Concentration- protects against short-term effects and is based on analysis of data on acute (short-term) toxicity.	EQSD, WFD
PNEC	Predicted no effects concentration- precautionary, derived value, below a concentration that will have an effect.	WFD
PEL	Probable effect level (PEL) defines the level above which adverse effects are expected to occur frequently.	Canadian Sediment Quality Guidelines

Notes. The monitoring and regulatory framework for pollutants in UK waters is based on the Water Framework Directive (WFD -Directive 2000/60/EC), the Environmental Quality Standard Directive (EQSD-Directive 2008/105/EC) and OSPAR. The Water Framework Directive 2000/60/EC establishes limits, Environmental Quality Standards, (EQS) for 33 priority substances (including 13 priority hazardous substances) and an additional 8 substances regulated under previous legislation. Two types of EQS are set annual average concentrations (AA) and Maximum Allowable Concentrations (MAC). The chemical status assessment is used alongside the ecological status assessment to determine the overall quality of a water body. In addition, EQSs are used to set discharge permits to water bodies, so that chemical emissions do not lead to EQS exceedance within the receiving water.

A7.6. List of non-native species considered in assessment and used for search terms

Species name	Common name	Comments
Codium fragile subsp. fragile		May dominate algal cover in infralittoral rocky reefs
Sargassum muticum	Wireweed	May dominate algal cover on sheltered rocky and coarse substratum shores penetrating into estuaries
Undaria pinnatifida	Wakame	May dominate algal cover on rocky shores from low tide down to 15m
Spartina anglica	Common cordgrass	May dominate lower saltmarsh
Marenzelleria viridis	A polychaete	May dominate faunal assemblage in low salinity shallow subtidal muds
Ficopomatus enigmaticus	A polychaete	May dominate substratum.
Eriocheir sinensis	Chinese mitten crab	Structuring component of high intertidal in upper estuaries
Crepidula fornicata	Slipper limpet	May smother subtidal muddy and sandy seabed
Urosalpinx cinerea	American oyster drill	Predator on oysters
Magallana (syn. *Crassostrea*) *gigas*	Portuguese oyster	May form oyster beds on coarse or hard substrata in estuaries
Perophora japonica	A sea squirt	May cover up to 10% of seabed surface in lagoons

Species name	Common name	Comments
Didemnum vexillum	Carpet sea squirt	May encrust submerged structures but may also affect sheltered shallow subtidal hard substrata
Styela clava	A sea squirt	May occupy space and dominate substratum (but also provide substratum)
Asparagopsis armata	Harpoon weed	May dominate rock pools and sublittoral
Asterocarpa humilis	A sea squirt	
Austrominius modestus	Australasian barnacle	
Bonnemaisonia hamifera	A red seaweed	
Botrylloides diegensis	A sea squirt	
Botrylloides violaceus	A sea squirt	
Caprella mutica	Japanese skeleton shrimp	May foul aquaculture, e.g. mussel ropes
Codium fragile subsp. fragile	A green seaweed	
Cordylophora caspia	A hydroid	
Corella eumyota	A sea squirt	
Monocorophium sextonae	Tube-dwelling mud shrimp	
Ensis directus	Razor shell	
Gammarus tigrinus	A sand shrimp	

Species name	Common name	Comments
Grateloupia turuturu	A red alga	
Hemigrapsus sanguineus	Asian shore crab	
Hemigrapsus takanoi	Asian shore crab	
Heterosiphonia japonica	A red seaweed	
Hydroides elegans	A tube worm	
Hydroides ezoensis	A tube worm	
Mytilopsis leucophaeta	Dark false mussel	
Dyspanopeus sayi	Say mud crab	
Neosiphonia harveyi	A red seaweed	
Rhithropanopeus harrisii	Harris mud crab	
Schizoporella japonica	A bryozoan	
Tricellaria inopinata	A bryozoan	
Watersipora subatra	A bryozoan	

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