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Assessing the sensitivity of *Sabellaria spinulosa* reef biotopes to pressures associated with marine activities

Gibb, N., Tillin, H., Pearce, B. & Tyler-Walters, H.

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For further information please contact:

Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough PE1 1JY
www.jncc.defra.gov.uk

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Summary

The Joint Nature Conservation Committee (JNCC) commissioned this project to generate an improved understanding of the sensitivities of *Sabellaria spinulosa* reefs based on the OSPAR habitat definition. This work aimed to provide an evidence base to facilitate and support management advice for Marine Protected Areas, development of UK marine monitoring and assessment, and conservation advice to offshore marine industries.

The OSPAR list of threatened and declining species and habitats refers to subtidal *S. spinulosa* reefs on hard or mixed substratum. *S. spinulosa* may also occur as thin crusts or individual worms but these are not the focus of conservation. The purpose of this project was to produce sensitivity assessments with supporting evidence for *S. spinulosa* reefs, clearly documenting the evidence behind the assessments and the confidence in these assessments.

Sixteen pressures, falling in five categories - biological, hydrological, physical damage, physical loss, and pollution and other chemical changes - were assessed in this report. To develop each sensitivity assessment, the resistance and resilience of the key elements of the habitat were assessed against the pressure benchmark using the available evidence. The benchmarks were designed to provide a 'standard' level of pressure against which to assess sensitivity. The highest sensitivity ('medium') was recorded for physical pressures which directly impact the reefs including:

- habitat structure changes – removal of substratum;
- abrasion and penetration and sub-surface disturbance;
- physical loss of habitat and change to habitat; and
- siltation rate changes including and smothering.

The report found that no evidence for differences in the sensitivity of the three EUNIS *S. spinulosa* biotopes that comprise the OSPAR definition. However, this evidence review has identified significant information gaps regarding sensitivity, ecological interactions with other species and resilience. No clear difference in resilience was established across the OSPAR *S. spinulosa* biotopes that were assessed in this report. Using a clearly documented, evidence based approach to create sensitivity assessments allows the assessment and any subsequent decision making or management plans to be readily communicated, transparent and justifiable. The assessments can be replicated and updated where new evidence becomes available ensuring the longevity of the sensitivity assessment tool. Finally, as *S. spinulosa* habitats may also contribute to ecosystem function and the delivery of ecosystem services, understanding the sensitivity of these biotopes may also support assessment and management in regard to these.

Whatever objective measures are applied to data to assess sensitivity, the final sensitivity assessment is indicative. The evidence, the benchmarks, the confidence in the assessments and the limitations of the process, require a sense-check by experienced marine ecologists before the outcome is used in management decisions.

Contents

1 Introduction

The Joint Nature Conservation Committee (JNCC) commissioned this project to generate an improved understanding of the sensitivities of subtidal *Sabellaria spinulosa* biotopes (as defined on the OSPAR list of threatened and declining species (OSPAR 2008b) to pressures associated with human activities in the marine environment. This work will provide an evidence base that will facilitate and support management advice for Marine Protected Areas, development of UK marine monitoring and assessment, and conservation advice to offshore marine industries.

The purpose of this project was to produce sensitivity assessments with supporting evidence for *S. spinulosa* habitats as defined by OSPAR. The OSPAR Commission distinguishes two sub-types of reef: *S. spinulosa* reefs on rock (EUNIS code: A4.22; National Marine Habitat Classification for UK and Ireland code: CR.MCR.CSab), and *S. spinulosa* reefs on mixed (sediment) substrata (EUNIS code: A5.611; National Marine Habitat Classification for UK and Ireland code: SS.SBR.PoR.SspiMx). This assessment does not include *S. spinulosa* habitats that occur in the intertidal. The objective of this review was to develop the sensitivity assessments, clearly document the evidence behind the assessments and identify any differences with the existing generic assessments made by project MB0102 (Tillin *et al* 2010) for *S. spinulosa*.

2 Key concepts and methodology

2.1 Definition of sensitivity, resistance and resilience

The concepts of resistance and resilience described by Holling (1973) are widely used to assess sensitivity (Table 2.1). 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 [pressure] and the time taken for its subsequent recovery’.

Resistance is an estimate of an individual’s, a species population, and/or a habitat’s, ability to resist damage or change as a result of an external pressure. It is assessed in either quantitative or qualitative terms, against a clearly defined scale. While the principle is consistent between approaches, the terms and scales vary. Resistance and tolerance are often used for the same concept, although other approaches assess ‘intolerance’ which is the reverse of resistance.

Table 2.1. Definition of sensitivity and associated terms

Term	Definition	Sources
Sensitivity	A measure of susceptibility to changes in environmental conditions, disturbance or stress which incorporates both resistance and resilience.	Holt *et al* (1995), McLeod (1996), Tyler-Walters *et al* (2001), Zacharias & Gregr (2005)
Resistance (Intolerance/tolerance)	A measure of the degree to which an element can absorb disturbance or stress without changing in character.	Holling (1973)
Resilience (Recoverability)	The ability of a system 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)

Resilience is an estimate of an individual’s, a species population, and/or a habitat’s, ability to return to its prior condition, or recover, after the pressure has passed, been mitigated or removed. The term resilience and recovery are often used for the same concept, and are effectively synonymous[1].

Sensitivity can, therefore, be understood as a measure of 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).

The detailed definitions used in this study are given in Appendix 1.

2.2 Sensitivity assessment methodology

Tillin *et al* (2010) developed a method to assess the sensitivity of certain marine features, considered to be of conservation interest, against physical, chemical and biological

[1] The terms ‘resilience’ and ‘recoverability’ are used to describe an ability or characteristic, while ‘recovery’ and or ‘recovery rate’ are used to denote the process.

pressures resulting from human activities. The sensitivity assessments made by Tillin *et al* (2010) were based on expert judgement. For the purpose of this report, the Tillin *et al* (2010) methodology was modified to include a review of available evidence as the basis for sensitivity assessment in this study. The methodology, definitions and terms are summarised in Appendix 1.

The sensitivity assessment method used here (a modification of methods described by Tillin *et al* 2010) involves the following stages, which are explained more fully in Appendix 1.

A. Defining the key elements of the feature to be assessed (this step is not applicable to this review).
B. Assessing feature resistance (tolerance) to a defined intensity of pressure (the benchmark).
C. Assessing the resilience (recovery) of the feature to a defined intensity of pressure (the benchmark).
D. The combination of resistance and resilience to derive an overall sensitivity score.
E. Assess level of confidence in the sensitivity assessment.
F. Written audit trail.

To ensure that the basis of the sensitivity assessment is transparent and repeatable the evidence base and justification for the sensitivity assessments have been recorded in full. A complete and accurate account of the evidence used to make the assessments is presented for each sensitivity assessment in Section 4 (literature review) and summarised in the Excel ‘pro-forma’ spreadsheet which presents the summary of the assessment, the sensitivity scores and the confidence levels.

2.3 Human activities and pressures

A pressure is 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 (e.g. sub-surface abrasion or damage), chemical (e.g. organic enrichment) or biological (e.g. introduction of non-native species).

An activity may give rise to more than one pressure. For example, a number of pressures are linked to the cultivation of oysters on trestles including, possible introduction on non-native species, change in water flow, increased siltation/organic matter sedimentation, shading and trampling (physical abrasion and sub-surface damage) of sediments as trestles are visited. Rather than assessing the impact of activities as a single impact, the pressure-based approach supports clearer identification of the pathway(s) through which impacts on a feature may arise from the activity. If the pressures are not separated then it could be difficult to identify the stage in the operation which gives rise to the impact. This approach is especially useful to assess the impacts of activities that involve a number of different stages that are carried out in different habitats.

It should be noted that the same pressure can also be caused by a number of different activities, for example, fishing using bottom gears and aggregate dredging both cause abrasion and sub-surface damage which are classified as a habitat damage pressure (Tyler-Walters *et al* 2001; Robinson *et al* 2008).

Adoption of a pressure based approach means that a wide range of evidence, including information from different types of activities that produce the same pressures, field observations and experimental studies can be used to inform sensitivity assessments and to check these for consistency. To be meaningful and consistent sensitivity to a pressure should be measured against a defined pressure benchmark.

Pressure definitions and an associated benchmark were supplied by JNCC for each of the pressures that were to be assessed (Appendix 2). The pressures JNCC supplied were a modified version of the pressures list developed by the Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR 2011). The ICG-C list contained a list of pressure definitions, but not benchmarks; as it was developed after the MB0102 project (Tillin *et al* 2010). MB0102 has very similar pressures to the ICG-C list and therefore JNCC have taken the benchmarks from MB0102 and applied to the ICG-C list of pressures. The pressures considered relevant to *Sabellaria spinulosa* reefs are assessed in Section 4.

2.4 Literature review

The literature review used the following resources to identify relevant published literature and grey literature:

- the MarLIN Biology and Sensitivity Key Information database;
- latest reports by the project team relevant to the project and the project teams personal collections of papers and references;
- National Marine Biological Library (NMBL) library catalogue and ePrints Archive;
- abstracting journals provided by the NMBL, for example:
    - Aquatic Sciences and Fisheries Abstracts (ASFA);
    - Web of Science (citation index) and Web of Knowledge;
    - Science Direct;
    - Wiley On-line library;
    - NMBL electronic journal access; and
    - Google Scholar.

Relevant habitat/species experts were also consulted to ensure all of the key literature has been sourced including, where possible, research currently in press. All literature collated was managed through the referencing software EndNote. A systematic approach to the literature review was undertaken based on a defined list of key words and search terms. The literature review examined the following areas.

- Concepts of resistance and resilience relevant to the habitat and characteristic species.
- Effects of the agreed pressures on the habitats with an emphasis on UK but with other examples where relevant/required.
- Evidence of the magnitude, extent (spatial) and duration (temporal) of direct and indirect effects of pressures.
- Structural and functional effects of pressures, including effects on the habitats and associated species assemblages.
- Likely rates of recovery based on the habitat and the characteristic species present within the habitats.

3 Description of *Sabellaria spinulosa* reef habitats

This section briefly describes the OSPAR *Sabellaria spinulosa* reef biotopes and relevant definitions, characteristic species and ecology. Pressures arising from human activities that impact this habitat and the relevant impact pathways are outlined. This section also summarises key recovery information for this habitat.

3.1 Definition and characteristics of feature– including characteristic species

Sabellaria spinulosa, also known as ross worm, is a tube-building polychaete worm found in the subtidal and lower intertidal/sublittoral fringe on all European coasts except for the Baltic. *S. spinulosa* can occur as isolated individuals on the seabed, small aggregations, thin crusts or large encrusting reefs that are several centimetres thick and cover extensive areas. This project assesses the sensitivity of *S. spinulosa* reef biotopes included in the OSPAR definition; these are all subtidal (Table 3.1). Reefs in the intertidal are not assessed although information about these has been used as supporting evidence where applicable.

Defining and quantifying what constitutes a *S. spinulosa* reef is not straight forward. The issues are discussed in Gubbay (2007) and Hendrick and Foster-Smith (2006) who proposed a scoring system for assessing 'reefiness' using different indices. The OSPAR definition of *S. spinulosa* reefs refers to the cover of the reef (30% or more on mixed strata and 50% or more on rock). The definition also refers to reef thickness and persistence (OSPAR 2008).

The reef structures, rather than the individual worms, appear to be relatively rare although surveying is inhibited in the subtidal, turbid areas that are favourable to reef development and hence the full extent of reefs in UK waters is unknown. Mapping work is ongoing and some important sites have been identified. Reefs extending for several kilometres, have been identified on the East Coast (Pearce *et al* 2011a). The Wash area is also an important location for *S. spinulosa* reefs (Foster-Smith & White 2001) however within this area the distribution of reefs is patchy with areas of high density close to patches with sparse *S. spinulosa* (Foster-Smith & White 2001).

Step A of the sensitivity assessment methodology (see Appendix 1 for a description) requires that key elements of the feature are selected as the basis for sensitivity assessment. As *S. spinulosa* is the species that creates the habitat, the sensitivity assessments are based on *S. spinulosa* alone and do not consider the sensitivity of associated species that may be free-living or attached to the reef. Although a wide range of species are associated with reef biotopes which provide habitat and food resources (see Appendix 3), these characterising species occur in a range of other biotopes and are therefore not considered to be obligate associates. The reef and individual *S. spinulosa* worms are not dependent on associated species to create or modify habitat, provide food or other resources. OSPAR (2008) note that where reefs consist of empty tubes rather than tubes with living *S. spinulosa* they point to the presence of suitable habitat and should be reported as *S. spinulosa* reef. Within the sensitivity assessments however, reference has been made to impacts on living worms and tubes rather than empty tubes alone.

The OSPAR habitat definition (reviewed within this report) refers to the biotopes outlined below in Table 3.1. A fuller description of the biotopes and associated species is presented in Appendix 3.

Table 3.1. The EUNIS code and title of *Sabellaria spinulosa* biotopes within the OSPAR definition

EUNIS code	Title
A4.22	*Sabellaria* reefs on circalittoral rock
A4.221	*S. spinulosa* encrusted circalittoral rock
A4.2211	*S. spinulosa* with a bryozoan turf and barnacles on silty turbid circalittoral rock
A4.2212	*S. spinulosa*, didemnid and small ascidians on tide-swept moderately wave-exposed circalittoral rock
A5.611	*S. spinulosa* on stable circalittoral mixed sediment

3.2 Ecological function and conservation

Reefs formed by living organisms (biogenic reefs) are of scientific and conservation interest primarily based on the stabilising effects they have on the physical environment and their ecological role. Biogenic reefs have been found to modify habitats, structure diversity and play a role in supporting food webs (Holt *et al* 1998).

Although a number of studies have identified or suggested a relationship between *Sabellaria spinulosa* and species diversity (e.g. Foster-Smith & White 2001; George & Warwick 1985), focussed studies are rare (although see Pearce *et al* (2011b) and Fariñas-Franco 2014) and the role of *S. spinulosa* in supporting or enhancing diversity and the role within local food webs is unclear. Pearce *et al* (2011b) found that in the East Coast Regional Environmental Characterisation (REC) study area the effect of *S. spinulosa* reefs on density and diversity depended on the substratum on which they were found. The greatest differences in fauna were observed where *S. spinulosa* reefs had developed on sand deposits. In these instances the reef structure provides an attachment surface which facilitates colonisation by epifauna such as the mussel *Mytilus edulis* which could not otherwise exist in sand dominated habitats. The structure also adds complexity to the habitat, providing crevices which are utilised by small crustaceans such as the porcelain crab *Pisidia longicornis*. In more complex sandy gravel habitats where both crevices and attachment surfaces are abundant the effect was lessened. These findings support the conclusions of George and Warwick (1985) who found significant enhancement of diversity within the sandy sediments of the Bristol Channel and Pearce *et al* (2007) who found no significant change in diversity associated with *S. spinulosa* reefs on mixed sediments.

Stomach analyses showed that *S. spinulosa* within the East Coast REC study area supported local food webs as food items for fish including Dover sole, dab and plaice (Pearce *et al* 2011).

3.3 Resilience (recovery) rates of *Sabellaria spinulosa* reef biotopes

The sensitivity assessments developed in this review consist of two parts, an assessment of the degree of impact (resistance) and an assessment of the likely rate of recovery (resilience) of reefs following exposure to the pressure. In general where features recover more rapidly the sensitivity is considered lower than where recovery is protracted or not possible (see Appendix 1 for further detail). Recovery rates are therefore an integral element of the sensitivity assessment score.

Empirical evidence to assess the likely recovery rate of *Sabellaria spinulosa* reefs from impacts is limited. There are significant information gaps regarding recovery rates, stability and persistence of *S. spinulosa* reefs. It is not clear how information regarding the recovery of low density *S. spinulosa* populations or thin reef crusts relates to reefs within the OSPAR definition. Any extrapolation between different population densities e.g. between thin crusts and thick reefs and between *S. spinulosa* and the congener *S. alveolata* must therefore be treated cautiously as the evidence may not be applicable. It should also be noted that the recovery rates are indicative of the recovery 'potential'. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Due to evidence limitations it is also unclear whether recovery rates vary between the specific reef biotopes included in the OSPAR definition. The resilience assessments developed for the sensitivity assessments are therefore generic across biotope types.

Studies carried out on reefs of the congener *S. alveolata* within the low inter-tidal suggest that areas of small, surficial damage within reefs may be rapidly repaired by the tube building activities of adult worms. Vorberg (2000) found that trawl impressions made in *S. alveolata* reefs disappeared four to five days later due to the rapid rebuilding of tubes by the worms. The daily growth rate of the worm tubes during the restoration phase was significantly higher than undisturbed growth (undisturbed: 0.7mm, after removal of 2cm of surface: 4.4mm). Similarly, studies of intertidal reefs of the congener *Sabellaria alveolata* by Cunningham *et al* (1984) have found that reefs are able to repair minor damage to the worm tube porches, as a result of trampling, (i.e. treading, walking or stamping on the reef structures) within 23 days. However, severe damage caused by kicking and jumping on the reef structure, resulted in large cracks between the tubes, and removal of sections (ca 15x15x10cm) of the structure (Cunningham *et al* 1984). Subsequent wave action enlarged the holes or cracks. However, after 23 days, at one site, one side of the hole had begun to repair, and tubes had begun to extend into the eroded area. At another site, a smaller section (10x10x10cm) was lost but after 23 days the space was already smaller due to rapid growth (Cunningham *et al* 1984). *S. spinulosa* reefs are more fragile than *S. alveolata* (B. Pearce, pers comm) and therefore the sensitivity and recovery rates of reefs made by the two species may vary but this has yet to be established.

Where reefs are extensively damaged or removed, then recovery occurs through larval recolonisation. Aspects of *S. spinulosa* reproduction have been studied (Wilson 1970; Pearce *et al* 2007; Pearce *et al* 2011b). Individuals may reach sexual maturity rapidly as Pearce (2008) reported that *S. spinulosa* inhabiting the intertidal spawned at one or two years old and growth rate studies by Pearce *et al* (2007) also suggest sexual maturity for subtidal populations could be reached within the first year. The reproductive phase (see below) appears to be relatively long and *S. spinulosa* spend 6 - 8 weeks as planktonic larvae (Wilson 1970). As a result there is a good larval supply with high dispersal potential. Pearce *et al* (2011a) found that separating the adult *S. spinulosa* from tubes in the laboratory induced gamete release. Pearce *et al* (2011a) suggest this could represent a 'significant evolutionary development whereby sabellariid polychaetes spawn in response to disturbance as a means of potentially securing the future population'.

Aside from induced spawning by disturbance, a number of studies have indicated that the major spawning event is in the spring. Plankton trawls during a survey by Pearce *et al* (2011a) revealed a high abundance of *S. spinulosa* larvae in February 2008 and smaller numbers in September and November 2009, suggesting that *S. spinulosa* are most likely to have a main spawning event at the beginning of the year but do also produce larvae throughout the subsequent months. These findings suggest colonisation of suitable habitats could occur over extended periods and supports previous work. George and Warwick (1985) and Wilson (1970) reported larval settlement in March in the Bristol Channel and Plymouth areas respectively while Garwood (1982) found planktonic larvae on the north east coast of England from August to November. Pearce *et al* (2007) constructed size-frequency histograms based on cephalic width and biomass (wet weight) of complete *S. spinulosa* collected from the Hastings Shingle Bank. These suggested that *S. spinulosa* was capable of rapid growth, approaching maximal adult biomass within months (Pearce *et al* 2007).

The longevity of *S. spinulosa* reefs is not known and may vary between sites depending on local habitat conditions. In naturally disturbed areas, reefs may undergo annual cycles of erosion and recolonisation (Holt *et al* 1998). Surveys on the North Yorkshire and Northumberland coasts found that areas where *S. spinulosa* had been lost due to winter storms appeared to be recolonised up to the maximum observed 2.4cm thickness during the following summer (R. Holt pers comm., cited from Holt *et al* 1998). Recovery of thin encrusting reefs may therefore be relatively rapid.

In some areas reefs may persist for long periods, although there is a significant lack of studies on the temporal stability of *S. spinulosa* reefs (Limpenny 2010). It has been suggested that the tubes of the worm are able to persist for some time in the marine environment, therefore, the age of the colony may exceed the age of the oldest individuals present (Earll & Erwin 1983). Laboratory experiments have suggested that larvae settle preferentially on old tubes (Wilson 1970) . Therefore, providing environmental conditions are still favourable, recovery of senescent or significantly degraded reefs through larval settlement of *S. spinulosa* is stimulated by the presence of existing tubes (Earll & Erwin 1983).

Successful recruitment may be episodic. Wilson (1971) cites the work of Linke (1951) who recorded the appearance of *S. spinulosa* reefs on stone-work of intertidal protective groynes. In 1943 no colonies were present (time of year of this observation is unknown) but by September 1944 there were reefs 6-8m wide and 40-60cm high stretching for 60m. Linke (1951) assumed that settlement took place in 1944. In the summer of 1945 many colonies were dead and those remaining ceased growth in the autumn. Thick reefs may therefore develop rapidly and may also decline quickly.

Other evidence, such as the studies undertaken within and adjacent to the Hastings Shingle Bank aggregate extraction area demonstrated a similarly rapid recolonisation process (Cooper *et al* 2007; Pearce *et al* 2007). Recolonisation within two previously dredged areas appeared to be rapid. Substantial numbers of *S. spinulosa* were recorded in one area in the summer following cessation of dredging activities and another area was recolonised within 16-18 months (Pearce *et al* 2007). Recruitment was therefore annual rather than episodic in this study. Recovery to the high abundance and biomass of more mature reefs was considered to require three to five years assuming larval recruitment was successful every year (Pearce *et al* 2007).

In some cases, however, when reefs are removed they may not recover. The Wadden Sea has experienced widespread decline of *S. spinulosa* over recent decades with little sign of recovery. This is thought to be partly due to ecosystem changes that have occurred (Reise *et al* 1989; Buhs & Reise 1997) exacerbated by fishing pressures that still continue (Riesen & Reise 1982; Reise & Schubert 1987). Likewise, no recovery of *S. spinulosa* has occurred in the approach channels to Morecambe Bay (Mistakidis 1956, cited from Holt *et al* 1998). There is no overriding explanation of this but it is believed it may be due to a lack of larval supply or larval settlement, since larvae may preferentially settle on existing adult reefs (although direct settlement on sediments also occurs) or alterations in habitat (Holt *et al* 1998).

3.3.1 Resilience (recovery) assessment

The evidence for recovery rates of *Sabellaria spinulosa* reefs from different levels of impact is very limited and hence the assessment of resilience has low confidence. The rates at which reefs recover from different levels of impact and whether these rates are similar or not between biotopes have not been documented. Recovery rates are likely to be determined by a range of factors such as degree of impact, season of impact, larval supply and local environmental factors including hydrodynamics.

The evidence from *Sabellaria alveolata* reefs (Vorberg 2000; Cunningham *et al* 1984) suggests that areas of limited damage on a reef could be repaired rapidly (within weeks) through the tube-building activities of adults). It is not known if *S. spinulosa* exhibits the same response but the assessment of resilience in this instance as 'High', indicating that recovery would be likely to occur within two years, is considered to be relatively precautionary for this species.

Predicting the rate of recovery following extensive removal is more problematic. Some thin crusts of *S. spinulosa* are relatively ephemeral and disappear following natural disturbance such as storms but recover the following year (Holt *et al* 1998), suggesting that recovery is 'High' (within 2 years). Where resistance is 'High' then there is no effect to recover from and resilience is assessed as 'High'

In other instances, recolonisation has been observed within 16-18 months but full recovery to a state similar to the pre-impact condition of high adult density and adult biomass is suggested to require three to five years where recruitment is annual (Pearce *et al* 2007). Recovery from significant impacts (where resistance is assessed as 'None') is therefore predicted to be 'Medium' (2-10 years).

The evidence varies between peer reviewed literature on life histories and grey literature on recovery from impacts. Therefore, the confidence in the quality of the evidence is assessed as 'Medium'. The applicability of the evidence is also 'Medium' based on limited studies of direct impact and inference from the life history of the species, while the concordance is assessed as 'Medium' based on agreement in direction but not magnitude, that is, the rate of recovery.

4 Review of pressures

This section reviews the current understanding of the resistance and resilience of *Sabellaria spinulosa* reef biotopes, to the relevant pressures. Each pressure is considered in a separate section that describes the characteristics and properties of the particular feature that are likely to be affected by the pressure. The pathways through which effects are transmitted are described and evidence or hypotheses for the direction and potential magnitude of effects and the spatial and temporal scale at which change might occur are outlined.

Evidence or hypotheses for the rates at which affected characteristics are likely to recover are also provided for each pressure where these were found. This evidence, alongside the generic recovery information outlined in Section 3, was used to create the subsequent resilience assessments.

It should be noted that absence of an activity within a pressure discussion for this habitat, does not mean that there is no pressure-activity linkage, only that there may be a lack of evidence for the effect of that activity on this habitat. For more information, please refer to the standardised UK pressure-activities matrix (JNCC 2013).

4.1 Summary of pressures reported to affect *Sabellaria spinulosa* reef biotopes

From the initial list of pressures provided, (see Appendix 2) the pressures listed in Table 4.1 were included in the *Sabellaria spinulosa* assessment.

Table 4.1. Assessed pressures

Pressure Theme	ICG-C Pressure
Biological pressures	Introduction or spread of non-indigenous species (NIS)
	Removal of non-target species
	Removal of target species
Hydrological changes (inshore/local)	Salinity changes - local
	Temperature changes - local
	Water flow (tidal current) changes - local, including sediment transport considerations
	Wave exposure changes - local
Physical damage (Reversible Change)	Abrasion/disturbance of the substratum on the surface of the seabed
	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion
	Changes in suspended solids (water clarity)
	Habitat structure changes - removal of substratum (extraction)
	Siltation rate changes, including smothering (depth of vertical sediment overburden)
Physical loss (Permanent Change)	Physical change (to another seabed type)
	Physical loss (to land and freshwater habitat)
Pollution and other chemical changes	Nutrient enrichment
	Organic enrichment

It was decided in consultation with the expert reviewer and the JNCC project group that the following pressures (Table 4.2) would not be assessed as they are not relevant to the OSPAR *S. spinulosa* reef biotopes:

Table 4.2. Non-assessed pressures

Pressure theme	ICG-C Pressure	Reason for exclusion
Biological pressures	Genetic modification and translocation	Not exposed. *S. spinulosa* is not farmed or translocated.
	Introduction of microbial pathogens	Not exposed. The pressure benchmark refers to shellfish pathogens.
	Visual disturbance	*S. spinulosa* has limited visual acuity and occur where light penetration is limited by depth or by suspended sediment concentrations. This pressure is therefore not considered relevant.
Hydrological changes (inshore/local)	Emergence regime changes-local	Not exposed. The - the biotopes considered are all subtidal.
Other physical pressures	Barrier to species movement	Not exposed. Considered applicable only to mobile species e.g. fish and marine mammals.
	Death or injury by collision	Not exposed. Considered applicable to mobile species e.g. fish and marine mammals.
	Electromagnetic changes	No evidence to support assessment.
	Introduction of light	Not exposed. The reefs considered in this report are circalittoral and light penetration is limited.
	Litter	No benchmark proposed.
	Underwater noise changes	*S. spinulosa* has no hearing perception but vibrations may cause an impact, however no evidence exists to support an assessment.
Pollution and other chemical changes	Nutrient enrichment	*S. spinulosa* is not considered sensitive at the pressure benchmark.
	Hydrocarbon and PAH contamination	*S. spinulosa* is not considered sensitive at the pressure benchmark.
	Introduction of other substances (solid, liquid or gas)	No benchmark proposed.
	Radionuclide contamination	Considered very unlikely to be a significant risk and no evidence base to support assessment.
	Synthetic compound contamination	*S. spinulosa* is not considered sensitive at the pressure benchmark.

4.2 Biological pressures

4.2.1 Introduction of non-indigenous species

ICG-C pressure description
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, 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 benchmark
A significant pathway exists for introduction of one or more invasive non-indigenous species (NIS) (e.g. aquaculture of NIS, untreated ballast water exchange, local port, terminal harbour or marina); creation of new colonisation space >1ha.

Evidence description
No direct evidence relating to the impacts of the introduction of non-indigenous species on *Sabellaria spinulosa* reefs was found to support this assessment. For many of the non-indigenous species that are found in UK seabed habitats, there are no records to suggest that their distribution overlaps with *S. spinulosa* reefs.

The oyster drill, *Urosalpinx cinerea*, is not known to predate on polychaetes (Brown & Richardson 1988) therefore their introduction is not considered a threat to *S. spinulosa*. There is, however, some overlap between the environmental niche of *S. spinulosa* and the oysters that *U. cinerara* selectively feed on (Brown & Richardson 1988).

Japanese knotweed *Sargassum muticum* and green sea fingers *Codium fragile* have the potential to compete for space where *S. spinulosa* reefs occur intertidally, however, intertidal biotopes are not included in this assessment and these species are unlikely to impact deeper subtidal reefs.

No records of the carpet sea squirt *Didemnum vexillum,* the reef building serpulid *Ficopomatus enigmaticus, Perophora japonica,* or Japanese kelp *Undaria pinnatifida,* suggest these species occur on or near *S. spinulosa* reefs. However, further spread may impact subtidal *S. spinulosa* reefs through smothering or competition, although this is entirely speculative.

Two species that potentially pose a threat to *S. spinulosa* reefs are the pacific oyster *Crassostrea gigas* and the slipper limpet *Crepidula fornicata*.

Reefs of *Sabellaria alveolata* in the bay of Mont Saint Michel, France are becoming increasingly colonised by the pacific oyster *C. gigas* (Dubois *et al* 2006). Given the high filtration rates of *C. gigas,* it is believed that they can out compete *S. alveolata* for feeding resources (Dubois *et al* 2006). In the Wadden Sea *C. gigas* has replaced blue mussels (Foster-Smith 2000) suggesting that *C. gigas* may impact filter feeding, reef forming organisms in general. The reasons underlying the species shift from *Mytilus edulis* to *C. gigas* have not been elucidated, however, and may be due to recent changes in climactic conditions (Thieltges 2005) rather than competitive interactions. It should be noted that even though *C. gigas* is distributed throughout UK waters following an initial introduction in 1926 (Linke 1951) there is currently no evidence, in the absence of any targeted studies, that this species is impacting native *S. spinulosa* or *S. alveolata* reefs (Crisp 1964; Hendrick *et al* 2011).

S. spinulosa reefs support a variety of attached epifauna including species of bryozoans, hydroids and sponges. As *S. spinulosa* reefs are known to support encrusting organisms without apparent adverse effect, the stalked sea squirt *Styela clava,* as a solitary sea squirt is considered unlikely to have greater negative impacts than native species.

When the slipper limpet *C. fornicata* settles in an area it can increase the amount of pseudofaeces and subsequently the substratum may be altered from hard substratum to soft sediment which will reduce the substratum available for settlement by other species. This was observed when a 28-30% mortality of *M. edulis* occurred after the introduction of *C. fornicata* to mussel beds (Thieltges 2005). *C. fornicata* has been recorded in association with *S. spinulosa* reefs at Hastings Shingle Bank (up to 66 individuals per grab, Pearce 2007) and in lower numbers in the East Coast REC area (maximum 4 per grab (Pearce *et al* 2011a)). The relationship between *C. fornicata* and *S. spinulosa* has not been investigated. However, potential impacts on *S. spinulosa* reefs could occur through changes to substratum suitability or other interactions.

Sensitivity assessment

No evidence was found that non-indigenous species are currently significantly impacting *S. spinulosa* reef biotopes. Based on current evidence**, resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from), so that all the *S. spinulosa* reef biotopes are assessed as **'Not Sensitive'.** However, it should be noted that *C. fornicata* and *C. gigas* may pose a potential threat in terms of competition for food and space and so this assessment may require updating in the future as the distributions and interactions between these species are better understood.

Resistance confidence

Quality of evidence is 'Low' - as the assessment is based on expert judgement.
Applicability is 'Not assessed' - as the assessment is based on expert judgement.
Concordance is 'Not assessed' -as the assessment is based on expert judgement.

Resilience confidence

Quality of evidence is 'High' - based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.2.2 Removal of target species

ICG-C pressure description
The commercial exploitation of fish and shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on sea bed communities are addressed by the "abrasion" pressure type so this pressure addresses the direct removal/harvesting of biota.

Pressure benchmark
Removal of target species that are features of conservation importance or sub-features of habitats of conservation importance at a commercial scale.

Evidence description
Sabellaria spinulosa may be directly removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures (section 4.4.1). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on *S.*

spinulosa biotopes. *S. spinulosa* has no economic value and is not commercially harvested. The OSPAR *S. spinulosa* biotopes are not, therefore directly impacted by this pressure and all biotopes within the OSPAR definition are considered, by default, to be **'Not Sensitive'**.

The evidence review also evaluated the evidence regarding potential biological effects of the removal of other target species on the *S. spinulosa* reef biotopes. Experimental laboratory work reported that scallop shells, especially *Pecten maximus*, induced *S. spinulosa* larvae to settle (Earll & Erwin 1983). However; the settlement-inducing property of *P. maximus* shells related mostly to the upper valve which was covered in sand grains (an existing requirement of larvae settlement) and given the diverse range of substrata that *S. spinulosa* have been reported in (see physical change pressure below) it is unlikely that the removal of scallops will have a significant negative impact on larvae recruitment.

The removal of target species that prey on *S. spinulosa* could potentially be beneficial to this species. Assessment of this indirect effect is limited by the lack of empirical evidence for predator-prey relationships. Stomach analysis of fish by Pearce (2001) found that juvenile flatfish captured in reef areas including Dover sole, dab and plaice fed preferentially on *S. spinulosa*. Where these species are removed as target species then predation rates on *S. spinulosa* could be reduced. However, as the rate of predation on *S. spinulosa* and impacts on reefs through population effects and the rate of removal of the predator species are not known, the impact of this potentially beneficial effect could not be assessed.

Removal of predators of species that feed on *S. spinulosa* reefs could lead to an indirect effect of increased predation. However, there has been little research into the identity of predators and extent of predation rates on *S. spinulosa* to assess this potential effect.

Sensitivity assessment

No evidence for significant biological effects of removal of target species associated with *S. spinulosa* reef biotopes was identified. Any local increases in predators are likely to be short-lived unless fishing intensity changes. As significant negative effects are not predicted to arise from the removal of target species all *S. spinulosa* biotopes were assessed, by default, as **'Not Sensitive'** to this pressure. **Resistance** and **resilience** are therefore assessed as **'High'.**

Resistance confidence

Quality of evidence is 'Low' - as the assessment is based on expert judgement.
Applicability is 'Not assessed' - as the assessment is based on expert judgement.
Concordance is 'Not assessed' - as the assessment is based on expert judgement.

Resilience confidence

Quality of evidence is 'High' - based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.2.3 Removal of non-target species

ICG-C pressure description
By-catch associated with all fishing activities. The physical effects of fishing gear on sea bed communities are addressed by the "abrasion" pressure type and this pressure 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.

Pressure benchmark
Removal of features through pursuit of a target fishery at a commercial scale.

Evidence description
Sabellaria spinulosa biotopes may be removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures (section 4.4.1). The assessment for this pressure considers evidence for the biological impacts of the removal of non-target species on *Sabellaria spinulosa* populations e.g. whether *S. spinulosa* has any symbiotic relationships etc. Evidence for ecological interactions between *S. spinulosa* and other species is limited. The removal of *S. spinulosa* predators as bycatch may be beneficial. Pearce *et al* (2011b) found that as well as the commercially targeted species mentioned above (section 4.2.2) butterfish *Pholis gunnelis* and dragonet *Callionymus lyra* predated on *S. spinulosa*. Previous studies have also shown that *Carcinus maenas* feeds on *S. spinulosa* (Taylor 1962; Bamber & Irving 1997). Other invertebrates such as *Pandalus montagui* and *Asterias rubens* found in association with *S. spinulosa* reefs may also be feeding on the worms or on species associated with the reefs rather than *S. spinulosa*. Due to the limited information available on predator-prey relationships the impact of predator removal on *S. spinulosa* reef biotopes cannot be assessed.

Dense aggregations of the brittle star, *Ophiothrix fragilis,* have been suggested to compete with *S. spinulosa* for space and food and potentially to consume the gametes inhibiting recruitment (George & Warwick 1985). Removal of this species as by-catch could potentially be beneficial to the reef biotopes.

A further potential interaction has been identified between *S. spinulosa* and the sand mason *Lanice conchilega*. It has been observed that sand stabilised by the sand mason *Lanice conchilega* is stable enough for colonisation by *S. alveolata* (Larsonneur *et al* 1994). It is believed that the same may also be possible for *S. spinulosa,* as *L. conchilega* and *S. spinulosa* are sometimes found together (Holt *et al* 1997). However, a decline in *S. spinulosa* numbers was coincident with an increase in *L. conchilega* numbers (CEFAS 1998; CEFAS 1999; DFR 1995; DFR 1996a; DFR 1996b; DFR 1997, cited in Limpenny *et al* 2010). It is not clear from the available evidence therefore whether removal of *L. conchilega* would have any impact on *S. spinulosa* reefs (Foster-Smith 2001a).

Sensitivity assessment

No evidence for significant biological effects from the removal of non-target species associated with *S. spinulosa* biotopes was identified. The removal of non-target species, including crustaceans and fish, that are competitors or predators of *S. spinulosa* may be beneficial rather than detrimental. Although discarding of unwanted species may attract predators no evidence was found to assess this. Any local increases in predators are likely to be short-lived unless fishing intensity changes. As significant effects are not predicted to arise from the removal of target species all *Sabellaria spinulosa* reef biotopes were assessed, by default, as **'Not Sensitive'** to this pressure. **Resistance** is assessed as **'High'** and **resilience** as **'High'** (based on no effect to recover from).

Resistance confidence

Quality of evidence is 'Low' - as the assessment is based on expert judgement.
Applicability is 'Not assessed' - as the assessment is based on expert judgement.
Concordance is 'Not assessed' -as the assessment is based on expert judgement.

Resilience confidence

Quality of evidence is 'High' - based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.3 Hydrological changes (inshore/local)

4.3.1 Salinity changes - local

ICG-C pressure description
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.

Pressure benchmark
Increase from 35 to 38 units for one year. Decrease in Salinity by 4-10 units a year.

Evidence description
No evidence for the range of physiological tolerances to salinity changes were found for *Sabellaria spinulosa*. The sensitivity assessment is therefore based on recorded habitat preferences. No evidence was found for tolerance of hypersaline conditions and sensitivity to this benchmark is not assessed.

The biotopes for this assessment do not refer to estuarine habitats and *S. spinulosa* does not seem to occur in very low salinity areas (Holt *et al* 1998). *S. spinulosa* has been recorded from estuaries including the Crouch, Mersey (Killeen & Light 2000) and the Thames (Limpenny 2010). Buhs and Reise (1997) surveyed 12 channel systems in the Wadden Sea and found that *S. spinulosa* reefs occurred in the northern tidal inlets which experienced salinity levels ranging from 28 to 30psu. There is some speculation (Foster-Smith & Hendrick 2003) that Mcintosh (1922) misidentified samples of *S. spinulosa* as *S. alveolata* from the Humber estuarine population (Holt *et al* 1998). These records indicate that reduced and variable salinities can be tolerated to some extent but the paucity of records suggests that areas of reduced salinity do not provide optimal habitat.

Sensitivity assessment

The salinity tolerances of *S. spinulosa* are unclear and therefore the impact of salinity change, at the pressure benchmark, is not clear. As reefs are largely subtidal they are less exposed to hypersaline conditions resulting from coastal brine discharge and natural evaporation (lagoons). There is therefore no direct or indirect evidence for sensitivity to an increase in salinity and this element of the pressure is not assessed. The reported distribution of *S. spinulosa* from fully marine to estuarine habitats does suggest some tolerance of changes in salinity although a decrease in salinity at the extreme of the pressure benchmark (reduction in 10psu) may not be tolerated. **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of extent). Reef r**esilience** (following habitat recovery) is considered to be **"Medium'** (2-10 years**). Sensitivity,** based on combined resistance and recovery, is therefore assessed as **'Medium'.**

Resistance confidence

Quality of evidence is ‘Medium’ - as the assessment is based on expert judgement supported by habitat records.
Applicability is ‘Low’ - as the habitat records are used as a proxy for the pressure.
Concordance is ‘Not assessed’ - as this assessment is not based on multiple sources of evidence.

Resilience confidence

Quality of evidence is ‘High’ - based largely on Pearce *et al* (2007) but supported by the other evidence described within Section 3.
Applicability is ‘Low’ - as the evidence does not relate directly to this pressure.
Concordance is ‘High’ - as reports largely agree on the recoverability potential (e.g. the direction of change) of *S. spinulosa* although variations in resilience rates are reported.

4.3.2 Temperature changes – local

ICG-C pressure description
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 sub-sea power cables. This pressure only applies within the thermal plume generated by the pressure source.

Pressure benchmark
A 5°C change in temp for one month period, or 2°C for one year.

Evidence description
Sabellaria spinulosa has the greatest geographical range of all the sabellariids, according to current records, encompassing Iceland, the Skagerrak and the Kattegat, the North Sea, the English Channel, the northeast Atlantic, the Mediterranean, the Wadden Sea and the Indian Ocean, (Achari 1974; Riesen & Reise 1982; Reise & Schubert 1987; Hayward & Ryland 1998; Foster-Smith 2000; Collins 2005).

There is a lack of evidence on the temperature tolerance of *S. spinulosa;* nevertheless, its widespread distribution suggests that it is tolerant to temperature variations.

S. spinulosa occurs north to the Arctic and is therefore considered tolerant of decrease in temperature (Jackson & Hiscock 2008). This conclusion is supported by observations made on oyster grounds in the River Crouch throughout the severe winter of 1962–1963 that *S. spinulosa* appeared unaffected by the cold. The mean daily temperature was recorded at a depth of 1 fathom (1.8m) below low water (equinoctial spring tide) and the lowest temperature recorded was -1.8°C (Crisp 1964). At Penmon in Bangor, *S. spinulosa* also appeared not to suffer from the low temperatures and live individuals were readily found (Crisp 1964). This case study exemplifies the tolerance of *S. spinulosa* to rapid but minor alterations in temperature but more evidence is needed to determine the effect of larger temperature differences in short time periods, for example, observations of *S. spinulosa* during extreme weather changes or experiments that manipulate temperature within the laboratory.

Sensitivity assessment

There are currently no laboratory studies on the temperature tolerance of *S. spinulosa*. Given the widespread distribution of *S. spinulosa* it is unlikely that this species is sensitive to temperature variations at the pressure benchmark. Resistance is therefore assessed as

'High' and **resilience** is assessed as **'High'** (no impact to recover from), so that all the OSPAR *Sabellaria* biotopes are assessed as **'Not Sensitive'.** However, it should be noted that this evidence does not demonstrate the impacts of an acute change in temperature at the pressure benchmark.

Resistance confidence

Quality of evidence is 'Medium' - as the assessment is based on expert judgement supported by habitat records.
Applicability is 'Low' - as the habitat records are used as a proxy for the pressure.
Concordance is 'Not assessed' - as a single source (habitat records) is used.

Resilience confidence

Quality of evidence is 'High' – based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.3.3 Water flow (tidal current) changes – local

ICG-C pressure description
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, canalisation and/or structures may alter flow speed and direction, managed realignment (e.g. Wallasea, England) may also alter flow. 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 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.

Pressure benchmark
A change in peak mean spring tide flow speed of between 0.1m/s to 0.2m/s over an area > $1km^2$ or 50% if width of water body for more than 1 year.

Evidence description
Sabellaria spinulosa tend to occur in areas of high water movement where larvae, tube building materials and food particles are suspended and transported (Jones *et al* 2000). The relative importance of tidal versus wave induced movements to support reefs is unclear (Holt *et al* 1998).

There is currently limited *in situ* data on the environmental preferences of *S. spinulosa* although colonies have been found in areas with sedimentary bed forms that suggest current velocities in the range of 0.5m/s to 1.0m/s (Mistakidis 1956; Jones *et al* 2000; Davies *et al* 2009). In the southern North Sea close to the coast of England, *S. spinulosa* reefs have been recorded in areas exposed to peak spring tidal flows of 1.0m/s (Pearce *et al* in press).

Davies *et al* (2009) also found through laboratory experiments that increasing the water flow to an average of 0.03m/s is adequate to begin distribution of the sediment rain from the airlift throughout the tank and that doubling the water flow to almost 0.07m/s further improved particle distribution throughout the tank. It is therefore likely that *S. spinulosa* will exist in habitats with a water flow anywhere above 0.07m/s so that particles are suspended and distributed for the use of tube building and feeding.

Tillin (2010) used logistic regression to develop statistical models that indicate how the probability of occurrence of the congener *S. alveolata* changes over environmental gradients within the Severn Estuary. Model predicted response surfaces were derived for each biotope for each of the selected habitat variables, using logistic regression. From these response surfaces the optimum habitat range for each biotope could be defined based on the range of each environmental variable where the probability of occurrence, divided by the maximum probability of occurrence, is 0.75 or higher. These results identify the range for each significant variable where the habitat is most likely to occur. The modelled ranges should be interpreted with caution and apply to the Severn Estuary alone (which experiences large tidal ranges, high currents and extremely high suspended sediment loads and is therefore distinct from many other estuarine systems). However, these ranges do provide some useful information on environmental tolerances. The models indicate that for subtidal *S. alveolata* the maximum optimal current speed (the range in which it is most likely to occur) ranges from 1.26-2.46m/s and the optimal mean current speed ranges from 0.5-1.22m/s. Although not directly applicable to *S. spinulosa* this data suggests that tube-building sabellariid species are able to occur within a broad range of current speeds.

In cases of reduced water flow *S. spinulosa* is likely to suffer a reduction in the supply of suspended food and particles that are integral for growth and repair. A long-term decrease in water flow may reduce the viability of populations by limiting growth and tube building. No evidence was found for threshold levels relating to this impact.

Sensitivity assessment

The range of flow tolerances recorded (50m/s to 1m/s cited by Jones *et al* 2000; Braithwaite *et al* 2006; Davies *et al* 2009) suggest that the worms have a broad tolerance of different flow levels. Tillin (2010) modelled optimal flow speeds of 0.5-1.22m/s for the congener *S. alveolata*. The worms may retract into tubes to withstand periods of high flows at spring tides and some non-lethal reduction in feeding efficiency and growth rate may occur at the edge of the range. Similarly a reduction in flow may reduce supply of tube-building materials and food but again, given the range of reported tolerances a change at the pressure benchmark is not considered to result in mortality**. Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). All the biotopes within the OSPAR habitat definition are therefore considered to be **'Not sensitive'.**

Resistance confidence

Quality of evidence is 'High' - assessment is based on a range of literature sources including evidence from peer-reviewed papers supported by evidence from the grey literature.
Applicability is 'Low' - as the evidence is based on models, laboratory experiments or distribution records rather than pressure impacts.
Concordance is 'High' - as the evidence agrees on the magnitude and direction of impact.

Resilience confidence

Quality of evidence is 'High' – based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.3.4 Wave exposure changes - local

ICG-C pressure description
Local changes in wave length, 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.

Pressure benchmark
A change in nearshore significant wave height >3% but <5%.

Evidence description
No evidence was found to assess this pressure. Intertidal *S. spinulosa* are directly exposed to waves but wave exposure can also potentially affect subtidal *S. spinulosa* reefs. At depth the motion from surface waves becomes oscillatory and produces back-and-forth water movement at the seabed (Dubois *et al* 2006). In sublittoral habitats water movements are likely to provide sand and food particles that are necessary for *S. spinulosa* to build tubes, feed and subsequently grow and develop.

Sensitivity assessment

Sabellaria spinulosa reefs are found subtidally in naturally disturbed environments and areas with high water flow. Therefore, changes (decrease or increase) in wave height at the pressure benchmark are not considered to affect the reefs. All *S. spinulosa* reefs within the OSPAR definition are considered to have **'High' resistance** to this pressure, **resilience** is assessed as **'High'** (no impact to recover from) and all subtidal reef biotopes are considered to be **'Not Sensitive'.** Intertidal populations of *S. spinulosa* would be more exposed to the impacts of wave exposure but the corresponding biotopes to these habitats are not included in this assessment.

Resistance confidence

Quality of evidence is 'Low' - as the assessment is based on expert judgement.
Applicability is 'Not assessed' - as the assessment is based on expert judgement.
Concordance is 'Not assessed' - as the assessment is based on expert judgement.

Resilience confidence

Quality of evidence is 'High' - based on 'High' resistance.
Applicability is 'High' - based on 'High' resistance.
Concordance is 'High' - based on 'High' resistance.

4.4 Physical damage (reversible change)

4.4.1 Abrasion/disturbance of the substratum on the surface of the seabed

ICG-C pressure description
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 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 gravity and hydraulic dredging 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 sea bed surface layers. Activities associated with abrasion can cover relatively large spatial areas and include: fishing with towed demersal trawls (fish and shellfish); bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonisation remain suitable or relatively localised activities including: seaweed harvesting, recreation, potting, aquaculture.

Pressure benchmark
Damage to seabed surface features.

Evidence description
Sabellaria spinulosa reef biotopes are directly exposed to physical damage that affects the surface layers (abrasion). The effects of abrasion coupled with penetration of sub-surface layers is described below in section 4.4.2, for fishing and other impacts that may lead to sub-surface damage. This section describes abrasion of the surface only.

No evidence was found for the impacts of activities that impact the surface only. Studies of intertidal reefs of the congener *Sabellaria alveolata* (Cunningham *et al* 1984) have found that the reef recovered within 23 days from the effects of trampling, (i.e. treading, walking or stamping on the reef structures) by repairing minor damage to the worm tube porches. However, severe damage caused by kicking and jumping on the reef structure, resulted in large cracks between the tubes, and removal of sections (ca 15x15x10cm) of the structure (Cunningham *et al* 1984). Subsequent wave action enlarged the holes or cracks. However, after 23 days, at one site, one side of the hole had begun to repair, and tubes had begun to extend into the eroded area. At another site, a smaller section (10x10x10cm) was lost but after 23 days the space was already smaller due to rapid growth.

To address concerns regarding damage from fishing activities in the Wadden Sea, Vorberg (2000) used video cameras to study the effect of shrimp fisheries on *S. alveolata* reefs. The imagery showed that the 3m beam trawl easily ran over a reef that rose to 30 to 40cm, although the beam was occasionally caught and misshaped on the higher sections of the reef. At low tide there were no signs of the reef being destroyed although the trawl had left impressions but all traces had disappeared four to five days later due to the rapid rebuilding of tubes by the worms. The daily growth rate of the worms during the restoration phase was significantly higher than undisturbed growth (undisturbed: 0.7mm, after removal of 2cm of surface: 4.4mm) and indicated that as long as the reef was not completely destroyed recovery could occur rapidly. These recovery rates are as a result of short-term effects following once-only disturbance. In addition, Vorberg's (2000) experiments focused on large sections of *S. alveolata* reef probably attached to bedrock substrata. It is possible that patchier clumps of *S. spinulosa* on mixed sediment could be more sensitive to trawling activity (Last *et al* 2012).

S. spinulosa reefs are suggested to be more fragile than *S. alveolata* (B. Pearce, pers comm) and therefore surface abrasion may lead to greater damage and lower recovery rates than observed for *S. alveolata*. No direct observations of reef recovery, through repair, from abrasion were found for *S. spinulosa*.

Sensitivity assessment

Abrasion at the surface of *S. spinulosa* reefs is likely to damage the tubes and result in sub-lethal and lethal damage to the worms. **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of tubes and worms within the impact footprint). **Resilience** is assessed as **'Medium'** (within 2 years) and **sensitivity** is therefore assessed as **'Medium'.** This assessment is relatively precautionary and it should be noted the degree of resilience will be mediated by the character of the impact. The recovery of small areas of surficial damage in thick reefs is likely to occur through tube repair and may be relatively rapid.

Resistance confidence

Quality of evidence is ‘Low’ - as the assessment is based on expert judgement.
Applicability is ‘Not assessed’ - as the assessment is based on expert judgement.
Concordance is ‘Not assessed’ - as the assessment is based on expert judgement.

Resilience confidence

Quality of evidence is ‘Low’ - as the assessment is based on expert judgement.
Applicability is ‘Not assessed’ - as the assessment is based on expert judgement.
Concordance is ‘Not assessed’ - as the assessment is based on expert judgement.

4.4.2 Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion

ICG-C pressure description
See description provided above for abrasion/disturbance of the substratum on the surface of the seabed.

Pressure benchmark
Structural damage to seabed sub-surface.

Evidence description
Sabellaria spinulosa reef biotopes are directly exposed to physical damage that affects the surface layers (abrasion) and penetrates deeper beneath the surface of the reef. Fishing activities and aggregate dredging are examples of physical disturbance that are likely to impact *S. spinulosa* reefs and are the most studied activities leading to this pressure. Much of this evidence is anecdotal or the observations are incidental to the focus of the study. No quantitative studies were found and although Vorberg (2000) is widely cited (see above in the abrasion section) the study used a light shrimp trawl on *Sabellaria alveolata* reefs and the relevance to *S. spinulosa* and the use of heavy fishing trawls is questionable.

S. spinulosa reefs in the Wadden Sea suffered great losses in the 1950s which are thought to be due to heavy anchor chains being dragged over grounds in association with shrimp fishing (Reise & Schubert 1987; JNCC 2013). It is believed that local fishermen targeted areas of *S. spinulosa* reef due to their association with the brown shrimp *Crangon crangon*, and that deliberate attempts to remove the reefs were made so that fishing gear was not snagged and damaged (Defra 2004; JNCC 2013). Similar activity has been reported by fishermen at Ramsgate on *S. spinulosa* reefs in the Thames Estuary area but no direct evidence has been identified (Fariñas-Franco 2014).

Other studies have found significant evidence of trawl scars from unspecified fisheries through *S. spinulosa* reefs (Collins 2003; Pearce *et al* 2007) indicating that damage from fishing gear is a real possibility (Hendrick *et al* 2011). Obvious evidence of the destruction of *S. spinulosa* reef clumps by a beam trawler has been reported off the coast of Swanage, Dorset (Collins 2003, cited from Benson *et al* 2013). The loss of reefs within a monitoring zone may have been due to bottom trawling based on the presence of trawl scars within the survey area, although the loss cannot be directly attributed to this activity based on the lack of direct observation (Pearce *et al* 2011a).

S. spinulosa reefs remain extensive at Hastings Shingle Bank (Cooper *et al* 2007; Pearce *et al* 2007) and at the Thanet offshore windfarm site (Pearce *et al* in press) despite clear damage from bottom trawling. However in other areas such as the Wadden Sea (Riesen & Reise 1982) and Morecambe Bay (see references in Holt *et al* 1998), reefs which have been thought to have been trawled have disappeared and have not recovered. It is acknowledged that the limited evidence available does not allow these losses to be directly attributed to fishing

At the Hastings site a newly developed reef (six months old) demonstrated the same multivariate community structure of fauna inhabiting a nearby reef that had been observed over the past five years (Pearce *et al* 2007). This suggests that the epifauna community associated with *S. spinulosa* reefs could also recover from fishing activity quickly, but it should be noted that the older reef had experienced on-going fishing activity and so the associated assemblage may be at a relatively early successional stage (Pearce *et al* 2007). The quick recovery of the reef and associated biota was not seen in the Wadden Sea after shrimping activity in the 1950's. Instead, together with a loss of mussel beds and seagrass, community composition in the subtidal zone changed and a significant decline in sessile species was observed (Reise *et al* 1989; Buhs & Reise 1997; Reise & Buhs 1999; Reise 2005).

Sensitivity assessment

Structural damage to the seabed sub-surface is likely to damage and break-up tube aggregations leading to the loss of reef within the footprint of direct impact. *S. spinulosa* is assessed as having **'No' resistance** to this pressure (removal of >75% of reef in the pressure footprint). Based on evidence (Pearce *et al* 2007; Pearce *et al* 2011a) **resilience** was assessed as **'Medium'**, therefore, **sensitivity** of *S. spinulosa* reef biotopes is considered to be **'Medium'.**

Resistance confidence

Quality of evidence is 'Medium' – as the assessment is based on a range of literature sources including evidence from peer-reviewed papers supported by evidence from the grey literature but no empirical, quantitative evidence was found and the assessment also uses expert judgement.
Applicability is 'High' - as the evidence is based on observations related to this pressure (especially (Pearce *et al* 2007; Pearce *et al* 2011a).
Concordance is 'High' - as the evidence agrees on the magnitude and direction of impact.

Resilience confidence

Quality of evidence is 'High' – based on peer-reviewed and grey literature (especially Pearce *et al* (2007)).
Applicability is 'Medium' – as available studies refer to extraction but also include some evidence relating to this pressure in UK waters.
Concordance is 'High' - as the evidence agrees, in general, on the magnitude and direction of recovery.

4.4.3 Change in suspended solids (water clarity)

ICG-C pressure description
Changes in water clarity from sediment and organic particulate matter concentrations, related to activities that disturb and mobilise sediment and/or organic particulate matter. Sources of this disturbance include 'natural' land run-off and riverine discharges or anthropogenic activities such as dredging, disposal at sea, cable and pipeline burial and

secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed and direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration of this disturbance. This pressure also relates to changes in turbidity from suspended solids of organic origin. Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter. These anthropogenic disturbances are mostly short lived and over relatively small spatial extents.

Pressure benchmark
a change in one rank on the WFD (Water Framework Directive) scale (WFD 2009) for one year (see Table 4.3).

Table 4.3. Water turbidity ranks (based on WFD 2009) based on mean concentration of suspended particulate matter mg/l)

Water Turbidity	Definition
>300	Very Turbid
100-300	Medium Turbidity
10-100	Intermediate
<10	Clear

Evidence description
Sabellaria spinulosa does not rely on light penetration for photosynthesis. It is also believed that visual perception is limited and that this species does not rely on sight to locate food or other resources. In a recent review of sensitivity of *S. spinulosa* reefs to anthropogenic disturbance, Fariñas-Franco *et al* (2014) concluded that impacts on *S. spinulosa* due to a decrease in water clarity resulting from an increase in suspended solids (inorganic or organic) are unlikely although no thresholds regarding tolerance or intolerance were found. Decreases in suspended particles that reduce the supply of food or tube-building materials may, however, negatively impact this species Davies *et al* (2009) and Last *et al* (2011). *S. spinulosa* relies on a supply of suspended solids and organic matter in order to filter feed and build protective tubes and so they are often found in areas with high levels of turbidity. Davies *et al* (2009) and Last *et al* (2011) developed Vortex Resuspension Tanks (VoRT) which are able to test the effects of a change in the composition of suspended sediment on benthic species. This laboratory experiment manipulated turbidity and current flow and demonstrated the susceptibility of *S. spinulosa* to a decrease in suspended inorganic particulate matter (SPM). A clear erosion of tubes was observed in the absence of SPM and subsequent starvation of tube building materials. At high and intermediate sediment regimes (high SPM ~71mg/l) conditions were comparable to what might be expected within only a few hundred meters distance of immediate primary aggregate extraction site and *S. spinulosa* maintained a cumulative growth rate at these rates of SPM. This supports the view that availability of SPM is necessary for *S. spinulosa* development and that tolerance of elevated levels is likely (Davies *et al* 2009; Last *et al* 2011).

Indirect evidence for the tolerance of *S. spinulosa* for changes in turbidity is provided by the persistence of reefs on the outskirts of aggregate dredging areas (Pearce *et al* 2007, 2011a) which appear unaffected by extraction which is likely to have led to sediment plumes. Such plumes, however, are short-lived (Tillin *et al* 2011) and therefore the long-term effect depends on the duration of dredging activities.

Tillin (2010) used logistic regression to develop statistical models that indicate how the probability of occurrence of the congener *Sabellaria alveolata* changes over environmental gradients within the Severn Estuary. The model predicted response surfaces were derived for each biotope for each of the selected habitat variables, using logistic regression. From these response surfaces the optimum habitat range for each biotope could be defined based on the range of each environmental variable where the probability of occurrence, divided by the maximum probability of occurrence, is 0.75 or higher. These results identify the range for each significant variable where the habitat is most likely to occur. The modelled ranges should be interpreted with caution and apply to the Severn Estuary alone (which experiences large tidal ranges, high currents and extremely high suspended sediment loads and is therefore distinct from many other estuarine systems). However, these ranges do provide some useful information on environmental tolerances. The models indicate that for subtidal *S. alveolata* the optimal mean neap sediment concentrations range from 515.7-906mg/l and optimal mean spring sediment concentrations range from 855.3-1631mg/l. Although not directly applicable to *S. spinulosa* this data suggests that tube-building sabellariids are tolerant to very high levels of suspended sediment. Fine sediments such as mud may clog the gills and feeding tentacles of some polychaetes and therefore the potential impact will be mediated by the character of the pressure.

Sensitivity assessment

The benchmark for this pressure refers to a change in turbidity of one rank on the Water Framework Directive (WFD) scale. *S. spinulosa* do not photosynthesise and do not rely on sight to locate resources and therefore no effects are predicted for reef biotopes from an increase or decrease in clarity resulting from a change in one rank on the water framework directive scale. Experiments (Davies *et al* 2009) and predictive modelling (Tillin 2010) indicate that tube building sabellariids can tolerate a broad range of suspended solids. Therefore, they are likely to be **'Not sensitive'** to an **increase** in suspended sediment.

However, Davies *et al* 2009 and Last *et al* 2011 observed a clear erosion of tubes in the absence of SPM and subsequent starvation of tube building materials. Therefore, a **decrease** in SPM for a year (the benchmark) may result in erosion of the reef. **Resistance** to this pressure is therefore assessed as **'Low'** and **resilience** as **'High'**. All the reef biotopes assessed by this project are therefore considered to be of **'Low' sensitivity.**

Resistance confidence

Quality of evidence is 'High' – as the assessment is based on a range of literature sources including peer-reviewed papers supported by evidence from the grey literature.
Applicability is 'Low'- as the evidence is based on models, laboratory experiments or distribution rather than pressure impacts.
Concordance is 'High' – 'High' as the literature agrees on the magnitude and direction of tolerance.

Resilience confidence

Quality of evidence is 'Medium' – based on peer reviewed literature on life histories and grey literature on recovery from impacts.
Applicability is 'Medium' - based on limited studies of direct impact and inference from the life history of the species.
Concordance is 'Medium' - based on agreement in direction but not magnitude, that is, the rate of recovery.

4.4.4 Habitat structure changes - removal of substratum (extraction)

ICG-C pressure description
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-colonise; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.

Pressure benchmark
Extraction of sediment to 30cm.

Evidence description
The removal of sediment or substratum down to 30cm depth is likely to remove the whole reef. No reefs were present in the active dredge zone when dredging was taking place at the Hastings Shingle Bank, for example (Pearce *et al* 2007). Therefore **resistance** to this pressure is assessed as **'None'**. However, if suitable substrata was to remain (as specified in the pressure benchmark), recovery is likely through larval settlement.

Hill *et al* (2011) recently reviewed what is known about the recoverability of seabed sediments following marine aggregate extraction. Rapid recovery was reported in areas with high levels of sediment mobility (eight months) which is likely to include the habitat that *S. spinulosa* is commonly found in (Holt *et al* 1998). For example in areas such as the Bristol Channel (where *S. spinulosa* is currently distributed) physical traces of dredging that had been carried out in mobile sandy habitats disappeared within a few tidal cycles (Newell *et al* 1998). Similarly, dredge tracks at an area of the North Sea exposed to high levels of wave action disappeared in less than a year (Hill *et al* 2011). With regards to *S. spinulosa* specifically, rapid recovery after the cessation of dredging has been observed at high dredging intensity zones in the Hastings Shingle Bank area (new establishment observed in less than a year (Pearce *et al* 2007).

Sensitivity assessment

As *S. spinulosa* reefs are present on the surface they will be directly removed by extraction of the sediment, **resistance** to this pressure is therefore assessed as **'None'**. **Resilience** informed by Pearce *et al* (2007) is considered to be **'Medium'**. All *S. spinulosa* reef biotopes are therefore considered to have **'Medium' sensitivity** to this pressure**.**

Resistance confidence

Quality of evidence is 'High' –as the assessment is based on peer-reviewed and grey literature supported by information on species traits.
Applicability is 'High'- as the evidence relates to this pressure in UK waters.
Concordance is 'High' - as studies agree on the direction and magnitude of effects.

Resilience confidence

Quality of evidence is 'High' – based on peer-reviewed and grey literature (especially Pearce *et al* 2007).
Applicability is 'High' – as available studies (Pearce *et al* 2007) refer to this pressure in UK waters.
Concordance is 'High' - as the evidence agrees, in general, on the magnitude and direction of recovery.

4.4.5 Siltation rate changes, including smothering (depth of vertical sediment overburden)

ICG-C pressure description
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 the disposal of dredged materials where sediments are deliberately deposited on the sea bed. 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 seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the sea bed. 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 pressure would be assessed through ‘physical change (to another seabed type)’ (see Section 4.5.1).

Pressure benchmark
Up to 30cm of fine material added to the seabed in a single event.

Evidence description
Siltation resulting from human activities occurs at the pressure benchmark when large amounts of material are placed on the seabed as in the disposal of capital and maintenance dredge spoils. The disposal of sewage sludge may also result in thick deposits on the seabed, although the disposal of wastes at seas is controlled through licensing and disposal sites are selected with high levels of water movement and low sensitivity so that disturbance is minimised. Aggregate dredging accompanied by screening of fine sediments may also lead to the deposition of sediment layers although this is unlikely to reach the benchmark level. Some siltation may also result from activities that lead to abrasion or disturbance of the seabed and consequent re-suspension of sediments that are transported and re-deposited. Such activities will however, typically result in deposits much thinner than the pressure benchmark.

S. spinulosa are often found in areas of high water movement with some degree of sediment transport essential for tube-building and feeding (Jackson & Hiscock 2008). Given their preference for turbid waters their tolerance to the suspension and/or settlement of fine material during adjacent dredging activity may be high (Tyler-Walters 2007; Jackson & Hiscock 2008; Tyler-Walters 2008). *S. spinulosa* reefs adjacent to aggregate dredging areas appear unimpacted by dredging operations (Pearce *et al* 2007; Pearce *et al* 2011a). Evidence suggests that given the dynamic sedimentary environments in which sabellariids live, their populations can certainly persevere in turbid conditions in spite of ‘typical’ natural levels of burial (Last *et al* 2011) and that recovery from burial events is high. *S. alveolata* was reported to survive short-term burial for days and even weeks in the south west as a result of storms that altered sand levels up to two meters, they were, however killed by longer-term burial (Earll & Erwin 1983).

Direct evidence for the effects of siltation on *S. spinulosa* is limited to the experiments undertaken by Last *et al* (2011). The experimental conditions do not, however, relate to the pressure benchmark (30cm of siltation in a single event). Last *et al* (2011) buried *S. spinulosa* worms (isolated into artificial tubes), under three different depths of sediment – shallow (2cm), medium (5cm) and deep (7cm). The results indicated that *S. spinulosa* could survive short term (32 days), periodic sand burial of up to 7cm. Last *et al* (2011) suggested that the formation of ‘emergence tubes’ (newly created tubes extending to the surface) under sediment burial allowed *S. spinulosa* to tolerate gradual burial and that perhaps this mechanism allows for continued adult dispersal. This mechanism occurred most rapidly throughout the eight day burial at ~1mm per day (Last *et al* 2011) but even though tube-growth still seems possible under burial, it is likely that a dumping of fine and coarse material will block feeding apparatus and therefore worm development will be curtailed (Jackson and Hiscock 2008).

A *S. spinulosa* reef off the coast of Dorset has shown periodic burial from large sand waves (Collins 2003). The displacement of some colonies that had established themselves on a gas pipeline 1km off the coast of Aberdeen was also associated with burial (Mistakidis 1956; cited by Holt *et al* 1998). Furthermore the loss of a 2km^2 area of *S. spinulosa* reef in Jade Bay, North Sea was attributed to burial as a consequence of mud deposition, although fishing activity may have contributed to the decline (Dörjes 1992, cited from Hendrick *et al* 2011).

The evidence above suggests that *S. spinulosa* reefs are sensitive to damage from siltation events (Hendrick *et al* 2011). However, recovery is likely to be rapid given that larval dispersal is not interrupted and new reefs are likely to be able to establish themselves over old buried ones as postulated by Fariñas-Franco (2014).

Sensitivity assessment

No direct evidence was found for the length of time that *S. spinulosa* can survive beneath 30cm of sediment. In areas of high water flow dispersion of fine sediments may be rapid and this will mitigate the magnitude of this pressure by reducing the time exposed. However, this mitigating effect was not taken into account as it depends on site-specific conditions. **Resistance** was assessed as **'None'** due to the depth of overburden. **Resilience** was assessed as **'Medium'** (2-10 years) and **sensitivity** was therefore categorised as **'Medium'.**

Resistance confidence

Quality of evidence is 'Low' - as the assessment is based on expert judgement.
Applicability is 'Not assessed' - as the evidence is based on expert judgement.
Concordance is 'Not assessed' - as the evidence is based on expert judgement.

Resilience confidence

Quality of evidence is 'High' – based on peer-reviewed and grey literature reports (especially Pearce *et al* 2007).
Applicability is 'Low' – as available studies (Pearce *et al* 2007) refer to recovery in response to other pressures.
Concordance is 'High' - as the evidence agrees, in general, on the magnitude and direction of recovery.

4.5 Physical loss (permanent change)

4.5.1 Physical change (to another seabed type)

ICG-C pressure description
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 pressure involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Activities that could lead to this pressure include the installation of infrastructure (e.g. 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 substratum (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. The placement of cuttings piles from oil & gas activities could be considered under this pressure type, however, there may be an additional pressures associated with contaminants and this is activity is therefore dealt with under "pollution and other chemical changes". This pressure excludes navigation dredging where the depth of sediment is changed locally but the sediment typology is not changed.

Pressure benchmark
A change of one Folk class for two years.

Evidence description
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) which 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.

The OSPAR *Sabellaria spinulosa* reef biotopes are found on a range of substratum types including rock and mixed sediments. The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that *S. spinulosa* can colonise artificial structures and have been found on a gas pipeline off the coast of Aberdeen (Mistakidis 1956). An increase in the availability of hard substratum may be beneficial in areas where sedimentary habitats were previously unsuitable for colonisation. However this pressure at the benchmark is not considered applicable to *S. spinulosa* biotopes that occur on hard substratum and this effect is not assessed.

Dredging and dumping of sediment, and infrastructure developments, can lead to changes in sediment character. The impact of the change will depend on the sediment changes that result. Foster-Smith (2001b) reported that the best *S. spinulosa* reefs identified in an area of the Wash were associated with ground clearly scarred by dredging activities. It is believed that this was most likely due to a reduction in the overburden of sand resulting in a substratum more suitable for *S. spinulosa* (Foster-Smith 2001b).

S. spinulosa biotopes that occur on mixed sediments are not considered to be affected by a change in sediment type of one Folk class that leads to a change to ‘coarse sediments’ characterised as gravel, sandy gravel or gravelly sand (based on the Long (2006) simplified Folk classification) or a change to sands and muddy sand as this species is found on sands (George & Warwick 1985). However, this biotope is considered to be negatively impacted by a change to the finest sediment class e.g. a change in the sediment classification to ‘mud and sandy mud’ (based on the Long (2006) classification). This assessment is based on the lack of records of reefs occurring on these sediment types. This is most likely due to the mobility of the sediment, the lack of sand for tube-building and possibly the re-suspension of fine sediments clogging feeding structures and gills, however this is assumed rather than based on direct evidence.

Sensitivity assessment

The sensitivity assessment applies to *S. spinulosa* biotopes that occur on circalittoral mixed sediment (EUNIS code A5.611) as the pressure benchmark is not considered applicable to biotopes occurring on hard substratum. The pressure benchmark is understood to refer to the simplified Folk classification developed by Long (2006). Based on reported habitat preferences and evidence from Foster-Smith (2001), where a change in 1 Folk class results in increased coarseness (e.g. a change to a coarse sediment of gravel, sandy gravel or gravelly sand) then the biotope is considered to be **'Not Sensitive'** as the resulting habitat is suitable for this species. However, an increase in fine sediments to the degree that sediments are re-classified as mud or sandy mud would severely reduce habitat suitability. **Resistance** is therefore assessed as '**None**' (loss of >75% of extent), **resilience** (following habitat recovery) is assessed as **'Medium'** (2-10 years). **Sensitivity**, based on combined resistance and resilience is assessed as **'Medium'**.

Resistance confidence

Quality of evidence is 'Medium' – as the assessment is based on expert judgement supported by information on distribution in relation to sedimentary habitats.
Applicability is 'Low'- as the evidence is based on a proxy rather than directly relating to this pressure.
Concordance is 'Not assessed' - as the evidence relates to proxies.

Resilience confidence

Quality of evidence is 'High' – based on peer-reviewed and grey literature reports (especially Pearce *et al* 2007).
Applicability is 'Low' – as available studies (Pearce *et al* 2007) refer to recovery rates from other pressures.
Concordance is 'High' - as the evidence agrees, in general, on the magnitude and direction of recovery.

4.5.2 Physical loss (to land or freshwater habitat)

ICG-C pressure description
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 one marine habitat type to another marine habitat type.

Pressure benchmark
Permanent loss of existing saline habitat.

Evidence description
All marine habitats and benthic species are considered to have '**No' resistance'** to this pressure and to be unable to recover from a permanent loss of habitat. **Sensitivity within the direct spatial footprint of this pressure is therefore 'High'.** Although no specific evidence is described confidence in the resistance assessment is 'High', due to the incontrovertible nature of this pressure. Adjacent habitats and species populations may be indirectly affected where meta-population dynamics and trophic networks are disrupted and where the flow of resources e.g. sediments, prey items, loss of nursery habitat etc. is altered. No recovery is predicted to occur and the rate and confidence in resilience are not assessed.

4.6 Pollution

4.6.1 Organic enrichment

ICG-C pressure description
Resulting from the degraded remains of dead biota and microbiota (land and 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 benchmark
A deposit of 100gC/m^2/yr.

Evidence description
Limited evidence was found to assess the direct effects of this pressure. *Sabellaria spinulosa* reefs are found in areas of high water movement (up to 1m/s (Pearce *et al* in press), see change in water flow, section 4.3.3 for further details) that would naturally disperse some organic matter preventing accumulation and siltation. In larger, dense colonies of *S. spinulosa*, sand, detritus, and finer faecal materials collect in between worm tubes. These detritus layers do not interrupt the normal growth of the individuals or of the colony as a whole (Schafer 1972). Taking into consideration these points it seems likely that *S. spinulosa* are resistant to the deposition of a fine layer of organic materials.

That reefs are resistant to a high level of organic enrichment is suggested by the presence of *S. spinulosa* adjacent to a sludge dumping area in Dublin (Walker & Rees 1980). Information on the levels of organic matter in Dublin Bay was not provided however, and so it is unclear how the levels experienced relate to the pressure benchmark.

Indirect effects arising from inputs of organic matter are also possible where habitat quality and species interactions are altered. In the Wadden Sea large subtidal areas of *S. spinulosa* reefs have been completely lost since the 1920s. This decline has been partly attributed to an increase in coastal eutrophication that has favoured blue mussel beds (Dörjes 1992; Hayward & Ryland 1998; Benson *et al* 2013). However, a direct causal link has not been established and it is possible that the decline of *S. spinulosa* reefs was due to physical damage from fishing activities rather than competitive interactions (Jones *et al* 2000).

Sensitivity assessment

Little evidence was found to support this sensitivity assessment. Habitat preferences for areas of high water movement suggest that organic matter would not accumulate on reefs, limiting exposure to this pressure. *S. spinulosa* and the associated species assemblage (which typically includes attached filter feeders from a number of phyla) are likely to be able to consume extra organic matter. This conclusion is supported by the enhanced growth rates that have been recorded on the vicinity of sewage disposal areas (Walker & Rees 1980). **Resistance** is therefore assessed as **'High'** to this pressure and **recovery** is assessed as **'High'** (no impact to recover from). All *S. spinulosa* reef biotopes are considered to be **'Not Sensitive'** at the pressure benchmark.

Resistance confidence

Quality of evidence is ‘Medium’ - as the assessment is supported by peer-reviewed evidence (Warren and Rees 1980) but also uses expert judgement.
Applicability is ‘High’ - as the evidence relates to this pressure (although the relevance to the benchmark is not clear).
Concordance is ‘Not assessed’ - as the primary evidence consists of a single source.

Resilience confidence

Quality of evidence is ‘High’ - based on ‘High’ resistance.
Applicability is ‘High’ - based on ‘High’ resistance.
Concordance is ‘High’ - based on ‘High’ resistance.

5 Overview of information gaps and confidence in assessments

Defining *Sabellaria spinulosa* reefs presents some difficulties. *S. spinulosa* may occur at low densities, as thin crusts or as thick reefs, it is the latter that are of conservation and management concern. It appears that reefs may be patchy in occurrence (Foster-Smith 2001b) which means that surveys may not identify true reef extents and characteristics. Small-scale differences in structure mean that samples taken from grabs may not be representative of the reef types present and changes over fine scales hinder studies of ecology and sensitivity where it is not clear how representative samples are.

Practical difficulties in classifying reef types has hindered determination of key differences between different types of *S. spinulosa* habitats in terms of diversity, ecosystem function, and response and recovery to pressures. A number of studies have been undertaken to distinguish different types of reefs (Hendrick & Foster-Smith 2006; Gubbay 2007). However, for the purposes of surveys it is difficult to practically define and map reef types (see Limpenny *et al* 2010). Ongoing work to map reefs and the development of survey techniques and equipment (e.g. Last *et al* 2012) will address some of these issues. Enhanced survey and mapping would support better understanding of the sensitivity, in particular, to the hydrological pressures by identifying optimal habitats.

Difficulties in researching and conducting experiments on reef aggregations means that there is a lack of empirical data and general observations on the sensitivity of *S. spinulosa* reef aggregations to the assessed pressures. In particular, there is very little evidence to understand the impacts of changes in environmental factors. The assessment for hydrological changes, were based either on distribution (changes in temperature) or expert judgement supported by distribution records (changes in water flow, changes in wave exposure, changes in habitat type).

This project identified numerous evidence gaps relating to *S. spinulosa* ecology and in particular, there is little information regarding reef longevity, stability and recovery on which to base assessments of resilience although recent work by (Pearce *et al* 2007) has added considerably to the existing knowledge base. The lack of ecological knowledge is underscored by the uncertainties in assessing the impact of non-indigenous species and the ecological effect of removing species that are either directly targeted or harvested or that are removed as by-catch.

In some instances where experimental studies have been conducted e.g. in relation to siltation, the experimental factors did not relate to the pressure benchmarks and therefore were of limited relevance.

In general, the available evidence suggests that *S. spinulosa* is most sensitive to physical damage pressures. However, the evidence to assess these pressures is limited. The aggregate industry has driven much of the recent work and surveys and monitoring relating to the impacts of aggregate dredging has enhanced the understanding of impacts such as siltation and added to the knowledge of resilience (Pearce *et al* 2007).

The information gaps and the lack of empirical data in relation to pressure impacts means that in many instances confidence in the applicability of data to assess the pressure is low because proxies are used e.g. distribution records to assess tolerances to changes in habitat factors such as changes in water flow. As the evidence base is generally limited, confidence in the degree of concordance is frequently scored as ‘Low’ or ‘Not assessed’ as many sensitivity assessments are based on evidence from single sources, expert judgement or proxies.

6 Comparison with MB0102 sensitivity assessments

Fifteen pressures were assessed in this evidence review. The sensitivity ranks assessed by this project and the previous MB0102 project are compared in Table 6.1. For eight of the pressures the evidence review assessment has supported the existing MB0102 assessment, although it should be noted that for siltation the underlying resistance score developed by this evidence review suggests that the initial impact is greater than that indicated by MB0102 (although the overall score is the same). The two sets of assessments agreed that *Sabellaria spinulosa* reefs are not sensitive to the biological pressures assessed and are generally insensitive to the hydrological pressure assessed (at the benchmark level) including changes in temperature, water flow, suspended solids and wave exposure. Both the MB0102 assessments and assessments within this report found that *S. spinulosa* was sensitive to reductions in salinity. However, in this evidence review we suggest that *S. spinulosa* reefs have a resistance of low rather than medium as in MB0102 (Tillin *et al* 2010) and thus the sensitivity is greater.

Table 6.1. Comparison of sensitivities between this report and in MB0102 (Tillin *et al* 2010). Sensitivity scores are shown in each box; resistance and resilience separated by (/). The range of sensitivities across the component biotopes is indicated by (-). Scores are abbreviated as follows: High (H), Medium (M), Low (L), Very low (VL), Not sensitive (NS), and Not assessed (NA).

Pressure Theme	ICG-C Pressure	MB102	OSPAR	Comments
Biological pressures	Introduction or spread of non-indigenous species (NIS)	NS (H/H)	NS (H/H)	The MB0102 assessment was supported by evidence review approach.
	Removal of non-target species	H (L/L)	NS (H/H)	There is uncertainty regarding the benchmark used in the MB0102 assessment which may account for the difference in score.
	Removal of target species	NS (H/H)	NS (H/H)	The MB0102 assessment was supported by evidence review approach.
Hydrological changes (inshore/local)	Salinity changes - local	L (M/H)	M (L/M)	The evidence review suggests that *S. spinulosa* has lower tolerance (resistance) than the MB0102. However the assessments are based on expert judgement rather than direct evidence.
	Temperature changes - local	NS (H/H)	NS (H/H)	The evidence review supports the assessment made by project MB0102.
	Water flow (tidal current) changes - local, including sediment transport considerations	L (NA/NA)	NS (H/H)	The MB0102 assessment was precautionary and the expert developing the assessment indicated further research was in progress. The evidence review finds that this further research, now published, supports an assessment of Not Sensitive.
	Wave exposure	NS	NS	MB0102 assessment supported by

Pressure Theme	ICG-C Pressure	MB102	OSPAR	Comments
	changes - local	(NA/NA)	(H/H)	evidence review approach.
Physical damage (reversible change)	Abrasion/disturbance of the substratum on the surface of the seabed	L (M/H)	M (L/M)	The evidence review has suggested that resistance to surface abrasion and hence resilience is lower than the MB0102 assessment suggests.
	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	H (N/L)	M (N/M)	The evidence review and MB0102 agree on resistance but differ in the resilience assessment so that the final sensitivity scores differ.
	Changes in suspended solids (water clarity)	NS (H/H)	NS (H/H)	The evidence review supports the assessment made by project MB0102.
	Habitat structure changes - removal of substratum (extraction)	H (N/L)	M (N/M)	The evidence review suggests that sensitivity is lower, based on more rapid recovery.
	Siltation rate changes, including smothering (depth of vertical sediment overburden)	M (M/M)	M (N/M)	The final sensitivity score is the same between the evidence review and MB0102, however it should be noted the underlying resistance scores were considered to be different.
Physical loss (permanent change)	Physical change (to another seabed type)	H (N/L)	M (N/M)	The underlying resistance scores between the two assessments are the same, however the evidence review and the MB0102 assessment differ in the resilience scores and hence the final sensitivity score.
	Physical loss (to land or freshwater habitat)	H (N/L)	H (N/VL)	The evidence review supports the assessment made by project MB0102.
Pollution and other chemical changes.	Organic enrichment	NS (H/H)	NS (H/H)	The evidence review supports the assessment made by project MB0102.

Both the MB0102 assessments and those developed for the evidence review suggest that *S. spinulosa* is sensitive to direct impacts from physical damage pressures and physical loss. However, project MB0102 judged that resilience rates were low (between 10-25 years) following significant impacts. We have suggested that resilience should be assessed as medium (between 2-10 years), when resistance is none or low. The medium resilience assessment was based on the weight of available evidence particularly the work by (Pearce *et al* 2007) but it is acknowledged that in some instances reefs have not recovered following removal of the pressure or that recovery has been protracted. The difference in resilience assessment means that the MB0102 assessments have reported higher sensitivities for the pressures; 1) abrasion and penetration of the seabed, 2) extraction and 3) physical change.

The sensitivity scores for the removal of non-target species differ but this is considered to be due to differences in the application of the pressure benchmark rather than an underlying disagreement between sensitivity.

In general, it should be noted that the confidence in both the resilience and resistance scores is low (for quality, applicability and degree of concordance) for both studies as there is a lack of focussed studies relevant to the assessed pressures and a lack of quantitative, empirical data.

7 Application of sensitivity assessments – assumptions and limitations

The assumptions inherent in, and limitations in application of, the sensitivity assessment methodology (Tillin *et al* 2001) as modified in this report, are outlined below and explained in detail in Appendix 4.

- 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'[2].

- 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 assessment 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.

- The assessments are based on the magnitude and duration of pressures (where specified) but do not take account of spatial or temporal scale.

- The significance of impacts arising from pressures also needs to take account of the scale of the features.

- There are limitations of the scientific evidence on the biology of features and their responses to environmental pressures on which the sensitivity assessments have been based.

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, we have assumed recovery to a 'recognisable' habitat or similar population of species, rather than presume recovery of all species in the community and/or total recovery to prior biodiversity.

It follows from the above, that the 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 concern. They need to be **interpreted within each region (or site)** against the range of activities that occur within that region (or site) and the habitats and species present within its waters.

It should also be noted that the evidence provided, and the nature of the species and habitat features will **need interpretation by experienced marine biologists**.

[2] Where 'environmental range' indicates the range of 'conditions' in which the species or community occurs and includes habitat preferences, physic-chemical preferences and, hence, geographic range.

In particular, interpretation of any specific pressure should pay careful attention to:

- the benchmarks used;
- the resistance, resilience and sensitivity assessments listed;
- the evidence provided to support each assessment; and
- the confidence attributed to that assessment based on the evidence.

It is important to remember that benchmarks are used as part of the assessment process. While they are indicative of levels of pressure associated with certain activities they are **not deterministic**, i.e. if an activity results in a pressure lower than that used in the benchmark this does not mean that it will have no impact. **A separate assessment will be required**.

Similarly, all assessments are made based ‘on the level of the benchmark’. Therefore, a **score 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.

A further limitation of the methodology is that it is only able to assess single pressures and does not consider the cumulative risks associated with multiple pressures of the same type (e.g. anchoring and beam trawling in the same area which both caused abrasion) or different types of pressure at a single location (e.g. the combined effects of siltation, abrasion, synthetic and non-synthetic substance contamination and underwater noise). When considering multiple pressures of the same or different types at a given location, a judgment will need to be made on the extent to which those pressures might act synergistically, independently or antagonistically.

8 Conclusion

The aim of this project was to support the development of sensitivity assessments for the subtidal *S. spinulosa* reef biotopes that are included in the OSPAR habitat definition. The sensitivity of these biotopes to a range of relevant human induced pressures was assessed using the sensitivity assessment methodology developed by project MB0102 (Tillin *et al* 2010). The sensitivity assessment methodology takes account of both resistance and resilience (recovery).

This project identified numerous evidence gaps relating to *S. spinulosa* ecology and sensitivity to human induced pressures. In particular, there is little information regarding reef longevity, stability and recovery on which to base assessments of resilience. Scientific understanding of some of the pressures and their effects on *S. spinulosa* reef biotopes is also poor, for example, litter, introduction of light, electro-magnetic fields and underwater noise. It has therefore not been possible to undertake assessments for these pressures. Many of the assessments have low confidence reflecting the lack of empirical evidence. This uncertainty highlights that further work on this species and reef biotopes to support management would be desirable.

For the hydrological pressures sensitivity was generally inferred from the reported distribution of *S. spinulosa* reef biotopes, e.g. changes in salinity, temperature and wave height. This approach is compromised by unknown bias in recording and reporting reefs. However, given the data limitations this was the best available approach.

In some cases where the evidence base was better developed the information did not apply to the pressure benchmarks and assessments were developed based on expert judgement. *S. spinulosa* reefs were considered to be most sensitive to physical damage pressures. The evidence base for these pressures was better developed but there are still significant information gaps relating to impacts and resilience.

The sensitivity assessment methodology takes account of both resistance and resilience (recovery). Recovery of reefs following significant decline or loss is assessed as 'medium' (based on available evidence) so that full recovery is predicted to require from two to ten years. This means that the highest sensitivity assessment that can be returned using the assessment methodology is 'Medium'. Recovery pre-supposes that the pressure has been alleviated but this will generally only be the case where management measures are implemented. The headline sensitivity assessment score might therefore suggest that there was less need for management measures. In the absence however of management, impacts could be significant and preclude recovery and achievement of conservation objectives. Therefore users of the sensitivity assessment scores should consider both the absolute sensitivity assessment score and the separate resistance score. Where resistance is 'low' or 'none', the need for management measures may be indicated based on the level of impact, irrespective of the overall sensitivity score.

The sensitivity assessments are accompanied by confidence assessments which take account of the relative scientific certainty of the assessments on a scale of high, medium and low. The level of confidence should be taken into account in considering the possible requirements for management measures.

Assessments are particularly sensitive to the pressure benchmark level used and therefore may not be applicable to pressures associated with a specific activity in a given location. Whatever objective measures are applied to data to assess sensitivity, the final score or ranking is indicative, and a sense-check by experienced marine ecologists is advised before the assessments are used to inform management decisions.

Using a clearly documented, evidence based approach to create sensitivity assessments allows the assessment basis and any subsequent decision making or management plans to be readily communicated, transparent and justifiable. The assessments can be replicated and updated where new evidence becomes available ensuring the longevity of the sensitivity assessment tool.

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Acronym List

ASFA - Aquatic Sciences and Fisheries Abstracts

CCW - Countryside Council for Wales (now called Natural Resources Wales)

EUNIS - European Union Nature Information System

ICG-C - Intercessional Correspondence Group on Cumulative Effects

JNCC - Joint Nature Conservation Committee

MCZ - Marine Conservation Zone

MHW - Mean High Water

MLW - Mean Low Water

MNCR - Marine Nature Conservation Review

NIS - Non-indigenous Species

NMBL - National Marine Biological Library

OSPAR - Oslo and Paris Commission

Appendix 1 Sensitivity assessment methodology

Introduction

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'. Sensitivity can therefore be understood as a measure of 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).The concepts of resistance and resilience are widely used in this way to assess sensitivity.

As part of the process of establishing a UK network of marine protected areas (MPAs), Defra led on a piece of work designed to assess the sensitivity of certain marine features, considered to be of conservation interest, against physical, chemical and biological pressures resulting from human activities (Tillin *et al* 2010).The approach was adapted from a number of approaches in particular; Hollings (1973); MarLIN (Hiscock & Tyler-Walters 2006; Tyler-Walters *et al* 2009); OSPAR Texel-Faial Criteria (OSPAR 2003); the CCW 'Beaumaris approach' (Hall *et al* 2008); Robinson *et al* (2008) and the Review of Marine Nature Conservation (Laffoley *et al* 2000).

- The OSPAR commission used these concepts to evaluate sensitivity as part of the criteria used to identify 'threatened and declining' species and habitats within the OSPAR region - the Texel-Faial criteria (OSPAR 2003). A species is defined as very sensitive when it is easily adversely affected by human activity (low resistance) and/or it has low resilience (recovery is only achieved after a prolonged period, if at all). Highly sensitive species are those with both low resistance and resilience.

- The Marine Life Information Network (MarLIN) developed an approach to sensitivity assessment based on species tolerance and ability to recover from pressures (Hiscock & Tyler-Walters 2006; Tyler-Walters *et al* 2009). Based on this methodology detailed assessments are available on-line[3] for a number of biotopes and species.

- The Countryside Council for Wales (CCW) developed the Beaumaris approach (Hall *et al* 2008) that focused on the sensitivity of benthic habitats to fishing activities around the Welsh coast and coastal waters. They compared the severity of a fishing event at four levels of intensity against the rate of habitat recovery to derive a habitat sensitivity score (high, medium or low). The study assessed 30 habitat categories to the intensity of the disturbance and the spatial footprint of the disturbance (which were used together to assess the severity of the disturbance event) and the rate of recovery from the disturbance.

- Robinson *et al* (2008) developed an assessment methodology which was used for OSPAR and Charting Progress II. This assessment was based on expert-judgement and follows the DPSIR (Drivers-Pressures-State-Impacts-Responses) framework.

The Tillin *et al* (2010) methodology was modified by Tillin and Hull (2012-2013), who introduced a detailed evaluation and audit trail of evidence on which to base the sensitivity assessments.

[3] Available on-line at www.marlin.ac.uk

To facilitate the assessment of features, pressure definitions and benchmarks were established. Pressure definitions and associated benchmarks were supplied by JNCC for each of the pressures that were to be assessed (Appendix 2). The pressure descriptions used in this report were created by the Intercessional Correspondence Group on Cumulative Effects (ICG-C). The benchmarks were taken from Tillin *et al* (2010) and applied to the relevant ICG-C pressure (Appendix 2).

Sensitivity assessment

The sensitivity assessment method used (Tillin *et al* 2010; Tillin & Hull 2012-2013) involves the following stages.

A. Defining the key elements of the feature to be assessed (in terms of life history, and ecology of the key and characterising species).
B. Assessing feature resistance (tolerance) to a defined intensity of pressure (the benchmark).
C. Assessing the resilience (recovery) of the feature to a defined intensity of pressure (the benchmark).
D. The combination of resistance and resilience to derive an overall sensitivity score.
E. Assess level of confidence in the sensitivity assessment.
F. Written audit trail.

A) Defining the key elements of the feature

When assessing habitats/biotopes the key elements of the feature that the sensitivity assessment will consider must be selected at the outset.

B and C) Assessing feature resistance (tolerance) and resilience to a defined intensity of pressure (the benchmark)

To develop each sensitivity assessment, the resistance and resilience of the key elements are assessed against the pressure benchmark using the available evidence. The benchmarks are designed to provide a 'standard' level of pressure against which to assess sensitivity.

The assessment scales used for resistance (tolerance) and resilience (recovery) are given in **Table 10.1** and **Table 10.2** respectively.

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

D) The combination of resistance and resilience to derive an overall sensitivity score

The resistance and resilience scores can be combined, as follows, to give an overall sensitivity score as shown in Table 10.3.

Table 10.1. Assessment scale for resistance (tolerance) to a defined intensity of pressure

Resistance (Tolerance)	Description
None	Key functional, structural, characterising species severely decline and/or 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 element e.g. loss of 75% substratum (where this can be sensibly applied).
Low	Significant mortality of key and characterising 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 element e.g. loss of 25-75% of substratum.
Medium	Some mortality of species (can be significant where these are not keystone structural/functional and characterising species) without change to habitats relates to the loss <25% of the species or element.
High	No significant effects to the physico-chemical character of habitat and no effect on population viability of key/characterising species but may affect feeding, respiration and reproduction rates.

Table 10.2. Assessment scale for resilience (recovery)

Resilience (Recovery)	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

Table 10.3. Combining 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 options can also be used for pressures where an assessment is not possible or not felt to be applicable (this is documented and justified in each instance):

No exposure - where there will be no exposure to a particular pressure, for example, deep mud habitats are not exposed to changes in emersion.

Not assessed (NA) – where the evidence base is not considered to be developed enough for assessments to be made of sensitivity

No evidence (NE) - unable to assess the specific feature/pressure combination based on knowledge and unable to locate information regarding the feature on which to base decisions. This can be the case for species with distributions limited to a few locations (sometimes only one), so that even basic tolerances could not be inferred. An assessment of 'No Evidence' should not be taken to mean that there is no information available for features.

E) Confidence Assessments

Confidence scores are assigned to the individual assessments for resistance (tolerance) and resilience (recovery) in the pro-forma in accordance with the criteria in Table 10.4. The confidence assessment categories for resistance (tolerance) and resilience (recovery) are combined to give an overall confidence score for the confidence category (i.e. quality of information sources, applicability of evidence and degree of concordance) for each individual feature/pressure assessment, using Table 10.5.

Table 10.4. Confidence assessment categories for evidence

Confidence Level	Quality of Information Sources	Applicability of evidence	Degree of Concordance
High	High – based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies (give number) on the feature.	High - assessment based on the same pressures acting on the same type of feature in the UK.	High - agree on the direction and magnitude of impact.
Medium	Medium - based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature or similar features.	Medium - assessment based on similar pressures on the feature in other areas.	Medium - agree on direction but not magnitude.
Low	Low - based on expert judgement.	Low - assessment based on proxies for pressures e.g. natural disturbance events.	Low - do not agree on concordance or magnitude.

Table 10.5. Combined confidence assessments (Based on Quality of Information Assessment only)

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

F) Written Audit Trail

So that the basis of the sensitivity assessment is transparent and repeatable the evidence base and justification for the sensitivity assessments is recorded. A complete and accurate account of the evidence that was used to make the assessments is presented for each sensitivity assessment in the form of the literature review and a sensitivity 'pro-forma' that records a summary of the assessment, the sensitivity scores and the confidence levels.

Appendix 2 List of pressures and their associated definitions and benchmarks

Pressures and definitions from the Intercessional Correspondence Group on Cumulative Effects (OSPAR 2011) and benchmarks taken from Tillin *et al* (2010).

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Biological pressures	Genetic modification and translocation of indigenous species.	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, and live bait, species traded as live seafood or 'natural' migration.	Translocation outside of a geographic areas; introduction of hatchery–reared juveniles outside of geographic area from which adult stick derives.
Biological pressures	Introduction of microbial pathogens.	Untreated or insufficiently treated effluent discharges and run-off from terrestrial sources and 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 release contaminated faecal matter, from which pathogens could enter the food chain.	The introduction of microbial pathogens *Bonamia* and *Martelia refringens* to an area where they are currently not present.
Biological pressures	Introduction or spread of non-indigenous species (NIS).	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, 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 imported or from accidental releases.	A significant pathway exists for introduction of one or more invasive non-indigenous species (NIS) (e.g. aquaculture of NIS, untreated ballast water exchange, local port, terminal harbour or marina); creation of new colonisation space >1ha.
Biological pressures	Removal of non-target species.	By-catch associated with all fishing activities. The physical effects of fishing gear on sea bed 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).	Removal of features through pursuit of a target fishery at a commercial scale.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Biological pressures	Removal of target species.	The commercial exploitation of fish and shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on sea bed 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.	Removal of target species that are features of conservation importance or sub-features of habitats of conservation importance at a commercial scale.
Biological pressures	Visual disturbance.	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.	None proposed.
Hydrological changes (inshore/local)	Emergence regime changes - local, including tidal level change considerations.	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, saltmarsh 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 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 very 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 which is considered under the climate change pressures.	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. 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 shoreline length >1km.
Hydrological changes (inshore/local)	Salinity changes - local.	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 hydro-morphological 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	Increase from 35 to 38 units for one year. Decrease in Salinity by 4-10 units a year.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
		event/activity and local environment.	
Hydrological changes (inshore/local)	Temperature changes – local.	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 sub-sea 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).	A 5°C change in temp for one month period, or 2°C for one year.
Hydrological changes (inshore/local)	Water flow (tidal current) changes - local, including sediment transport considerations.	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, canalisation and/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 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.	A change in peak mean spring tide flow speed of between 0.1m/s to 0.2m/s over an areas >1km2 or 50% if width of water body for more than 1 year.
Hydrological changes (inshore/local)	Wave exposure changes – local.	Local changes in wave length, 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.	A change in nearshore significant wave height >3% but <5%.
Other physical pressures	Barrier to species movement.	The physical obstruction of species movements and including local movements (within and between roosting, breeding, feeding areas) and regional/global migrations (e.g. birds, eels, salmon, whales). Both include up-river movements (where tidal barrages and 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 birds, fish, and mammals.	10% change in tidal excursion, or temporary barrier to species movement over ≥50% of water body width.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Other physical pressures	Death or injury by collision.	Injury or mortality from collisions of biota with both static and/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 and mammal collisions with tidal devices and shipping (moving). Activities increasing number of vessels transiting areas, e.g. new port development or construction works will influence the scale and intensity of this pressure.	0.1% of tidal volume on average tide, passing through artificial structure.
Other physical pressures	Electromagnetic changes.	Localised 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).	Local electric field of 1V m-1. Local magnetic field of 10µT.
Other physical pressures	Introduction of light.	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 and 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.	None proposed.
Other physical pressures	Litter.	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).	None proposed.
Other physical pressures	Underwater noise changes.	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental man-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 and 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 sound 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 sea bed topography. Noise levels associated with construction activities, such as pile-driving, are typically significantly	MSFD indicator levels (SEL or peak SPL) exceeded for 20% of days in calendar year within site.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
		greater than operational phases (i.e. shipping, operation of a wind farm).	
Physical damage (Reversible Change)	Abrasion/disturbance of the substratum on the surface of the seabed.	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 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 and 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 sea bed 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 and shellfish); bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonisation remain suitable or relatively localised activities including: seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substratum would adversely affect herring spawning grounds.	Damage to seabed surface features.
Physical damage (Reversible Change)	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion.		Structural damage to seabed sub-surface.
Physical damage (Reversible Change)	Changes in suspended solids (water clarity).	Changes in water clarity from sediment and 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 forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed and 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.	A change in one rank on the WFD (Water Framework Directive) scale e.g. from clear to turbid for one year.
Physical damage (Reversible Change)	Habitat structure changes - removal of substratum (extraction).	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-colonise; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.	Extraction of sediment to 30cm.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Physical damage (Reversible Change)	Siltation rate changes, including smothering (depth of vertical sediment overburden).	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, and 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 sea bed. 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 seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the sea bed. 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. Eleftheriou and McIntyre (2005) describe that the majority of animals will inhabit the top 5-10cm in open waters and the top 15cm in intertidal areas. The depth of sediment overburden that benthic biota can tolerate is both trophic group and particle size/sediment type dependant (Bolam 2010). Recovery from burial can occur from: - planktonic recruitment of larvae - lateral migration of juveniles/adults - vertical migration (see Chandrasekara & Frid 1998; Bolam *et al* 2003; Bolam & Whomersley 2005). Spatial scale, timing, rate and depth of placement all contribute the relative importance of these three recovery mechanisms (Bolam *et al* 2006). As such the terms “light” and “heavy” smothering are relative and therefore difficult to define in general terms. Bolam (2010) cites various examples: - *H. ulvae* maximum overburden 5cm (Chandrasekara & Frid 1998) - *H. ulvae* maximum overburden 20cm mud or 9cm sand (Bijerk 1988) - *S. shrubsolii* maximum overburden 6cm (Saila *et al* 1972, cited by Hall 1994) - *N. succinea* maximum overburden 90cm (Maurer *et al* 1982)	Up to 30cm of fine material added to the seabed in a single event.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
		- gastropod molluscs maximum overburden 15cm (Roberts *et al* 1998). Bolam (2010) also reported when organic content was low: - *H. ulvae* maximum overburden 16cm - *T, benedii* maximum overburden 6cm - *S. shrubsolii* maximum overburden <6cm - *Tharyx* sp. maximum overburden <6cm	
Physical loss (Permanent Change)	Physical change (to another seabed type).	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 substratum (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 and gas activities could fit this pressure type, however, there may be an additional pressures, e.g. "pollution and other chemical changes" theme. This pressure excludes navigation dredging where the depth of sediment is changes locally but the sediment typology is not changed.	Change in 1 Folk class for 2 years.
Physical loss (Permanent Change)	Physical loss (to land or freshwater 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 one marine habitat type to another marine habitat type.	Permanent loss of existing saline habitat.
Pollution and other chemical changes	De-oxygenation.	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.	Compliance with WFD criteria for good status.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Pollution and other chemical changes	Hydrocarbon and PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	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 and animals) Ecological consequences include tainting, some are acutely toxic, carcinomas, growth defects.	Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls.
Pollution and other chemical changes	Introduction of other substances (solid, liquid or gas).	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.	None proposed.
Pollution and other chemical changes	Nutrient enrichment.	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. waste water 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.	Compliance with WFD criteria for good status.
Pollution and other chemical changes	Organic enrichment.	Resulting from the degraded remains of dead biota and microbiota (land and 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.	A deposit of $100gC/m^2/yr$.

Pressure theme	ICG-C Pressure	ICG-C description	MB0102 benchmark
Pollution and other chemical changes	Radionuclide contamination.	Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea-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 10µSv 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 ~2700µSv/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.	An increase in 10µGy/h above background levels.
Pollution and other chemical changes	Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in Annex II of Directive 2008/105/EC.	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) and 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD) are persistent and often very toxic. Pesticides vary greatly in structure, composition, environmental persistence and toxicity to non-target organisms. Includes: insecticides, herbicides, rodenticides and 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).	Compliance with all AA EQS, conformance with PELs, EACs, ER-Ls.

Appendix 3 Biotope descriptions (EUNIS)

OSPAR *Sabellaria spinulosa* reef biotope descriptions, based on Connor *et al* (2004) and sourced from the EUNIS website.

Sabellaria reefs on circalittoral rock (EUNIS A4.22 Marine Habitat Classification Britain/Ireland v 0405 code: CR.MCR.CSab)

This habitat type occurs on moderately wave-exposed, circalittoral bedrock, boulders and cobbles subject to moderately strong tidal streams. It is characterised by dense crusts of the polychaete *S. spinulosa* covering the substratum. Other fauna present in many cases reflects the biotopes found on nearby rock, so to a certain extent, is quite variable. Species typically present include the bryozoans *Flustra foliacea*, *Alcyonidium diaphanum* and *Pentapora foliacea*, the hydroid *Nemertesia antennina*, the sponges *Tethya aurantium* and *Phorbas fictitius*, the anemones *Urticina felina* and *Sagartia elegans*, and the ascidians *Distomus variolosus*, *Polycarpa pomaria* and *Polycarpa scuba*. The barnacle *Balanus crenatus*, the polychaetes *Pomatoceros triqueter* and *Salmacina dysteri*, the starfish *Crossaster papposus*, and *Alcyonium digitatum* may also be recorded.

Sabellaria spinulosa encrusted circalittoral rock (EUNIS A4.221, Marine Habitat Classification Britain/Ireland v 0405 CR.MCR.CSab.Sspi)

This biotope is typically found encrusting the upper faces of wave-exposed and moderately wave-exposed circalittoral bedrock, boulders and cobbles subject to strong/moderately strong tidal streams in areas with high turbidity. The crusts formed by the sandy tubes of the polychaete worm *S. spinulosa* may even completely cover the rock, binding the substratum together to form a crust. A diverse fauna may be found attached to, and sometimes obscuring the crust, often reflecting the character of surrounding biotopes. Bryozoans such as *Flustra foliacea, Pentapora foliacea* and *Alcyonidium diaphanum*, anemones such as *Urticina felina* and *Sagartia elegans*, the polychaete *Pomatoceros triqueter*, *Alcyonium digitatum*, the hydroid *Nemertesia antennina* and echinoderms such as *Asterias rubens* and *Crossaster papposus* may all be recorded within this biotope. There are two variants which are described below.

A4.2211 _Sabellaria spinulosa_ with a bryozoan turf and barnacles on silty turbid circalittoral rock (EUNIS A4.2211; Marine Habitat Classification Britain/Ireland v 0405,CR.MCR.CSab.Sspi.ByB)

This variant is typically found encrusting the upper faces of exposed and moderately exposed circalittoral rock and mixed substrata, subject to strong and moderately strong currents and high turbidity levels. The crusts formed by the sandy tubes of the polychaete worm *S. spinulosa* may completely cover the rock, binding gravel and pebbles together. A diverse fauna may be found attached to this crust, and in many cases reflects the character of nearby biotopes. There is normally considerable variation in the associated fauna encountered. There may be a sparse bryozoan turf (*Flustra foliacea*, *Alcyonidium diaphanum*, *Bicellariella ciliata*, *Bugula plumosa* and *Vesicularia spinosa*) attached to the Sabellaria crust and available rocky substrata. Other scour-tolerant species such as *Urticina felina* are occasionally observed. Clumps of robust hydroids such as *Tubularia indivisa*, *Nemertesia antennina*, *Hydrallmania falcata* and *Halecium halecinum* may also be observed. Other species which may be present include the polychaete *Pomatoceros triqueter*, *Balanus crenatus*, *Asterias rubens*, *Pagurus bernhardus* and *Gibbula cineraria*. Occasionally, sponges such as *Haliclona oculata* and *Halichondria panicea*, and ascidians such as *Dendrodoa grossularia* may also be observed.

A4.2212 *Sabellaria spinulosa*, didemnid and small ascidians on tide-swept moderately wave-exposed circalittoral rock CR.MCR.CSab.Sspi.As

This variant is typically found on tide-swept, moderately wave-exposed circalittoral bedrock, boulders and cobbles subject to slight sand-scour. It occurs predominantly in the lower circalittoral. This variant normally appears as a bedrock/boulder outcrop or reef with a dense crust of the polychaete *S. spinulosa* and a dense turf of didemnid ascidians and scour-tolerant bryozoans such as *Flustra foliacea*, *Pentapora foliacea* and *Cellaria* species. There may be discreet clumps of *Alcyonium digitatum* and sparse sponges such as *Tethya aurantium* and *Phorbas fictitius*. Patchy occurrences of the small ascidians *Polycarpa scuba*, *Polycarpa pomaria* and *Distomus variolosus* may be present on the tops of rocks and boulders whilst in crevices between, the anemone *Urticina felina* may be found. Species such as *Asterias rubens*, *Crossaster papposus*, the serpulid worm *Salmacina dysteri* and the anemone *Sagartia elegans* are occasionally seen on the rock surface. This variant has been recorded from the Lleyn Peninsula, the Skerries and around Pembrokeshire in Wales.

A5.611 *Sabellaria spinulosa* on stable circalittoral mixed sediment SS.SBR.PoR.SspiMx

The tube-building polychaete *S. spinulosa* at high abundances on mixed sediment. These species typically forms loose agglomerations of tubes forming a low lying matrix of sand, gravel, mud and tubes on the seabed. The infauna comprises typical sublittoral polychaete species such as *Protodorvillea kefersteini*, *Pholoe synophthalmica*, *Harmothoe* spp, *Scoloplos armiger*, *Mediomastus fragilis*, *Lanice conchilega* and cirratulids, together with the bivalve *Abra alba*, and tube building amphipods such as *Ampelisca* spp. The epifauna comprise a variety of bryozoans including *Flustra foliacea*, *Alcyonidium diaphanum* and *Cellepora pumicosa*, in addition to calcareous tubeworms, pycnogonids, hermit crabs and amphipods. The reefs formed by *Sabellaria* consolidate the sediment and allow the settlement of other species not found in adjacent habitats leading to a diverse community of epifaunal and infauna species. The development of such reefs is assisted by the settlement behaviour of larval *Sabellaria* which are known to selectively settle in areas of suitable sediment and particularly on existing *Sabellaria* tubes (Tait & Dipper 1997; Wilson 1929). *S. spinulosa* reefs are often found in areas with quite high levels of natural sediment disturbance. Temporal variation: In some areas the reefs are periodically destroyed by storm events leading to a cyclical shift in biotopes from A5.611 to other biotopes e.g. A5.143 or A5.261 with re-establishment of the *Sabellaria* colonies in the following year.

Appendix 4 Sensitivity assessments, assumptions and limitations

The assumptions inherent in, and limitations in application of, the sensitivity assessment methodology (Tillin *et al* 2010) as modified in this report, are outlined below.

Key points

Sensitivity assessments need to be applied carefully by trained marine biologists, for the following reasons.

- 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'[4];

- 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;

- The assessments are based on the magnitude and duration of pressures (where specified) but do not take account of spatial or temporal scale;

- The significance of impacts arising from pressures also needs to take account of the scale of the features;

- 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; and

- There are limitations of the scientific evidence on the biology of features and their responses to environmental pressures on which the sensitivity assessments have been based.

Generic nature of assessments

Detailed assessment of environmental impacts is very dependent on the specific local character of the receiving environment and associated environmental features. Generalisation of impact assessments inevitably leads to an assessment of the average condition. This may over or under-estimate impact risks.

Sensitivity of assessment scores to changes in pressure levels

Sensitivity assessments are not 'absolute' values but 'relative' to the level of the pressure. Assessment of sensitivity is very dependent on the benchmark level of pressure used in the assessment. The benchmarks were designed to represent a likely level of pressure, in relation to the likely range of activities that could cause the pressure. The benchmark provides a 'standard' level of pressure (and hence potential effect) against which the range of species and habitats can then be assessed. The benchmarks are intended to be

[4] Where 'environmental range' indicates the range of 'conditions' in which the species or community occurs and includes habitat preferences, physic-chemical preferences and, hence, geographic range.

pragmatic guidance values for sensitivity assessment, to allow comparison of sensitivities between species and habitats, and to allow comparison with the predicted effects of project proposals. In this way, those species or habitats that are most sensitive to a pressure or range of pressures can be identified.

In translating from the sensitivity assessments present to assessments at a site level, it is thus important that there is a good understanding of the level of actual pressure caused by an activity at a local level. If the pressure level is significantly different from the benchmark, the sensitivity score should be re-evaluated.

Spatial and temporal scale of pressures

The sensitivity assessments provided relate to the magnitude of a pressure and its proposed duration (where stated in the benchmark). Thus in seeking to make use of the assessments at site level, it is also important to obtain further information on both the frequency and spatial extent of a pressure before discussing possible requirements for management measures. For example, deployment of a ship's anchor could cause damage through penetration of the sea-bed. However, the spatial extent of such damage may be very small and, on its own, of no particular consequence. Although, if multiple anchoring events were occurring on a daily basis, the cumulative effect of such damage could be more significant.

Scale of features relative to scale of pressures

In considering possible requirements for management advice or measures, it is also necessary to consider the scale of a pressure in relation to the scale of the features of conservation interest that it might affect. Thus, for example, the change in substratum type caused by the placement of scour protection around an offshore structure on a large subtidal sandbank feature may be of little consequence. However, should such scour protection be placed on a more spatially limited seagrass bed, this could result in the loss of a large proportion of the feature.

Assumptions about recovery

The sensitivity assessment methodology takes account of both resistance and resilience (recovery). 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, we have assumed recovery to a 'recognisable' habitat or similar population of species, rather than presume recovery of all species in the community and/or total recovery to prior biodiversity.

Recovery pre-supposes that the pressure has been alleviated but this will often only be the case where management measures are implemented. For certain resistance-resilience combinations, it may be possible to obtain a 'low' sensitivity score even where resistance is 'medium' or 'low', simply because of assumed 'high' recovery. The headline sensitivity assessment score might suggest that there was less need for management measures.

However, in the absence of such measures the impacts could be significant and preclude achievement of conservation objectives. Therefore in considering the possible requirement for management measures users of the matrix should consider both the sensitivity assessment score and the separate resistance and recoverability scores. As a general rule, where resistance is 'low', the need for management measures should be considered, irrespective of the overall sensitivity assessment.

Limitations of scientific evidence

The sensitivity assessment process chosen provides a systematic approach for the collation of existing evidence to assess resistance, recovery and hence sensitivity to a range of pressures. Expert judgement is often required because the evidence base itself is incomplete both in relation to the biology of the features and understanding of the effects of human pressures.

Biology of species and habitat features

In the marine environment, there is a relatively good understanding of the physical processes that structure sedimentary and rocky habitats but less understanding of biological processes. For example, sediment type in strongly correlated with water flow and wave energy and changes in hydrology will influence the sediment and hence the communities it is capable of supporting. In contrast, biological processes can be highly variable between sites and within assemblages, so that responses to impacts can be unpredictable.

In particular, there is a lack of basic biological knowledge about many of the species of conservation concern, or important species that make up habitats of conservation concern. For example, the life history (e.g. larval ecology) of species such as *Eunicella verrucosa*, *Atrina pectinata* and *Leptopsammia pruvoti*, and hence their recruitment and potential recovery rates, are poorly known. Even where life histories are well known and recovery rates might be expected to be good (due to highly dispersive and numerous larvae), other factors influence their recovery. For example, native oyster and horse mussel have not recovered from past losses due to a multitude of factors including poor effective recruitment, high juvenile mortality, continued impact, or loss of (or competition for) habitat.

Deep sea species and habitats have generally been less well studied than those in coastal areas and information both on their biology and their response to human pressures is limited. The assessments for these features therefore relied heavily on the expert judgment of deep-sea biologists.

Understanding the Effects of Pressures

There are significant limitations in understanding of the effects associated with some of the pressures. For example, there is a paucity of research concerning the effects of underwater noise or particle on marine invertebrates. While it is generally believed that invertebrates are relatively insensitive to these pressures, compared to other marine receptors such as marine mammals and fish, the evidence base for this is poor (Tasker *et al* 2010).

Galgani *et al* (2010) recently reviewed information on the prevalence of litter in the marine environment. This identified a lack of good quantitative data and an absence of studies concerning the effects of litter on marine invertebrates.

Potential effects from electromagnetic fields have been identified for a range of invertebrate species (ICES 2003; Gill 2005; OSPAR 2008a). OSPAR (2008) states that ‘In regard to effects on fauna it can be concluded that there is no doubt that electromagnetic fields are detected by a number of species and that many of these species respond to them. However, threshold values are only available for a few species and it would be premature to treat these values as general thresholds. The significance of the response reactions on both individual and population level is uncertain if not unknown.’

There is very limited information on the effects of the introduction of light on marine invertebrates. Tasker *et al* (2010) did not consider this pressure when developing indicators relating to the introduction of energy for the purposes of the Marine Strategy Framework

Directive 'due partly to their relatively localised effects, partly to a lack of knowledge and partly to lack of time to cover these issues'.

Use of confidence scores

Notwithstanding the limitations of the evidence base, there is a large volume of general evidence to call on against which to make judgements on the most likely effects of pressures on species and habitats based on past experience; especially with respect to fishing, industrial effluents and accidents (e.g. oil spills). Most lacking are specific studies that look at the specific impacts of a given activity (or pressure) on a large number of species and habitats. While, such studies are available for the effects of fishing and pollutants, the effects of many pressures have to be inferred from the available evidence base, in the knowledge that the evidence base will continue to grow.

The sensitivity assessments are accompanied by confidence assessments which take account of the relative scientific certainty of the assessments on a scale of high, medium and low. In the revised methodology adopted here, confidence assessments distinguishes between the quality of the evidence (peer review, vs. grey literature), and its applicability to the assessment in question, and the degree of concordance (agreement) between studies in the magnitude and direction of the effect. The level of confidence should be taken into account in considering the possible requirements for management measures.

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.

Limitations – general

It follows from the above, that the 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 concern. They need to be interpreted within each region against the range of activities that occur within that region and the habitats and species present within its waters.

In particular, interpretation of any specific pressure should pay careful attention to:

- the benchmarks used;
- the resistance, resilience and sensitivity assessments listed;
- the evidence provided to support each assessment; and
- the confidence attributed to that assessment based on the evidence.

It is important to note that benchmarks are used as part of the assessment process. While they are indicative of levels of pressure associated with certain activities they are not deterministic, i.e. if an activity results in a pressure lower than that used in the benchmark this does not mean that it will have no impact. A separate assessment will be required.

Similarly, all assessments are made based 'on the level of the benchmark'. Therefore, a score 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. It is particularly true of the pollution (contaminant) benchmark, which are set to Water Framework Directive compliant levels so that all features are 'not sensitive' by definition. However, this does not mean that feature are 'not sensitive' to accidental spills, localised discharges or other pollution incidents.

A further limitation of the methodology is that it is only able to assess single pressures and does not consider the cumulative risks associated with multiple pressures of the same type (e.g. anchoring and beam trawling in the same area which both caused abrasion) or different types of pressure at a single location (e.g. the combined effects of siltation, abrasion, synthetic and non-synthetic substance contamination and underwater noise). When considering multiple pressures of the same or different types at a given location, a judgment will need to be made on the extent to which those pressures might act synergistically, independently or antagonistically.

It should also be noted that the evidence provided, and the nature of the species and habitat features may need interpretation by experienced marine biologists. Agencies, managers and projects should, therefore, turn to the marine biologists (preferably from different disciplines) within their teams for advice on interpretation or seek to engage scientists within stakeholder groups.