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Assessing the sensitivity of sublittoral rock habitats to pressures associated with marine activities

Maher, E., Cramb, P., de Ros Moliner, A., Alexander, D. & Rengstorf, A.

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For further information please contact:

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

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Summary

There are numerous human activities which occur in the marine environment. These activities can cause a variety of pressures on the seafloor habitats and the species they support. These pressures can occur in isolation or in combination, and their effects can be complex. To better understand the implications of anthropogenic pressures, it is crucial to be aware of how the pressures affect different species and functional ecological groups.

The sensitivity of marine habitats has previously been assessed by Tillin *et al* (2010) and Tillin and Tyler-Walters (2014). Work by Tillin *et al (*2010) focused on the species, habitats and broadscale habitats recommended for designation within Marine Conservation Zones (MCZs) as part of a wider project (Tillin *et al* 2010). Tillin and Tyler-Walters (2014) focussed on systematic habitat level assessments of subtidal sedimentary habitats. Where possible, assessments were determined using available evidence and expert judgement.

The aim of this project is to use the methods developed by Tillin and Tyler-Walters (2014) to assess the sensitivity of pre-defined ecological groups in sublittoral rock habitats in the UK to various anthropogenic pressures. The sensitivity assessments outlined in this report are conducted on groups of ecologically similar species which have been considered to have comparable traits likely to affect their sensitivity. The project consisted of two phases:

Phase 1 – Following a literature review, ecological groups were defined based upon similarities in biological and habitat preference traits (Maher *et al* 2016).

Phase 2 - Following a literature review, sensitivity assessments were conducted for characterising species from within the ecological groups to determine the sensitivity of the groups to pre-determined human pressures. The sensitivity assessments were tabulated based upon the findings for each of each ecological group.

The ecological groups were defined in Phase 1 and are based upon 57 key and characterising Level 5 EUNIS biotopes, all of which fall beneath the umbrella of either ‘Infralittoral Rock’ or ‘Circalittoral Rock’ biotopes at EUNIS Level 2. From the selected biotopes, 76 characterising species were identified to represent sublittoral rock habitats and form the ecological groupings.

The Tillin and Tyler-Walters (2014) sensitivity assessment method was applied to the ecological groups of the sublittoral rock habitats, this report outlines the findings of the the sensitivity assessments for those ecological groupings. Information regarding the resistance and resilience of the species was recorded with the objective of determining an eventual sensitivity score. The sensitivity assessments were conducted for the nine ecological groups defined in Phase 1, using this resistance and resilience evidence. Confidence in the assessments based upon the evidence used was continually appraised using the same methods as those outlined by Tillin and Tyler-Walters (2014). The rationale for each sensitivity score was recorded with relevant references to ensure transparency of the assessments. Assumptions and generalisations of the methods were outlined to summarise the limitations of the sensitivity assessment approach using the methods detailed in this report.

Across sublittoral rock habitats as a whole, six pressures were assessed to be not relevant: ‘Emergence regime changes – local, including tidal level change considerations’, ‘Habitat structure changes - removal of substratum (extraction), ‘Penetration and/or disturbance of the substratum below the surface, including abrasion’, ‘Physical change (to another substratum type)’, ‘Death by injury or collision’ and ‘Noise changes’. In addition, the pressure

‘Barrier to species movement’ was only relevant to ecological groups 2 (non-predatory mobile species) and 3 (mobile predators and scavengers), due to their mobility.

All of the ecological groupings were assessed as not sensitive to ‘Visual disturbance’, ‘Organic enrichment’ and ‘Nutrient enrichment’, with the exception of Group 1 (macroalgae) which was assessed as not exposed to ‘Visual disturbance’. In summary, nine pressures are not relevant or not thought to cause immediate damage to sublittoral rock habitats (not considering frequency and duration of pressure).

Generally, few occurences of *‘High’* sensitivity were found; a total of 10.8% across the sensitivity assessments as a whole. Groups 3 (mobile predators and scavengers) and 4 (bivalves and brachiopods) demonstrated ‘*High*’ sensitivity to four pressures each while 6C (attached erect species) displayed *‘High’* sensitivity to five pressures. All groups were found to be highly sensitive to the pressure ‘Physical loss (to land or freshwater habitat)’. The pressures ‘Smothering and siltation rate changes’ and ‘Introduction of microbial pathogens’, were also found to be particularly damaging to sublittoral rock habitats, especially Group 3 (mobile predators and scavengers), Group 4 (bivalves and brachipods) and sub-group 6C (permanently/temporarily attached, erect epifauna).

The tolerance of each ecological group was found to vary in response to different pressures, for example, although sub-group 6C (attached erect species) demonstrated the highest sensitivity overall it was also tolerant of many pressures. Group 4 (bivalves and brachiopods) and Group 1 (macroalgae) showed the lowest sensitivities in general with 25 and 24 pressures, respectively, recorded as either *‘Not sensitive’* or *‘Low’* sensitivity. Group 2 (non-predatory mobile fauna) and Group 3 (mobile predators and scavengers) each recorded 23 *‘Not sensitive’* or *‘Low’* sensitivity scores.

The majority of the sensitivity assessments were found to be either ‘*not sensitive’* (44.3%) or ‘*Low’* (28.6%), with a proportion of the ‘*low*’ sensitivity scores attributed to the generally ‘*high*’ resilience of the groups. When a resilience score was *‘High’*, a final score of *‘Low’* sensitivity was derived even if the resistance to a pressure was *‘Low’*. As this may not capture the full vulnerability of the group, it is advised that where resistance is recorded as ‘*low*’, the need for management measures should be considered irrespective of the overall sensitivity assessment.

Contents

1 Introduction

The Joint Nature Conservation Committee (JNCC) has commissioned this project to develop and improve the understanding of the effects that human activities have on sublittoral rock habitats in the UK. This report represents Phase 2 of this project and focuses on the findings of the sensitivity assessments conducted on the ecological groups proposed in Phase 1. By contributing to our understanding of habitat-level responses to pressures caused by anthropogenic activities, this work will support management advice for Marine Protected Areas (MPAs), UK marine monitoring and further assessments.

The marine environment is subject to numerous human activities which apply pressures on the species that occupy seafloor habitats. These pressures can occur in isolation, in combination (multiple different pressures) or cumulatively (the same pressure on many occasions). Previous sensitivity assessments conducted by Tillin and Tyler-Walters (2013, 2014) looked to diminish uncertainty around identifying the sensitivity of sedimentary habitats. Information was collected on biological assemblages and ecological groups were defined based on similarities in sensitivity to known pressures. Following this, sensitivity assessments were conducted on individual species, habitats or ecological groups using information gathered from an in-depth literature review on the resistance and resilience of the characterising species.

This project uses the methods for conducting sensitivity assessments developed in Tillin and Tyler-Walters (2014) and consists of two phases:

Phase 1 – A literature review was conducted to gather information on species traits based upon species selected for the ‘Conceptual Ecological Modelling of Sublittoral Rock Habitats to Inform Indicator Selection’ report (Alexander *et al* 2015), commissioned by JNCC. Consequent ecological groups were defined using characterising species based upon shared similarities of biological and habitat traits.

Phase 2 (this report) – A literature review was conducted to inform sensitivity assessments on the ecological groups defined in Phase 1. Information collected during this process was used to determine resistance, resilience and sensitivity of individual characterising species and ecological groups. Confidence in the the sensitivity assessments and supporting literature was assessed and documented throughout the process.

The definition of ecological groups in Phase 1 has reduced the need to conduct sensitivity assessments for all of the species present in sublittoral rock biotopes. The sensitivity assessments are conducted on groups of ecologically similar species which have been considered to have comparable features likely to affect their sensitivity. The ecological groups defined in Phase 1 are based upon 57 key and characterising Level 5 EUNIS biotopes all of which fall beneath the umbrella of either ‘Infralittoral Rock’ or ‘Circalittoral Rock’ biotopes at EUNIS Level 2. The full list of biotopes and species considered in this project are available in Maher *et al* (2016). From the selected biotopes, Alexander *et al* (2015) identified 76 characteristic species of sublittoral rock habitat. These species have been used as the basis for this project.

Nine ecological groups were proposed as part of the Phase 1 outputs based upon available literature, expert judgement and multivariate analyses:

- Ecological Group 1: Macroalgae
- Ecological Group 2: Non-Predatory Mobile Species
- Ecological Group 3: Mobile Predators and Scavengers
- Ecological Group 4: Bivalves and Brachiopods

- Ecological Group 5: Tube-Dwelling Fauna
- Ecological Group 6A: Attached Soft-Bodied Species
- Ecological Group 6B: Attached Encrusting Species
- Ecological Group 6C: Attached Erect Species
- Ecological Group 6D: Attached Robust species

2 Methods

Section 2 describes the methods used to assess the sensitivities of ecological groups against a defined list of pressures, sometimes known as the ICG-C pressures (appendix 2), considered in this report.

2.1 Sensitivity, Resistance and Resilience

The methods used for this project are based upon those used in Tillin *et al* (2010) and Tillin and Tyler-Walters (2014). For the purposes of consistency, definitions of resistance (tolerance), resilience (recovery) and sensitivity are the same as those used in Tillin and Tyler-Walters (2013) and are defined below in Table 1. The scales used to assess resistance, resilience and the overall sensitivity of the groups can be found in Appendix1.

The concepts of resistance and resilience were examined and emphasised by Holling (1973). Resistance and resilience are frequently used to assess the sensitivity of features which may be an individual species, a population or a habitat. The sensitivity assessments conducted as part of this project categorise the sensitivity of ecological groups based upon a combination of shared biological and habitat traits.

Table 1. Definitions of sensitivity, resistance, resilience and pressure (Tillin & Tyler-Walters 2013).

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 (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)

In the context of this report, resistance refers to a species' ability to withstand a pressure of a particular nature at a specific exposure level. Potential exposure levels are defined by benchmarks, these are provided alongisde the described pressures in appendix 2. Resilience is the estimate of the features ability to recover from the impacts of a given pressure (should there be any) and re-establish a population at a baseline level. Where resistance is considered high, resilience is automatically considered to be high due to the measured assumption that there is no impact from which a species or ecological group must recover.

Upon establishing the resistance and resilience for a feature, sensitivity can be measured. This gives an indication of the possible change of a species under a particular pressure, based upon a species or ecological group's ability to tolerate adverse effects and to recover from any impacts.

2.2 Sensitivity Assessments

The sensitivity assessments conducted in Tillin *et al* (2010) to assess marine features were based upon expert judgement from a series of workshops and additional information from The Marine Life Information Network (MarLIN)[1]. This approach was subject to several major limitations including a lack of available experts to undertake assessments and a lack of consensus on the assessments themselves. As such, this project has used the modified methods developed by Tillin and Tyler-Walters (2014) which are based upon available literature. By reviewing the available pressure evidence in relation to the ecological groups, more robust assessments of the sensitivity of sublittoral rock species to physical, chemical and biological pressures stemming from human activities can be made. A full breakdown of the definitions and terms can be found in Appendix 1.

Due to time constraints, sensitivity assessments could not be conducted for all of the species included in the scope of the project. Representative species were selected from the ecological groups which were suitable for the sensitivity assessments. The pre-requisite requirements for the species chosen during this process were that they should be well documented to enable literature sourcing and that they should be representative of the species in the group. As such, taxonomy of the species was carefully considered so that each major group within an ecological group would have a representative where possible. For example, Group 1 (macroalgae) contained 14 species which needed to be reduced to 2-5 representatives as outlined by Tillin and Tyler-Walters (2014). The species were divided according to high level taxonomy into categories of green, red and brown algae and kelp. One species was then chosen from each of these groups based upon which had been best researched and therefore had the most information available for the sensitivity assessments. Distribution was also taken in to account and preference was shown for the most widely distributed species. In the case of Group 1, this resulted in the selection of the following four species: *Laminaria hyperborea* (large brown kelp), *Halidrys siliquosa* (small brown), *Cladophora rupestris* (green) and *Palmaria palmata* (red). The species selections and rationale can be found in the 'Sublittoral Rock EG Sensitivity Assessment Literature Review' spreadsheet which accompanies this report and is available from JNCC. Initially up to five species were selected for the more taxonomically diverse groups though frequently there was not enough evidence available to include all species. As such, the maximum number of representative species for each ecological group was four.

Following the species selection for each ecological group, a literature review was conducted to gather information on the species and their responses to the pressures related to human activities. The information gathered from the literature review can be found in the 'Sublittoral Rock EG Sensitivity Assessment Literature Review' spreadsheet, which accompanies this report and is available from JNCC. Literature was sourced from peer reviewed journals where possible using Science Direct and Web of Knowledge amongst other academic literature search engines. The Marine Life Information Network (MarLIN)[1] was utilised where possible and Government Agency reports were also used.

[1] http://www.marlin.ac.uk/

Subsequent to the literature gathering process for each species, the sensitivity assessments involved the following steps:

1. Assessing species resistance to the related benchmark pressure.
2. Conducting confidence assessments for:
   i. Quality of information (resistance).
   ii. Applicability of evidence (resistance).
   iii. Degree of concordance (resistance).
3. Assessing species resilience to the related benchmark pressure.
4. Conducting confidence assessments for:
   i. Quality of information (resilience).
   ii. Applicability of evidence (resilience).
   iii. Degree of concordance (resilience).
5. Combining the resistance and resilience outcomes to form a score for the sensitivity of the species.
6. Conducting confidence assessments for:
   i. Combined quality of information based upon the resistance *and* resilience scores for quality of information.
   ii. Applicability of evidence.
   iii. Degree of concordance.
7. Providing a written audit trail within a single spreadsheet.

The resistance and resilience scores were determined by examining the relevant literature and assessing the gathered information alongside the score descriptions and a combined matrix outlined in Appendix 1. Relevant information was sought regarding both the effect that a pressure would have on an ecological group and the potential for a population to recover following the removal of the given pressure. The key traits which defined the ecological groups were considered when calculating resistance as the traits used to form the groups were important in determining the sensitivity of group members. For example, when assessing the sensitivity of 'Tube-dwelling fauna' (Group 5) to the pressure of 'Abrasion/disturbance at the surface of the substratum', the degree of protection that the tubes of the species in the group would afford them was considered. Resolving the resilience score required the examination of life history, fecundity, growth rate and distribution. The resilience score for each group remained constant between pressures as life-history and other influencing factors were not considered influential on the factors which predispose resilience. The only exception was when the resistance was '*high*', the resilience was also automatically '*high*' as there was no impact from which the group would need to recover. Though the overall sensitivity scores were largely based upon the assessments conducted for the representative species, all of the group members were briefly consulted prior to the final sensitivity score to ensure that they were all covered by the assessment. Crucially, the group members were assessed in relation to the traits that were used to determine the ecological groups. Thus the overall group scores were representative of the entire group and were based upon the factors considered to be most relevant when considering the sensitivity of sublittoral rock species.

Where the sensitivity assessment score for each representative species in an ecological group was the same, the combined group score given was the same as the collective scores for the individual species. However, when species within the groups demonstrated different resistance and resilience scores despite similarities in biological and habitat traits, the individual sensitivity assessments resulted in divergent scores. When this occurred and the scores were one category apart (i.e. '*Not sensitive'* to *'Low'*, *'Low'*, to *'Medium'* or *'Medium'* to *'High*') the most conservative score was given to all of the members. For example, if the relevant literature established that under a given pressure, one of the representative species demonstrated *'Low'* sensitivity and the others in the group were assessed as '*Not sensitive'*, the overall group score was *'Low'*. This ensured that any species in the group which demonstrated heightened sensitivity because of a reduced resistance or resilience to a pressure was accounted for in the group score.

On the few occasions where scores for representative species were disparate beyond one sensitivity category, assessments were separated out and the species within the ecological group were considered independently from the rest of the group. Therefore, some pressures have multiple sensitivity scores. Unless the evidence suggested otherwise, the overall group score was then considered to be the most conservative score so that the species with the highest sensitivities were not underrepresented in terms of sensitivity. Due to life history evolution and ecological niches, individual species which elicited similar responses to many pressures demonstrated variability under others.

Where peer reviewed literature was not available, grey literature was referred to and MarLIN was frequently consulted. The references cited on MarLIN were sourced where possible but when they could not be accessed, the MarLIN page author was referenced alongside the original author. Expert judgement was applied (if possible) when little information was available for a pressure or a particular species. This was most often based upon the traits and how these might affect the sensitivity of the species within the group if no specific information was available. Proxies were sometimes used for species where appropriate to do so, when information was only available at genus or family level for example. Where no evidence was available at all regarding a pressure, ‘No evidence’ was recorded with ‘Not assessed’ noted for the confidence assessments. Where it was determined that a species was not exposed to a pressure, a record of ‘Not exposed’ was made. For full definitions of the terms used during the sensitivity assessments and for the confidence assessment categories refer to Appendix 1.

2.3 Human Activities and Pressures

Pressures exerted on the marine environment as a result of human activities can be physical, chemical or biological. These, in turn can be broken down in to pressure themes such as hydrological changes or pollution and other chemical changes. A pressure can be defined as the mechanism through which an activity has an effect on any part of the ecosystem (Robinson *et al* 2008). A human activity may give rise to more than one pressure being exerted on a habitat. It is important to examine each constituent pressure individually and in a consistent manner; to achieve this, benchmarks are necessary.

Pressure themes, pressures, benchmarks and pressure descriptions were provided by JNCC for each of the pressures to be considered for assessment within this project. Some of the pressures were excluded for the purposes of this project based upon their lack of relevance to sublittoral rock habitats. The pressures excluded were: ‘Emergence regime changes - local, including tidal level change considerations’, ‘Habitat structure changes - removal of substratum (extraction)’, ‘Penetration and/or disturbance of the substratum below the surface, including abrasion’, ‘Physical change (to another substratum type)’, ‘Death or injury by collision’ and ‘Noise changes’. The ‘barrier to species movement’ pressure was considered ‘Not relevant’ for burrowing and sessile species so was only assessed for ecological groups containing mobile group members.

3 Pressure Review

The pressures and benchmarks used to conduct the sensitivity assessments in this report were developed by the OSPAR Intercessional Correspondence Group on Cumulative Effects (Appendix 2). The pressures, descriptions, and benchmarks have subsequently been modified for standardisation purposes by JNCC and other statutory Nature Conservation Bodies (SNCBs).

In order to identify strengths and limitations within the sensitivity assessments, it is important to review the pressures which were used to inform those decisions. Ultimately, the outcomes of the sensitivity assessments are affected by the abundance and quality of available literature regarding each species. For some pressures, no information could be found, or the applicability of the resources was limited at the species level, and generalisations at higher taxonomic levels were inferred. Identification of current knowledge gaps provides evidence to guide future research efforts into areas which urgently need to be addressed. Targeted studies, relating to specific benchmark values, will facilitate a better overall understanding of the sensitivity of the species in this biotope. Twenty-six pressures were examined in total though one of these (barrier to species movement) was only considered for groups 2 and 3 as it was only applicable to groups containing highly mobile species. As such, 25 pressures were assessed for groups 1, 4, 5, 6A, 6B, 6C and 6D and 26 pressures for groups 2 and 3.

Twenty-five representative species were selected and evaluated for sensitivity to benchmark pressures in this report. Where there were less than five species across the groups with no evidence available, the pressure was classified as having a 'well developed evidence base'. Where no evidence was available for more than half of the species (>13), the pressure was classified as having 'little or no evidence base'. Between these cut off values (>6 and <12) the pressure was classified as having an 'intermediate evidence base'. These categories relate specifically to the availability of evidence and not necessarily the applicability which is addressed in-text for each pressure.

All of the pressure descriptions have been taken directly from the pressure and benchmark list provided by JNCC and are located in Appendix 2.

3.1 Pressures with well-developed evidence base

There were 11 pressures included in this category. Pressures were considered to have a well-developed evidence base if there were five or fewer species where no evidence, for that pressure, could be obtained.

3.1.1 Hydrological changes (inshore/local)

All four of the hydrological pressures considered had a well-developed evidence base.

Salinity changes - local

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.

Benchmark
A decrease in 1 MNCR salinity category outside the usual range of the biotope/habitat. An increase in one MNCR salinity category outside the usual range of the biotope/habitat.

Evaluation
Salinity tolerance was well documented for most species, with evidence found for all taxa. Evidence of targeted studies, that documented the upper and lower lethal limits of adults and/or juveniles, was found for some species. The distribution of a species, e.g. presence in

estuarine conditions, or along a salinity gradient, was used as an indication of salinity tolerance in many cases. The MNCR salinity category from the sublittoral rock habitat is 'fully marine' (30-40). Information relating to the benchmark was frequently found for decreases in salinity, as one MNCR salinity category below 'fully marine' is 'variable' (18-40). Information regarding hyper saline conditions was less accessible. However, hypersaline conditions (above 40) generally occur in enclosed bodies of water where water exchange is limited and evaporation occurs. Although brine discharge from anthropogenic activities (desalination plant, salt cavern washings, etc.) may increase the local salinity levels, the distance of the sublittoral rock habitat from the coast, and the free exchange of water, would limit the occurrence of hypersaline conditions forming. As all of the species considered in the scope of this project are fully marine (though some demonstrate variable preferences), an increase beyond the benchmark was not considered possible given that there is no higher MNCR category than 'fully marine'. As such, information was always available for this pressure.

Temperature changes – local

Pressure description
Events or activities which increase or decrease local water temperature. This is most likely from thermal discharges, e.g. the release of cooling waters from power stations. This could also relate to temperature changes in the vicinity of operational subsea power cables. This pressure only applies within the thermal plume generated by the pressure source. It excludes temperature changes from global warming which will be at a regional scale (and as such are addressed under the climate change pressures).

Benchmark
A 5°C increase in temperature for a one month period, or 2°C for one year. A 5°C decrease in temperature for a one month period, or 2°C for one year.

Evaluation
Information regarding temperature changes was obtained for every species; however, the applicability of this information to the benchmark values was varied. Resistance to temperature changes was largely inferred from global species distributions. This approach is not without limitations, as populations acclimate to the prevailing temperature in their habitat and may not display the same tolerance to a rapid temperature change. Additionally, if a species is at the edge of its range then a change in temperature can have a greater influence on its survival capabilities. The assessments were conducted using distribution as a proxy for species tolerance to temperature changes, and a greater tolerance was inferred from a wider geographical range.

Occasionally, evidence from targeted studies into the upper and/or lower lethal temperature limits of a species were found, but this quality of information was rare. Anecdotal evidence was also utilised, for example, levels of resistance to low temperature for many of the species was inferred from accounts of a severe winter around the British Isles (Crisp 1964). There was no evidence found relating directly to thermal discharges (hot or cold) within the sublittoral habitat.

Water flow (tidal current) changes – local, including sediment transport considerations

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 downstream 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.

Benchmark
A change in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than one year.

Evaluation
Evidence relating to water flow was found for every species considered, except one. Largely, categorical information was sourced from the MarLIN website under the section 'Habitat preferences - Tidal strength preferences'. Where the range was broad, e.g. from 'very weak (negligible)' to 'very strong (>3m/s)', the species was considered to have a high resistance to a change in peak flow at the benchmark levels. Lower resistance levels were recorded in accordance with narrower ranges.

Targeted experiments relating to this pressure were scarce, but occasionally relevant evidence could be derived from descriptive studies that indicated the presence or absence of species along a gradient of flow velocities e.g. Lough Ine study series. Where descriptive studies were used, the range of velocities was used as a proxy for resistance as above.

The effects of sedimentation on the biota were considered under 'Smothering and siltation rate changes'.

Wave exposure changes - local

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.

Benchmark
A change in near shore significant wave height >3% but <5% for more than 1 year.

Evaluation
No evidence relating to wave exposure was recorded for only one of the species considered in the sensitivity assessments. For the majority of the species, categorical information was sourced primarily from the MarLIN website 'Habitat preferences – Wave exposure preferences'. The range of exposures for each species was used as a proxy for resistance. Where there was a wide range of exposures listed, e.g. from 'extremely sheltered' to 'extremely exposed' the resistance was regarded as high, whereas with much narrower ranges the resistance was regarded as being lower. Much of the additional evidence was gathered from previous sensitivity assessments on the MarLIN website.

No targeted studies were found relating to increases or decreases in wave exposure, therefore changes in relation to the benchmark could only be inferred. Occasionally anecdotal or presence/absence derived evidence was sourced. Evidence of behavioural responses, such as hiding among rocks to obtain shelter, was also included.

In this sublittoral habitat, the pressure resulting from wave exposure relates more to the sub-surface oscillation, rather than breaking on shores. No evidence relating specifically to the effect of sub-surface waves was recorded.

3.1.2 Physical damage (reversible change)

All of the physical pressures considered as "reversible change" had a well-developed evidence base.

Changes in suspended solids (water clarity)

Pressure description
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. This 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.

Benchmark
A change in one rank on the WFD (Water Framework Directive) scale, e.g. from clear to intermediate for one year (Table 2).

Table 2. Description of the water turbidity ranks (UKTAG 2014) based on mean concentration of suspended particulate matter mg/l (Tillin & Tyler-Walters 2014).

Water Turbidity	Definition
>3000	Very Turbid
100 - 300	Medium Turbidity
10 - 100	Intermediate
<10	Clear

Evaluation
Evidence relating to the effects of water clarity was recorded for the majority of species considered, with only five where no evidence was found. Changes in water clarity at the benchmark level can indicate an increase or decrease in clarity from a background level. There was no information sourced which related directly to the values at these benchmark levels. Many of the sources gave general statements relating to feeding ability or shading preferences, and heavily relied on information provided in previous sensitivity assessments on MarLIN.

Although there was evidence recorded for almost all of the species, the applicability of the sources for informing sensitivity assessments against the benchmark could be stronger. This is a pressure which would certainly benefit from more targeted research.

Abrasion/disturbance at the surface of the substratum

Pressure description

Physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats. The effects are relevant to epiflora and epifauna living on the surface of the substratum. In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g. kelps) or other intertidal species (trampling) or of epifaunal species (e.g. oysters). In sublittoral habitats, passing bottom gear (e.g. rock hopper gear) may also cause surface abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with surface abrasion can cover relatively large spatial areas e.g. bottom trawls or bio-prospecting or be relatively localized activities e.g. seaweed harvesting, recreation, potting, and aquaculture.

Benchmark

Damage to surface features (e.g. species and physical structures within the habitat).

Evaluation

There was evidence available for almost all of the species which related to the effect of abrasion/disturbance of the seabed. There was only two species for which no information was sourced. The majority of evidence was in relation to disruption from trawling or dredging. Evidence was gathered from previous sensitivity assessments on the MarLIN website, but for some of the species those assessments appeared to be based on expert judgement, informed by ecological traits. For many species, however, other supporting literature was also found. The sourced evidence was highly applicable and could be related to the benchmark pressure. Information relating to the recoverability of an individual to physical damage was often used i.e. re-growth of an arm, or mending a shell. Evidence of the ability of populations to recolonise following disruption events was also used to inform the sensitivity assessment for this pressure.

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

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 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.

Benchmark
'Heavy' - up to 30cm of fine material added to the seabed in a single event.

Evaluation
Evidence was gathered, concerning smothering and siltation rate changes, for all of the species considered. Generally, where information was available, inference related it more to 'light' depositional events rather than the 'heavy' depositional events although metrics were seldom given. Direct reference to the lower benchmark value was given on the MarLIN website for previous sensitivity assessments, but several of these assessments appear to be based on expert judgement rather than empirical evidence. Where other literature was used, direct information relating to the benchmarks was limited, resulting in inference of the sensitivity from studies where the species was observed to react to some level of siltation. To achieve robust evidence at the benchmark levels, targeted experiments are required.

3.1.3 Physical pressure (other)

Only one of the five physical pressures considered as "other" had a well-developed evidence base.

Visual disturbance

Pressure description
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*.

Benchmark
Daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature

Evaluation
There were five species for which no evidence was recorded regarding visual disturbance resistance, and in addition, the four algal species were considered not exposed to this pressure. Evidence for the rest of the species was gained almost exclusively from the sensitivity assessments on the MarLIN website. The evidence was broad and appeared to be based on expert judgement. Many of the species were reasoned to be resistant to visual disturbance but, where the resistance was lower, no empirical information was provided relating to the benchmark.

Targeted research at the benchmark level is necessary to improve the applicability of the evidence for this pressure.

3.1.4 Pollution and other chemical changes

Only three of the eight pollution pressures considered had a well-developed evidence base.

Organic enrichment

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 de-oxygenation, algal blooms, changes in community structure of benthos and macrophytes.

Benchmark
A deposit of 100gC/m^2/yr.

Evaluation
There were only three species for which evidence concerning organic enrichment could not be found. A degree of expert judgement had to be applied because of the general nature of the information which was sourced.

Tillin and Tyler-Walters (2014) commented on the issue of clarity in regards to the rate of deposition, for example, the impact of one major depositional event will likely have a larger immediate impact on species survival opposed to lower magnitude chronic seepage over the year. Additionally, the overall effect of organic enrichment on each species will largely depend on the conditions present in the environment pre-enrichment, and if the cumulative total is above the threshold of the species resilience (Tillin & Tyler-Walters 2014).

Empirical evidence for the quantity of organic enrichment was absent in the literature sourced. Inferences about resistance were thus made based on distributional information (e.g. presence/absence along sewage outflow gradients); evidence from eutrophication and algal bloom events; and evidence from the sensitivity assessments on the MarLIN website.

Direct evidence on the effect of organic enrichment was used to make sensitivity assessments by Tillin and Tyler-Walters (2014). In the absence of direct evidence, reference was made to the AMBI index, supplemented by any other relevant evidence on the effects of organic enrichment on habitats. Tillin and Tyler-Walters (2014) struggled to define how an increase in organics by 100g/C/m^2/yr would actually affect the ecosystem. However, they did note that high values are required to enrich open water systems, citing a study by Eleftheriou *et al (*1982) where 767gC/m^2/yr to an unpolluted sea loch was required to enrich the fauna. It is therefore possible that the evidence obtained in this literature review exceeded the benchmark values, but without targeted empirical research it is impossible to quantify. More research at the benchmark level is required to improve the applicability of the evidence for this pressure.

Nutrient enrichment

Pressure description
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, and 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 de-oxygenation, algal blooms, changes in community structure of benthos and macrophytes.

Benchmark
Compliance with WFD criteria for good status.

Evaluation
In essence, the sources of evidence for nutrient enrichment were the same as for organic enrichment. There were only three species for which evidence concerning nutrient enrichment could not be found. A degree of expert judgement had to be applied where evidence was sourced, because of the general nature of the information available.

Empirical evidence for the quantity of nutrient enrichment was absent in the literature sourced. Inferences about resistance were thus made based on distributional information; evidence from eutrophication and algal bloom events; and evidence from the sensitivity assessments on the MarLIN website.

More research at the benchmark level is required to improve the applicability of the evidence for this pressure.

Transition elements and organometal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC

Pressure description
The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments the main elements of concern are arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc organo-metallic compounds (e.g. tributyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. imposex in molluscs.

Benchmark
Compliance with all AA EQS, conformance with PELs, EACs, ER-Ls.

Evaluation
Resistance to transition metals and organometal contamination was classified as well documented for most species, as there were only five for which no information could be sourced. A degree of expert judgement had to be applied where evidence was sourced, because of the general nature of most of the information available.

Empirical evidence for the resistance to transition elements and organometals was occasionally sourced for some species. However, the majority of the evidence gathered was about the ability of each species to absorb and/or excrete heavy metal compounds, or the presence/absence of species in relation to heavy metal or TBT contamination events. It is worth noting that these sources did not always address the effects of all of the metals listed in the description in tandem, and species may have specific responses to one metal type but not another. Inferences about resistance were thus made based on a combination of these resource types, and evidence from the sensitivity assessments on the MarLIN website.

More empirical research at the benchmark level is required to improve the applicability of the evidence for this pressure.

3.2 Pressures with an intermediate evidence base

There were six of the pressures which were included in this category. Pressures were considered to have an intermediate evidence base if there were between six and 12 species where no evidence, for that pressure, could be obtained.

3.2.1 Pollution and other chemical changes

Half of all the pollution pressures considered were classified as having an intermediate evidence base.

De-oxygenation

Pressure description
Any de-oxygenation 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 de-oxygenated 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 de-oxygenated via treatment with inert gases to kill non-indigenous species.

Benchmark
Exposure to dissolved oxygen concentration of less than or equal to 2mg/l for one week (a change from WFD poor status to bad status).

Evaluation
De-oxygenation was fairly well documented among the species considered. However, there were nine species for which no evidence could be obtained.

There was a mixture of evidence types for this pressure, but applicability was usually good. Targeted studies existed for several of the species, where information on resistance directly relating to the benchmark was obtained. Presence/absence descriptions and anecdotal evidence of mortality following anoxic events were also used to indicate species resistance to de-oxygenation. Expert judgement was applied in these cases, and the sensitivity assessments from the MarLIN website were used in conjunction with the other resources. Further targeted studies would fill in the remaining species knowledge gaps relating to the benchmark values.

Introduction of other substances (solid, liquid or gas)

Pressure description
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.

Note: P1, P2 and P3 are the codes for the other pressures from the ‘Pollution and other chemical changes’ pressure theme from the JNCC pressures list available in appendix 2 and on the JNCC website (JNCC 2015).

Benchmark
Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls.

Evaluation
The introduction of other substances was considered very closely alongside hydrocarbon & PAH contamination (see below) as the ICG-C pressure description stated ‘in relation to produced waters from the oil industry’. This pressure was reasonably well documented among the species considered. However, there were 10 species for which no evidence could be obtained. The sourced evidence was often anecdotal or descriptive and derived from events such as oil spills, subsequent clean-up operations, dredge spoil, and gas leaks. Large events, such as an oil spill, increase the presence of other substances in the

environment far beyond the benchmark for this pressure. A degree of expert judgement was thus exercised when determining resistance of each species at the benchmark level. There were several studies which did provide values of contaminants in the area, however specific targeted studies to determine thresholds were lacking.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC

Pressure description
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) and 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) and biogenic hydrocarbons (from plants & animals). Ecological consequences include tainting, acute toxicity, carcinomas and growth defects.

Benchmark
Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls.

Evaluation
The hydrocarbon and PAH contamination pressure was considered very closely alongside introduction of other substances (see above). This pressure was reasonably well documented among the species considered. However, there were 11 species for which no evidence could be obtained. The sourced evidence was often anecdotal or descriptive, derived from events such as oil spills and subsequent clean-up operations. Large events, such as an oil spill, increase the presence of hydrocarbons and PAHs in the environment far beyond the benchmark for this pressure. A degree of expert judgement was thus exercised when determining resistance of each species at the benchmark level. There were several studies which did provide values of contaminants in the area, however specific targeted studies to determine thresholds were lacking.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC

Pressure description
Increases in the levels of these compounds compared with background concentrations. These compounds are synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds include polychlorinated biphenols (PCBs), dichlor-diphenyltrichloroethane (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. Pesticides include 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 detection in most aquatic environments, they have become an emerging concern. Ecological consequences include physiological changes (e.g. growth defects, carcinomas).

Benchmark
Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls.

Evaluation
Evidence relating to the synthetic compound contamination pressure was found for many of the species, with only eight where no information was sourced. However, much of this evidence was based on broad statements or, less often, on documented effects using higher taxonomic levels as proxies. Where there was information relating to specific threshold resistances, it was usually for one or two types of chemicals and not the whole suite identified in the pressure description. Resistance to synthetic chemicals was based upon the information available, where different chemicals form the basis of the assessments for different species. Therefore a degree of expert judgement was necessary. For a greater understanding of the sensitivity of species to this broad pressure category, much more targeted research needs to be applied for each type of synthetic chemical.

3.2.2 Biological pressures

Only two of the five biological pressures were considered to have an intermediate evidence base.

Removal of non-target species

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 'Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion' so the 'Removal of non-target species' 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).

Additional Comment: It is considered that this pressure addresses only the biological effects of removal of species and not the effects of the removal process on the species. Food-web impacts are only relevant to higher trophic levels (birds, fish, mammals and turtles): for benthic habitats and associated species the pressure has been interpreted as specifically referring to the risk of ecological effects arising from the removal of species that are not directly targeted by fisheries.

The assessment considers whether species present in the biotope are likely to be damaged or removed by relevant activities and whether this removal is likely to result in measurable effects on biotope classification, structure (in terms of both biological structure e.g. species richness and diversity and the physical structure, sometimes referred to as habitat complexity) and function. Examples of biotopes that are sensitive to this pressure are therefore i) biogenic habitats that are created by species which may be removed by fishing activities, e.g. maerl beds and hard substrata that are dominated by plant and animal assemblages, ii) biotopes characterized by ecosystem engineers or keystone species that strongly determine the rate of some ecological processes, e.g. beds of suspension feeders that cycle nutrients between the water column and substratum and iii) biotopes with key characterizing species, (e.g. those named in the biotope description or identified as important by the biotope description) that are likely to be removed or displaced as by-catch.

Benchmark
Removal of features or incidental non-targeted catch (bycatch) through targeted fishery, shellfishery or harvesting at a commercial or recreational scale.

Evaluation
Evidence was gathered on the effects or removing non-target species for the many of species considered, although there were nine for which information could not be sourced.

Only the biological effects relating to the removal of non-target species were considered for this pressure, e.g. predation, competition, *etc*. Generally, the information applicability was strong for this pressure, with many studies relating directly to the pressure and the benchmark. The sensitivity assessments on the MarLIN website were also used to provide evidence.

Removal of target species

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 'Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion', so 'Removal of target species' 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.

Additional Comment: It is considered that this pressure addresses only the biological effects of removal of species and not the effects of the removal process on the species, community or habitat itself. Food-web impacts are only relevant to higher trophic levels (birds, fish, mammals and turtles): for benthic habitats and associated species the pressure has been interpreted as specifically referring to the risk of ecological effects arising from the removal of species that are directly targeted.

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

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

Evaluation
There were seven species where no evidence was recorded for the removal of target species pressure. However, using expert judgement, a further nine species were deemed 'Not exposed' because they are unlikely to ever be part of a commercial fishery, e.g. *Dexamine spinosa*. The sourced evidence is from a mixture of peer reviewed literature and information from sensitivity assessments on the MarLIN website. Often the evidence only provided information that targeted extraction of the species occurs, and the expected recovery rates, with little information about wider effects on the ecosystem. Expert judgement was applied to determine the resistance and resilience of the species. Where information existed to suggest that removal of a target species may occur in the future, e.g. for medicinal research, the category of 'No evidence' was applied. This classification was deemed appropriate because there is no current evidence to suggest the removal, but it cannot categorically be said it won't occur in the future.

3.3 Pressures with little or no evidence base

There were several pressures which were included in this category. Pressures were considered to have little or no evidence base if there were more than half (13) of the species where no evidence, for that pressure, could be obtained.

3.3.1 Physical pressure (other)

Four of the five pressures considered in this category were found to have little or no evidence base.

Barrier to species movement

Pressure description
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, and whales). Both include upriver 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 highly mobile birds, fish, and mammals.

Benchmark
Permanent or temporary barrier to species movement ≥50% of water body width or a 10% change in tidal excursion.

Evaluation
The barrier to species movement pressure was considered not relevant to the following sessile/sedentary organisms: *Laminaria hyperborea; Halidrys siliquosa; Cladophora rupestris; Palmaria palmata; Lanice conchilega; Sabella pavonina; Alcyonium digitatum; Clavelina lepadiformis; Dysidea fragilis; Cliona celata; Electra pilosa; Axinella dissimilis; Flustra foliacea; Eunicella verrucosa; Balanus crenatus; Spirobranchus triqueter; Mytilus edulis; Pholas dactylus.* No evidence was found for the remaining seven species in relation to this type of pressure.

Electromagnetic changes

Pressure description
Localized electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). Such cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (e.g. sharks and rays).

Benchmark
Local electric field of 1Vm-1. Local magnetic field of 10µT.

Evaluation
The evidence base for this pressure is not very developed and relevant information was difficult to source. The only information sourced was relating to the commercially valuable species, *Cancer pagurus*. Presence at a wind farm, despite electromagnetic fields was described by Hooper and Austen (2014), and the use of electromagnetic tags on crabs and lobsters was studied by Smith *et al (*2000). This pressure is poorly represented in the literature and targeted research is required.

Introduction of light

Pressure description

Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24 hour working and 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.

Benchmark

None proposed.

Evaluation

The evidence base for this pressure was not very well developed, with no evidence recorded for over half of the species considered (18). Much of the evidence accessed was in relation to species responses to light in general, whether from peer reviewed literature or from previous sensitivity studies on the MarLIN website. This information was used, with expert judgement, as a proxy for the potential disruption to species, e.g. affecting spawning cues, settling cues, predation avoidance *etc*.

More research into the effects of artificial light on species would be beneficial to address this knowledge gap.

Litter

Pressure description

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).

Additional Comment - We are not aware of any evidence on the effects of 'litter' on benthic marine species. While there is documented evidence of the accumulation of micro-plastics in some species, no ecological effects have been shown to date. The only exception is the effect of ghost fishing on large crustaceans (crabs *etc*.). Therefore, the sensitivity to litter was not assessed for habitats and was scored 'No evidence' by Tillin and Tyler-Walters (2014). Clearly it is relevant for large macrofauna such as fish, birds and mammals.

Benchmark

Introduction of man-made objects able to cause physical harm (surface, water column, sea floor and/or strandline).

Evaluation

The evidence base for the effects of litter on the species considered was limited. There were 19 species where no evidence was found. Specific, applicable, information was sourced for *Mytilus edulis* concerning micro-plastic ingestion. However, for several other species, information for higher taxonomic levels was used as a proxy to infer resistance, in addition to expert judgement. The presence of species in locations where litter levels were high was also used to infer resistance to this pressure.

There is still a clear knowledge gap in the scientific literature concerning this type of pressure on marine biota for many species.

3.3.2 Pollution and other chemical changes

Only one pressure considered in this category was found to have little or no evidence base**.**

Radionuclide contamination

Pressure description
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.

Benchmark
An increase in 10μGy/h above background levels.

Evaluation
There was limited information available for radionuclide contamination. There was relevant evidence sourced for only three species*.* Mostly, the information indicated that these species are known to take radionuclides up from their surroundings and store them in their body tissues, to varying degrees. Information about the actual quantities was limited, and so expert judgement was exercised in determining resistance relating to the benchmark.

This is a pressure for which there is an extensive knowledge gap in the literature, and more targeted studies testing effects at the benchmark threshold are needed.

3.3.3 Biological pressures

Three of the five biological pressures considered were found to have little or no evidence base**.**

Genetic modification and translocation of indigenous species

Pressure description
Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated with radionuclide contamination). Former related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, scallops if GM practices employed. Scale of pressure compounded if GM species *‘*captured*’* and translocated in ballast water. Mutated organisms from the latter could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration.

Additional Comment - 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). The former is related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, and scallops if GM practices or breeding programmes are employed. The scale of pressure is compounded if GM species *'*captured*'* and translocated in ballast water. GM species could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration. The pressure also relates to the translocation of indigenous species which may compete with local populations of species, alter the community of the receiving habitat, or provide the opportunity for hybridization between similar species (e.g. *Spartina* spp. and *Mytilus* spp.).

Benchmark
Translocation of indigenous species and/or introduction of genetically modified or genetically different populations of indigenous species, which may result in changes in genetic structure of local populations, hybridization, or change in community structure.

Evaluation
Genetic modification and translocation of indigenous species was a pressure where very little evidence was sourced. The only available evidence was for *Mytilus edulis,* but it was highly applicable and from peer reviewed sources*.* More research of this nature would be beneficial for a wider range of species.

Introduction or spread of invasive non-indigenous species (INIS)

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 outcompeting 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.

Benchmark
The introduction of one or more invasive non-indigenous species (IINIS). IINIS to be based on Great Britain's Non Native Species Information Portal (GBNNSIP).

Evaluation
There was not very much evidence available regarding the introduction or spread of invasive non indigenous species in relation to the species considered in this report. Evidence was available for only seven of the species and where information was sourced, it generally referred to the spread of competitor species who occupied similar environmental niches. The weak evidence base for this pressure is most likely to refer to the fact that most documented non-indigenous species are intertidal, not subtidal. The evidence was mixed between peer reviewed records, information from the MarLIN sensitivity studies, and expert judgement was applied in conjunction with these resources.

Introduction of microbial pathogens

Pressure description
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.

Benchmark
Introduction of relevant microbial pathogens or metazoan disease vectors to an area where they are currently not present (e.g. *Martelia refringens* and *Bonamia*, Avian influenza virus, viral Haemorrhagic Septicaemia virus).

Evaluation
There were 14 species where no evidence relating to the introduction of microbial pathogens was found. Where information was found, it primarily addressed susceptibility of the species to known diseases for the taxa, but not the susceptibility of the species to new diseases. Occasionally, broad statements for resistant at higher taxonomic levels were also utilised as evidence for this pressure. A combination of this information was utilised as a proxy to predict the resistance of each species to the potential spread of new diseases, or expansion of existing diseases into previously unaffected populations.

4 Sensitivity of subtidal rock habitats to human pressures

The sensitivity assessments for the ecological groups determined in Phase 1, are outlined in Section 5. A description of each ecological group with a brief account of the species that were selected for the sensitivity assessments is given.

The assessment scales for resistance (tolerance) and resilience (recovery) and the sensitivity score matrix can be found in Appendix 1. The outcome of the sensitivity assessment can be one of four scores: ‘High’, ‘Medium’, ‘Low’ or ‘Not sensitive’. Confidence assessments were conducted on all sensitivity assessments and the results presented alongside the sensitivity results. The confidence assessment categories (Appendix 1) are different to those used as part of the literature reviews (Appendix 2) for Phases 1 and 2 and are consistent with those developed by Tillin *et al (*2010) and Tillin and Tyler-Walters (2014).

4.1 Ecological group 1: Macroalgae

This group is entirely composed of macroalgal species which represent the primary producers in the sublittoral rock habitat. Along with other primary producers, macroalgae form the basis of the food web and the species themselves provide habitats for other algae and fauna. As such, macroalgae are a crucial group within the sublittoral rock habitat. They most commonly occupy the infralittoral region and attach to a range of substratum types (Connor *et al* 2004) though relatively clear water and suitable conditions for holdfasts to survive are prerequisite.

The representative macroalgae species selected for the sensitivity assessments for this group are: *Laminaria hyperborea, Halidrys siliquosa, Cladophora rupestris and Palmaria palmata.* Although there are some differences between the species in this group which influence sensitivity (notably size), they are all structurally similar. *L. hyperborea* was selected as the only brown kelp species within the project. It is widely distributed and can be considered a generic brown representative of large algae. *H. siliquosa* has been selected as a well documented though smaller brown algae. *C. rupestris* was chosen as a green algal species with a fairly constant morphology across habitat conditions and lastly, *P. palmata* was selected as a representative for the red macroalgae in the ecological group.

Given the sessile nature of the species in the macroalgae group, they are unlikely to be able to avoid many of the pressures considered in this project. The lack of mobility greatly affects the resistance of macroalgae to many pressures whether chemical, physical or biological. The size of the member species has also be taken in to consideration when assessing resistance. There is a range of species sizes within the ecological group which is of particular importance when assessing group sensitivity to physical pressures such as smothering. Variations in pressure response between species may be attributable to a number of factors including the depths which are occupied by the group members and chromatic adaptation through photosynthetic pigments. Though the resistance of species to pressures is variable, the resilience is often considered to be high for the group, though this is dependent on the extent of tolerance demonstrated to individual pressures. Reproduction is a complex and variable process for all macroalgal species though for some, reproduction can occur throughout the year (Budd 2007) and sexual maturity is achieved at a young age (Hill 2008). The ability of many macroalgal species to propagate rapidly acts to increase resilience and decrease the overall sensitivity of the group under certain pressures. Many species also demonstrate the ability to grow quickly (Fortes & Lüning 1980; Tyler-Walters 2007; Moss & Sheader 1973; Hill 2008) and establish populations which in turn increases resilience to pressures as recovery is likely to be swifter.

4.1.1 Sensitivity assessments

Table 3. Group 1 Macroalgae sensitivity assessments for pressures (H = High; M = Medium; L = Low; VL = Very low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	M	H	Low	M	H	M
Temperature changes - local - Group	H	H	Not sensitive	M	H	M
Temperature changes - local - *L. hyperborea*	L	M	Medium	M	H	H
Water flow (tidal current) changes - local	M	H	Low	M	H	L
Wave exposure changes - local	M	H	Low	M	H	L
Changes in suspended solids (water clarity)	M	H	Low	M	H	M
Abrasion/disturbance at the surface of the substratum	M	H	Low	M	H	L
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	L	M	Medium	L	M	M
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	No evidence					
Litter	No evidence					
Visual disturbance	Not exposed					
Organic enrichment	H	H	Not sensitive	H	H	M
De-oxygenation	H	H	Not sensitive	H	H	M
Introduction of other substances (solid,	M	H	Low	L	H	L

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
liquid or gas)						
Nutrient enrichment	H	H	Not sensitive	H	H	M
Hydrocarbon & PAH contamination	M	H	Low	M	H	L
Radionuclide contamination	H	H	Not sensitive	M	H	M
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	M	H	Low	M	H	M
Transition elements & organo-metal (e.g. TBT) contamination	M	H	Low	M	H	M
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens	H	H	Not sensitive	M	H	M
Introduction or spread of non-indigenous species (INIS)	M	H	Low	H	H	M
Removal of non-target species	M	H	Low	H	H	M
Removal of target species	M	H	Low	M	H	M

Salinity changes - local
The individual species in this group demonstrated some disparity in response to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology and habitat preference.

The sessile nature of the macroalgal species means that they are not able to avoid changing water chemistry though examination of the representative species illustrates that resistance for most species at the benchmark is relatively high. Lüning (1984, in Tyler-Walters 2007) suggests that kelps are stenohaline and that like the green algae *C. rupestris,* their tolerance to salinity covers a range between low to fully marine conditions. Smaller brown species such as *H. siliquosa* are also likely to be tolerant of variable salinity conditions (Tyler-Walters & Pizzola 2008). As such, should there be a change in salinity within the benchmark; many macroalgal species would not be adversely affected.

Some species are less resistant than other algal species at extreme salinities but not within the benchmark considered. This was demonstrated by Hopkin and Kain (1978, in Tyler-Walters 2007) who state that young sporophytes *of L. hyperborea* grew optimally between 20-35psu but underwent a high degree of mortality at <10psu. Though intertidal biotopes are not considered in the scope of this project, some species within the group such as *H. siliquosa* are known to occur in rock pools, which may undergo regular variations in salinity due to freshwater input and evaporation. In addition, *C. rupestris* found in intertidal pools can tolerate a salinity of 5-30psu (Jansson 1974). In laboratory experiments, maximum rates of photosynthesis and respiration in *P. palmata* was observed at 32psu and photosynthetic rates were high down to a salinity of 21psu (Robbins 1978, in Hill 2008) which suggests that decreasing salinity had adverse effects on this rhodophytes though no evidence of mortality was recorded. Though the resistance of the group members to changing salinity is variable, the resilience of macroalgae to the pressure is considered to be '*High*' due to the rapid growth rate of many macroalgal species (Tyler-Walters 2007; Moss & Sheader 1973) and the ability of some species to reproduce and propagate throughout the year (Budd 2007).

As sublittoral marine organisms, the species in this group inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been assessed.

Temperature changes - local

Some variability to this pressure within the macroalgae group was evident and as such*, L. hyperborea* has been considered separately for sensitivity analysis.

Combined group

Although temperature is acknowledged to be a limiting factor in macroalgal growth (Fortes & Lüning1980) the species in this group have been scored as *'Not sensitive'* to the benchmark for changing temperature at the benchmark considered. Largely this is due to the wide distribution of the characterising species which demonstrates the ability of the group members to adjust to fluctuating temperatures.

Water temperature is variable in the UK and a change in the benchmark pressure is observed on a seasonal basis for all macroalgae species. In addition, other algal species such as *H. siliquosa* are recorded from northern to southern Europe and can occur in intertidal pools (Tyler-Walters & Pizzola 2008) which may undergo substantial temperature variations on a daily and intra-annual basis. Certain alga can withstand relatively extreme temperature decreases. For example, observations of *C. rupestris* from France suggested to Cambridge *et al* (1984) that it was tolerant of temperatures as low as -5°C which is substantially within the benchmark. Resilience was considered to be '*High*' for this ecological group due to minimal impacts to recover from under this pressure. *P. palmata,* another widely distributed species, reacts less significantly to temperature differences than some other red algae. This demonstrates a degree of variability within the red algal species and ability for some sublittoral species to tolerate increasing temperatures within the benchmark. Resilience was '*High*' for the group as reproduction would not be inhibited for most of the species by a temperature change at the considered benchmark.

Laminaria hyperborea

L. hyperborea has been assessed separately for sensitivity to this pressure due to the difference in response when compared to the other species. When assessing sensitivity to temperature change it was scored with *'Medium'* sensitivity. Kelps dominate cold-water coastal zones and are known to become physiologically stressed at high sea temperatures, (Steneck *et al* 2002). This species is much larger than the other macroalgal species considered in the group and it has a deeper depth range than most other group members. As such, it is not regularly subject to such significant temperature increases unlike other group species which can be observed in the intertidal zone (Tyler-Walters & Pizzola 2008; Budd 2007). Resilience has been recorded as '*Medium*' as gametogenesis cannot occur for this species when it is undergoing temperature stress from an increase in sea temperature (Tyler-Walters 2007). Therefore, recovery would be impeded and it has been estimated that it would take 2-10 years for damaged populations to return to a pre-impact state.

Water flow (tidal current) changes - local, including sediment transport considerations

The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology and habitat preference.

As primary producers, the group members rely on water movement for gaseous exchange which makes the group species susceptible to changes in water flow though at the benchmark considered for this pressure, it is unlikely that significant damage to the population would be observed. The sessile nature of the species in this group means that they cannot relocate to tidal streams with alternative flow rates should their preference be for faster flowing water. However, many species in the group are able to tolerate a wide range of tidal flow conditions which increases resistance of some group members. Some of the group species including *L. hyperborea* and *H. siliquosa* occur in moderately strong to weak tidal streams, and many species are found in rock pools (though intertidal biotopes are not considered in the scope of this project) which undergo periods of stagnation. Species which are recorded in the intertidal zone are regularly exposed to and therefore likely to be tolerant of still water for short periods (Tyler-Walters & Pizzola 2008). The green alga *C. rupestris* which demonstrates a preference for stronger tidal flow has also been determined as tolerant to a decreased water flow. Following a reduction in flow, the fronds of the alga splay out and photosynthesis concurrently increases (Budd 2007) encouraging the population to grow. Furthermore, species like *C. rupestris* which prefer moderately strong water flow have been recorded in the upper littoral fringe (Budd 2007) which is not generally a zone that is subject to high water flow, suggesting a tolerance to reduced current. Like the other species in this group, *P. palmata* is also found in a range of water flow regimes from moderately strong to weak (Hill 2008).

The species in this group rely on strong holdfasts and anchorage to keep them attached to the substrate. Therefore, the group members are unlikely to be displaced as a result of an increase in tidal current at the benchmark level. Macroalgae also demonstrate relatively high flexibility which acts to increase resistance to tidal current. An increase in tidal flow would also increase the dispersal potential for gametes which may increase the distribution of the algal population. Many of the group species are recorded in areas with strong tidal flow. *H. siliquosa* was reported from the 'rapids approaches' and may occur in association with *Laminaria digitata* in strongly flowing tidal streams (Lewis 1964, in Tyler-Walters & Pizzola 2008) though populations are predicted to decrease following an increase in flow (Tyler-Walters & Pizzola 2008). Where an algal species is located in an area at the lower end of its water flow tolerance, an increase in tidal current may be beneficial though if it is already at the upper limit of its tolerance, the opposite would be true. Increasing tidal current may amplify the growth rate of *P. palmata* by arranging the thallus so that it receives higher levels of UV radiation (Hill 2008). However, an increase to very strong flows may reduce settlement rates of spores and may even dislodge adults and germlings (Hill 2008). Smaller species in the group such as *C. rupestris* is able to withstand a very high degree of water flow stress (Lewis 1964, in Tyler-Walters & Pizzola 2008) though the water flow at which *C. rupestris* can function without any observed loss in the population is not universal for all macroalgal species. Any impact resulting from this pressure on macroalgae is likely to be temporary due to fast growth rates and life-history.

Wave exposure changes - local, including sediment transport considerations
The individual species in this group demonstrated some variable tolerances to wave exposure changes and therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology and habitat preferences.

Some of the species within the group demonstrate a high tolerance to wave exposure changes. For example, *C. rupestris* has been recorded from sheltered to very exposed environments (Budd 2007) which would mean it is subject to a range of exposure conditions. Similarly, *H. siliquosa* is associated with sheltered to exposed conditions (Lewis 1964, in Tyler-Walters & Pizzola 2008). Furthermore, all of the species within this group demonstrate relatively high flexibility which increases resistance to increasing wave exposure as the species are able to move with internal oscillations in water movement.

The macroalgae in this group are restricted to a degree by wave exposure, though the effects of an increase at the benchmark would not be significant. Larger kelp species may be susceptible to damage resulting from an increase in exposure because they have brittle stipes which may be prone to snapping when exposed to a force from waves (Tyler-Walters 2007). Smaller algae may also be vulnerable to increasing wave height though not always due to anatomical weaknesses. For example, increased wave height could create a preferable habitat for rival species such as *Laminaria digitata* (Lewis 1964, in Tyler-Walters & Pizzola 2008) which as a result may be able to out-compete existing species. Conversely, *C. rupestris* is known to have an especially high tolerance to very hydrodynamic environments and is able to physically adapt by branching when wave energy increases (Van den Hoek 1982, in Budd 2007). Resistance is increased further due to the smaller size and shrub-like form of this species which means that it has less surface area exposed to waves and stands less erect in water column. However, the smaller, more shrub-like members of the ecological group may still be prone to competition with changing wave height. Recovery for all species in the group was considered to be '*High*' due to life-history and growth rates.

Changes in suspended solids (water clarity)
The sensitivity of the macroalgae group to this pressure has been assessed as *'Low'*. As primary producers, decreased suspended solids in the water column (hence increased light penetration) are likely to benefit all macroalgae (Tyler-Walters & Pizzola 2008). However, increased light penetration can adversely affect the survival of *P. palmata* sporelings (Edwards & Dring 2011) due to its preference to shady environments though evidence of any mortality to this species due to increasing water clarity could not be found. This is most likely to be the case for other red algae species within the group which are more sensitive to high irradiance conditions in sublittoral habitats.

The light attenuating effects of increased turbidity are likely to impact on the photosynthetic efficiency of algal species, with consequential effects on growth (Budd 2007) and as such, the resilience has been assessed as *'Medium'*. However, as primary producers which utilise daylight for energy through photosynthesis, recovery from any degree decreased water clarity is '*High*'. Light penetration determines the upper limit at which algal species can grow and increased turbidity due to human activities such as coastal engineering have been reported to result in the loss of kelp species (Tyler-Walters 2007). This is likely to be the case for all members of this group. Shade tolerant rhodophytes such as *P. palmata* may be more resistant than the other algal species of algae to low light conditions and so may be tolerant of increased turbidity (Hill 2008).

Abrasion/disturbance at the surface of the substratum
An overall sensitivity of *'Low'* has been given for this ecological group when considering abrasion. Group species are unable to relocate to areas less impacted by abrasion and impact on the softer forms of algae may damage the tissue significantly and due to a lack of mobility. As such, all species have been scored with a '*Medium*' resistance. All macroalgal species in this ecological group are physically flexible which means that they can avoid the impacts that abrasion may have on more solid, brittle species. However, physical disturbance by a scallop dredge may damage or remove some algae due to their sessile nature. The smaller, shrub like species may be more resistant to abrasion than larger, erect species such as *L. hyperborea* due to a smaller surface area being exposed to the impact. Though some loss of species in this group may occur as a result of abrasion, damaged individuals with unharmed holdfasts are likely to survive (Tyler-Walters & Pizzola 2008). Harvesting and impact assessments (Stagnol *et al* 2013; Tyler-Walters 2007) have

demonstrated that many algal species considered are fairly resilient to surface feature damage, therefore, resilience has been assessed as '*High*'.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
An overall sensitivity of *'Medium'* has been proposed for this group as a response to a deposition of 30cm of sediment. The sessile nature of the member species of this ecological group is key for consideration when assessing sensitivity to smothering and siltation. Size was also deemed to have a substantial bearing on the sensitivity of a species to smothering. Many of the group members are able to withstand a significant degree of sedimentation as adult specimens are >30cm in height. However, several species are smaller than this and would be unlikely to survive a deposition of 30cm. Additionally a heavy degree of siltation would prevent settlement of juvenile sporophytes which increases the recovery time for impacted populations. This is salient when considering smothering as heavy deposition would be potentially detrimental to establishing and maintaining a new population. It should also be considered that although smothering of larger adults may reduce photosynthetic activity, it is unlikely to cause damage (Tyler-Walters 2007).

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence could be found relating the species in this group to electromagnetic changes.

Introduction of light
No evidence could be found relating the species in this group to introduction of artificial light.

Litter
No evidence could be found relating the species in this group to litter.

Visual disturbance
Not exposed - macroalgae are not known to react to the rapid changes in light and shade that would be related with movement (Tyler-Walters 2007) and have no known visual receptors.

Organic enrichment
The species in this group have been assessed as '*Not sensitive'* to organic enrichment. As sessile primary producers, macroalgae are unable to relocate in order to source energy and are often nutrient limited. Therefore, an increase in organic enrichment is likely to result in enhanced growth and propagation (Hill 2008). All kelp species are known to be efficient absorbers of nitrates and phosphates (Tyler-Walters 2007) and the growth of green algae species such as *Cladophora* can be encouraged by sewage inputs (Knox 1986, in Budd 2007) which represent a source of organic enrichment. Holt *et al (*1995) suggest that *L. hyperborea* may be tolerant of eutrophication since healthy populations are located next to untreated sewage outfalls in the Isle of Man. Rhodophyte species have also been found to be resistant to organic enrichment. *P. palmata* for example continued to grow in the presence of increased nitrogen from fish farm waste (Matos *et al* 2006). Excessive enrichment may lead to eutrophication and de-oxygenation of the water which may lead to the eventual mortality of macroalgal populations though this is unlikely to occur at the benchmark considered for this pressure.

De-oxygenation
The sensitivity of this group to de-oxygenation at the considered benchmark is '*Not sensitive'*. Kinne (1972) reports that reduced oxygen concentrations inhibit both

photosynthesis and respiration of macroalgae though this is not likely to be significant at the benchmark level considered in this project. Many of the species in this group (such as *C. rupestris* and *P. palmata*) extend into the intertidal and are able to respire throughout periods of emersion (Hill 2008) which demonstrates a tolerance to oxygen depletion. Additionally, Bidwell and McLachlan (1985) conducted a trial which showed that oxygen tension had little or no effect on macroalgae. When effects did occur they were much lower than those normally observed in angiosperms.

Introduction of other substances (solid, liquid or gas)
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

Due to a lack of mobility, the species in these groups are unable to relocate and avoid the impacts of pollution. However, ecological traits such as habitat and depth preference increase the resistance and resilience of some species to the impacts resulting from this pressure. The Exxon Valdez oil spill in 1989 occurred in the close vicinity of large kelp forests. Concurrent research determined that kelps were minimally impacted and they recovered rapidly (Steneck *et al* 2002). For most of the kelp population, full recovery took two years or less which suggests a high resilience following damage. Other, algal species such as *H. siliquosa* may be protected from the direct effects of oil spills due to their subtidal distribution (Tyler-Walters & Pizzola 2008). As such, a species' physical habitat may act to increase its tolerance to pollution. Many of the biotopes considered in the scope of this project are subtidal which would afford the species in these biotopes a significant amount of protection when pollutants are limited to the surface of the water though where pollutants are more dispersed, this would not be the case. Some species in the group demonstrate positive responses to the introduction of substances. The green alga *Cladophora* showed a significant population increase following an influx of oil at a low oil site (Cullinane *et al* 1975) which demonstrates a high potential for the species to tolerate the input of potentially harmful substances. In contrast, O'Brien and Dixon (1976) suggest that red algae were the most sensitive group to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. Due to the mixed resistance of the species in the group and their increased vulnerability to pollution attributable to their sessile nature, resistance has been assessed as *'Medium'*. It should be considered that not all forms of solids, liquid and gas pollution have been accounted for.

Nutrient enrichment
The species in this group have been assessed as '*Not sensitive'* to nutrient enrichment. As sessile primary producers, macroalgae are unable to relocate in order to source energy and are often nutrient limited. Therefore, an increase in organic enrichment is likely to result in enhanced growth and propagation (Hill 2008). All kelp species are known to be efficient absorbers of nitrates and phosphates (Tyler-Walters 2007) and the growth of green algae species such as *Cladophora* can be encouraged by sewage inputs (Knox 1986, in Budd 2007) which represent a source of organic enrichment. Holt *et al* (1995) suggest that *L. hyperborea* may be tolerant of eutrophication since healthy populations are located next to untreated sewage outfalls in the Isle of Man. Rhodophyte species have also been found to be resistant to organic enrichment; for example, *P. palmata* continued to grow in the presence of increased nitrogen from fish farm waste (Matos *et al* 2006). Excessive enrichment may lead to eutrophication and de-oxygenation of the water which may lead to the eventual mortality of macroalgal populations though this is unlikely to occur at the benchmark considered for this pressure.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

Due to a lack of mobility, the species in this group are unable to relocate and avoid the impacts of pollution. However, ecological traits such as habitat and depth preference increase the resistance and resilience of some species to the impacts resulting from this pressure. The Exxon Valdez oil spill in 1989 occurred in the close vicinity of large kelp forests. Concurrent research determined that kelps were minimally impacted and they recovered rapidly (Steneck *et al* 2002). For most of the kelp population, full recovery took two years or less which suggests a high resilience following damage. Other, algal species such as *H. siliquosa* may be protected from the direct effects of oil spills due to their subtidal distribution (Tyler-Walters & Pizzola 2008). As such, a species' physical habitat may act to increase its tolerance to pollution. Many of the biotopes considered in the scope of this project are subtidal which would afford the species in these biotopes a significant amount of protection when pollutants such as PAHs are limited to the surface of the water. Some species in the group demonstrate positive responses to the introduction of hydrocarbon. The green alga *Cladophora* showed a significant population increase following an influx of oil at a low oil site (Cullinane *et al* 1975) which demonstrates a high potential for the species to tolerate the input of potentially harmful substances. In contrast, O'Brien and Dixon (1976) suggest that red algae were the most sensitive group to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. Due to the mixed resistance of the species in the group and their increased vulnerability to pollution attributable to their sessile nature, resistance has been assessed as *'Medium'*.

Radionuclide contamination
This group has been assessed as *'Not sensitive'* to radionuclide contamination, though limited evidence was available for the group. Alginates found in fucoids strip heavy metals and some radionuclides from seawater and store them in inert forms. Hence, adult plants are considered to be relatively tolerant of radionuclide contamination (Tyler-Walters & Pizzola 2008). Bonotto *et al (*1988) found that the highest concentration of radionuclides was found in brown algae and the lowest in the red and green algae. This suggests that there is some variation to the responses of the species in the group though there is no evidence of mortality as a result of this pressure.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this ecological group have been assessed with '*Low*' sensitivity to this pressure. Assessments have been made based upon species' reactions to large scale events which have been used as a proxy as the benchmarks being considered for this pressure are of a smaller magnitude. As such, recorded effects observed in the evidence were due to pollution on a larger scale than that considered for this project. Macroalgae have demonstrated tolerance to synthetic pollution in a number of investigations. Holt *et al (*1995) state that adult *L. hyperborea* may be relatively resistant to chemical pollution due to the presence of alginates within the species. Alginates have ability to sequester heavy metals and some radionuclides from the surrounding water and hold them in an inert form (Tyler-Walters & Pizzola 2008). This is likely to be the same for all fucoids. Macroalgae species have also demonstrated tolerance to other synthetic pollutants such as antifoulants. *Fucus* sp. were reported to thrive in TBT-polluted waters by Bryan and Gibbs (1991, in Tyler-Walters & Pizzola 2008), though some brown algae have been recorded as being susceptible to toxicity by chlorate (Rosemarin *et al* 1994). Macroalgae are unable to avoid synthetic pollutants in the marine environment and though tolerance has been observed for

species in the group to some contaminants, intolerance is recorded for others. Therefore, a resistance of '*Medium*' has been determined though due to fast growth rates and life-history features; the group is likely to be quick to recover from any impacts from this pressure.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The algal species in this group have been assessed with *'Low'* sensitivity to transition element and organo-metals contamination. The effects of the pressure on algal species varied depending on the contaminant and type of algae considered. Hopkin and Kain (1978) found that heavy metals had a sub-lethal effect on *L. hyperborea* sporophyte development, growth and respiration, though no mortality was recorded. Conversely, Holt *et al (*1995) state that adult *L. hyperborea* may be relatively resistant to chemical pollution due to the presence of alginates in the species. Alginates have ability to sequester heavy metals and some radionuclides from the surrounding water and hold them in an inert form (Tyler-Walters & Pizzola 2008). This is likely to be the same for all fucoids. It is acknowledged that kelp have also demonstrated high tolerance in halogenated effluent (Hopkin & Kain 1978). A report by Ingólfsson and Svarasson (1995) recorded that the smaller algae species *C. rupestris,* was significantly more abundant on transects closer to a dumping ground for old cathodes rich in heavy metals and cyanide. However, Bryan (1984, in Tyler-Walters & Pizzola 2008) states that accumulation of an iron ore dust load may well be detrimental to algal species. Macroalgae are unable to avoid transition elements and organo-metals in the marine environment and though tolerance has been observed for species in the group to some contaminants, intolerance is recorded for others. Therefore, a resistance of '*Medium*' has been determined though due to fast growth rates and life-history features, the group is likely to be quick to recover from any impacts from this pressure.

Genetic modification and translocation of indigenous species
No evidence could be found relating the species in this group to genetic modification and translocation of indigenous species.

Introduction of microbial pathogens
The algal species in this group have been assessed as *'Not sensitive'* to this pressure. Disease is documented for some of the species in this group though no evidence of mortality as a result could be sourced. Galls on the blade of *L. hyperborea* and spot disease are associated with the endophyte *Streblonema* sp. although the cause of this disease is unknown (Tyler-Walters 2007). Galls and tumour like growths are found on numerous algal species and these growths are most often characterised by unorganised cell proliferation (Apt 1988). Often, growths are associated with bacteria in intercellular spaces though the effects of these pathogens are limited to tumours in most algae (Apt 1988). Some species such as *H. siliquosa* are able to discourage microbial growth by generating products that prevent biofilm formation on their exterior (Busetti *et al* 2015). The impacts of known disease for the species in this group are not thought to be detrimental and recoverability is understood to be fast, therefore sensitivity is low.

Introduction or spread of non-indigenous species (INIS)
Based upon available evidence, the sensitivity for the ecological group for the introduction or spread of non-native species has been assessed as *'Low'.* Though intertidal biotopes are not considered in the scope of this project, *H. siliquosa* has been reported to be displaced as the dominant species in rock pools by the non-native *Sargassum muticum* on the south coast of England (Eno *et al* 1997). However, *H. siliquosa* is highly fecund and its distribution is widespread in British waters. Therefore, if a population is damaged or reduced in any way, local recruitment would be good (Tyler-Walters & Pizzola 2008). *Undaria pinnifitada* (wakame) has spread to the south coast of England from France where it was introduced for aquaculture. Presently it is mainly limited to manmade structures but could spread in ballast water (Tyler-Walters 2007) and given the sessile nature of macroalgae the introduction of

non-native competitors could result in a degree of mortality. No evidence was available for the other species in the group which may suggest that this pressure currently has limited impacts on macroalgal species in the UK or that there is a lack of research in this area.

Removal of non-target species
This group has been scored with a sensitivity score of *'Low'*. An increase in urchin populations has been attributed to the extraction of urchin predators such as lobsters by commercial fisheries. In turn, this has resulted in the loss of kelp beds (Birkett *et al* 1998) which is of significance for this ecological group. Svendsen (1972) reported that *H. siliquosa* became one of the dominant macroalgae species three years after kelp harvesting in Norway. This suggests that removal of other algae species that compete with *H. siliquosa* for space and light would be beneficial. The red algae *P. palmata* is an epiphyte on *Fucus serratus* and in trials where *F. serratus* was harvested, an initial decline in *P. palmata* cover was observed but this was followed by early stages of recovery after three months (Stagnol *et al* 2013). It is evident that commercial fisheries impact macroalgae indirectly through the removal of grazer predators. However, species in this group have shown high resilience to this pressure meaning that recovery would be almost immediate following the removal of the pressure.

Removal of target species
This group has been scored with a sensitivity score of *'Low'*. Research on harvested *L. hyperborea* suggests that kelp forest abundance returned to pre-harvesting levels after 1-2 years but that the plants were smaller and that the population was dominated by juvenile individuals (Tyler-Walters *et al* 2007). A 12-month monitoring programme of *P. palmata* by *Stagnol et al (*2013) following harvesting demonstrated that there was no significant impact on the viability of the population following targeted removal. This alga was epiphytic on the dominant canopy of *F. serratus*, which was thus maintained, so that the impact of the harvest was reduced. There was a significant decrease of cover initially, followed by a significant increase again by 12 months resulting in no difference between impacted sites and the controls. The species cannot avoid targeted removal but the recovery of the species in the group is rapid which acts to decrease overall sensitivity of the group.

4.2 Ecological group 2: Non-predatory mobile species

Ecological Group 2 comprises those fauna classified as non-predatory mobile fauna. The group contains several distinct taxonomic groups as specified below:

Echinoderms
This is the only group to which echinoderms have been allocated due to their taxonomic similarities and ecological traits. A large portion of Group 2 is made up of a diverse range of free-living, grazing and suspension feeding echinoderms. The echinoderms in this group comprise of feather stars, brittle stars, sea urchins and a large bodied holothurian.

Polychaetes
Polydora ciliata is the only polychaete and the only burrower in Group 2. It has been grouped according to its feeding habits as a suspension and deposit feeder which it has in common with several of the echinoderms which were also allocated to this group. The other polychaetes included as characterising species for the rock habitats are either predatory or form encrusting tubes, making them potentially vulnerable to different pressures.

Gastropoda
There are two grazing gastropod species within this group: the pearly top shell, *Margarites helicinus* and the grey top shell *Gibbula cineraria* which is widely distributed throughout the British coastline (Pizzolla 2002). Both species are physically fragile and possess similar

feeding preferences, predominantly grazing on algae on the lower rocky shore. As grazers, the gastropods show similar feeding preferences to echinoderms allocated within the group and like most of the echinoderm species, their environmental position is also epifaunal/epilithic.

Shrimp

The cold water shrimp *Pandalus montagui* is the only crustacean allocated to the group as unlike many other crustaceans which are grouped in the 'Mobile predator' group, it is a scavenger.

The characterising species selected for this group were *Echinus esculentus, Gibbula cineraria* and *Polydora ciliata*. As the only crustacean in the group, *Pandalus montagui* was originally chosen as a characterising species but was later excluded due to a lack of available evidence. *E. esculentus* was chosen to be representative of the non-predatory echinoderms in the group as it was better documented than the other species in the group and is more widespread in the UK. *G. cineraria* was chosen to represent the molluscs of the group as it was present in the highest amount of biotopes considered in this study and was better documented in terms of sensitivity than *J. cristatus* and *M. helicinus*. *P. ciliata* was the only annelid in ecological Group 2 and was therefore chosen as a characterising species.

Any additional variability in resilience between species in the group is most likely to be attributable to life-history and physiology. Resistance in particular may be affected by physical form when considering pressures generated by human activities. *G. cineraria* for example have a shell which may afford it some protection while *P. ciliata* does not. However, *P. ciliata* is able to burrow in to hard surfaces which *E. esculentus* and *P. ciliata* cannot. Crucially, all of the species in the group are mobile though slow moving and to a limited extent may be able to avoid certain pressures. This groups them all in terms of trait response to anthropogenic pressures.

Some variability in resilience between species in the group may be attributable to life-history. Most of the species considered in this group are dioecious though reproductive habits vary between group members. For example, *E. esculentus* and *P. ciliata* reproduce with annual frequency; while *G. cineraria* and other gastropods in the group are able to reproduce throughout the year though has a preference for breeding annually (Underwood 1972). Generation time is also faster for some species in the group than others and this is generally related to lifespan. *P. ciliata* for example lives for less than a year and as such its generation time is less than 12 months. Longer lived species such as *E. esculentus* and *G. cineraria* have a longer generation time (1-2 years) which can affect recruitment time. The characterising species are all highly fecund and have a large larval dispersal potential of >10km which has been considered as a factor which acts to increase resilience of the species within the group. Recruitment for *E. esculentus* in particular is poorly understood and reproduction can be sporadic and may vary according to the location of the population (Bishop & Earll 1984). However, where there is a sizable resident population in the surrounding region, *E. esculentus* populations are thought to be able to quickly recolonise from losses by migration capability (Tillin & Tyler-Walters 2014). Due to the mobility of all of the species and life-history and growth potential, the resilience score for this group is considered to be *'High'*.

4.2.1 Sensitivity assessments

Table 4. Group 2 Non-predatory mobile species sensitivity assessments for pressures (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	M	H	Low	M	M	L
Temperature changes - local	H	H	Not sensitive	M	H	M
Water flow (tidal current) changes - local	H	H	Not sensitive	M	H	M
Wave exposure changes - local	H	H	Not sensitive	M	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	M	H	M
Abrasion/disturbance at the surface of the substratum	M	H	Low	M	H	L
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	L	H	Low	L	M	M
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Barrier to species movement	No evidence					
Electromagnetic changes	No evidence					
Introduction of light	No evidence					
Litter	No evidence					
Visual disturbance	H	H	Not sensitive	M	H	M
Organic enrichment	H	H	Not sensitive	M	M	H
De-oxygenation	M	H	Low	M	H	L
Introduction of other substances (solid, liquid or gas)	L	H	Low	M	M	L
Nutrient enrichment	H	H	Not sensitive	M	M	H
Hydrocarbon & PAH contamination	L	H	Low	L	M	L
Radionuclide contamination	No evidence					
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	L	H	Low	M	M	L

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Transition elements & organo-metal (e.g. TBT) contamination	L	H	Low	M	M	L
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens	M	H	Low	L	H	M
Introduction or spread of non-indigenous species (INIS)	H	H	Not sensitive	M	H	M
Removal of non-target species	M	H	Low	L	H	M
Removal of target species	H	H	Not exposed	L	H	M

Salinity changes - local
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and the sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiological differences and habitat preference. All species in this group are mobile and it is likely that if they were exposed to salinity ranges beyond their environmental preferences the populations would be able to relocate should alternative locations be available.

Though intertidal biotopes are not considered in the scope of this project, many of the species in the group are found on the rocky shore in intertidal pools and are regularly subjected to fluxes in salinity due to freshwater input. Several species in this group are known to be tolerant to a decrease in salinity at the benchmark. For example, *G. cineraria* live in salinities as low as 25ppt (Graham 1988) which is classified as a reduced salinity environment. This is beyond the benchmark for the pressure therefore this species has high resistance to changes in salinity.

P. ciliata is a euryhaline species inhabiting fully marine and estuarine habitats (Gulliksen 1977) so is also tolerant to a decrease in salinity by one MNCR category. In contrast, some echinoderms such as *E. esculentus* are less tolerant to changes in salinity. *E. esculentus* populations in the sublittoral fringe are likely to be exposed to fluctuations in salinity due to freshwater inputs such as runoff and heavy rain so may tolerate low salinity for a limited period of time. However, it is well documented that echinoderm larvae have a fairly narrow range of salinity tolerances and develop abnormally which can be fatal if exposed to prolonged reduced salinity (Tyler-Walters 2008). Due to a wide dispersal potential, it is likely that larvae will be able to survive and establish new populations should the salinity be localised though some loss of population may be expected.

As sublittoral marine organisms, the species in this group inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been assessed.

Temperature changes - local
The species in this group have been assessed as *'Not sensitive'* to changing temperature. The only annelid in the group, *P. ciliata,* is a eurythermal species (Murina 1997) and as such is tolerant to variable temperature conditions. Many of the group members are widely distributed from northern to southern Europe (Hayward & Ryland 1996; Tyler-Walters 2008) which demonstrates tolerance of group members to the pressure. Like the other members of this group, *E. esculentus* is likely to exhibit a *'High'* tolerance to long term temperature change. However, it is likely that it would be less tolerant of abrupt or severe short term change in temperature (Tyler-Walters 2008). All species in this group are mobile so it is likely that if they were exposed to temperature ranges beyond their environmental preferences the populations would be able to relocate should alternative locations be available or adjust to a change in temperature.

Water flow (tidal current) changes - local, including sediment transport considerations
All of the species in this group have been assessed as '*Not sensitive'* to changing water flow. Due to the mobile nature of the group members, species are able to relocate should there be a localised change in tidal current or reposition themselves if the pressure is temporary. Though intertidal biotopes are not considered in the scope of this project, some of the group members are recorded inhabiting intertidal pools where water flow is reduced. Filter feeders such as *P. ciliata* may be affected by a decrease in flow as reduced food supply may accompany tidal current changes. A decrease in wave exposure may also affect the distribution of larvae though at the baseline this is not considered to be likely to result in loss of a population given that several species in the group show a tolerance to a range of currents.

Most of the group members demonstrate resistance to increased water flow speeds. Following disturbance from strong currents, *E. esculentus* has been observed to migrate up the shore, a reaction to being involuntarily transported to deeper water (Lewis & Nichols 1980, in Tyler-Walters 2008). Therefore, increased water flow may cause the population to relocate from the affected region though populations are unlikely to undergo any significant mortality in the process (Tyler-Walters 2008). Gastropods such as *G. cineraria* are often found in a range of tidal currents on the lower levels of rocky shores which are susceptible to variable tidal flow regimes. This demonstrates a high tolerance for the species to this pressure. Furthermore, polydorids inhabiting burrows in rock are unlikely to be removed by tidal currents though very strong water flow rate may hinder feeding and tube construction (Hill 2007). Within the benchmark for the pressure, no mortality would be expected for an increase in water flow. Recovery for *P. ciliata* is good as damaged populations can re-build tubes and like the other species in the group, juvenile larvae are planktonic and capable of dispersal over substantial distances.

Wave exposure changes - local, including sediment transport considerations
All of the species in this group have been assessed as '*Not sensitive'* to changing wave exposure. Though intertidal biotopes are not considered in the scope of this project, some of the group members inhabit intertidal pools where wave exposure is reduced compared to the sublittoral. All species in the group are mobile and as such may be able to relocate locally should wave exposure adjust to a level beyond their preference. Filter feeders such as *P. ciliata* may be affected by a decrease in wave exposure should food transport be reduced. A decrease in wave exposure may also affect the distribution of larvae for the species in this group though at the baseline this is not considered to be likely to result in loss of a population given that most species in the group show a tolerance to a range of exposures.

Following disturbance from strong currents, *E. esculentus* has been observed to migrate up the shore, a reaction to being involuntarily transported to deeper water (Lewis & Nichols 1980, in Tyler-Walters 2008). Therefore, increased wave exposure may cause the population to relocate from the affected region though populations are unlikely to undergo any significant mortality in the process (Tyler-Walters 2008). Gastropods such as *G. cineraria* are often found in a range of exposures on the lower levels of rocky shores on which are susceptible to variable conditions. This demonstrates a high tolerance for the species to this pressure. Furthermore, polydorids inhabiting burrows in rock are unlikely to be removed by changes in oscillations resulting from wave exposure changes though very strong water flow rate may hinder feeding and tube construction (Hill 2007) though within the benchmark for the pressure, no mortality would be expected. Recovery for *P. ciliata* is good as damaged populations can re-build tubes and like the other species in the group, juvenile larvae are planktonic and capable of dispersal over substantial distances.

Changes in suspended solids (water clarity)
This group has been assessed as *'Not sensitive'* to changes in suspended solids (water clarity). Filter feeders may receive increased food loads due to intensified food supply which would positively affect local populations if an increase in solids was observed. Conversely, grazers such as gastropods may not benefit if solids in the water column increase beyond a certain threshold because reduced irradiance may affect their food supply (algae). However, the grazers in this group are mobile and may be able to avoid areas of reduced clarity locally. Echinoderms such as *E. esculentus* are considered to be unaffected by turbid conditions (Moore 1977, in Tyler-Walters 2008) while filter feeders such as *P. ciliata* are tolerant to siltation because they normally inhabit waters with high levels of suspended sediment. Occasionally, siltation rates have been observed to increase as a result of the presence of *P. ciliata* (Hill 2007) confirming the high tolerance of this species to the pressure.

Abrasion/disturbance at the surface of the substratum
The species in this group have been assessed with '*Low*' sensitivity to this pressure. The physical abrasion/disturbance of *E. esculentus* due to trawling and dredging activity or the impact of an anchor is likely to result in mortality for a proportion of the population (Tyler-Walters 2008). Echinoderms in particular are known to be brittle and larger urchins have inflexible tests which if damaged will result in mortality. A proportion of a *P. ciliata* population may survive abrasion impacts due to the ability of individuals to withdraw into burrows. However, due to the soft bodied nature and small size of this species, direct impacts are likely to be fatal and could potentially remove a large amount of the population in a single event. Prognosis for recovery for the group following damage is good because all species have have planktonic larvae that are capable of dispersal over long distances and the reproductive stage lasts several months (Hill 2007; Tyler-Walters 2008). In armed echinoderms, regeneration of limbs will aid the recovery of damaged populations and for all group members mobility will aid resilience following any loss of life. Due to the potential for populations to recover quickly by recruitment to other local populations, the resilience has been considered to be '*High*' for the species in the group to this pressure.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
Some of the species in this group demonstrated variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is largely due to differences in physiology and size. The group members have been assessed with '*Low*' sensitivity to this pressure with a '*Medium*' resistance and '*High*' resilience score. Though most of the species in this group inhabit environments above the seafloor and are mobile, it is unlikely given the restrictions of their mobility and the size of most species that populations would entirely avoid mortality under this pressure. Larger mobile species such as *E. esculentus* are less likely to be harmed by a heavy deposition of sediment due to their size and mobility though their delicate tests may undergo damage. A 30cm deposition of sediment would result in a high degree of mortality, even to species such as *P. ciliata* who are normally tolerant of sedimentation, as their burrows would be smothered and they would not be able to feed. Additionally, sedimentation can be a key

source of stress for grazers such as *G. cineraria* as additional sedimentation can impair movement and attachment while reducing grazing activity (Jenkins *et al* 1999). However, several studies have demonstrated negative effects of sedimentation on the abundance of gastropod grazers (Airoldi & Hawkins 2007) which indirectly increases potential resilience of populations that may be vulnerable to this pressure. Due to the potential for populations to recover quickly by recruitment to other local populations, the resilience has been considered to be '*High*' for the species in the group to this pressure.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Barrier to species movement
No evidence could be found relating the species in this group to the 'Barrier to species movement' pressure.

Electromagnetic changes
No evidence could be found relating the species in this group to electromagnetic changes.

Introduction of light
No evidence could be found relating the species in this group to introduction of artificial light.

Litter
No evidence could be found relating the species in this group to litter.

Visual disturbance
This group has been assessed as *'Not sensitive'* to this pressure. All of the species for which there was evidence available have demonstrated behaviour that signals tolerance to visual disturbance. *E. esculentus* has been recorded reacting to the approach of divers at close proximity though it has been suggested that any effect on the individual is likely to be short term and will not result in any mortality (Tyler-Walters 2008). It has been acknowledged that *P. ciliata* is likely to have a high resistance to visual disturbance by moving boats and humans (Hill 2007).

Organic enrichment
This group has been assessed as *'Not sensitive'* to this pressure. Organic enrichment at the benchmark is likely to encourage populations of benthic invertebrates by stimulating food supply to nutrient limited primary producers. Suspension feeders in particular are able to take advantage of an influx of organic matter (Pearson & Rosenberg 1978, in Ager 2008). *P. ciliata* is common in both organically poor areas as well as nutrient sufficient areas (Hill 2007) and so is likely to have high tolerance to changes in nutrient concentrations. The addition of nutrients may encourage kelp and algae density and therefore increase the food available to other populations (Tyler-Walters 2008).

De-oxygenation
There were some small differences in sensitivity between the species in this group which are resultant of variations in resistance due to anatomical thresholds and resilience due to life-history factors. Overall, the group has been scored with '*Low*' sensitivity to de-oxygenation. All species in this group are mobile and it is likely that if they were exposed to very local hypoxic conditions beyond their preference the populations would be able to relocate should alternative locations be available.

Benthic communities generally decline as a result of oxygen reduction when concentrations fall below a hypoxic threshold of 0.5-0.4ml/L (Moffitt *et al* 2015). Molluscs demonstrate a wide range of sensitivities to a reduction in oxygen though gastropods are associated with a lower lethal threshold than bivalves. Similarly, echinoderms demonstrate variable tolerances of de-oxygenation (Moffitt *et al* 2015). Under hypoxic conditions echinoderms are known to become less mobile and cease feeding (Tyler-Walters 2008) which may result in the loss of a proportion of the population. Unlike the other species in this group, *P. ciliata* is known to have a high tolerance to changes in oxygenation as *Polydora* spp. are repeatedly found at locations which are oxygen depleted (Hill 2007). Due to the potential for populations to recover quickly by recruitment to other local populations, the resilience for the species in this group has been considered to be '*High*' for this pressure.

Introduction of other substances (solid, liquid or gas)
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

Though the species in this ecological group are mobile, some of the species' mobility over large distances is restricted and as such, populations are unlikely to be able to avoid large-scale pollution events in the marine environment. Therefore, the resistance of a species is largely dependent on biological tolerances to individual pollutants. The negative effect of numerous substances on echinoderms and other species within the group has been well documented. *E. esculentus* for example exhibited developmental abnormalities in their skeletons following exposure to pollution (Gomez & Miguez-Rodriguez 1999). Flesh contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu). However, it is unclear whether the observed effects were due to a single contaminant or synergistic effects of all contaminants present. Echinoidea, particularly the eggs and larvae, are often used for toxicity testing and environmental monitoring (Tyler-Walters 2008). Similarly, gastropods are also used as environmental indicators due to their susceptibility to accumulate heavy metals. In contrast, *P. ciliata* is considered to be less sensitive than the others in this group when regarding pollution and contaminants. *Polydora* sp. have been found associated with sites highly polluted with organic matter, trace metals and petroleum hydrocarbons (Ajao & Fagade 1990) which demonstrates a high tolerance and even a preference towards polluted sites.

Nutrient enrichment
This group has been assessed as *'Not sensitive'* to this pressure. Nutrient enrichment at the benchmark is likely to encourage populations of benthic invertebrates by stimulating food supply to nutrient limited primary producers. Suspension feeders in particular are able to take advantage of an influx of nutrients (Pearson & Rosenberg 1978, in Ager 2008). *P. ciliata* in particular is common in organically poor areas as well as nutrient sufficient areas (Hill 2007) and so is likely to have high tolerance to changes in nutrient concentrations. The addition of nutrients may encourage kelp and algae density and therefore increase the food available to *E. esculentus* and other grazing populations (Tyler-Walters 2008).

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
There were some small differences in sensitivity between the species in this group which are the result of variations in resistance due to anatomical thresholds and habitat preference. Overall, the group has been scored with '*Low*' sensitivity to this pressure.

This group has been scored with '*Medium*' sensitivity to this pressure. Though the species in this ecological group are mobile, some of the species' mobility over large distances is restricted and as such, populations are unlikely to be able to avoid large-scale pollution events in the marine environment. Therefore, the resistance of a species is largely dependent on biological tolerances to individual pollutants. The negative effect of numerous substances on echinoderms and other species within the group has been well documented. *E. esculentus* for example exhibited developmental abnormalities in their skeletons following exposure to pollution (Gomez & Miguez-Rodriguez 1999). Flesh contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu). However, it is unclear whether the observed effects were due to a single contaminant or synergistic effects of all contaminants present. Echinoidea, particularly the eggs and larvae, are often used for toxicity testing and environmental monitoring (Tyler-Walters 2008). Similarly, gastropods are also used as environmental indicators due to their susceptibility to accumulate heavy metals. *P. ciliata* is considered to be less sensitive than the other species in this group when regarding pollution and contaminants as *Polydora* spp. have been found associated with sites highly polluted with organic matter, trace metals and petroleum hydrocarbons (Ajao & Fagade 1990) which demonstrates a high tolerance and even a preference towards polluted sites.

Radionuclide contamination
No evidence could be found relating the species in this group to radionuclide contamination.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

Though the species in this ecological group are mobile, some of the species' mobility over large distances is restricted and as such, populations are unlikely to be able to avoid large-scale pollution events in the marine environment. Therefore, the resistance of a species is largely dependent on biological tolerances to individual pollutants. The eggs and larvae of Echinoidea are used for toxicity testing and environmental monitoring which demonstrates the availability synthetic compounds to sea urchins. It is likely therefore that *E. esculentus* and especially its larvae are intolerant of synthetic contaminants (Tyler-Walters 2008). The effects of antifoulant paints on gastropods are well documented and the group is acknowledged to be susceptible to synthetic compounds. In particular, tributyltin (TBT) and triphenyltin (TPT) are known endocrine disruptors in gastropods (Titley-O'Neil *et al* 2011; Horiguchi 2006) and have substantial impacts on marine mollusc populations, often in the form of female imposex. This may result in reproductive failure in severely affected populations and as such a resistance of *'Low'* was assigned to the group. In contrast *P. ciliata* is considered to be less sensitive than the others in this group when regarding pollution and contaminants as *Polydora* spp. have been found associated with sites highly polluted with organic matter, trace metals and petroleum hydrocarbons (Ajao & Fagade 1990) which demonstrates a high tolerance and even a preference towards polluted sites.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

The species in this group have been assessed with '*Low*' sensitivity to this pressure. Though the species in this ecological group are mobile, some of the species' mobility over large distances is restricted and as such, populations are unlikely to be able to avoid large-scale pollution events in the marine environment. Therefore, the resistance of a species is largely dependent on biological tolerances to individual pollutants. The eggs and larvae of Echinoidea are used for toxicity testing and environmental monitoring which demonstrates the availability synthetic compounds to sea urchins. It is likely therefore that *E. esculentus* and especially its larvae are intolerant of synthetic contaminants (Tyler-Walters 2008). The effects of antifoulant paints on gastropods are well documented and the group is acknowledged to be susceptible to synthetic compounds. In particular, tributyltin (TBT) and triphenyltin (TPT) are known endocrine disruptors in gastropods (Titley-O'Neil *et al* 2011; Horiguchi 2006) and have substantial impacts on marine mollusc populations, often in the form of female imposex. This may result in reproductive failure in severely affected populations and as such a resistance of *'Low'* was assigned to the group. In contrast, *P. ciliata* is considered to be less sensitive than the others in this group when regarding pollution and contaminants as *Polydora* spp. have been found associated with sites highly polluted with organic matter, trace metals and petroleum hydrocarbons (Ajao & Fagade 1990) which demonstrates a high tolerance and even a preference towards polluted sites.

Genetic modification and translocation of indigenous species
No evidence could be found relating the species in this group to genetic modification and translocation of indigenous species.

Introduction of microbial pathogens
Little information was available regarding the introduction of microbial pathogens in relation to this pressure therefore much of the sensitivity is based upon the information available for *E. esculentus*. *E. esculentus* is vulnerable to 'bald-sea-urchin disease', which is transmitted by two pathogens and results in numerous symptoms including lesions, spine loss, loss of tube feet and pedicellariae, damage to the skeletal tissue and in some cases, mortality. However, no evidence of mass mortalities as a result of the disease has been recorded in the UK (Tyler-Walters 2008). The species in this group are mobile and able to recruit well in to adult populations and therefore a sensitivity of '*Low*' has been recorded for this pressure.

Introduction or spread of non-indigenous species (INIS)
The species in this group have been considered '*Not sensitive*' to this pressure, though limited information was available. The species in this group are not known to have any invasive competitors at present. However, it is of interest that *Boccardia proboscidea* has been recorded in British waters in recent years (Hatton & Pearce 2013). This species is adept at dominating suitable benthic habitats though no evidence of it out-competing *P. ciliata* is available at present. Based on the current widespread distribution of *P. ciliata*, the presence of *B. proboscidea* is not considered a threat at present. No known alien competitors for other species are known at present.

Removal of non-target species
The species in this group have been scored with '*Low'* sensitivity to this pressure, though limited information was available. Therefore, much of the sensitivity is based upon the information available for *E. esculentus*. It is likely that kelp harvesting has some impact but not a substantial effect on *E. esculentus.* Edible urchins are able to find alternative food sources other than kelp if needed (Tyler-Walters 2008) which reduces the impact of harvesting.

Removal of target species
The majority of species in this group are considered to be *'Not exposed'* to removal of target species based upon the available evidence for this pressure. *E. esculentus* has been targeted for removal in the past though it is not believed to be extracted in substantial numbers at present. The pink shrimp, *Pandalus montagui* is included in Group 2 and is subject to large scale fishing extraction across Europe, Canada and North America and as such, this species alone is considered to have '*Low*' sensitivity. Though a large proportion of the population is subject to targeted removal, recruitment to adult populations is likely to be high following the removal of the pressure so resilience has been recorded as '*High*'.

4.3 Ecological group 3: Mobile predators and scavengers

Ecological Group 3 comprises those fauna classified as mobile predators. The group contains several distinct taxonomic groups as specified below:

Crustacea
With the exception of *Pandalus montagui*, all of the characterising crustaceans for rocky habitats are allocated to this group. The crab and lobster species are tightly clustered with the amphipods *Dexamine spinosa* and *Dyopedos porrectos.* All of the crustaceans allocated to this group are epifaunal.

Polychaeta
The only annelid in this group, the scale-worm *Harmothoe impar* demonstrates predatory feeding behaviour, placing it in the mobile predator ecological group alongside predatory crustaceans, gastropods and molluscs. Like the other mobile predators assigned to Group 3, *Harmothoe impar* is also epifaunal.

Gastropoda
A single species of gastropod, *Nucella lapillus* is grouped in 'Mobile predatory' fauna. *N. lapillus* is widely distributed and although found in the sublittoral is mostly found on rocky shores across the UK. It is acknowledged to avoid low salinities and excessive algal cover but is tolerant of a wide range of exposures (Tyler-Walters 2007). Like most of the other species in this group, *N. lapillus* is also an epifaunal crawler.

Nudibranchia
Janolus cristatus is the only sea slug within this group. Like all of the other species in this ecological group, *J. cristatus* is a predator and is known to feed on bryozoans, *Bugula* sp. in particular (Picton & Morrow 2015). It is exclusively sublittoral and restricted to hard substrata beneath clean and calm water and is an epifaunal crawler.

The characterising species selected for close examination to inform the sensitivity assessments for this group were: *Cancer pagurus, Dexamine spinosa, Asterias rubens* and *Nucella lapillus*. Initially, *Harmothoe impar* was also chosen to for sensitivity assessment though not enough literature could be sourced for the species to inform the process and was consequently not included*. J. cristatus* could also not be included as a representative species due to a lack of information available. *C. pagurus* was selected as a well documented species to represent the larger bodied Crustacea in this group while *D. spinosa* was selected to represent the smaller Crustacea though it was not as well documented as *C. pagurus*. *D. spinosa* was chosen over *D. porrectos,* the only other amphipod in the group, as it was better researched and has a wider distribution. *A. rubens* was chosen to represent the large-bodied starfish in the group as it was more widespread and thoroughly documented than *Luidia ciliaris,* the other predatory starfish in the group*. N. lapillus* was chosen as the only gastropod in the group. Though the only nudibranch in the group, *J. cristatus* was not selected as a characterising species as there was little literature relating to this species and the pressures considered in this project.

Variability regarding sensitivity within the group can be accounted for by examining life-history and anatomical form. Resistance in particular may be affected by physical form when considering pressures generated by human activities. For example, *C. pagurus, Homarus gammarus* and the other large Crustacea in the group may be afforded some protection by their hard exoskeletons. Likewise, *N. lapillus* may be less sensitive than some species to pressures such as abrasion because of its hard shell. Conversely, large, soft bodied species such as *A. rubens* and *C. luidia* may be more fragile but have the ability to regenerate arms if necessary. Size is also a factor that may result in variation between species in the group when regarding sensitivity. Smaller species such as the amphipods in the group may be subject to different pressures resulting from human activities because of their small size.

Any additional variability in resilience between species in the group is most likely to be attributable to life-history. The large Crustacea (e.g. *C. pagurus*) and Asteroidea (e.g. *A. rubens*) all have larval stages with large dispersal distances of >10km (Neal & Wilson 2008; Budd 2008a) which is likely to aid the resilience of the populations of these species. Conversely, the Amphipoda and Gastropoda species within the group are oviparous and do not have larval phases which means that their dispersal potential is greatly reduced. However, all species are gonochoristic and capable of producing a large amount of offspring. *C. pagurus* and *A. rubens* in particular are highly fecund, each capable of producing >1 million eggs. The dog whelk *N. lapillus,* may produce up to 1000 hatchlings per season (Tyler-Walters 2007) while *D. spinosa* is able to produce 120 eggs in one reproductive episode (Bellan-Santini 1982), though a female may spawn 8-10 times within her one-year lifespan following each moulting episode (Greze 1963). *N. lapillus* and *D. spinosa* are less fecund than some of the other species in the group, although they are widespread in the biotopes in which they are found and as such recruitment to local populations (where these are established) is likely. In areas where neighbouring populations are less established the resilience of populations may be lower. In addition, amphipods and other short lived species are likely to demonstrate higher resilience because of shorter lifecycles and small generation periods. However, due to the reproductive capabilities and life-histories of all species within this group, recovery time is assumed to be within two years. As such, the resilience of the species in this ecological group is considered to be '*High*'.

4.3.1 Sensitivity assessments

Table 5. Group 3 Mobile predator and scavengers species sensitivity assessment for pressures (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	H	H	Not sensitive	M	M	M
Temperature changes - local	H	H	Not sensitive	M	H	M
Water flow (tidal current) changes - local	M	H	Low	M	M	L
Wave exposure changes - local	M	H	Low	M	H	L
Changes in suspended solids (water clarity)	M	H	Low	M	H	L
Abrasion/disturbance at the surface of the substratum	M	H	Low	M	H	M
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	L	H	Medium	L	M	M
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Barrier to species movement	No evidence					
Electromagnetic changes	H	H	Not sensitive	L	M	M
Introduction of light	H	H	Not sensitive	L	L	M
Litter	No evidence					
Visual disturbance	H	H	Not sensitive	H	H	M
Organic enrichment - Group	H	H	Not sensitive	H	H	M
Organic enrichment - *N. lapillus*	L	L	High	H	H	H
De-oxygenation	H	H	Not sensitive	H	H	M
Introduction of other substances (solid, liquid or gas)	M	M	Medium	L	H	M
Nutrient enrichment - Group	H	H	Not sensitive	H	H	M
Nutrient enrichment - *N. lapillus*	L	L	High	H	H	H
Hydrocarbon & PAH contamination	M	H	Low	M	H	L
Radionuclide contamination	No evidence					
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - Group	L	L	High	M	H	L
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - *D. spinosa*	H	H	Not sensitive	M	H	M
Transition elements & organo-metal (e.g. TBT) contamination - *C. pagurus & D. spinosa*	H	H	Not sensitive	M	H	M
Transition elements & organo-metal (e.g. TBT) contamination - Group	L	L	High	M	M	M
Genetic modification & translocation of indigenous species	No evidence					

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Introduction of microbial pathogens	M	M	Medium	H	H	H
Introduction or spread of non-indigenous species (INIS)	No evidence					
Removal of non-target species	H	H	Not sensitive	M	H	H
Removal of target species	M	H	Low	M	H	L

Salinity changes - local
The species in this group are considered to be *'Not sensitive'* to local salinity changes. All species in this group are mobile and it is likely that if they were exposed to salinity ranges beyond their environmental preferences the populations would be able to relocate should appropriate and alternative locations be available.

Though intertidal biotopes are not considered in the scope of this project, several of the species in the group are found on the rocky shore in intertidal pools which means that they are regularly exposed to fluxes in salinity due to freshwater input and evaporation. Several species are known to be tolerant to a decrease in salinity at the benchmark and in addition, group species are mobile, though some show a tendency for higher dispersal than others. If necessary, populations may avoid freshwater inputs beyond their environmental preferences. For example, *C. pagurus* is a highly mobile species and would most likely be able to avoid extremely diluted water bodies (Neal & Wilson 2008). Additionally, adult *C. pagurus* are osmoconformers, meaning that they have the ability to maintain the ionic balance of the haemolymph at a similar concentration to that of the surrounding water though they are intolerant of salinities <17psu (Wanson *et al* 1983). However, the tolerance of this species and similar species within the group to the decrease of salinity within the benchmark is highly likely.

Vader (1969) recorded that the amphipod *D. spinosa* was found at stations in the lower reaches of an estuary, inside a lagoon where the salinity range was 24-35, which falls within the variable salinity benchmark considered for this project. Salinity preferences for Asteroidea species such as *A. rubens* are both full (30-40psu) and variable (18-40psu) which demonstrates a level of tolerance to salinity variation. However, echinoderms are stenohaline owing to the lack of an excretory organ which causes body fluid volume to adjust when individuals are transferred to different salinities (Budd 2008a). This may heighten the sensitivity of other species to this pressure. Like the other species in this group, *N. lapillus* can withstand a degree of decreasing salinity but beyond the benchmark would suffer (Tyler-Walters 2007) as it is not able to feed when exposed to lower salinity.

As marine organisms, the species in this group inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been considered for the sensitivity assessment. However, it is of note that most of the group species are considered as tolerant to an increase in salinity as some species within the group have demonstrated resistance to hypersaline conditions. *C. pagurus* has a significant behavioural response to extremely saline brine, being able to detect and avoid areas of hypersalinity once their threshold for salinity was reached (50psu) (Smyth *et al* 2014). Kirby *et al* (1994 in: Tyler-Walters 2007) simulated the effects of hyper-osmotic in *N. lapillus* by exposing it to salinities of up to 75psu.

No mortalities were observed during the experiment though specimens modified behavioural traits and were generally immobile.

Temperature changes - local
The species in this group have been assessed as *'Not sensitive'* to a local change in temperature. The majority of the species in this group are distributed from Norway to the Mediterranean (Hayward & Ryland 1996; Neal & Wilson 2008; Budd 2008a; Bellan-Santini 1982) which demonstrates a degree of adaptation to a range of temperatures. All species are also mobile which means that they will be able to avoid localised temperature decreases though the extent of avoidance is likely to be higher for very mobile species such as crabs and lobsters than less mobile species such as gastropods and small amphipods.

A sudden change in temperature may affect the species in the group with more than a long term gradual change. *C. pagurus* will not feed between 0°C and 5°C (Karlsson & Christiansen 1996) and embryos will not develop below 8°C (Thompson *et al* 1995). Therefore if an acute decrease in temperature took the absolute temperature below 5°C, productivity of *C. pagurus* might be affected although mortality is unlikely (Neal & Wilson 2008). A chronic increase in temperature is unlikely to affect *C. pagurus* though adult *C. pagurus* are not tolerant of temperatures over 20°C (Karlsson & Christiansen 1996).

The geographic range of *A. rubens* illustrates that the species is tolerant of a range of temperatures and probably becomes locally adapted. *A. rubens* was reported to be unaffected by the severe winter of 1962-1963 in Britain when uncharacteristically low temperatures persisted for two months (Crisp 1964). However, the reaction of *A. rubens* to increasing temperature is more extreme. When exposed to long-lasting high temperatures, *A. rubens* sheds its arms, a behaviour which is followed by death (Schäfer 1972) though this would only occur at temperatures which are greater than those considered for this pressure benchmark. The geographic range of *A. rubens* illustrates that the species is tolerant of a range of temperatures and probably becomes locally adapted though feeding activity may become disrupted (Budd 2008a).

The northern geographical limit of *N. lapillus* is close to the 0°C winter isotherm (Tyler-Walters 2007). Therefore, Crothers (1985) suggested that they were limited by ice; however, ice patches are unlikely to form on sublittoral substrates. Newell (1979) noted that oxygen consumption (hence metabolic rate) for *N. lapillus* fell with decreasing temperature and was accompanied by starvation. This resulted in a high scope for activity in the summer with dog whelks respond rapidly to increases in temperature in the spring.

It should be noted that any effect resulting from a change in temperature on most species in the group would depend on the time of year. If an acute change in temperature occurred in summer when sea temperatures are already high, some species may suffer from a degree of mortality if the temperature increased beyond the species' threshold. However, for the purpose of this project, it is assumed that the species inhabit environmental conditions in the middle of their tolerance ranges.

Water flow (tidal current) changes - local, including sediment transport considerations
The species in this group demonstrated some variable tolerances to this pressure in relation to the increasing and decreasing benchmarks. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. A decrease in water movement probably would not affect the mobile species in this group as they do not rely on water movement for feeding or gaseous exchange. As active predators and scavengers, the suspension and delivery of detritus and organic material is not of primary concern to this group. Though it is known to have a preference for strong water flows, *D. spinosa* has been found inhabiting photophillic algae, which is noted to exist in areas with low hydrodynamics and low turbidity. It is unlikely that a decrease in water flow

rate will directly affect gastropod species even though the longer foot associated with strong flows becomes redundant (Tyler-Walters 2007).

Asteroidea species such as *A. rubens* are more sensitive to an increased water flow than some other sublittoral rock species. An increased water flow rate is likely to scour the substrata over which it flows and can cause displacement of epibenthic species of starfish which may result in small losses to the population. However, the resilience of starfish is considered to be high due to their ability to recruit in to established populations.

The other species in the group demonstrate some degree of sensitivity to increased water flow though displacement of populations is less likely due to the physical construct of the other species. In a trial conducted by Nickell and Moore (1992), *C. pagurus* was able to navigate to prey in a current of 0.1m/s. However, when the current speed rose to 0.3m/s (above the benchmark for the scope of this project), only 15% of crabs could make headway. As such, it is assumed that at the benchmark of 0.2m/s, much of the population would remain unharmed though this is likely to depend on the size of the crab which means that maturity and sex may be important. The tidal current preference for *D. spinosa* is listed as Strong (3-6kn) (Scipione & Zupo 2010) and as such it is likely to be tolerant of increased tidal flows. *N. lapillus* exhibits considerable flexibility in response to wave exposure and most likely current flow. However, the larger adults of the population are probably intolerant of increases in water flow rates, younger, smaller specimens, will most likely adapt to the increase water flow regime (Tyler-Walters 2007).

Wave exposure changes - local, including sediment transport considerations
The species in this group demonstrated some variable tolerances to this pressure in relation to the increasing and decreasing benchmarks. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group.

Reduced oscillations resulting from a decrease in wave exposure would diminish the chances of mobile species becoming dislodged from the substrate. A decrease in water movement as a result of this pressure would also have little bearing on food supply as none of the species are filter feeders therefore do not rely on the delivery of suspended sediments. The recorded exposure preferences for small crustaceans such as *D. spinosa* are 'sheltered' to 'extremely sheltered' and therefore this species is likely to demonstrate a high resistance to a decreasing wave exposure but is more sensitive to increased flow. Gastropods such as *N. lapillus* exhibit considerable flexibility in response to wave exposure and current flow and are commonly found along the rocky shore where they are exposed to a full range of wave exposures.

C. pagurus and other large crustaceans inhabit 'very exposed' to 'extremely sheltered' environments and are therefore considered to be tolerant to increased wave exposure. Increased exposure has occasionally been observed to reduce the feeding activity and movement of crabs which can prevent them from moving to shallower depths to seek shelter (Neal & Wilson 2008). However, at the benchmark considered for the scope of this project, this impact is unlikely. Gastropods like *N. lapillus* can adapt to wave action through their shell shape and size of foot (Crothers 1985). Bryan (1968, in Tyler-Walters 2007) reported that adult *N. lapillus* that had been washed below the low water line recolonised the shore within 6 months, suggesting that displaced individuals can return to the their original habitats. This is likely to be dependent on size however, as smaller individuals are more likely to become prey for larger crustaceans though *H. gammarus* is capable of crushing an adult of any size (Crothers 1985).

The Asteroidea and Amphipoda species in this group demonstrate a higher level of sensitivity to this increased water flow due to differing habitat preferences and physical traits.

Thorpe and Spencer (2000) described a mass stranding of *A. rubens* upon the northern shore of the Isle of Man as a result of increased wave exposure. In total 6,000-10,000 small individuals were washed up along the shoreline. A small amount of larger starfish were found which suggests that size (as a result of maturity) has bearing on the impacts of this pressure. The stranding coincided with a very large spring tide and a period of prolonged and strong winds so that a large swell developed (Thorpe & Spencer 2000). This event demonstrates that the Asteroidea species are susceptible to increased wave exposure impacts though the nearshore oscillations caused by the conditions described by Thorpe and Spencer (2000) are considered to be above the benchmark considered for this project.

Changes in suspended solids (water clarity)
The species in this group demonstrated some variable tolerances to this pressure in relation to the increasing and decreasing benchmarks due to differences in habitat preferences and anatomical evolution. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group.

Though the majority of the species in the group have visual receptors, they rely little on sight as a method for sourcing food or navigating. *C. pagurus* occasionally relies on vision to find prey so although mortality due to a decrease in suspended sediment is unlikely, some perturbation may be expected and the same is true for other large crustaceans. Starfish including *A. rubens* do not have the visual capability to perceive objects not normally found in the marine environment and therefore water clarity is unlikely to affect it. Gastropods such as *N. lapillus* often have light sensitive eyes on their tentacles (Tyler-Walters 2007), however, its visual ability is probably low and it is doubtful that it would be adversely affected by alterations in water clarity. Amphipods such as *D. spinosa* or any species for whom algae is a primary habitat are likely to be more sensitive to increases in suspended solids as a reduction in water clarity may result in decreased irradiance. In turn, this may result in a reduction of available habitat which would have negative outcomes for the affected population.

Abrasion/disturbance at the surface of the substratum
The sensitivity for this ecological group to abrasion is scored as *'Low'*. *C. pagurus* and other large crustaceans are found in large numbers in and adjacent to scallop beds (Neal & Wilson 2008) which are commonly subject to dredging. Crab and lobster shells are typically brittle and easily damaged or killed by abrasive impacts. Though a high proportion of individuals die as a result of scallop dredging, the entire population is unlikely to be affected (Neal & Wilson 2008). Jenkins *et al (*2001) found that 63% of *Cancer pagurus* struck by a scallop dredge sustained damage and 68% of those (43% of the total number struck) were killed. *A. rubens* are also likely to be damaged by physical abrasion, especially loss of arms or tissue damage. However, lost limbs can regenerate and the Asteroidea species therefore more likely to be resilient. The intensity of the activity leading to abrasion may affect the ability of *A. rubens* to regenerate arms, an affect that was observed by Kaiser (1996) who collected specimens that were subjected to different intensities of commercial trawling. The occurrence of starfish with damaged or regenerating arms increased with increased trawl intensity suggesting high levels of resistance and resilience to the pressure. Gastropod shells like that of *N. lapillus* are often show signs of abrasion due to natural forces of abrasion such as sediment scour (Tyler-Walters 2007). Therefore, abrasion from human pressures is likely to be apparent if present. *N. lapillus* collected using beam trawls demonstrated shell damage in 17–75% of the specimens and severe damage was observed in 10–83% (Mensink *et al* 2000). Most individuals exhibited signs of former shell damage, which had since been repaired which suggests an ability to recover from damage caused by abrasion. Due to the high potential of most of the species in this group, resilience has been deemed as '*High*' for the group. As such, large crustaceans in particular are unlikely to be vulnerable to the impacts of this pressure and smothering is unlikely to cause mortality. Like the other species in this group, *A. rubens* is mobile but with a higher degree of body

flexibility. Given the size of mature individuals, it is highly likely that it would have the ability to emerge from beneath 5cm of fine material (Budd 2008). *N. lapillus* is found at the mouths of dynamic estuaries, such as the Severn Estuary which are often subject to high levels of sedimentation and siltation (Tyler-Walters 2007) therefore, mortality resulting from this pressure is unlikely. Smaller amphipod species such as *D. spinosa* are also mobile and able to ascend the algae stipes on which they position themselves so would most likely avoid this degree of sedimentation.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The species in this group have been scored with '*Medium*' sensitivity, with a resistance of '*Low*' being given. Though the species in this group are mobile, some of them are small and many are not fast moving so most likely would be smothered following a deposition of this extent. As such, it is possible that 25-75% of the population may be lost due to the impacts of this pressure. Crabs often demonstrate burrowing behaviour and are able to move from beneath a layer of silt and migrate to an area where sediment deposition is reduced (Neal & Wilson 2008) though this is highly dependent on the size and juvenile populations of all of the group species are likely to undergo a substantial degree of mortality. Schäfer (1972) reported the smothering of *A. rubens* in the North Sea by sand stirred up as a result of winds, demonstrating that the deposition of a heavy layer of fine material may result in mortality for the species. Following the removal of this pressure, the population would be likely to recover quickly given the strong potential to recruit.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Barrier to species movement
No evidence was available for the species in this group regarding 'Barrier to species movement'.

Electromagnetic changes
Information on electromagnetic changes was only available for *C. pagurus*, therefore the sensitivity score of *'Not sensitive'* has been based on this species alone with a low confidence as expert judgement has been used. The presence of *C. pagurus* on offshore wind farms suggests that electromagnetic field effects are not sufficient to prevent larval settlement or development or to deter adults. However, there is no information about the more subtle effects on biology or behaviour (Hooper & Austen 2014). No evidence for the effects of the introduction of electromagnetic changes on the other species in this group could be found so expert judgement has been used to infer from the one species for which information was available.

Introduction of light
The species in this group have been assessed as '*Not sensitive*' to the introduction of artificial light. All of the species in this group are mobile and could relocate themselves to afford some shelter from introduced light if necessary. Some species in the group such as *C. pagurus* are known to be more active at night (Veale *et al* 1990; Skajaa *et al* 1998), so light avoidance behaviour may be expected should artificial light be introduced. However, the presence of artificial white light is not known to inhibit the normal function of *C. pagurus* or other Crustacea. Gastropods such as *N. lapillus* bear light sensitive eyes on their tentacles (Tyler-Walters 2007). However, its visual capabilities are thought to be low and it is unknown how it would be affected by the introduction of light though this was taken in to consideration when applying expert judgement for the combined group sensitivity score. *A. rubens* has no eyes and though the amphipods in this group have eyes, they are not thought to be sensitive

to artificial light given that starfish may bury themselves and *D. spinosa* may descend from its elevated position on the algae it inhabits should it be disturbed by light.

Litter
Microplastic particles (MPPs) were ingested by a detritivorous amphipod *Allorchestes compressa* (Chua *et al* 2014) which is a grazing amphipod like *D. spinosa*. However, the effects of ingesting litter on amphipods is as yet unclear and no further information could be sourced for this species or any others within the group. Therefore, '*No evidence'* could be found relating the species in this group to litter.

Visual disturbance
The species in this group have been assessed as *'Not sensitive'* to visual disturbance. All of the group members are mobile and could relocate themselves to afford some shelter from introduced visual cues if necessary *C. pagurus* is the only species in this group with well developed eye-sight but despite this, is not likely to be disturbed by the addition of optical cues within the scope of the benchmark considered. *C. pagurus* is nocturnal and any lights that are present in the water are likely to affect their activity patterns, however damage to the population as a result is unlikely. Large objects in the water such as divers and vessels may cause active crabs to seek shelter (Neal & Wilson 2008). *A. rubens* does not have the visual capability to perceive objects not normally found in the marine environment (Budd 2008) and is considered not sensitive to this factor. *N. lapillus* bears light sensitive eyes but like *A. rubens,* sight is not thought to be good (Budd 2008a) and it is unlikely to be adversely affected by this pressure.

Organic enrichment
The sensitivity of the species in Group 3 to organic enrichment was variable. Therefore the combined group has been assessed separately from *N. lapillus*.

Combined Group
All of the species in the combined group (excluding *N. lapillus*) have been scored as *'Not sensitive'*. Increased organic enrichment stimulates primary producers which are normally limited by nutrients and this concurrently increases food supply throughout the impacted habitat. This would result in positive outcomes for all faunal populations at the benchmark level, even for predators and scavengers who do not rely on primary producers directly for food. Asteroidea populations in particular may benefit indirectly from an increased nutrient availability because major food items such as mussels filter feed upon phytoplankton and increase in abundance following nutrient enrichment. Smaller Crustacea in the group have demonstrated tolerances to organic enrichment above the considered baseline, demonstrating a high tolerance to the pressure. *D. spinosa* has been recorded at sites contaminated with storm water containing numerous pollutants including sewage (Carvalho *et al* 2007), and Grall and Glémarec (1997) also identified *D. spinosa* as tolerant to organic enrichment.

Nucella lapillus
Unlike the other species in the group, *N. lapillus* is affected by this pressure and is indirectly impacted by organic enrichment due to its susceptibility to harmful effects stemming from toxic algal blooms (Tyler-Walters 2007). *N. lapillus* is less mobile than the other species in this group and as such may be less able to avoid the harmful effects of phytoplankton populations. Algal blooms can be a result of organic enrichment by human activity but can also be a source of organic input themselves, representing a large flux of organic matter in to marine systems. Due to the sensitivity of *N. lapillus* has been assessed with *'High'* sensitivity to this pressure.

De-oxygenation

The species in this group has been scored as *'Not sensitive'* to de-oxygenation. If the de-oxygenation was localised, the species in this group would be able to avoid it though if the hypoxia was more widespread, some of the species with lower mobility may struggle to do so. However, at the bench mark level, most of the species in the group would be likely to survive long enough to relocate if an alternative, suitable location was available. Many of the species in the group burrow in to the top layer of sediment to afford themselves some protection which may expose them to reduced oxygen conditions. In a benthic survey following a phytoplankton bloom collapse, dead *C. pagurus* were found though most were healthy and this was most likely because the species' tolerance to hypoxic conditions (Boalch 1978). The resistance of *C. pagurus* to this pressure was described by Spicer and Weber (1992) who state that *C. pagurus* can survive for at least 18 hours in oxygen-depleted conditions and can probably survive longer if necessary. Though intertidal biotopes are not considered in the scope of this project, some of the species in this group such as *A. rubens* and *N. lapillus* are found on the rocky shore and are able to survive in rock pools which can be subject to low oxygen conditions. Due to low water circulation in some of its preferred habitats, *A. rubens* is adept to coping with reduced oxygen (Budd 2008a). However, a large scale mortality of *A. rubens* was reported by Bokn *et al* (1990, in Budd 2008) in response to hypoxic conditions though these conditions lasted longer than the benchmark time considered for this project and it is likely that the oxygen depletion was greater. *N. lapillus* is able to maintain aerobic respiration when immersed (Sandison 1968; Houlihan *et al* 1981; Innes & Houlihan 1985, in Tyler-Walters 2007) though little information could be found regarding the effects of hypoxia. Gibbs *et al (*1999) suggested that its ability to respire aerobically at low tide would compensate for any anoxia experienced when immersed and as such is relatively tolerant of hypoxic conditions.

Introduction of other substances (solid, liquid or gas)

Based upon the evidence available on this pressure for this group, the sensitivity score given is *'Medium'*. Though the species in the group are generally mobile, many environmental disasters which have resulted in the introduction of pollutants are large-scale and unavoidable. Survival following the introduction of contaminants often depends on the location of the habitat: intertidal or subtidal. Several of the species within this group are found both intertidally and subtidally. Numerous intertidal *C. pagurus* juveniles were found dead following the Torrey Canyon oil spill and though some deceased adults were found subtidally, many healthy individuals were found as well (Smith 1968). The adults affected subtidally may have been killed by dispersants rather that oil as oil tends to mix poorly in to the water column. Since juvenile *C. pagurus* spend the first three years post-settlement in intertidal habitats (Regnault 1994, in Neal & Wilson 2008), recovery of an adult populations from a mortality event is likely to take several years which ensured a resilience rating of *'Medium'*. Some evidence for *D. spinosa* suggests that it is susceptible to mortality from pollution from oil and other substances (Baden 1990) but other sources suggest that is tolerant of pollution from a variety of contaminants (Kinsella & Crowe 2015), which fits the sensitivity rating for the group overall. *A. rubens* and other Asteroidea species are likely to demonstrate less resistance if smothered by impermeable or viscous substance such as oil. Uptake of oxygen is through the tube feet and across the body wall, so smothering by viscous material may cause death (Budd 2008a). However, the degree of mortality is unclear. Depending on the pollutant being considered, mixed sensitivity of *N. lapillus* has been recorded in the relevant literature. Crapp (1970b, in Tyler-Walters 2007) reported that *N. lapillus* was relatively resistant, exhibiting a 1hr LC50 of between 10,000 - 500,000ppm, depending on season, being very resistant in winter. Crapp (1970b, in Tyler-Walters 2007) also noted that individuals took longer to recover from exposure in winter while Crapp (1970a, in Tyler-Walters 2007) reported that *N. lapillus* was highly affected by direct treatment with BP1002 in the field (exposed for approximately 6hrs at low tide). This additional resistance when compared to some of the other species in the group is likely to be attributed to physiological adaptations of this species.

Nutrient enrichment
The sensitivity of the species in this group to nutrient enrichment was variable. Therefore, *the combined group* has been assessed separately from *N. lapillus*. The outcome is very similar to that of the organic enrichment sensitivity assessment due to the cross over between pressures.

Combined Group
All of the species in the combined group (excluding *N. lapillus*) have been scored as *'Not sensitive'*. Increased nutrient enrichment stimulates primary producers which are normally limited by nutrients and this concurrently increases food supply throughout the impacted habitat. This would result in positive outcomes for all faunal populations at the benchmark level, even for predators and scavengers who do not rely on primary producers directly for food. Asteroidea populations in particular may benefit indirectly from an increased nutrient availability because major food items such as mussels filter feed upon phytoplankton and increase in abundance following nutrient enrichment. Smaller Crustacea in the group have demonstrated tolerances to organic enrichment above the considered baseline, demonstrating a high tolerance to the pressure. *D. spinosa* has been recorded at sites contaminated with storm water containing numerous pollutants including sewage (Carvalho *et al* 2007) and Grall and Glémarec (1997) also identified *D. spinosa* as tolerant to organic enrichment.

Nucella lapillus
Unlike the other species in the group, *N. lapillus* is affected by this pressure and is considered to be negatively impacted by nutrient enrichment due to its susceptibility to harmful effects from toxic algal blooms (Tyler-Walters 2007). *N. lapillus* is less mobile than the other species in this group and as such may be less able to avoid the harmful effects of phytoplankton populations. Algal blooms can be a result of nutrient enrichment by human activity but can also be a source of nutrient input themselves. Due to the sensitivity of *N. lapillus* has been assessed with *'High'* sensitivity to this pressure.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The sensitivity of this group to hydrocarbon and PAH contamination has been determined as *'Low'*. Though the species in the group are generally mobile, many environmental disasters which have resulted in the introduction of pollutants are large-scale and unavoidable.

Large crustaceans in particular have demonstrated resistance to this pressure following large-scale environmental disasters. Many *C. pagurus* juveniles were found dead following the Torrey Canyon oil spill and some deceased adults were found subtidally, though numerous healthy individuals were also found (Smith 1968). However, it is possible that the adults affected subtidally were killed by dispersants rather than oil. Further to this, *C. pagurus* in the vicinity of the Braer oil spill contained more than 12 times the PAH concentration of unaffected crabs (Topping *et al* 1997, in Neal & Wilson 2008). As with the Sea Empress oil spill, no mortality resulted from PAH contamination but the crab fishery was closed for a short time (Topping *et al* 1997, in Neal & Wilson 2008). Smaller crustaceans in the group have also exhibited a degree of tolerance beyond the benchmark considered for this project. Amphipods such as *D. spinosa* have been recorded in sea grass beds 2km from an oil refinery. However, the seasonal abundance of amphipods here was 15% of the abundance in the other non-contaminated beds (Baden 1990). In the contaminated site, the percentage of female amphipods with empty brood pouches increased during the season. It is suggested that low abundances and fecundity of amphipods could result from oil pollution. However, information has also been sourced for *D. spinosa* which suggests that it is tolerant to PAH contamination at the benchmark.

Following an experimental exposure of *A. rubens*, half of the total PAHs the specimens were exposed to were eliminated in two to four days (Joly-Turquin *et al* 2009). However, 20 days later, a small amount of contamination remained. Experimental observations suggest that the longer the exposure to pollution continues, the higher the level of PAHs accumulated. Neither growth nor reproductive capability of starfish was affected by PAH exposure Joly-Turquin *et al (*2009). Conversely, crude oil from the Torrey Canyon spill in 1967 and the detergent used to disperse it caused mass mortalities of echinoderms including *A. rubens*.

Overall, while *N. lapillus* is probably more resistant to oiling and emulsifiers than most gastropods, the evidence indicates that population are affected by oil but especially emulsifiers though this is dependent on the concentration (Tyler-Walters 2007). The degree of concordance for this pressure was generally low with case studies demonstrating the varying effects of hydrocarbons and PAHs on the species within the group depending on the nature of the contamination. An overall resistance of '*Medium*' was given for the species in this group and a resilience of '*High*' was recorded. However, if the nature of the contamination is severe enough to affect the fecundity of a species by physiologically altering the population, the resilience would need to be lower.

Radionuclide contamination
'No evidence' has been recorded for the species in this group due to a lack of available information. Radionuclides are taken up into the body by *A. rubens*, seemingly from the water rather from their food source. Depending on the type of radionuclide the persistence in the tissues can be long or short. There is no information as to whether the exposure and accumulation of such contaminants is damaging to the health of the species. Radionuclides are also taken up by large crabs and lobsters species (Smith *et al* 1998) though the effects of this are unknown.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The sensitivity of the species within this group to synthetic compound contamination is varied and separate assessments have been conducted for the combined group and *D. spinosa*.

Combined group
The species in this group have been scored with '*High*' sensitivity to this pressure. Though the species in the group are generally mobile, many environmental disasters which have resulted in the introduction of pollutants are large-scale and unavoidable. Survival following the introduction of contaminants often depends on the location of the habitat: intertidal or subtidal. As predators and scavengers, the species in this group are more susceptible to bioaccumulation of metals and transition elements, making them less resistant to this pressure. Little documentation concerning the biological effects of synthetic chemicals on Asteroidea species including *A. rubens,* is available*.* However*,* in coastal areas, starfish are known to concentrate synthetic chemicals though limited evidence exists regarding the biological effects of synthetic chemical exposure to the starfish in this group. den Besten *et al (*1989) reported that exposure of *A. rubens* to polychlorinated biphenyls (PCBs) resulted in production of defective offspring, though the extent to which this damaged the population and under what concentrations of PCBs is unclear. The effects of tributyl tin (TBT) used in anti-fouling paints on populations of *N. lapillus* have been well documented (Tyler-Walters 2007). The effects of tributyl tin (TBT) used in anti-fouling paints on populations of *N. lapillus* have been well documented and it is known to induce imposex in female *N. Lapillus.* Virtually all females in a population will be sterile at 3-5ng Sn/l of TBT contamination. This affect is irreversible and the population will decline due to natural mortality and poor recruitment (Tyler-Walters 2007).

Dexamine spinosa
In an investigation by Kinsella and Crowe (2015), *D. spinosa* was recorded as present at every site contaminated with storm water, which indicates a tolerance to the pollutants in the water which included a combination of contaminants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), heavy metals, freshwater, pesticides, sediment, nutrients, bacteria and sewerage. This demonstrates that *D. spinosa* is able to tolerate some exposure to synthetic contamination though it is unknown at what concentrations lethal and sub-lethal effects are observed. As such a sensitivity score of *'Not sensitive'* was given.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species within this group demonstrated variation in sensitivity to the pressure of transition elements and organo-metal contamination and were split in to two subgroups for the purpose of sensitivity assessments.

Combined group
Though not all of the species within this group demonstrate '*High*' sensitivity to this pressure, for the purposes of assessments and eventual management procedure, it was deemed appropriate to consider species for which little information was available with a higher degree of sensitivity. As some of the species have demonstrated very low tolerances to the introduction on transition elements and organo-metals, the combined group has been considered to also have a *'Low'* resistance. As predators and scavengers, the species in this group are more susceptible to bioaccumulation of metals and transition elements, making them less resistant to this pressure. The effects of tributyl tin (TBT), used in anti-fouling paints, on *N. lapillus* have been well documented. *N. lapillus* is highly sensitive to TBT contamination (Tyler-Walters 2007), while females may be killed at concentrations above 5ng Sn/l, imposex and hence reduced reproductive capacity can occur at lower concentration. This concurrently leads to a population decline due to natural mortality and poor recruitment. Where populations have become extinct, recovery is dependent on recolonisation, and may take many years (Tyler-Walters 2007). As such, *N. lapillus* has been classified with *'High'* sensitivity. In semi-field experiments, *A. rubens*, were exposed to 25ug Cd/litre (den Besten *et al* 1989). After five months of exposure, Cd concentrations in testes and ovaries were respectively 17 and 50 times higher than those in unexposed sea stars. Maturation of oocytes from Cd-exposed animals was delayed and early development of embryos from Cd- or PCB-exposed animals was disturbed and due to aberrations during the early development only 24% and 30% of the embryos obtained from Cd- or PCB-exposed sea stars, respectively, developed to normal bipinnaria larvae den Besten *et al (*1989). Therefore, *A. rubens* has been assessed with *'High'* sensitivity to this pressure.

Cancer pagurus and Dexamine spinosa
These two species have been determined as '*Not sensitive'* to this pressure. Due to the detoxification of metals with metallothioneins, *C. pagurus* is unlikely to suffer mortality unless inputs are very high (Neal & Wilson 2008). In addition, *C. pagurus* naturally accumulates metal, and levels of metals in the hepatopancreas have been recorded as high as 200ppm of copper, 29ppm cadmium and 20ppm zinc in crabs that were considered uncontaminated by anthropogenic input (Overnell 1982, 1984, both in Neal & Wilson 2008). Therefore, *C. pagurus* generally seems to be tolerant of metal pollution and has been scored *'Not sensitive'*. *D. spinosa* was recorded as present at every site contaminated with storm water, which indicates a certain tolerance to the pollutants that may be in the water (e.g. a combination of contaminants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), heavy metals, freshwater, pesticides, sediment, nutrients, bacteria and sewerage). This suggests that *D. spinosa* demonstrates a level of tolerance to synthetic contamination though it is unknown at what concentrations the pollutants were recorded.

Genetic modification and translocation of indigenous species
No evidence was available for the species in this group regarding 'Genetic modification and translocation of indigenous species'.

Introduction of microbial pathogens
The species in this group have been scored with *'Medium'* sensitivity to this pressure. Smith *et al (*2014) showed that moderately large numbers of juvenile *C. pagurus* carry low levels of bacteria in their hemolymph. Based on a survey of pre-recruit *C. pagurus*, it was determined that bacterial infections from two locations were relatively rare and are therefore not likely to be of major significance to the health status and recruitment of the species. However, *C. pagurus* can also contract Burn Spot Disease and Pink Crab Disease. Prevalence of the disease can be high and infection levels can be substantial in heavily polluted waters (Neal & Wilson 2008). In addition, male *A. rubens* are prone to gonad parasitisation by *Orchitophrya stellarum*. Larval production of the parasite by one population may result in settlement a considerable distance away while not infecting the original population (Morgan 1995, in Budd 2008). Consequently, it may take more than two generations for a population to return to a pre-impact state (Vevers 1951, in Budd 2008; Bouland & Claereboudt 1994). A population of *A. rubens* in the English Channel, was found to have >20% of males parasitised with *O.stellarum* in spring 1947 though the evidence was tentative (Vevers 1951). Like other species in the group, Gastropoda are also prone to pathogens and parasites *N. lapillus* may be infected by larvae of the trematode *Parorchis acanthus* which may lead to castration and may eventually result in a decline in population size. Recoverability is dependent on recruitment from within the population where reproductive capability is concerned so the specific parasites should be considered when assessing this pressure.

Introduction or spread of non-indigenous species (INIS)
No evidence could be sourced for the species in this group relating directly to this pressure in terms of sensitivity. The introduced American oyster drill *Urosalpinx cinerea* may feed on barnacles as a secondary food sources and as such may compete with *N.lapillus* (Tyler-Walters 2007). However, no further information was found on the pressures of non-indigenous species to *N. lapillus*. *C. pagurus* is not known to compete with or be affected by any non-native species (Neal & Wilson 2008) though no information regarding this pressure could be found for *D. spinosa* and *A. rubens* or the other species in this group.

Removal of non-target species
The species within this group have been assessed as *'Not sensitive'*. The species in this group are all predators and scavengers and as such are reliant on a sufficient supply of prey. Scavengers are generally opportunistic and consume a variety of food which acts to increase the resistance of the group members to this pressure. Though some of the dominant prey species for the ecological group species are subject to removal, they are generally so numerous that present extraction rates are not adversely affecting the populations. Mussels are subject to extraction and are a major food species for gastropods including *N. lapillus* where they occur. However, *N. lapillus* is able to switch to a more abundant prey, such as barnacles if required (Tyler-Walters 2007). *A. rubens* like other large starfish species in the group is an opportunistic scavenger that has been shown to gain extra food by foraging in fished areas upon damaged and displaced by-catch (Ramsay *et al* 1998). Many of the prey items of large crustaceans, including *C. pagurus*, are also commercially exploited, particularly large bivalves such as scallop. If populations of prey items were overexploited it is likely that the populations of *C. pagurus* would decrease or growth would be slower leading to a later maturation.

Removal of target species
The species in this group have been assessed with '*Low*' sensitivity to this pressure. All around the UK there are well established and large fisheries for large crustaceans including

H. gammarus and *C. pagurus* (Bennett 1979, in Neal & Wilson 2008, 1995; Brown & Bennett 1980, in Neal & Wilson 2008; Eaton *et al* 2001, in Neal & Wilson 2008; Fahy *et al* 2002, in Neal & Wilson 2008; Howard 1982, in Neal & Wilson 2008), which although causing substantial mortality, are rigorously regulated by minimum landing sizes (Neal & Wilson 2008). The other crab species in this group are not known to be targeted as food sources at present. *N. lapillus* is deemed to be unpalatable and not subject to targeted extraction in the UK (Tyler-Walters 2007) like the remaining species in this group. The small size of the amphipods would be likely to afford them protection should there be any demand for extraction of the species' in this group, none of which is known at present.

4.4 Ecological group 4: Bivalves and brachiopods

Group 4 contains the common piddock *Pholas dactylus* which is well known for its formation of burrows in hard substrate. Though it does not support any other species, its old burrows provide refuge for other species and this has an influence on overall diversity at locations where piddocks are found. The common mussel *Mytilus edulis* is also represented by this Ecological Group; *M. edulis* is a widespread and common bivalve which has the ability to form dense biogenic aggregations. Finally, the brachiopod *Neocrania anomala* is also placed within this group. *N. anomala* is capable of recovery from considerable damage to the shell and soft tissue (James *et al* 1992, in Jackson 2000). Like the other species placed within Group 4, its resilience is largely attributable to a hard shell which can be used as protection from a number of threats.

The representative species selected for the sensitivity assessments in this group are *Mytilus edulis and Pholas dactylus. M. edulis* was chosen to be a characterising species as it is an extensively studied marine organism and is widespread across the UK. *P. dactylus* was selected to be representative of burrowing bivalves which share many traits with the other bivalves in the group but form burrows so may respond differently to pressures.

The species in this group have some disparate characteristics in terms of environmental position and attachment. Resistance in particular may be affected by differences in habitat preference and exposure. As a burrowing species, *P. dactylus* will be less exposed to physical pressures such as wave action or abrasion because its environment may afford it additional protection compared to other bivalve and brachiopod species. In addition, *M. edulis* occurs in dense aggregations and forms biological reefs while the other species populations are less densely aggregated. This may have implications for reproductive success and is likely to affect predation pressures. However, all species considered in this group are immobile and source food using suspension feeding methods meaning they are equally reliant on suspended organic matter in the water column. The group members are similar sizes and exhibit similar life histories. The characterising species considered are dioecious, annual reproducers and have larval stages with high distribution potential (Hill 2006; Tyler-Walters 2008b). Bivalves are highly fecund with species such as *M. edulis* producing >1 million eggs annually (Tyler-Walters 2008b). High reproductive output will act to improve the recovery of the species in the group following any damage to the population. *P. dactylus* is slower growing than the other species in the group and has a much longer lifespan of up to 14 years. Though the generation time is unknown, the species is still likely to have good recruitment potential as the reproductive season for this species is prolonged over a series of months rather than episodic (Hill 2006). Due to the reproductive capabilities and life-histories of all species within this group, recovery time is assumed to be within 2 years. As such, the resilience of the species in this ecological group is considered to be '*High*'.

4.4.1 Sensitivity assessments

Table 6. Group 4 Bivalves and brachiopods species sensitivity assessment for pressures (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	L	H	Low	M	H	L
Temperature changes - local	L	H	Low	M	H	L
Water flow (tidal current) changes - local	H	H	Not sensitive	L	M	M
Wave exposure changes - local	H	H	Not sensitive	M	H	M
Changes in suspended solids (water clarity) (increase in clarity)	H	H	Not sensitive	M	H	M
Abrasion/disturbance at the surface of the substratum	M	H	Low	M	M	M
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	None	H	Medium	M	H	L
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	H	H	Not sensitive	M	H	M
Litter	H	H	Not sensitive	H	H	M
Visual disturbance	H	H	Not sensitive	M	H	M
Organic enrichment	H	H	Not sensitive	M	M	M
De-oxygenation	H	H	Not sensitive	M	H	M
Introduction of other substances (solid, liquid or gas)	L	H	Low	M	H	M
Nutrient enrichment	H	H	Not sensitive	M	M	M
Hydrocarbon & PAH contamination	M	H	Low	M	H	M
Radionuclide contamination	H	H	Not sensitive	M	M	M
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals	L	H	Low	M	M	M
Transition elements & organo-metal (e.g. TBT) contamination	L	H	Low	M	M	M

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Genetic modification & translocation of indigenous species	L	VL	High	L	H	M
Introduction of microbial pathogens	L	VL	High	M	M	L
Introduction or spread of non-indigenous species (INIS)	L	L	High	M	H	M
Removal of non-target species	H	H	Not sensitive	M	H	M
Removal of target species	M	H	Low	M	H	M

Salinity changes - local
The individual species in this group demonstrated some variable tolerances to the pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group.

P. dactylus displays a preference for full salinity and lives permanently within a burrow and is therefore unable to migrate, increasing the species sensitivity when exposed to conditions beyond its threshold (Hill 2006). The species occurs in circalittoral rock biotopes which have limited influence from fresh water inputs. As such, *P. dactylus* is considered vulnerable to a decrease from 'full' to 'variable' salinity. Conversely, *M. edulis* is considered '*Not sensitive'* to changing salinity at the benchmark level. Research has shown that exposure of *M. edulis* to salinities as low as 13ppt can inhibit growth rates (Almada-Villela 1984), however it has been reported to adapt and survive at salinities as low as 4-5ppt through phenotypic modifications (Tyler-Walters 2008b). Aggregations of *M. edulis* commonly occur on the lower rocky shore where they are subject to freshwater influence from heavy rainfall. Overall, this species is reported to possess the ability to acclimate over a variety of salinities (Tyler-Walters 2008b). Consequently, a reduction in salinity from 'full' to 'variable' will not adversely affect *M. edulis.* Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would result in an overall sensitivity score of '*Medium*' rather than '*Low*' for this pressure.

Temperature changes - local
The individual species in this group demonstrated variable tolerances to the pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. In particular the group is most sensitive to decreasing temperatures at the benchmark level.

The distribution of the species in this group is widespread with group members occurring from northern Europe to North Africa (Hill 2006; Tyler-Walters 2008b). Based on the extent of this distribution, the group members are likely to adapt to changing temperatures though *M. edulis* is more adaptable to temperature change than *P. dactylus*. *P. dactylus* is known to be at the northern limit of this range in the UK (Hill 2006) therefore a decrease in temperature is likely to adversely affect populations. Such an effect was reported during an extreme winter, where no individuals were found alive at Lyme Regis (Crisp 1964). The intolerance of *P. dactylus* to cold was further reinforced from an experiment by Knight (1984), who reported that siphon activity and oxygen consumption at 7°C was substantially reduced from the values recorded at 15°C and 18°C. In contrast, *M. edulis* is considered not sensitive to this pressure. This species is eurythermal (Tyler-Walters 2008b) and has been reported to survive temperatures as low as -10°C (Seed & Suchanek 1962, in Tyler-Walters 2008). The ability of species to withstand freezing increases after acclimation and during winter (Loomis 1995); suggesting that the timing of temperature change affects sensitivity.

Based on the extent of the southern distribution, an increase in temperature is unlikely to adversely affect populations of *P. dactylus or M. edulis* in the UK. Reproduction in bivalve and brachiopod species is triggered by temperature (Hill 2006; Tyler-Walters 2008b; Jackson 2000) and as spawning for these species occurs in warmer waters (Knight 1984). Therefore, increasing water temperature may result in an extended reproductive period. Additionally, *M. edulis* is eurythermal (Tyler-Walters 2008b) and has been reported to survive temperatures as high as 29°C (Almada-Villela 1984).

Water flow (tidal current) changes - local, including sediment transport considerations
Overall the species in this group were considered *'Not sensitive*' to decreases in water flow at the benchmark level. The group members are all immobile filter feeders therefore decreased water flow may limit food availability. However, at the benchmark level the resistance of this group is considered '*High*' as a reduction in water flow at this rate is unlikely result in mortality. The tidal strength preference of *M. edulis* ranges from weak (<0.5m/s) to strong (1.5-3m/s) while *P. dactylus* preferences range from weak (<0.5m/s) to moderately strong (1-3kn) and *N. anomala* preferences range from very weak (negligible) to moderately strong (1-3kn). The continued presence of each species in a range of flow regimes suggests that that decreased water flow at the benchmark will not adversely affect them, though it is possible that food could become more limited (Tyler-Walters 2008b). In addition, bivalves are able to orientate themselves to accommodate the direction of water flow while remaining attached to the substrate using strong byssal threads (Shields *et al* 2011). This attachment helps to prevent displacement as a result of higher water flows though the effectiveness depends largely on the substrate (Tyler-Walters 2008b).

Wave exposure changes - local, including sediment transport considerations
Overall this group was considered as '*Not sensitive'* to changes in wave exposure at the benchmark level. Increased wave exposure in sublittoral habitats is unlikely to result in population decline as wave exposure manifests as oscillations on the seafloor. Additionally, the *P. dactylus* burrow affords it protection from changes in wave exposure (Hill 2006). The other species in the group are firmly attached to the substratum by either byuss threads or a concrete-like secretion (Jackson 2000) which helps keep them attached should wave exposure threaten to dislodge them. An increase in wave exposure may result in an increase in food availability (Hill 2006) while a decrease in exposure may result in a reduction in food supply though this is unlikely at the benchmark level. There may be the risk of exposure from increased substrate erosion in relation to increased wave exposure (Tillin & Hill 2016). However, in the context of the benchmark, the resistance of this group has been considered '*High*', as is the resilience based on no impact to recover from.

Changes in suspended solids (water clarity)
Overall the species in this group were considered '*Not sensitive*' to changing water clarity at the benchmark level. None of the group members are reliant on algal species which would be affected by variation in irradiance levels because of suspended solids in the water column. Some group species such as *P. dactylus* are found in turbid habitats (JNCC 1999; Hill 2006) and in response to increased sediment loads, *P. dactylus* is able to effectively eject sediment from its body (Knight 1984; Hill 2006). Likewise, *M. edulis* has been recorded from waters which were very turbid and full of silt, and it possesses the capabilities to effectively expel sediment from its shell (Moore 1977, in Tyler-Walters 2008).

Abrasion/disturbance at the surface of the substratum
Overall the group sensitivity was considered to be '*Low*' at the benchmark level for this pressure. The sessile nature of the species in this group means that they are unable to avoid

the physical impacts of abrasion. All species are able to attach themselves strongly to the substrate though reattachment is impossible for many bivalves once removed. The burrowing activity of *P. dactylus* may make the sea bed more prone to damage from fishing activities (Pinn *et al* 2008) as the seafloor heterogeneity that is introduced by burrowing activity can make the substrate weaker to impacts. Though the burrow of the piddock may afford it some protection, the dependence of the species on their burrows can make them vulnerable to abrasion, as when excavated, they cannot re-burrow (Barnes 1980, in Hill 2006) leaving them open to predation (Micu 2007). Populations burrowing in harder rock are given greater protection from the substrate (Hill 2006).

Daly and Methieson (1977) reported that patches of an *M. edulis* population were lost due to the mechanical damage from a log caught in the waves. This can be likened to the abrasion impact of fishing gear (Tyler-Walters 2008b) which is known to disturb benthic species. Recoverability of *Mytilus* species depends on the availability of larvae and is quite variable over time (Tyler-Walters 2008b). Assuming a good supply of larvae, the recovery of populations in this group is estimated at two years, but this can be far longer depending on the extent of population loss and conditions. For the purposes here, a good supply of larvae is assumed, and resilience is categorised as '*High*'.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology and habitat.

All of the group members are considered to be sessile and movement away from the burrow or detachment from the substrate is likely to result in mortality. Though some of the species possess the ability to clear their feeding apparatus following heavy sedimentation, an overburden of 30cm would be likely to smother the populations of all species in the group. The shape of a *P. dactylus* burrow restricts any vertical migration through the sediment, thus *P. dactylus* is essentially sedentary (Tillin & Hill 2016). It has been recorded that this species can cope with mud or silt over-burdens of 1-5cm by extending their siphons to the surface but cannot cope with more substantial deposits (Tillin & Hill 2016). *M. edulis* possesses the ability to detach and move if there is a substantial sediment overburden (Holt *et al* 1998; Tyler-Walters 2008b). However, some mortality is reported from such events (Dare 1976, in Tyler-Walters 2008; Daly & Methieson 1977; Holt *et al* 1998). Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery of the group populations would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would still result in an overall sensitivity score of '*Medium*' for this pressure.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence could be found relating the species in this group to 'Electromagnetic changes'.

Introduction of light
The species in this group were classified as '*Not sensitive'* to the introduction of light. Although bivalve species such as *P. dactylus* and *M. edulis* react to light (Hecht 1928; Tillin & Hill 2016), it is suggested that this pressure will not adversely affect them in their habitat and no evidence could be found to suggest that any harm would come to species in this

group as a result of the pressure. The visual capabilities of the species in this group are thought to be low and it is unknown how they would be affected by the introduction of light. *M. edulis* have eyes which detect light (Bayne 1984; Robson *et al* 2010) and it has been shown to follow a light-driven circadian rhythm, with greater activity during the night (Robson *et al* 2010) though as a filter feeder this is unlikely to affect its feeding behaviour.

Litter
Based on the available evidence for this group, the species were assessed as '*Not sensitive'* However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. Marine litter, particularly in the form of plastics and fishing gear is more prevalent than ever (Islam & Tanaka 2004) and is likely to impact most marine environments in one way or another, though the path by which these impacts are felt for most of the species in this group is poorly documented. No evidence was found regarding the response of *P. dactylus* or other species in the group to litter. The group assessments were therefore based on the available evidence for *M. edulis*. While feeding, *M. edulis* can ingest polystyrene that then persists in the circulatory system for up to 48 days (Browne *et al* 2008). Despite this, the authors report that there was no impact on feeding, oxygen consumption, or immune system (Browne *et al* 2008). Although the plastics themselves may not impact on *M. edulis*, a study using *Mytilus galloprovincialis* reported that PAH contamination, (and the subsequent adverse effects), were transferred to the mussels via microplastic ingestion (Avio *et al* 2015). This specific pathway for contamination would not exist if microplastics were not present, however because there is no direct effect on population viability, a resistance of high has been recorded. Resilience is *'High*' because there is no impact to recover from.

Visual disturbance
The species in this group were considered *'Not sensitive'* to visual disturbance. Bivalve and brachiopod species demonstrate response to light but are not likely to have the visual acuity to perceive objects which are not normally found in circa- and sublittoral environments. *P. dactylus* displays a shadow avoidance response (Knight 1984). However at the level considered in this project, visual disturbance is unlikely to affect this species. Similarly, although *M. edulis* can detect light, visual disturbances in the manner considered for this pressure are also unlikely to disrupt this species (Tyler-Walters 2008b).

Organic enrichment
This group was considered '*Not sensitive'* to organic enrichment at the benchmark level. The species in this group are all filter feeders which are likely to respond positively to an increase in organic matter in the water column*. P. dactylus* can inhabit turbid waters, therefore an increase in organic enrichment will likely result in an increased availability of food (JNCC 1999). Similarly, *M. edulis* will likely benefit from increased food availability in the form of organic enrichment (Tyler-Walters 2008b). Studies have also reported negative effects of organic enrichment, such as smothering of mussels by glutinous material produced by algal blooms in Norway (Holt *et al* 1998). However, assuming background levels are not already heavily loaded with organics, addition of organics at the benchmark level is likely to provide more food, opposed to generate a large scale algal bloom.

De-oxygenation
The species in this group were considered to be '*Not sensitive*' to this pressure. Though generally immobile and unable to remove themselves from localised hypoxia, bivalves are acknowledged to be the most tolerant marine species to de-oxygenation (Gray *et al* 2002). The presence of *P. dactylus* in peat, has been reported by Knight (1984). These conditions are prone to low oxygen availability (Hill 2006) which demonstrates this species high resistance to limited oxygen supply. *M. edulis* is also well adapted to low oxygen availability, surviving in concentrations as low as 0mg/l for limited periods (de Zwaan & Mathieu 1992, in Tyler-Walters 2008b). *M. edulis* is able to withstand hypoxic conditions for 1-2 weeks by

closing their shells and respiring anaerobically (Jorgensen 1980; Cole *et al* 1999, in Tyler-Walters & Pizzola 2008) Anaerobic respiration is costly in metabolic terms which may lead to decreased growth rate (Tyler-Walters 2008b). However, aerobic respiration will recommence after return to normal oxic conditions (Tyler-Walters 2008b).

Introduction of other substances (solid, liquid or gas)
The species in this group have been scored with '*Low*' sensitivity. The species in this group are largely immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the intertidal and shallow circalittoral regions where contaminants such as oil may settle on bivalve and brachiopod populations. It is suggested that the introduction of materials such as tar or oil may smother species such as *P. dactylus*, which would result in mortality (Hill 2006). When *M. edulis* were exposed to contaminated sediment from a harbour for a week, the feeding activity was reduced as contaminants were assimilated, and after only two days feeding ceased (Eertman *et al* 1995). These effects will likely result in mortality, but the concentration considered in the evidence was higher than the benchmark. Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would result in an overall sensitivity score of '*Medium*' rather than '*Low*' for this pressure.

Nutrient enrichment
The species in this group were considered to be '*Not sensitive'* to nutrient enrichment at the benchmark level. The group members are all filter feeders who are likely to respond positively to an increase in nutrients in the water. *P. dactylus* is a filter feeder which can inhabit turbid waters and an increase in nutrients will likely result in an increased availability of food (JNCC 1999). Similarly, *M. edulis* is a filter feeder and will likely benefit from increase food availability resulting from nutrient enrichment (Tyler-Walters 2008b). Studies have also reported negative overall effects of nutrient enrichment, such as smothering of mussels by glutinous material produced by algal blooms in Norway (Holt *et al* 1998, in Tyler-Walters 2008b). However, assuming background levels are not already heavily loaded with nutrients, addition of nutrients at the benchmark level is likely to generate more food, opposed to a large scale algal bloom.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
Based on the available evidence for this group, the species were scored with '*Low'* sensitivity. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. The species in this group are largely immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the intertidal and shallow circalittoral regions where contaminants such as oil may settle on bivalve and brachiopod populations. No evidence was available regarding the effects of hydrocarbons on most of the species in this group therefore the group assessment was based on available evidence for *M. edulis*. When *M. edulis* were exposed to hydrocarbon and PAH contaminated sediment from a harbour for a week, the feeding activity was reduced as contaminants were assimilated and after just two days feeding stopped (Eertman *et al* 1995). Widdows and Donkin (1992, in Tyler-Walters 2008b) indicated that hydrocarbon contamination in *M. edulis* was more likely to manifest as reduced scope for growth than direct mortality, but that over time this could ultimately result in mortality. Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would result in an overall sensitivity score of '*Medium*' rather than '*Low*' for this pressure.

Radionuclide contamination
Based on the available evidence for this group, the species were scored as '*Not sensitive'* to radionuclide contamination. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. The species in this group are largely immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the intertidal and shallow circalittoral regions where contaminants may come in to contact with bivalve and brachiopod populations. Evidence regarding this pressure was only available for *M. edulis*. Several studies have reported *M. edulis* as concentrating radionuclides (Widdows & Donkins 1992, in Tyler-Walters 2008; Cole *et al* 1999, in Tyler-Walters & Pizzola 2008; Bustamante *et al* 2002) however no adverse effects have been documented (Tyler-Walters 2008b). The resistance to radionuclides is thus considered to be '*High*', as is the resilience.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been classified with '*Low'* sensitivity to this pressure. The group members are largely immobile which makes them susceptible to the effects of synthetic pollution. This is likely to be especially true when regarding populations in the intertidal and shallow circalittoral regions where contaminants such as antifoulant may come in to contact with bivalve and brachiopod populations. TBT has been found to adversely affect bivalves, which ultimately results in death (Beaumont *et al* 1989; Hill 2006). No specific information was found relating to the other species in the group, but using this evidence and expert judgement the resistance of this species was considered low, as the chemical character of the environment would be altered. *M. edulis* and bivalves in general are known to bio-accumulate numerous contaminants though the effects are usually sub-lethal (Hermsen *et al* 1994; Holt *et al* 1998). However, there are some chemicals which exhibit a greater effect on *M. edulis* and can result in substantial mortality of the population (Smith 1968; Liu & Lee 1975, in Tyler-Walters 2008; Donkin *et al* 1989; Widdows & Donkin 1992, in Tyler-Walters 2008; Holt *et al* 1995, in Tyler-Walter 2008). Based on this evidence, the resistance for the species was considered to be *'Low'*, as for many of the contaminants considered in the relevant evidence more than half of the population died. Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would result in an overall sensitivity score of '*Medium*' rather than '*Low*' for this pressure.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been scored with a *'Low'* sensitivity to this pressure. The group members are largely immobile which makes them susceptible to the effects of synthetic pollution. This is likely to be especially true when regarding populations in the intertidal and shallow circalittoral regions where contaminants may come in to contact with bivalve and brachiopod populations. TBT has been found to adversely affect bivalves, which ultimately results in death (Beaumont *et al* 1989; Hill 2006). *M. edulis* is known to be sensitive to TBT (Holt *et al* 1995, 1998) and a variety of other heavy metals (Crompton 1997; Holt *et al* 1998; Widdows & Donkin 1999, in Tyler-Walters 2008b). Based on this evidence, the resistance of this species was considered '*Low*'. Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be '*High*'. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be '*Medium*' which would result in an overall sensitivity score of '*Medium*' rather than '*Low*' for this pressure.

Genetic modification and translocation of indigenous species
Based on the available evidence for this group, the species were scored with '*High'* sensitivity. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. Evidence was only available on the effects of genetic modification or translocation of indigenous species for *M. edulis* therefore the assessment has been conducted based upon the information for this species alone*.* It is reported that following reproductive spawning behaviour, *M. edulis* hybridises with *M. galloprovincialis* where they occur together in close proximity (Gardner 1996; Coughlan & Gosling 2007)*.* Beaumont *et al (*2007) highlight the difficulty in distinguishing *M. edulis* from *M. galloprovincialis* and their hybrids in the field because shell morphology is very similar. However, it is predicted that the functionality of mussel beds will not be affected (Beaumont *et al* 1993). The resistance of the species is therefore considered '*Low*' because where the two species co-exist, separate species reproduction is not likely to re-establish. Targeted removal of the hybrid or *M. galloprovincialis* species would also be unlikely given the difficulty in distinguishing between species. The resilience is considered as '*Very low'* because once hybridisation occurs, the proportion of the population lost to the hybrids is unlikely to ever fully recover to a single species assemblage.

Introduction of microbial pathogens
Based on the available evidence for this group, the species were scored with '*High'* sensitivity. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. Though there is a microbial pathogen associated with *P. dactylus*, there is no evidence as to the effect on the host; therefore the group sensitivity assessment is based on the available applicable evidence for *M. edulis* alone. *Martiella* sp. are the microbial pathogens associated with *M. edulis* (Robledo *et al* 1995; Le Roux *et al* 2001; Berthe *et al* 2004; Tyler-Walters 2008b). The pathogen reduces food assimilation and results in mussels exhibiting poor condition, and reduced fecundity (Robledo *et al* 1995). The copepod vector for the pathogen is not currently common in the UK (Tyler-Walters 2008b), but significant mortality of spat occurred when they were relocated to France where the pathogen persists (Berthe *et al* 2004). Increased temperatures may exacerbate the distribution (Berthe *et al* 2004). Based on this evidence, the resistance of *M. edulis* to this introduced pathogen is considered '*Low*'. The resilience is considered as being very '*Low*', based on 100% mortality of spat in France (Berthe *et al* 2004) and lowered fecundity of the adults (Robledo *et al* 1995).

Introduction or spread of non-indigenous species (INIS)
The species in this group have been scored with '*High'* sensitivity to this pressure. The non-native American piddock was introduced to the UK with the American oyster (Naylor 1957) and has spread through northern Europe (Rosenthal 1980). No evidence regarding the effects of this species on *P. dactylus* has been found; therefore the group sensitivity of '*High*' is based on the available applicable and available information for *M. edulis.* There are reports that *Crassostrea gigas* can displace *M. edulis*, leading to the replacement of mussel beds with oysters (Padilla 2010), however no magnitude of this effect was given and the evidence on very exposed shores is limited (Tyler-Walters 2008b). Based on the available evidence the resistance was recorded as '*Low*', with substantial loss of species and significant changes to habitat occurring (loss of mussel beds). Recovery is likely to be '*Low'* if the species is being outcompeted, as availability of suitable habitat is restricted.

Removal of non-target species
Based on the available evidence, the species in this group were considered to be '*Not sensitive'* to the removal of non-target species. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. The assessment for the group was based on the available information for *M. edulis. M. edulis* is considered to be less affected by non-target fisheries than other species, and they may take advantage of newly available free space to colonise following a

fishing event (Holt *et al* 1998). Resistance is therefore considered to be ‘*High*’, as is resilience.

Removal of target species
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as ‘*Low*’, reflecting the more sensitive species within the group.

Bivalves are a common target for fisheries with a particularly high demand for *M. edulis* seen in the UK. Historically, *P. dactylus* was harvested for consumption, and bait which led to a decline in populations (Michelson 1978, cited in Pinn *et al* 2005). Other species in the family are still extracted for food (Pinn *et al* 2005) but this species is no longer targeted on a significant scale and there is no evidence for the continued consumption of *P. dactylus* currently (Hill 2006). As such, this characterising species has been scored as ‘*Not exposed’* though this is not representative of the group as a whole The group were assessed as having a sensitivity of ‘*Low*’ based on the evidence available for *M. edulis*. *M. edulis* is a commercially important species in addition to its role as a biogenic habitat and food source (Holt *et al* 1998). Where harvesting is conducted in a sustainable manner and recruitment is successful, minimal negative impacts occur, but over-harvesting or recruitment failures may alter this dynamic (Holt *et al* 1998). Therefore a resistance score of ‘*Medium’* was given for the group. Assuming the appropriate conditions and established neighbouring populations were present following the removal of the pressure, recovery would be ’*High*’. For the purposes of this investigation a good supply of larvae is assumed though were this not the case, resilience would be ‘*Medium*’ which would result in an overall sensitivity score of ‘*Medium*’ rather than ‘*Low*’ for this pressure.

4.5 Ecological group 5: Tube-dwelling fauna

Tube-dwelling fauna are represented by Ecological Group 5. The group consists of four species: the polychaetes *Protula tubularia*, *Sabella pavonina* and *Lanice conchilega*, and the anemone *Cerianthus lloydii*. All of the species included in this group construct and maintain a protective tube structure around their bodies made from either calcareous secretions (*Protula tubularia*) or mud or sand particles held together with mucus secretions (*Lanice conchilega*, *Sabella pavonina, Cerianthus lloydii*). All species are sessile suspension or deposit feeders which occur in the intertidal and sublittoral zones and as such, they are most likely to demonstrate similar reactions to pressures resulting from human activities.

The characterising species selected for the sensitivity assessments for this group are the polychaete species: *Lanice conchilega* and *Sabella pavonina*. *L. conchilega* was selected as the most extensively researched and widely spread polychaete in the group which builds erect sandy tubes. *S. pavonina* was also chosen as a well documented characterising species which is representative of erect, tube dwelling species with large feeding apparatus and a muddy tube. Like *L. conchilega, C. lloydii* has a soft sandy tube which projects above the sediment surface and like *S. pavonina* it possesses large feeding apparatus with which it feeds. The fourth species in this group, *P. tubularia* is also an erect tube-building polychaete with project feeding apparatus which is characteristic of this group and well represented by the characterising species. However, it is much less widespread and not so well researched so was not selected as a characterising species.

The species in this group have some minor disparate characteristics in terms of taxonomy, tube material and feeding apparatus. *C. lloydii* is a tube dwelling anemone while the other group members are annelids though the similarities between the species are numerous. The tube of *L. conchilega* for example is formed from sand particles while the tube of *S. pavonina* is mostly formed from mud while the tube of *P. tubularia* is calcareous. While *S. pavonina* and *P. tubularia* feed using a crown of feather-like tentacles (Avant 2008), *L. conchilega* and *C. lloydii* feed using a crown of long, filamentous tentacles. *L. conchilega, S. pavonina* and *C. lloydii* are all within the size range of 21-50cm when mature while P. tubularia is much smaller than this at only 0.5cm when fully grown. This is likely to impact the sensitivity of this species to pressures such as smothering. However, these physiological differences are minor and unlikely to affect sensitivity to human pressures to a large degree. *L. conchilega* can occur in dense aggregations while the other species populations are less densely aggregated, though *S. pavonina* displays a *'*clumped*'* distribution onshore, and recruits to the population tend to settle near adults (Murray *et al* 2011). This may have implications for reproductive success and is likely to affect predation pressures. However, all species considered in this group are immobile and source food using suspension and deposit feeding methods meaning they are equally reliant on suspended organic matter in the water column and matter deposited on the seafloor. The group members are similar sizes and exhibit similar life histories though little information on the life-history of *C. lloydii* could be accessed. Due to the reproductive capabilities and life-histories of all species within this group, recovery time is assumed to be 2-10 years. As such, the resilience of the species in this ecological group is considered to be '*Medium*'. The polychaete species in the group are gonochoristic and reproduce annually, producing planktonic larvae with a large dispersal potential (<10km). These species are also fast growing. However, *C. lloydii* is hermaphroditic (though still planktonic) and more slow growing than the annelid species in this group (Avant 2008b). As little information was available for *C. lloydii* regarding recruitment and fecundity, it has been determined as having '*Medium*' resilience like the other species in the group.

4.5.1 Sensitivity assessments

Table 7. Group 5 Tube-dwelling fauna sensitivity assessment for pressures (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	M	M	Medium	M	H	M
Temperature changes - local	L	M	Medium	L	M	M
Water flow (tidal current) changes - local	H	H	Not sensitive	M	H	M
Wave exposure changes - local	H	H	Not sensitive	M	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	L	H	M
Abrasion/ disturbance at the surface of the substratum	M	M	Medium	M	H	L
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	L	M	Medium	M	M	M
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Electro-magnetic changes	No evidence					
Introduction of light - Group	H	H	Not sensitive	M	H	H
Introduction of light - *S. pavonina*	M	M	Medium	M	M	M
Litter	H	H	Not sensitive	M	H	M
Visual disturbance	H	H	Not sensitive	M	H	M
Organic enrichment	H	H	Not sensitive	M	M	M
De-oxygenation	L	M	Medium	L	M	M
Introduction of other substances (solid, liquid or gas)	L	M	Medium	M	M	M
Nutrient enrichment	H	H	Not sensitive	M	M	M
Hydrocarbon & PAH contamination	L	M	Medium	M	M	M
Radionuclide contamination	No evidence					
Synthetic compound contamination (incl. pesticides, antifoulants, pharma-ceuticals)	H	H	Not sensitive	H	H	M
Transition elements & organo-metal (e.g. TBT) contamination	H	H	Not sensitive	M	H	M
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens	H	H	Not sensitive	M	L	M
Introduction or spread of non-indigenous species (INIS)	No evidence					
Removal of non-target species	Not exposed					
Removal of target species - Group	Not exposed					
Removal of target species - *S. pavonina*	No evidence					

Salinity changes - local
The individual species in this group demonstrated some variable tolerances to the pressure and the increasing and decreasing benchmarks. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group.

The species in this group are primarily sessile, tube-dwelling marine species, which are unable to migrate should they occur in conditions beyond their environmental thresholds as a result of human activity. *L. conchilega* demonstrates preferences for living in fully marine (30-40) and variable (18-40) salinities, however, in estuaries it has been recorded that population size is smaller than in fully marine habitats (Ager 2008). A decrease in salinity from fully marine to variable, as per the benchmark, may therefore result in a decline of population numbers. Resistance was thus recorded as '*Medium*'. Where a population of adults already exists, the settlement rate of *L. conchilega* larvae is greater than where adult populations are absent (Ager 2008). The time taken to repopulate substrate when adults are absent has been recorded as three years (Strasser & Pielouth 2001, in Ager 2008). It is likely that some of the population will still remain with a decrease in salinity; however specific timeframes were not established. The other annelids in the group are also tolerant to variable salinities though the tube-dwelling anemone *C. lloydii* demonstrates little tolerance to decreasing salinity. The annelid species in this group are often located on the intertidal zone where they are likely to be subject to freshwater inputs such as heavy rain. Conversely, *C. lloydii* is always submerged and exempt from regular exposure to variable salinities making it more vulnerable to salinity variations.

Temperature changes - local
The individual species in this group demonstrated some variable tolerances to the pressure and the increasing and decreasing temperature benchmarks. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group.

The species in this group are primarily sessile, tube-dwelling marine species unable to migrate when exposed to conditions beyond their environmental thresholds. The geographic extent of the group members reveals that they are widely distributed, though for most of the species, north-west Europe is the northern-most reach of their distribution (Ager 2008; Avant 2008a, 2008b). As such, they are unlikely to be able to tolerate waters much colder than those in the UK at present. Due to the wide distributions of the group members, acute increases in temperature are unlikely to result in mortality of populations, although some stress could occur (Ager 2008). A decrease in temperature past the normal range, will negatively affect *L. conchilega* populations as this species is not tolerant of low temperatures (Crisp 1964; Beukema 1990, in Ager 2008; Strasser & Pielouth 2001, in Ager 2008) though the magnitude of the impact on the population is variable. For example, the entire intertidal population was wiped out in the Wadden Sea due to decreasing temperature (Strasser & Pielouth 2001, in Ager 2008), whereas Crisp (1964) reported that only the portion of the population above the low tide mark were negatively affected by an extreme winter. *L. conchilega* populations have been reported to recover quickly after such events (Ager 2008) but the speed is dependent on the continued presence of adult populations. Though mortality resulting from a decrease in temperature has been observed, the extent of *L. conchilega* spreads to the Arctic. This suggests that it may be the time period over which the cooling occurs is a crucial factor for consideration when examining the effects of temperature change.

Reports from a severe winter where the average sea surface temperature dropped from 5°C to -1.8°C in some areas suggest that *S. pavonina* populations were wiped out in three locations, though in one area 80% of the tubes were still occupied (Waugh 1964). The survival of the population which underwent the 80% mortality demonstrates a degree of resistance for the species however; the severe impact on the other populations illustrates vulnerability to decreasing temperature.

Water flow (tidal current) changes - local, including sediment transport considerations
The species in this group have been assessed as '*Not sensitive'* to this pressure. As sessile filter feeders, the group members are reliant on water flow for food delivery therefore a decrease in flow may result in a reduction in food supply. However, each of the species in this group has a range of tidal stream preferences. The group members have a preference for tidal currents ranging from very weak (negligible) to strong (1.5-3m/s). Therefore, tube-dwelling fauna inhabiting environments in the middle of their tolerance range are not likely to undergo any damage. The range over which the species are present suggests that they are quite resistant to changes in water flow whether increasing or decreasing. Additionally, the stagnation of water in sublittoral habitats is unlikely, therefore any feasible reductions in water flow would not impact negatively on the population, and a resistance of *'High'* has been recorded.

Wave exposure changes - local, including sediment transport considerations
The species in this group have been assessed as '*Not sensitive'* to decreasing wave exposure. As sessile filter feeders, the group members are reliant on water movement for food delivery therefore a decrease in wave exposure may result in a reduction in food supply. However, each of the species in this group has a range of wave exposure preferences which demonstrates tolerance of this pressure. For example, the wave exposure range for *L. conchilega* is from extremely sheltered to moderately exposed (Ager 2008) so *L. conchilega* may not be adversely affected by a change in wave height at the benchmark level. The neotype of *S. pavonina* is recorded from an area which was very sheltered (Knight-Jones & Perkins 1998). As such, *S. pavonina* is not likely to be adversely affected by a decrease in wave height at the benchmark level as it is able to persist in very sheltered areas.

L. conchilega should not be adversely affected by an increase in wave height at the benchmark level as it is able to persist under a range of exposure conditions, and within the remit of the benchmark the increase in wave height is fairly minimal. Additionally, within the sublittoral habitat, wave height manifests as oscillations on the seafloor, and not as wave crash which is more likely to damage populations. Additionally, the species in this group are tube-dwelling and so are afforded some protection from wave impacts by their tubes.

Changes in suspended solids (water clarity)
None of the species in this group are dependent on irradiance, primary production or vision for sourcing food, as such the group has been assessed as '*Not sensitive*' to this pressure. It's most likely that increased water clarity would increase energy supply to primary producers which in turn would stimulate the food chain and thus food supply to all filter feeders. Some of the group members such as *L. conchilega* occur in estuaries which are subject to low water clarity (Ager 2008). A decrease in water clarity is likely to be accompanied by an increase in organic matter in the water column, which as filter feeders is likely to benefit all of the species in this group.

Abrasion/disturbance at the surface of the substratum
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. The variation between species to this pressure is due to differences in physiology.

It is likely that erect tube-dwelling organisms will be damaged by abrasive activities on the surface of the substratum (Ager 2008). Investigations into the effect of cockle harvesting demonstrate that benthic fishing activity extracts *L. conchilega* tubes and brings them to the surface, however it was noted that the undamaged worms have the capacity to rebuild their tubes (Ferns *et al* 2000). In other cases, species such as *L. conchilega* may avoid damage by retreating into the protection afforded by its tube (Rabaut *et al* 2008). Based on this evidence, an overall resistance of '*Medium'* was assigned for this pressure as some mortality may occur, but the habitat itself will be largely unchanged. Murray *et al (*2013) reported that when specimens of *S. pavonina* were cut into eight fragments, all fragments completed regeneration within four weeks and, of these, there was an 80% survivorship. This suggests that if abrasive activities damaged *S. pavonina*, then the population would be able to recover very rapidly, thus the resilience of this species may considered to be '*High*'. However, the group resilience has remained '*Medium*' to reflect the realistic recovery capabilities of the other species in the group.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The species in this group have been scored with '*Medium*' sensitivity to heavy depositions of sediment. Some of the group members (*L. conchilega* and *S. pavonina*) grow to >30cm when mature (Ager 2008, 2008a) meaning that older populations may be able to avoid the most damaging effects of heavy sediment deposition. However, the tubes of these species may sometimes project just 10cm above the substrate (Avant 2008a) therefore smaller individuals would be buried. As mobile species however, *L. conchilega* and *S. pavonina* may be able to burrow through the sediment should it exceed this deposition depth. In the event of sedimentation *L. conchilega* is able to burrow upwards and extend its tube to cope with the sediment overburden (Johnson & Frid 1995). This behaviour has been observed when *L. conchilega* have been trapped under nets and exposed to increased sediment loading (Toupoint *et al* 2008). If required, a new tube may be built within 48 hours (Toupoint *et al* 2008). Similarly, the size of the burrowing anemone may afford it some additional protection. Though only 15cm long when mature, *C. lloydii* forms tubes which can be up to 40cm long meaning it would be able to avoid smothering as a result of sedimentation. Conversely, *P. tubularia* is a much smaller species (0.5cm) which would be unable to avoid heavy smothering and siltation.

Though some of the mature species within the group might be able to avoid mortality resulting from this pressure, younger populations would be damaged therefore the group resistance has been scored as '*Low*' and a resilience score of '*Medium*' has been given.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is 'very low'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence was available for the species in this group regarding 'Electromagnetic changes'.

Introduction of light
Due to differences in the sensitivities of the species in this group to the introduction of light, separate assessments have been conducted.

Combined Group
It is thought that the species in this group are '*Not sensitive'* to this pressure. Though some of the species have visual receptors, they are all tube-dwelling and their exposure to changing light regimes is likely to be limited. *L. conchilega* has been recorded as not being affected by light (Ager 2008) and does not show nocturnal feeding habits. Therefore both resistance and resilience for this species and the rest of the group were recorded as '*High*'.

Sabella pavonina
In contrast to the rest of the group, *S. pavonina* displays nocturnal behaviour, potentially to avoid predation (Miron *et al* 1991). The introduction of light may consequently limit the potential for feeding and/or enhance the detection of *S. pavonina* by predators. Using this evidence, a resistance of '*Medium*' and an overall sensitivity of '*Medium*' has been recorded.

Litter
The species in this group have been assessed as *'Not sensitive'* to litter because of tolerant behaviour demonstrated by group members. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. Marine litter, particularly in the form of plastics and fishing gear is more prevalent than ever (Islam & Tanaka 2004) and is likely to impact most marine environments in one way or another Though the path by which these impacts are felt for most of the species in this group is poorly documented. *L. conchilega* populations have been recorded near a sewage disposal site, in which litter and waste such as: pieces of wood, tin cans, tampons, sanitary towels, pieces of plastic, and general refuse, were present (Birchenough & Frid 2009). This evidence suggests that the presence of human waste items do not exclude *L. conchilega* from an area, although specific information regarding the magnitude of the debris was not given.

Visual disturbance
The species in this group have been assessed as '*Not sensitive'* to this pressure. Though some of the species have visual receptors, they are all tube-dwelling and their exposure to visual stimuli is likely to be limited. Therefore both resistance and resilience for this species and the rest of the group were recorded as '*High*'.

Organic enrichment
The species in this group are considered to be *'Not sensitive'* to organic enrichment. An increase of organic particulates enhances populations of these filter feeders through increased food availability (Smith & Shackley 2006). *L. conchilega* was found to be abundant at sewage disposal/outflow sites (Smith & Shackely 2006; Birchenough & Frid 2009). It has been suggested that increased organic enrichment will lead to communities dominated by opportunistic species such as capitellids (Ager 2008). However, Birchenough and Frid (2009) suggest that *L. conchilega* actually inhibits large densities of cirratulids. *L. conchilega* was also reported as being unaffected by an algal bloom, which was suspected to have caused a mass mortality of lugworm in Wales (Olive & Cadnam 1990). No information for *S. pavonina* regarding organic enrichment was found; however, the response of another species in the same genus, *Sabella spallanzanii,* was used as a proxy for this pressure. A resistance of *'High'* was given because of the preference of *S. spallanznii* to form dense populations in eutrophic and polluted environments.

De-oxygenation
The sensitivity for this group has been recorded as *'Medium'* for de-oxygenation. As sessile tube-dwellers, the species in this group are not able to avoid conditions beyond their environmental preference. *L. conchilega* was one of the species found to be reduced in abundance or absent entirely in hypoxic areas (Niermann *et al* 1990). This study was conducted over a period of four weeks, and so well above the benchmark both in magnitude of oxygen availability and length of time. At temperatures of 10-12°C, *S. pavonina* survived at dissolved oxygen concentrations of 100%, 21%, and 10% for two weeks, but at 4% dissolved oxygen it died in less than four days (Newell 1979). It has been reported that oxygen concentrations below 2mg/l will likely have adverse effects on marine fauna (Cole *et al* 1999, in Tyler-Walters & Pizzola 2008). On balance, a resistance rating of *'Low'* was given for this group.

Introduction of other substances (solid, liquid or gas)
The species in this group have been scored with *'Medium'* sensitivity. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. The sensitivity for this group has been recorded as *'Medium'* for this pressure. Retention of oil in the environment particularly effects polychaetes, and may inhibit recolonisation of substrate by the species in this group (Suchanek 1993, in Ager 2008). However, it was reported the *L. conchilega* recolonised areas directly affected by the Amoco Cadiz oil spill, immediately after the event. No direct information was found relating to the resistance of *L. conchilega* to the initial impact, but it can be assumed that if recolonisation had to occur, then the majority of the population was removed. It should be noted that the benchmark for this pressure is well below the effects of an oil spill. Taking into consideration the contradictory evidence for the re-colonisation rates following an oil spill, the resilience was classified as medium. No information relating to the introduction of other substances was found for the other characterising species, thus the combined group assessment was based on the available information for *L. conchilega*.

Nutrient enrichment
The species in this group have been recorded as *'Not sensitive'* to this pressure. An increase of organic particulates enhances populations of these filter feeders through increased food availability (Smith & Shackley 2006). *L. conchilega* was found to be abundant at sewage disposal/outflow sites (Smith & Shackely 2006; Birchenough & Frid 2009). An increase of organic particulates enhances populations of these filter feeders through increased food availability (Smith & Shackley 2006). It has been suggested that increased nutrient enrichment will lead to communities dominated by opportunistic species such as capitellids (Ager 2008), however, Birchenough and Frid (2009) suggest that *L. conchilega* actually inhibits large densities of cirratulids persisting. *L. conchilega* was also reported as being unaffected by an algal bloom, which was suspected to have caused a mass mortality of lugworm in Wales (Olive & Cadnam 1990). It should be noted that the benchmark for nutrient enrichment is fairly low in comparison to the enrichment from sewage outfalls and algal blooms. No information for *S. pavonina* regarding nutrient enrichment was found; however, the response of another species in the same genus, *Sabella spallanzanii*, was used as a proxy for this pressure. *S. spallanznii* demonstrates a preference to form dense populations in eutrophic and polluted environments. Resistance of *'High'* was recorded based on no impact to recover from.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been scored with *'Medium'* sensitivity. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. As sessile tube-dwellers, the group members would not be able to relocate to avoid point sources of contamination. Retention of oil in the environment particularly effects polychaetes and may inhibit recolonisation of substrate by the species in this group (Suchanek 1993, in Ager 2008). However, it was reported the *L. conchilega* recolonised areas directly affected by the Amoco Cadiz oil spill, immediately after the event. No direct information was found relating to the resistance of *L. conchilega* to the initial impact, but it can be assumed that if recolonisation had to occur, then the majority of the population was removed. It should be noted that the benchmark for this pressure is well below the effects of an oil spill. Taking into consideration the contradictory evidence for the re-colonisation rates following an oil spill, the resilience was classified as medium. No information relating to the introduction of other substances was found for the other characterising species, thus the combined group assessment was based on the available information for *L. conchilega*.

Radionuclide contamination
No evidence was available for the species in this group regarding ‘Radionuclide contamination'.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been determined as ‘*Not sensitive’* to this pressure. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. As sessile tube-dwellers, the group members would not be able to relocate to avoid point sources of contamination. *L. conchilega* is able to withstand varying concentrations of PCBs from the environment, accumulating more in their tissues when exposed to greater environmental concentrations (Goerke & Weber 1998). Experiments by Ernst and Weber (1978) suggested that *L. conchilega* likely has the ability to handle halogenated phenols, as it contains natural brominated phenols. This evidence suggests that *L. conchilega* has a high resistance to PCBs. No information relating to other synthetic contaminants was found for this species and so the assessments were based on the available evidence.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
Overall the group was considered *‘Not sensitive’* to this pressure. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. As sessile tube-dwellers, the group members would not be able to relocate to avoid point sources of contamination. No information relating specifically to the ability of *L. conchilega* to withstand transition metals was found, however generic resources indicate that polychaetes are reasonably resistant to heavy metals (Bryan 1984, in Ager 2008; Crompton 1997). Crompton (1997) lists the lethal concentrations (4-14 days exposure) as follows: Cu 0.01-0.1mg/l; Cd 1-10mg/l; Zn 1-10mg/l; Pb 0.1-1mg/l; Cr 0.1-1mg/l; As 1-10mg/l; Ni 10-100mg/l. Based on this evidence a resistance and resilience of *‘High’* has been recorded. Further evidence was available for *S. pavonina*, where Koechlin and Grasset (1988) showed that *S. pavonina* could store substantial concentrations of silver in their tissues. Additionally, *S. pavonina* was able to constantly eliminate silver in its urine, and on return to uncontaminated conditions *S. pavonina* began to reverse the effects of silver contamination (Koechlin & Grasset 1988).

Genetic modification and translocation of indigenous species
No evidence was available for the species in this group regarding ‘Genetic modification and translocation of indigenous species'.

Introduction of microbial pathogens
Overall the group has been considered as *‘Not sensitive’* to the introduction of microbial pathogens. However, little information was available regarding the pressure and the species in this group so this assessment is tentative and made with caution. No evidence regarding the spread of microbial pathogens was found for *L. conchilega*, therefore the combined group assessment was based on the available information relating to *S. pavonina*. No direct evidence for *S. pavonina* was found, but information for a different species in the same genus was. Licciano *et al (*2005) reported that *S. spallanzanii* is very effective at removing bacteria from seawater, and that there could be potential for this species to be used as a bio-filter to remove Vibro species of bacteria responsible for infections in many shellfish and aquaculture sectors. From this evidence it appears that *S. spallanzanii* is resistant to a common microbial pathogen, therefore the resistance and resilience of *S. pavonina* to the introduction of microbial pathogens has been recorded as *‘High’*.

Introduction or spread of non-indigenous species (INIS)
No evidence was available for the species in this group regarding 'Introduction or spread of non-indigenous species (INIS)'.

Removal of non-target species
The sensitivity for this group has been assessed as *'Not exposed'*. The species considered in this group are not known to rely on any other species. As such, the ecological consequences such as food dependencies from fishing and other species removal activities on this group are minimal.

Removal of target species
'*L. conchilega* was considered '*Not exposed'* to this pressure because it is not known to be harvested for any purpose. '*No evidence'* was assigned to *S. pavonina*, rather than not exposed, because *S. pavonina* are used in ornamental fish tanks (Murray *et al* 2013). No evidence as to the extent or the method of removal was found, but laboratory culturing methods are being developed (Murray *et al* 2013), which would likely reduce any resultant pressure in the ecosystem.

4.6 Ecological group 6A: Attached soft-bodied species

The attached soft-bodied species group includes species from several Phyla which are all either permanently or temporarily attached to the seabed, and can be characterised as having soft or flexible-bodied taxa which are not encrusting and do not rise to a great height above the seabed. All species in this group are filter feeders that strain food particles from the water column. The group is found in both the infralittoral and circalittoral zones in a range of environmental conditions. The species represented in this group are: *Alcyonium digitatum, Anemonia viridis, Ascidia mentula, Ascidiella aspersa, Caryophyllia smithii, Ciona intestinalis, Clavelina lepadiformis, Corella parallelogramma, Dysidea fragilis, Epizoanthus couchii, Metridium senile, Phellia gausapata, Polyclinum aurantium, Urticina feline,* and *Suberites carnosus.*

The representative species selected for the sensitivity assessments for this group are: *A. digitatum, C. lepadiformis* and *D. fragilis. A. digitatum* was selected as the only well documented and soft-bodied coral in the group. *C. lepadiformis* was chosen as the most widespread and researched ascidian in the group whole *D. fragilis* was chosen as the only sponge.

The species in this group have some disparate characteristics in terms of taxonomy, size, habitat preference and life-history which account for differences in the sensitivity assessments. Resistance in particular may be affected by differences in habitat preference and physiology. *A. digitatum* colonies can reach 20cm in height and breadth (Budd 2008b) while *C. lepadiformis* squirts grow to a maximum of 0.2cm (Fish & Fish 1996, in Riley 2008; Picton 1997, in Riley 2008) and massive forms of *D. fragilis* may grow to 30cm in diameter (Rowley 2007). Some of the species in this group such as *D. fragilis* have more than one form, encrusting or massive, which is likely to increase the resistance of the species. The resilience of the species in the group is also affected by physiology and life-history. All of the group members are filter feeders though some are active and some are passive and this may determine their ability to cope with pressures such as changing suspended solids and water clarity. Some of the group members such as *A. digitatum* and *D. fragilis* are able to regenerate which following any damage is likely to aid recovery. Some species are also slower growing than others, though most of the species in this group are considered to grow relatively slowly. However, slow growth does not automatically infer low recovery potential. Many of the species in this group have a high recovery potential though the time period required is longer than for some other groups. *A. digitatum* for example is slow growing species but as a lecithotrophic broadcast spawner, fecundity is high. The developmental mechanism for all of the representative species in this ecological group is lecithotrophic which infers a good recovery potential for the group. An overall resilience score of '*Medium*' (2-10 years) has been given to the group to properly capture the sensitivity of the slower growing species in the group.

4.6.1 Sensitivity assessments

Table 8. Group 6A Attached soft-bodied species and associated biotope in sublittoral rocky habitats (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	H	H	Not sensitive	M	M	M
Temperature changes - local	H	H	Not sensitive	M	H	H
Water flow (tidal current) changes - local - Group	L	M	Medium	M	H	M
Wave exposure changes - local	H	H	Not sensitive	M	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	H	H	M
Abrasion/disturbance at the surface of the substratum	L	M	Medium	M	H	M
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	None	M	Medium	L	H	M
Physical loss (to land or freshwater habitat)	L	Very Low	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	H	H	Not sensitive	H	H	M
Litter	No evidence					
Visual disturbance	H	H	Not sensitive	M	H	H
Organic enrichment	H	H	Not sensitive	M	M	M
De-oxygenation	H	H	Not sensitive	M	H	M
Introduction of other substances (solid, liquid or gas)	M	M	Medium	L	H	M
Nutrient enrichment	H	H	Not sensitive	L	M	M
Hydrocarbon & PAH contamination	M	M	Medium	L	H	M
Radionuclide contamination	No evidence					

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) -	M	M	Medium	L	H	M
Transition elements & organo-metal (e.g. TBT) contamination	M	M	Medium	L	H	M
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens	H	H	Not sensitive	M	H	M
Introduction or spread of non-indigenous species (INIS)	H	H	Not sensitive	M	L	M
Removal of non-target species	Not exposed					
Removal of target species	Not exposed					

Salinity changes - local
The species in this group have been assessed as *'Not sensitive'* this pressure. Some of the species such as *A. digitatum* are known to inhabit sea lochs (Budd 2008b) which are subject to decreased salinity and as such this species is likely to be resistant to mortality from changing salinity at the benchmark. Similarly, *D. fragilis* demonstrates tolerance to reduced salinity as it is sometimes recorded in estuaries (Picton & Morrow 2015). Other species demonstrate an even greater tolerance to this pressure. *C. lepadiformis* for examples is able to tolerate salinities as low as 14psu (Fish & Fish 1996, in Riley 2008). Considering their sessile nature**,** the duration over which chemical changes occur is considered to be important for the species in this group.

As marine organisms, the group members inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been considered in this assessment.

Temperature changes - local
The species in this group have been assessed as *'Not sensitive'* to changing temperature. The spatial extent of the group members reveals that they are distributed from the most northern latitudes of Europe to the Mediterranean. The geographic distribution of *A. digitatum* ranges from Iceland to Portugal which demonstrates that the species is tolerant of a range of temperatures and it is improbable that this species will be harmfully affected by this pressure (Budd 2008). *A. digitatum* underwent minimal mortality during the particularly cold winter of 1962-1963 (Crisp 1964) which further illustrates tolerance to decreasing water temperature. Likewise, the distribution of *C. lepadiformis* suggests that it is tolerant to a reduction in temperature, though rapid and severe decreases may result in some damage to the population (Riley 2008). Some damage was observed in Ascidiacea species after the cold winter of 1962-63 though no mortality was recorded. Considering their sessile nature**,** the duration over which temperature changes occur is considered to be important for the species in this group.

Water flow (tidal current) changes - local, including sediment transport considerations
The species in this group have been scored with '*Medium*' sensitivity to changes in water flow. As sessile filter feeders, the group members are reliant on water flow for food delivery therefore a decrease in tidal current may result in a reduction in food supply. For example, *A. digitatum* would be likely to undergo a reduction in feeding efficiency as less food material would be brought into contact with the colonies (Budd 2008b). This also holds true to *D. fragilis* and the rest of the species in the group. However, if a species inhabits an environment in the middle of its tolerance range, the population will not undergo any damage. For example, *A. digitatum* has a preference for tidal strengths ranging from moderately strong (1-3kn) to strong (1.5-3m/s) and *D. fragilis* can survive with no adverse affects in a range of conditions from very weak (negligible) to strong (>6kn) (Budd 2008b; Riley 2008) meaning a change in low at the benchmark would not adversely affect populations. Because of the preference ranges, the group members are most likely to demonstrate tolerance of the pressure at the benchmark considered. However, each of the species in this group has a different range of tidal stream preferences and these are narrower for some than others. Unlike the other species in this group, *C. lepadiformis* prospers in areas where there is reduced water movement (e.g. quarries) as it is an active suspension feeder. As such it is not sensitive to decreasing water flow but is likely to be much more sensitive to increasing flow so the direction of the pressure at the considered benchmark is important for consideration. Passive suspension feeders in particular are likely to profit from increased flow of water and therefore increased food supply (Hiscock 2006). Naranjo *et al* (1996) state that increased water flow rates may be unfavourable to the feeding ability of *C. lepadiformis* but are unlikely to cause mortality. On removal of the pressure, condition should be restored quickly.

Wave exposure changes - local, including sediment transport considerations
This group has been assessed as *'Not sensitive'* to changing wave height at the benchmark level. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution.

Changes in wave exposure are not likely to have any significant effect on the occurrence of species such as *C. lepadiformis* which are tolerant to a wide range of exposures (Picton 1997). A decrease in wave action is likely to have an adverse effect on *A. digitatum* and other species more tolerant of higher water flow rates as food supplies will be reduced (Budd 2008b). However, no evidence of mortality resulting from a decrease in wave height within the benchmark could be found.

Changes in suspended solids (water clarity)
None of the species in this group are dependent on irradiance and primary production for their survival therefore, the group has been assessed as '*Not sensitive*' to this pressure. Increasing water clarity would increase energy supply to primary producers which in turn would stimulate the food chain and thus food supply to all filter feeders. *C. lepadiformis* in particular is accustomed to sheltered environments with minimal suspended solids (Hiscock & Hoare 1975, in Riley 2008). It has been found replacing other species in clear water creeks, as such; it is likely that it is tolerant to water with high clarity (Moore 1977, in Tyler-Walters 2008).

Some of the group members occur in estuaries (Picton & Morrow 2015) which are subject to low water clarity. *A. digitatum* in particular has been found to be tolerant of high levels of suspended sediment (Budd 2008b). Similarly, *C. lepadiformis* is frequently dominant in areas such as harbours with high levels of suspended solids. As filter feeders, all of the species in this group are likely to benefit in an increase in solids in the water column.

Abrasion/disturbance at the surface of the substratum
The sensitivity of this group to abrasion/disturbance at the surface of the substratum is *'Medium'*. Erect, epifaunal species including those in this ecological group are especially susceptible to physical abrasion as a result of anthropogenic activities (Hiscock 2006). Scallop trawling has been observed eradicating epifauna from the substratum and it has been noted that *A. digitatum* was more sensitive than other benthic species such as bivalves (Magorrian & Service 1998) to this pressure. Individuals and populations of non-mobile epifauna can be removed from rocky substrates by being displaced directly, or as bycatch. Fishing can move boulders and cobbles which might cause attached species to die because they have been irreparably damaged or they can no longer feed properly (Tillin & Tyler-Walters 2014). There is a general consensus that trawl and dredging activity depletes and breaks down biogenic structures and species such as Porifera, Bryozoa, gorgonians and corals (Wassenberg *et al* 2002). Attached species such as those considered in this ecological group are generally found attached to bedrock and large boulders; therefore they cannot be easily removed and replaced (Bell *et al* 2006).

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
These species have been scored with *'Medium'* sensitivity to this pressure with a resistance score of '*None*' being given. All of the species in this group are permanently attached to the seafloor and would be unable to avoid any degree of siltation. Larger colonial species such as *A. digitatum* can grow up to 20cm in height and therefore, larger, older colonies would be able to expand tentacles and the polyps would still be able to feed beneath a light deposition of sediment (Budd 2008b) though not at the benchmark of 30cm. Younger colonies of *A. digitatum* which form crusts just 5-10mm thick would be covered which would result in a high degree of mortality (Stamp 2015). *D. fragilis* is known to tolerate a degree of siltation and also forms massive cushions which sometimes grow up to 15cm in rocky estuaries (Stone 2007) though would still be too small to avoid such a degree of sedimentation.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence was available for the species in this group regarding 'Electromagnetic changes'.

Introduction of light
Based on the available evidence, the species in this group were considered to be '*Not sensitive'* to this pressure. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. This assessment has been based upon the available information for *A. digitatum* which showed no differences in feeding behaviour between light and dark periods (Bell *et al* 2006). Information for the other species in this group was not available in consideration of this pressure. None of the species in this group have light receptors which is likely to heighten the resistance of the group to the pressure.

Litter
No evidence was available for the species in this group regarding 'Litter'.

Visual disturbance
The sensitivity score given for this group is *'Not sensitive'* to visual disturbance. It is unlikely that Ascidiacea species such as *C. lepadiformis* and other sublittoral epifauna in this group are able to sense visual presence due to shading in the darker habitats in which they are

found (Riley 2008). In addition, the species in the group including *A. digitatum* do not have the ability to detect the visual presence of objects (Budd 2008b).

Organic enrichment
The species in this group are considered to be *'Not sensitive'* to organic enrichment. An increase of organic particulates is likely to enhance populations of filter feeders through increased food availability. *A. digitatum* is a passive suspension feeder and as such, enrichment of coastal waters that enhance the populations of phytoplankton may be beneficial to it (Hartnoll 1998). Similarly, Naranjo *et al* (1996) suggest that there is some benefit to adult ascidians when organic enrichment occurs as they too are filter feeders.

De-oxygenation
The sensitivity for this group has been assessed as *'Not sensitive'*. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. As sessile species, none of the group members would be able to avoid potentially harmful reductions in oxygen. Following a dense dinoflagellate bloom in Cornwall in 1978, local divers noted that Alcyonium spp. were in a poor state, though no mortality was reported (Griffiths *et al* 1979). *A. digitatum* has also been reported in hypoxic estuaries which illustrates a degree of tolerance of this species to a decrease in oxygen concentrations. *C. lepadiformis* live in very sheltered environments where low oxygen levels may be observed (Riley 2008). No evidence relating to this pressure for *D. fragilis* could be found.

Introduction of other substances (solid, liquid or gas)
Based on the very limited available evidence, the species in this group were scored with '*Medium*' sensitivity to this pressure. Little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. *A. digitatum* is able to retract its colonies and repel contaminants from its surface (Hartnoll 1998) so may be able to tolerate a light oiling which suggests it may be able to tolerate a degree of contamination but further information could not be accessed. However, the species in this group are largely immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the shallow circalittoral regions where contaminants such as oil may come in to direct contact with the species in this group.

Nutrient enrichment
The species in this group are considered to be *'Not sensitive'* to nutrient enrichment. An input of nutrients is likely to be beneficial for the sessile filter feeders in the group as it would be accompanied with a stimulation of phytoplankton and zooplankton populations thus increasing food supply.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
Based on the very limited available evidence, the species in this group were scored with '*Medium*' sensitivity to this pressure. Little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. *A. digitatum* is able to retract its colonies and repel contaminants from its surface (Hartnoll 1998) so may be able to tolerate a light oiling which suggests it may be able to tolerate a degree of contamination but further information could not be accessed. However, the species in this group are all immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the shallow circalittoral regions where contaminants such as oil may come in to direct contact with the species in this group.

Radionuclide contamination
No evidence was available for the species in this group regarding 'Radionuclide contamination'.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
Little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. A precautionary approach was taken when conducting the scoring and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. Porifera have the ability to accumulate high levels of metals and as such have been proposed as biomonitors (Genta-Jouve *et al* 2012). Possible sub-lethal effects of exposure to synthetic chemicals may result in a change in morphology, growth rate or disruption of the reproductive cycle for the species in this group but no additional, definitive information could be sourced. The species in this group are all immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the shallow circalittoral regions where contaminants such as oil may come in to direct contact with the species in this group.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
Little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. A precautionary approach was taken when conducting the scoring and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. Several species of ascidians are known to accumulate high concentrations of metals. De Caralt *et al* (2002) studied differences in certain aspects of the biology *of C. lepadiformis* and found that it accumulated copper, lead and vanadium with no undesirable affects. Sponges such *D. fragilis* are also acknowledged to have a capacity for metal accumulation and demonstrate tolerance to contamination (Cebrian *et al* 2007). However, the species in this group are all immobile which makes them susceptible to the effects of pollution. This is likely to be especially true when regarding populations in the shallow circalittoral regions where contaminants such may come in to direct contact with the species in this group.

Genetic modification and translocation of indigenous species
No evidence was available for the species in this group regarding 'Genetic modification and translocation of indigenous species'.

Introduction of microbial pathogens
Based on the available evidence, the species in this group were considered to be '*Not sensitive*' to this pressure. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. *A. digitatum* acts as the host for the endoparasitic species *Enalcyonium forbesi* and *Enalcyonium rubicundum*. Parasitisation may reduce the health of a colony but no record of mortality from this parasite could be found (Stock 1988). Past sponge disease outbreaks have been reported in a wide range of geographic locations (Webster 2007) though no information could be sourced regarding the representative species *D. fragilis*.

Introduction or spread of non-indigenous species (INIS)
Based on the available evidence, the species in this group were considered to be '*Not sensitive*' to this pressure. However, little information was available regarding the pressure for most group members so this assessment is tentative and made with caution. No alien or non-native species are known to compete with *C. lepadiformis* in Britain and Ireland (Riley 2008) at present. Little has been documented regarding the other representative species which suggests a lack of evidence at present.

Removal of non-target species
The sensitivity for this group has been assessed as *'Not exposed'*. The species considered in this group are not known to rely on any other species. As such, the ecological

consequences such as food dependencies from fishing and other species removal activities on this group are minimal.

Removal of target species
The species in this group are thought to be '*Not exposed'* to this pressure. There is increasing interest in the biomedical properties of sponge but it is understood that it may be cultured rather than harvested on site for medical research (van Treeck *et al* 2003).

4.7 Ecological group 6B: Attached encrusting species

This group comprises those epifaunal species which form crusts on the seabed, or are characterised as epilithic species that form crusts on other living species. The group includes exclusively sponge and bryozoan species with highly similar traits, all likely to display a similar level of sensitivity to pressures in the marine environment. The group is typically found in medium-high energy environments in both the infralittoral and circalittoral zones. The representative species selected for the sensitivity assessments for this group are *Cliona celata* and *Electra pilosa. C. celata* was selected as the best documented Porifera species in the group and *E. pilosa* as the most widespread and best researched Bryozoa.

Permanently attached species are inevitably exposed to biological, physical or chemical changes in their immediate environment and are therefore thought to be generally less resistant to such changes than mobile species. Due to their attached nature, these species are unable to use avoidance measures to mitigate any pressures in the marine environment. Due to their differing growth rates and life histories, the resilience of the individual species (a sponge and a bryozoan) considered in this ecological group tends to vary, often resulting in different sensitivities. Species from this group are thought to be generally less sensitive to physical damage than erect or soft bodied species, although more sensitive than robust attached species, making them more susceptible to physical damage due to storms, litter or abrasion. Both species characterizing this group are suspension feeders (Hiscock 2007; Tyler-Walters & Ballerstedt 2007; Jackson 2008), relying on water movement to ensure food delivery.

4.7.1 Sensitivity assessments

Table 9. Group 6B Attached encrusting species and associated biotope in sublittoral rocky habitats (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes local	M	H	Low	M	H	L
Temperature changes - local	M	H	Low	M	M	L
Water flow (tidal current) changes - local	H	H	Not sensitive	M	H	M
Wave exposure changes - local	H	H	Not sensitive	M	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	M	H	M
Abrasion/ disturbance at the surface of the substratum	L	H	Low	M	H	L

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	None	H	Medium	M	H	H
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	H	H	Not sensitive	H	M	M
Litter	M	H	Low	M	L	M
Visual disturbance	H	H	Not sensitive	M	H	H
Organic enrichment	H	H	Not sensitive	M	M	M
De-oxygenation	No evidence					
Introduction of other substances (solid, liquid or gas)	M	H	Low	M	H	H
Nutrient enrichment	H	H	Not sensitive	M	M	M
Hydrocarbon & PAH contamination	No evidence					
Radionuclide contamination	No evidence					
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	L	H	Low	M	H	M
Transition elements & organo-metal (e.g. TBT) contamination	L	H	Low	M	H	M
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens	No evidence					
Introduction or spread of non-indigenous species (INIS)	L	H	Low	M	M	M
Removal of non-target species	L	H	Low	M	H	M
Removal of target species	Not exposed					

Salinity changes - local
The individual species in this group demonstrated some variable tolerances to this pressure. A precautionary approach was therefore taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is most likely due to differences in physiology.

Attached encrusting species are unable to use avoidance measures in response to pressures, thus are likely to have increased susceptibility to salinity changes. Gymnolaemata, to which *E. pilosa* belongs, are usually restricted to full salinity and reductions may cause an impoverished fauna (Ryland 1970, in Tyler-Walters & Ballerstedt 2007). The species has been reported to adapt to salinities as low as 20, but mortality occurs after a short time in salinities of 17.5 (Hyman 1959, in Tyler-Walters & Ballerstedt 2007). It is expected, therefore, that a long term decrease in salinity to 'variable' would be tolerated by *E. pilosa* (Tyler-Walters 2005).

Other species in the group such as *C. celata* demonstrate a lower sensitivity to changing salinity than *E. pilosa.* Salinity preferences of *C. celata* were reviewed by Miller *et al (*2010). It was reported that, for this species, death occurs at salinities lower than 10. The largest sponges occur in salinity conditions between 27ppt and 31ppt, coinciding with the salinity where the greatest abundances were reported (25-30ppt) (references within Miller *et al* 2010). Because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005). Resilience for species in this group is thus recorded as *'High'*.

As marine organisms, the group members inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been considered as part of this assessment.

Temperature changes
The individual species in this group demonstrated some variable tolerances to the pressure and the contrasting increasing/decreasing benchmarks. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group.

Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in temperature. The distribution of *E. pilosa* is reported from north and south of Britain and is common in all temperate waters (Tyler-Walters 2005). Reduction of temperature by as little as 3°C interrupts the feeding capabilities of *E. pilosa*, and at 4°C colonies become unresponsive (Hyman 1959, in Tyler-Walters & Ballerstedt 2007). When exposed to extreme temperatures such as -4°C for two weeks, the zooids in the centre of the colony die, but those on the outside survive and regenerate when returned to warmer temperatures (Menon 1972). The sensitivity of this species to temperature reduction despite its global distribution in cold waters suggests that the temporal scale for temperature change is of importance when considering sensitivity. *E. pilosa* appears less sensitive when considering the impacts of temperature increase at the benchmark level. Population growth increases with temperature though as a result, the individual zooids are decreased in size (Menon 1972; Ryland 1976, in Tyler-Walters & Ballerstedt 2007; Hunter & Hughes 1994, in Tyler-Walters & Ballerstedt 2007). Acclimation temperature affects the upper lethal limit of *E. pilosa*, however it varies considerably, and with no real correlation (Menon 1972).

C. celata has a wide distribution from Norway to South Africa (van Soest 2010) and is reported to withstand large changes in temperature. However, it has been noted that decreasing temperature may inhibit boring activity (Duckworth & Petersen 2013) meaning that is may be somewhat more sensitive to reductions in temperature than increases.

Water flow (tidal current) changes - local, including sediment transport considerations
The attached encrusting faunal group has been assessed as *'Not sensitive'* to changes in localised water flow. The species in this group are attached encrusting filter feeders and a decrease in water flow rate is unlikely to adversely affect the characterising species provided the supply of food sources is maintained and that increased sedimentation does not occur.

The tidal flow preference for *E. pilosa* is recorded as ranging from weak (<0.5m/s) to strong (1.5-3m/s) (Tyler-Walters 2005). *E. pilosa* is a filter feeder and so stronger currents facilitate feeding (Okamura 1988; Tyler-Walters 2005) though it has been noted that at greater flow speeds, *E. pilosa* may be outcompeted by other bryozoans, resulting in a population decline (O'Connor *et al* 1979). Substrate availability is also noted to be greater in faster flows (Eggleston 1972b, in Tyler-Walters & Ballerstedt 2007; Ryland 1976, in Tyler-Walters & Ballerstedt 2007). Conversely, reduced flow rates may increase sedimentation, and reduce food availability (Tyler-Walters 2005) therefore the sensitivity of filter feeders is this group may vary slightly when considering increasing or decreasing water flow. It was suggested by Tyler-Walters (2005) that a decrease in flow rate to very weak (negligible) would cause a decline in populations, however at the benchmark considered here the populations are unlikely to be substantially affected, assuming an intermediate flow rate of 'moderately strong'. The evidence concerning flow rate effects on *C. celata* was broad, with the species being reported from environments with high and low currents (Bell 2002). This evidence suggests a resistance of *'High'* for a change in flow rate, and therefore the resilience is also *'High'*, leading to an overall sensitivity of '*Not sensitive'* for the group.

Wave exposure changes - local, including sediment transport considerations
Overall, this group was considered *'Not sensitive'* to changes in wave exposure. The species represented by this group are attached encrusting fauna, which do not extend extensively into the water column and are not considered overly fragile. As such, the group species are not likely to be heavily influenced by wave action changes at the benchmark level.

E. pilosa is reported to have wave exposure preferences from sheltered to moderately exposed (Tyler-Walters 2005). At the benchmark level, it is unlikely that a decrease in wave exposure will affect populations of *E. pilosa*, since they are capable of inhabiting sheltered habitats. It is probable that *E. pilosa* could also inhabit environments with greater exposure though their absence from more exposed locations in the intertidal is thought to be a result of loss of algal substrate (Tyler-Walters 2005). It is also unlikely that increased exposure at the benchmark would result in susceptibility of the species since they have the capacity to occupy niches in greater wave exposure.

C. celata is found over a range of wave exposures from exposed coasts to sheltered estuaries (Snowden 2007). In sublittoral habitats, wave exposure manifests as oscillations, and is less abrasive than in intertidal regions. The ability to withstand a range of exposures suggests that a change at the benchmark level will not negatively affect *C. celata* populations. Resistance for this group is therefore *'High'*, as is resilience based on no impact to recover from.

Changes in suspended solids (water clarity)
Based on the available evidence, the species in this group were considered to be '*Not Sensitive'* to this pressure. However, little information was available regarding suspended solids for species other than *E. pilosa* so this assessment is tentative and made with caution. Attached epifauna are not able to move to avoid areas of impact related to this pressure. However, attached encrusting fauna are not typically constrained by light attenuation which is likely to be the leading change associated with this pressure.

E. pilosa inhabits areas spanning a range of water clarities (Moore 1973, 1977, in Tyler-Walters 2008). It is suggested that a decrease in suspended solids will lead to greater photosynthetic capabilities for phytoplankton on which *E. pilosa* and the other filter feeders in this group feed (Tyler-Walters 2005). When considering a decrease in water clarity, it is possible that a reduction in water clarity and therefore light penetration could reduce the abundance of phyto- and zooplankton in the area, although this is not considered likely to have a large-scale effect. *E. pilosa* has been recorded in areas with fairly low water clarity (Moore 1973, 1977; O'Connor *et al* 1979; Seed 1985, in Tyler-Walters 2005). It is considered fairly tolerant to heavy suspended particle loads, although slight decreases in population may occur eventually (O'Connor *et al* 1979). Overall, at the benchmark, a change in water clarity will not negatively affect *E. pilosa*. *C. celata* displays a preference for habitats with heavy particle loads as they can out-compete other species (Carballo *et al* 1996) and may be found in silt-laden estuaries (Snowden 2007). This species and the ecological group are therefore considered to have a *'High'* resilience to changing suspended solids at the benchmark level. Resilience is also *'High'* as there is no impact to recover from.

Abrasion/disturbance at the surface of the substratum
The overall group sensitivity assigned to attached encrusting fauna this pressure is *'Low'*, although the individual species in this group demonstrated some variable tolerances to this pressure. A precautionary approach was therefore taken and sensitivity was assessed to reflect the more sensitive species within the group. *E. pilosa* has been scored with *'Low'* sensitivity and *C. celata* has been assessed as *'Not sensitive'*. The variation between species to this pressure is most likely due to differences in physiology.

E. pilosa forms extended spines to protect itself from small-scale abrasion from seaweeds (Bayer *et al* 1997). However, abrasion from fishing gear is likely to destroy the colony and/or remove some of the algal substrate which will then decay (Tyler-Walters 2005). The local destruction of colonies and/or removal of substrate suggest that the resistance of *E. pilosa* to abrasion is low. However, because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005). Resilience is thus recorded as *'High'*.

C. celata is a robust species of sponge with a tough outer surface (Snowden 2007). It is probable that fishing gear will pass over the surface of the massive type, perhaps with some damage but limited mortality, and the boring type will be afforded protection from its surroundings. The resistance has been recorded as *'High'* based on the evidence and application of expert judgement, resultantly the resilience is also recorded as *'High'*. The individual sensitivity assessments for these species produced different results and so the sensitivities were considered independently and not as a group.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The sensitivity of attached encrusting fauna to small-scale smothering and siltation was assessed as *'Medium'*. Attached encrusting fauna are unable to relocate to areas of preferred environmental conditions to mitigate the impacts of this pressure, and are not likely to extend to a great degree above the plane of the seabed, thus large changes in the degree of siltation may smother the organisms present.

The nature of *E. pilosa* and other species in this group as a thin layer on a substrate makes them particularly vulnerable to smothering events as migration through the sediment is not a possibility. A layer of sediment may disrupt feeding, reproduction, growth, and respiration, ultimately resulting in death (Tyler-Walters 2005). Other species in the group such as *C. celata* exist with two morphologies: boring and massive. The massive form can reach heights of 50cm (Picton & Morrow 2016) and should therefore have a *'High'* resistance to 30cm sediment deposition; however the boring form does not rise far above the surface of the substrate and will have no resistance. For the purposes of this assessment, the boring form is used as it is more sensitive and provides the most conservative information. A resistance of '*None*' at the benchmark of 30cm deposition has been recorded for this group.

Because of the ability for group members to colonise suitable habitats in ~six months or less, and maturation at around one year for *E. pilosa* and hermaphroditic behaviour for other species, populations are predicted to recover within a few years (Tyler-Walters 2005).

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is 'very low'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence was available for the species in this group regarding 'Electromagnetic changes'.

Introduction of light
Attached epifauna were assigned a sensitivity score of '*Not sensitive'* to the introduction of light as a pressure, although little information was available regarding the pressure for one of the group species (*E. pilosa*) so this assessment is tentative and made with caution. Overall attached epifauna are not constrained by excess light levels, although would be unable to relocate to other areas of seabed to mitigate this impact if necessary.

No evidence was available regarding the effect of introduction of light on *E. pilosa* therefore the sensitivity assessment was based on the available relevant evidence for *C. celata*. Light is a cue which sponges use for spawning (Davies *et al* 2015) however, *C. celata* has been shown to survive high light intensity (Carballo *et al* 1996). This evidence suggests that *C. celata* has a resistance of *'High'* to this pressure, and as there is no impact to recover from, a *'High'* resilience is also recorded.

Litter
Attached epifauna were assigned a sensitivity score of '*Low'* to the introduction of litter as a pressure, although little information was available regarding the pressure for one of the group species (*E. pilosa*) so this assessment is tentative and based on the information that was sourced for *C. celata*. Encrusting epifauna are unable to move to avoid the introduction of litter and thus may be subject to impacts from this pressure. Physical damage caused by litter is also likely to be a factor, although encrusting species do not generally tend to extend far above the seabed, potentially minimising likely interactions.

It is noted that marine debris e.g. fishing lines or plastics may negatively affect sponges if they cover them thus preventing feeding, or cause damage thereby increasing risk of infection (references within Kühn *et al* 2015). Based on this information, a resistance of *'Medium'* is given. The resilience was recorded as *'High'* because *C. celata* is both hermaphroditic and capable of reproducing asexually (van Soest 2010).

Visual disturbance
A group sensitivity of *'Not sensitive'* was assigned to attached encrusting epifauna with regard to visual disturbance as a pressure. No evidence was available regarding the effect of visual disturbance on *C. celata*, therefore the group assessment of *'Not sensitive'* is based on the evidence for *E. pilosa*, thus some caution should be applied when interpreting the assessment for this group. Attached epifauna generally lack visual capability, thus it has been reported that *E. pilosa* will be unaffected by visual disturbance at the benchmark level (Tyler-Walters 2005). The resistance is therefore *'High'*, as is the resilience, based on no impact to recover from.

Organic enrichment
Overall, this group was classified as *'Not sensitive'* to organic enrichment at the benchmark level. Increasing food availability increases the size of *E. pilosa* zooecia up until a point,

where the further addition had no greater effect on the population, and the variation in sizes stabilised (Hageman *et al* 2009). Based on this evidence, the tolerance of this species was assessed to be *'High'*, as was the resilience. Eutrophication can increase bio-erosion of sponges in general (references within Bell 2008), however *C. celata* is reported to be tolerant of high nutrient loads (references within Duckworth & Peterson 2013). Based on the benchmark considered here, 100mgC/y is unlikely to induce an eutrophication event, therefore the tolerance of *'High'* has been assigned to this species for this pressure, and resultantly the resilience is also classified as *'High'*.

De-oxygenation
No evidence was available for the species in this group regarding 'De-oxygenation'.

Introduction of other substances (solid, liquid or gas)
The overall sensitivity of attached encrusting fauna to the introduction of other substances has been assessed as *'Low'*, although no relevant evidence for this pressure could be sourced for *C. celata*, thus this tentative assessment is based on information for *E. pilosa* only. Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in contamination from solid, liquid or gas contamination.

E. pilosa are susceptible to smothering from substances such as oil (Tyler-Walters 2005). However, considering the benchmark and the location of the sublittoral habitat, the effects are likely to be minimal on this population therefore a conservative resistance of medium has been assigned for this pressure. Because of the ability to colonise suitable habitats in ~ 6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005).

Nutrient enrichment
Overall, this group was classified as *'Not sensitive'* to nutrient enrichment at the benchmark level. Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in nutrient enrichment, although being filter feeders may benefit from increased nutrient/food availability within the water column.

Increased nutrient supply will increase food availability (Tyler-Walters 2005). Increasing food availability increases the size of *E. pilosa* zooecia up until a point, where the further addition had no greater effect on the population, and the variation in sizes stabilised (Hageman *et al* 2009). Based on this evidence, the tolerance of this species was assessed to be *'High'*, as was the resilience. *C. celata* is reported to be tolerant of high nutrient loads (references within Duckworth & Peterson 2013). Based on the benchmark considered here, a tolerance of *'High'* has been assigned to this species for this pressure, and resultantly the resilience is also classified as *'High'*.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
No evidence was available for the species in this group regarding 'Hydrocarbon and PAH contamination'.

Radionuclide contamination
No evidence was available for the species in this group regarding 'Radionuclide contamination'.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The overall sensitivity of attached encrusting fauna to synthetic compound contamination has been assessed as *'Low'*, although no relevant evidence for this pressure could be sourced for *C. celata*, thus this tentative assessment is based on information for *E. pilosa* only. Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in transition element contamination.

Bryozoans have been reported to be unaffected by TBT with only one species exception (Bryan & Gibbs 1991, in Tyler-Walters & Pizzola 2008), although increased abundances of Bryozoa have been observed in some places since the banning of TBT (Rees *et al* 2001). However, the distribution of *E. pilosa* populations appear to be affected by acidified halogenated effluents, being absent in their direct proximity (Hoare & Hiscock 1974, in Tyler-Walters & Ballerstedt 2007). *E. pilosa* can thus be considered unaffected by TBT because some other factor may be responsible for the anecdotal observed increase in abundances following the banning of TBT, whereas Bryan and Gibbs (1991, in Tyler-Walters & Pizzola 2008) exposed the bryozoans directly. The resistance of *E. pilosa* to acidified halogenated effluents was thus assessed as being low. Because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005).

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The overall sensitivity of attached encrusting fauna to transition element and organo-metal contamination has been assessed as *'Low'*, although no relevant evidence for this pressure could be sourced for *C. celata*, thus this tentative assessment is based on information for *E. pilosa* only. Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in transition element contamination.

Overall, this group was classified as having *'Low'* sensitivity. No relevant evidence in regards to heavy metals on *C. celata* was found, therefore the overall sensitivity of the group was based upon the available evidence for *E. pilosa*. Bryozoans have been reported to be unaffected by TBT with only one species exception (Bryan & Gibbs 1991, in Tyler-Walters & Pizzola 2008), although increased abundances of Bryozoa have been observed in some places since the banning of TBT (Rees *et al* 2001). *E. pilosa* can thus be considered unaffected by TBT because some other factor may be responsible for the anecdotal observed increase in abundances following the banning of TBT, whereas Bryan and Gibbs (1991, in Tyler-Walters & Pizzola 2008) exposed the bryozoans directly. Bryozoans are, however, susceptible to copper-containing antifoulants (Soule & Soule 1979, in Tyler-Walters & Ballerstedt 2007; Holt *et al* 1995; Tyler-Walters 2005). The sensitivity assessment is thus based on copper contamination in *E. pilosa*, and the resistance has been assessed as *'Low'*, based on the probability of 25-75% of the population being affected. Because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005).

Genetic modification and translocation of indigenous species
No evidence was available for the species in this group regarding 'Genetic modification and translocation of indigenous species'.

Introduction of microbial pathogens
No evidence was available for the species in this group regarding 'Introduction of microbial pathogens'.

Introduction or spread of non-indigenous species (INIS)
Sensitivity of attached encrusting epifauna to the introduction of non-indigenous species has been assessed as *'Low'*, although the group sensitivity was based on available information for *E. pilosa* only as limited information for this pressure was available for *C. celata.* Attached epifauna are unlikely to be largely impacted by the introduction of non-native species, although due to their sessile nature cannot move to mitigate the effects of this pressure.

The invasive bryozoan, *M. membranacea*, out competes *E. pilosa* when space is not limited. However, where space is limited and expansion of the colony restricted, *E. pilosa* does better (Yorke & Metaxas 2011). This suggests that *E. pilosa* is restricted to smaller algal species in the presence of this competitor and so the available habitat is diminished. The resistance of *E. pilosa* has been assessed as *'Low'* because of the loss of habitat. Because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years should the pressure be removed (Tyler-Walters 2005).

Removal of non-target species
Overall the sensitivity of this group to the removal of non-target species was considered to be *'Low'*. Being permanently attached, the species in this group are unable to relocate to mitigate the impacts of this pressure, making them potentially susceptible to the removal of non-target species.

Where kelp is harvested, populations of *E. pilosa* may also be removed as they are an epiphytic species (Tyler-Walters 2005). The resistance of the population is recorded as *'Low'*, because significant proportions of the population may be removed, and the available substrate diminished. However, because of the ability to colonise suitable habitats in ~6 months or less, and maturation at around one year, populations are predicted to recover within a few years (Tyler-Walters 2005), therefore the resilience is *'High'*. The boring form of *C. celata* may be removed during shell fish harvesting, since they burrow into the shells of commercially important species such as oysters and mussels (Snowden 2007). The resistance of the population is recorded as low, because significant proportions of the population may be removed, and the available substrate diminished. However, resilience was recorded as *'High'* because *C. celata* is both hermaphroditic and capable of reproducing asexually (van Soest 2010).

Removal of target species
The species in this group are not harvested for any known purpose, therefore the group species are considered '*Not exposed*' to this pressure. Bio-exploration of *C. celata* for molecules useful in developing pesticides, antibiotics *etc.* has been occurring (Reegan *et al* 2013), however the extent to which these sponges are removed is unknown, and so no evidence has been recorded here.

4.8 Ecological group 6C: Attached erect species

Attached erect species are those which rise above the plane of the seabed and are typically flexible and mainly not soft-bodied (with exceptions). Erect bryozoans, hydroids soft corals and sponges typify this group, which is most frequently found in high-moderate energy circalittoral biotopes. The species represented within this group are likely to display similar sensitivities to pressures based on the larger body size of these species, their growth form and other similar traits.

The representative species selected for the sensitivity assessments for this group are: *Axinella dissimilis, Flustra foliacea* and *Eunicella verrucosa.* As the only sponge in this ecological group, *A. dissimilis* was selected as a representative species. *F. foliacea* was chosen as the best researched and widely distributed bryozoan while *E. verrucosa* was selected as the best documented and widely distributed anthozoan in the group.

Permanently attached species are inevitably exposed to biological, physical or chemical changes in their immediate environment and are therefore thought to be generally less resistant to such changes than mobile species. Species from this group are thought to be more fragile than attached robust species or attached encrusting species, making them more susceptible to physical damage. Erect, non-mobile species are situated with a large proportion of their body above the seafloor which increases their exposure to physical and chemical pressures in particular. However, the physiological form of particular erect species may offer them some increased resistance to the pressures considered. Some of the erect species in this group, such as *F. foliacea* have more flexible bodies which may enable them to better withstand other pressures such as crushing due to dredging activity. All three representative species in this group are sessile suspension feeders (Hiscock 2007; Tyler-Walters & Ballerstedt 2007; Jackson 2008), relying on water movement to ensure food delivery. A lack of mobility means that they are not able to avoid localised pressures of source alternative food supply.

The species in this group have some disparate characteristics in terms of taxonomy, size, habitat preference and life-history which account for differences in the sensitivity assessments. Resistance in particular may be affected by differences size and physiology. Due to their differing growth rates and life histories, the resilience of the individual species considered in this ecological group tends to vary, often resulting in different sensitivities. The growth rates of the bryozoan *Flustra foliacea* differs with location, but has been reported to reach up to 30mm per year (Tyler-Walters & Ballerstedt 2007). The species can repair physical damage to its fronds within 5-10 days (Silén 1981) which increases its recovery potential compared to some of the more slow growing species in the group. New colonies take one year to develop erect growth, and reach maturity after one to two years, (Tyler-Walters & Ballerstedt 2007), suggesting a relatively high resilience. As such, the resilience score for this species was determined as '*High*'.

In contrast, the growth rate of the sea fan *E. verrucosa* is approximately 10mm/year, though this can be highly variable (Hiscock 2007) depending on the conditions of the environment in which it is growing. The species has a life span of up to 100 years and little information is available regarding its life history or larval characteristics. Due to its relatively slow growth rate and high longevity, the species' resilience is considered to be moderate to low. To reflect the slower growing populations of *E. verrucosa*, the resilience score given for this species is '*Low*'.

No evidence was available regarding the growth rates, reproductive cycles, larval characteristics or longevity of *A. dissimilis*. ICES (2009) suggested a high sensitivity of sponge aggregations to human impacts based on longevity, slow growth, unknown reproduction patterns and slow if any recovery from physical damage. Considering the species' size range of up to 20cm (Jackson 2008), the resilience of *A. dissimilis* has been considered to be '*Low*'. Where scores for the representative species in the group have been disparate to one category (e.g. '*Not sensitive*' to '*Low*') the most conservative score has been given to capture the full extent of the sensitivity of the species within the group. Where the final scores for the representative sensitivity assessments have been differing by more than one category (e.g. *'Not sensitive'* and '*Medium*'), the scores have been separated out and the group score has been given to the category which is most representative of the species in the group based upon the characterising traits.

4.8.1 Sensitivity assessments

Table 10. Group 6C Attached erect species and associated biotope in sublittoral rock habitats (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local - Group	L	L	High	M	H	L
Salinity changes - local - *F. foliacea*	L	H	Low	M	H	M
Temperature changes - local - Group	M	L	Medium	M	H	L
Temperature changes - local - *F. foliacea*	H	H	Not sensitive	H	H	M
Water flow (tidal current) changes - local	M	L	Medium	M	H	M
Wave exposure changes - local - Group	M	M	Medium	M	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	M	H	M
Abrasion/disturbance at the surface of the substratum	M	L	Medium	M	H	L
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	None	L	High	L	H	M
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	No evidence					
Litter	M	M	Medium	M	H	M
Visual disturbance	H	H	Not sensitive	M	H	M
Organic enrichment	H	H	Not sensitive	M	H	M
De-oxygenation	M	L	Medium	L	H	M
Introduction of other substances (solid, liquid or gas)	No evidence					
Nutrient enrichment	H	H	Not sensitive	M	H	M
Hydrocarbon & PAH contamination	L	L	High	M	M	M
Radionuclide contamination	No evidence					

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	L	H	Low	M	H	L
Transition elements & organo-metal (e.g. TBT) contamination	L	H	Low	M	H	L
Genetic modification & translocation of indigenous species	No evidence					
Introduction of microbial pathogens - Group	L	L	High	M	M	M
Introduction of microbial pathogens - *F. foliacea*	H	H	Not sensitive	M	H	M
Introduction or spread of non-indigenous species (INIS)	No evidence					
Removal of non-target species	No evidence					
Removal of target species	M	M	Medium	M	H	M

Salinity changes - local

Due to differences in resilience and therefore sensitivity, *F. foliacea* has been assessed separately to the other species in the group when considering local changes in salinity. The overall sensitivity for the combined group was '*High*' while the sensitivity of *F. foliacea* was assessed as *'Low'*. The variation between species to this pressure is due to differences in resilience attributable to life history and growth rates.

Combined Group

A decrease in salinity at the benchmark for both *A. dissimilis* and *E. verrucosa* would result in conditions outside the species' preferred range (30-40psu) which would most likely result in mortality (Jackson 2008; Hiscock 2007). *A. dissimilis* grows at depths of >100m (Jackson 2008) and the other species are strictly sublittoral and are not at any time exposed to freshwater inputs. No information was available regarding the growth rate, reproduction or dispersal abilities of *A. dissimilis*. However, most sponges tend to be slow growing and long lived and slow growing which negatively impacts recovery potential. Like many of the other group members, *E. verrucosa* is a long lived species (20-100 years), has slow growth rates (~10mm/year), and recovery to a population with large individuals is likely to take more than 10 years (Hiscock 2007). Therefore the resilience for the group was recorded as *'Low'*, resulting in a '*High'* sensitivity score.

Flustra foliacea

The preferred salinity range of *F. foliacea* is full (30-40psu) and the introduction of freshwater, or hyposaline effluents may adversely affect colonies (Ryland 1970, in Tyler-Walters & Ballerstedt 2007; Dyrynda 1994, in Walters & Ballerstedt 2007; Tyler-Walters & Ballerstedt 2007). Dyrynda (1994, in Walters & Ballerstedt 2007) noted that *F. foliacea* was restricted to the vicinity of the Poole Harbour entrance by their intolerance to reduced salinity. Therefore, like the other species in this group, a resistance of '*Low*' was recorded. Unlike many of the other group members, new *F. foliacea* colonies are thought to take approximately one year to develop erect growth and 1-2 years to reach maturity (Tyler-Walters & Ballerstedt 2007), therefore a *'High'* resilience for the species, has been recorded and an overall sensitivity of '*Low'* was determined.

As marine organisms, the group members inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been considered as part of the assessment.

Temperature changes - local
The individual species in this group demonstrated some variable sensitivity to this pressure. Therefore, a precautionary approach was taken and the sensitivity for *F. foliacea* was considered separately to the combined group score. The overall group sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group while *F. foliacea* was considered '*Not sensitive'*. The variation between species to this pressure is due to differences in resilience attributable to life history and growth rates.

Combined Group
The species in this ecological group have been assessed with '*Medium'* sensitivity to localised temperature change. Being permanently attached, the group members are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in temperature. The distribution for most of the species in this group is widespread, with the extent of several group members spreading as far north as the Arctic Circle. Given the geographic distributions of the group species, *F. foliacea* and *E. verrucosa* are both unlikely to be adversely affected by changes in sea temperature in the UK (Tyler-Walters & Ballerstedt 2007; Bitschofsky *et al* 2011; Hiscock 2007). *F. foliacea* is an amphiboreal species which suggests that given a gradual decreasing temperature change, this species would not suffer a significant degree of mortality. Though a long-term decrease in temperature might lead to decreased recruitment rates of *E. verrucosa*, mortality within the population is unlikely (Hiscock 2007). In support of its resistance to decreasing temperature, a living *E. verrucosa* specimen collected from the UK possessed growth rings that demonstrated that the colony had survived the very cold winter temperatures of 1962/63 with little population damage (Hiscock 2007). When considering temperature increase, Hiscock (2007) suggests that it is a warmer water species likely to grow faster and reproduce more frequently under warm temperature regimes.

Hartnoll (1998) suggested that the species may be expected to extend their ranges with climate change induced rising temperatures. Conversely, Munro (2003, in Hiscock 2003) suggested that *E. verrucosa* in UK waters may be living close to its upper temperature limit as throughout the rest of its range it occurs only in deeper water. Furthermore, Hall-Spencer *et al (*2007) reported that when stressed by high temperatures, *E. verrucosa* becomes vulnerable to Vibrio spp. Vibrio isolated from *E. verrucosa* did not induce disease at 15°C, but, at 20°C. In the Mediterranean, Cerrano *et al (*2000) reported extensive gorgonian mortality during unusually warm water conditions in 1999, which Martin *et al (*2002) linked to infection by Vibrio spp. bacteria at elevated temperatures.

No direct evidence was available for the resistance of *A. dissimilis* to changing temperature though the species is found in warmer waters as far south as Spain (Jackson 2008), suggesting that the species is tolerant to a chronic increase in temperature at the benchmark. According to Jackson (2008), long term decreases in temperature may result in population shrinkage, while acute short term changes may cause death of the species. However, the extent of shrinkage was unclear and this species is found as far north as Iceland which demonstrates a degree of tolerance to the pressure.

Flustra foliacea
In contrast to the other two representative species in this ecological group, *F. foliacea* is considered *'Not sensitive'* to an increase in temperature at the benchmark level. This amphiboreal bryozoan occurs from the Arctic Circle to the south to the Bay of Biscay, and is unlikely to be adversely affected by long term changes in temperature within British waters (Tyler-Walters & Ballerstedt 2007; Bitschofsky *et al* 2011). Goodwin *et al (*2013) found very little evidence to suggest that rising temperatures had an effect on the species along the coast of Northern Ireland. Therefore a resistance of *'High'* was recorded.

Water flow (tidal current) changes - local, including sediment transport considerations
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and the sensitivity of the group to water flow changes was determined as '*Medium*'.

Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in tidal currents. As suspension feeders, the group species rely on a certain degree of water flow to ensure continuous food supply and to prevent siltation and/or clogging. A change in tidal flow might lead to increased siltation and smothering, loss of suitable substratum for larval settlement, and a reduction in food supply (Tyler-Walters & Ballerstedt 2007; Jackson 2008; Hiscock 2007).

Some of the species in this group such as *A. dissimilis* prefer wave exposed areas where water flow rate is potentially high. Therefore, a reduction in water flow rate may affect the feeding efficiency of populations (Jackson 2008). Increased flow rate may also be advantageous for erect Porifera populations as flow through sponges is thought to be enhanced by ambient current, which induces a pressure gradient across the sponge wall (Leys *et al* 2011).

F. foliacea is thought to decrease in abundance in weak currents, as decreased water flow may lead to a decrease in food availability, accumulation of fine sediments and siltation, as well as increased competition from other space occupying species (Tyler-Walters & Ballerstedt 2007). However, *F. foliacea* colonies are present in a wide range of tidal streams (weak to very strong) and the colonies are known to reach high abundances in areas subject to moderately strong to strong tidal streams (Hiscock 1983: Tyler-Walters & Ballerstedt 2007). The abundance of bryozoans in general is thought to be positively correlated with supply of stable hard substrata and hence with current strength (Eggleston 1972b, in Tyler-Walters & Ballerstedt 2007; Ryland 1976, in Tyler-Walters & Ballerstedt 2007).

E. verrucosa colonies require enhanced water flow rates for the delivery of food and the removal of silt (Hiscock 2007). Erect colonies deprived of food may be adversely affected and, without significant water flow to remove silt, silt may kill tissue leaving areas bare of coenenchyme to be colonized by encrusting organisms (Hiscock 2007). Tidal strength preferences of *E. verrucosa* are moderately strong 1-3 knots (Hiscock 2007) though when current velocity increases, sea fans may retract their polyps and are unable to feed (Hiscock 2007). In contrast to the other species within this group, an increase in tidal current could adversely affect *E. verrucosa*. Tidal streams exert a steady pull on the colonies and are therefore likely to detach only very weakly attached colonies (Hiscock 2007).

Wave exposure changes - local, including sediment transport considerations
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and the sensitivity and the overall group sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group.

Being permanently attached, the species in this group are unable to relocate making them potentially susceptible to a change in wave exposure beyond their environmental preferences. Water movement (either wave or water flow induced) is vital for attached, suspension feeding species, to ensure the continuous delivery of food and to prevent siltation and clogging. In the absence of tidal flow, a decrease or lack of wave action may lead to increased siltation and smothering, loss of suitable substratum for larval settlement, and a reduction in food supply (Tyler-Walters & Ballerstedt 2007). However, a decrease from very exposed to exposed wave conditions may be beneficial by reducing the populations vulnerability to storm damage (Walters & Ballerstedt 2007).

A. dissimilis' wave exposure preferences range from moderately to extremely exposed and a decrease in wave exposure may result in conditions outside the preferred range of the species, causing shrinkage in population distribution (Jackson 2008). However, when considering increased wave exposure, *A. dissimilis* is known to thrive in extremely exposed areas (Jackson 2008).

Other species in the group such as *E. verrucosa* occur in a wide range of wave exposure conditions, including sheltered, moderately exposed, exposed and very exposed conditions (Hiscock 2007). An increase from sheltered to exposed wave conditions is unlikely to have adverse effects on these species. However, an increase in wave action from exposed to extremely exposed (e.g. through heavy storms), combined with unstable substrata, could lead to displacement of erect and delicate species such as the sea fan. Hiscock (2007) reports that *E. verrucosa* may be detached from the substratum by storms, and that recovery to a population structure similar to before mortality is likely to be in excess of five years. Sea fans live in conditions where wave action or tidal flow bring food and keep colonies clear of silt. If tidal streams are weak, then wave action may be important and a decrease in wave exposure may result in some mortality.

F. foliacea appears to be adapted to a wide range of wave exposure conditions as it is known to occur in very exposed to sheltered waters (Tyler-Walters & Ballerstedt 2007). However, a decrease in wave action to very sheltered or ultra-sheltered in the absence of tidal flow may result in mortality due to lack of food and smothering (Tyler-Walters & Ballerstedt 2007). Conversely, an increase in wave action from sheltered to exposed to extremely exposed (e.g. through heavy storms), combined with unstable substrata, could lead to displacement of the colonies (Tyler-Walters & Ballerstedt 2007).

Changes in suspended solids (water clarity)
The group has been assessed as *'Not sensitive'* to changes in water clarity. Due to the lack of mobility, species from this group are unable to relocate to areas of increased water clarity, although are not dependent on light attenuation, hence the sensitivity score. It is possible that a reduction in water clarity and therefore light penetration could reduce the abundance of phyto- and zooplankton in the area, although this is not considered likely to have a large-scale effect.

Species represented by this group typically occur in clear water conditions, although have been reported from turbid waters of North Devon. Hiscock (2007) suggest that the characterising species will survive short-term increases in turbidity. Further, increased turbidity may lead to a reduction of algae (though lowered light attenuation) which compete for space with the species in this group. Group species have been reported to be abundant in the turbid, fast flowing waters of the Menai Straits (Moore 1977, in Tyler-Walters & Ballerstedt 2007). The species are therefore considered resistant to a change in water clarity at the benchmark level. The resistance to changing suspended water solids for the group has therefore been recorded as *'High'*.

Abrasion/disturbance at the surface of the substratum
The individual species in this group demonstrated some variability in tolerance to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. The variation between species to abrasion/disturbance at the surface of the substratum is due to differences in resilience as a result of differing life histories.

The species in this group are likely to be exposed to abrasion and disturbance at the surface of the substratum due to their erect nature and their extension above the seabed. The species are also attached to the substratum and are therefore incapable of changing their position or sheltering from physical damage. For example, abrasion due to scallop dredging over rocky-reef substrata is known to damage erect epifaunal communities (Boulcott & Howell 2011). In the case of *E. verrucosa* which is firmly attached to the seabed and unlikely to be detached, physical disturbance and abrasion is likely to damage the species' coenenchyme (Hiscock 2007). Bavestrello *et al (*1997) reported that major damage to the coenenchyme of gorgonians can lead to extensive epibiosis hindering water circulation among polyps and the eventual death of colonies, but also that colonies recovered rapidly. Hiscock (2007) reported that the coenenchyme covering the axial skeleton will re-grow over scrapes of one side of the skeleton in about one week, and the group resistance was therefore recorded as *'Medium'*. A resistance score of '*Medium' was* also assigned to all other species assessed within this group, based on growth rates, flexibility and toughness of the species (e.g. Hymen 1959; Tyler-Walters & Ballerstedt 2007; Boulcott & Howell 2011).

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The individual species in this group demonstrated some variable tolerances to this pressure. A precautionary approach was therefore taken and overall group sensitivity was assessed as '*High*', reflecting the more sensitive species within the group. The variation in sensitivity between species to heavy deposition of fine material is largely due to differences in resilience attributable to growth rate and life history.

All of the species in this group are permanently attached to the seafloor and would be unable to avoid any degree of siltation; resistance is therefore '*None*' for all species. Most of the group members are less than 25cm in height and a 30cm deposition would result in unavoidable smothering which would result in loss of function for all populations. Occasionally, *E. verrucosa* may reach heights of up to 50cm, though this is uncommon (Hiscock 2007) and rare for the other species in the group.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence was available for the species in this group regarding 'Electromagnetic changes'.

Introduction of light
No evidence was available for the species in this group regarding 'introduction of light'.

Litter
The individual species in this group demonstrated some variable tolerances to this pressure. A precautionary approach was therefore taken and overall group sensitivity was assessed as '*Medium*', reflecting the more sensitive species within the group. The variation in sensitivity between species to the presence of litter is largely due to differences in physiology.

The sensitivity of *A. dissimilis* and *E. verrucosa* was recorded as *'Medium'*, while the sensitivity of *F. foliacea* was recorded as *'Low'*. As this group comprises those species which are fixed to the seabed, there is no scope for organisms to avoid impacts from litter in the environment where this pressure occurs. Additionally, the erect nature of the species potentially makes the organisms represented by this group more likely to interact with marine litter.

Little species specific evidence was available on this pressure to inform the group sensitivity. Chiappone *et al (*2005) report that litter in form of lost hook-and-line fishing gear in the Florida Keys may lead to tissue abrasion in sponges and benthic cnidarians, causing partial individual or colony mortality. Kühn *et al* (2015) summarise that marine organisms entangled with plastic may no longer be able to acquire food. Plastic or other litter covering structurally complex biota such as sponges, gorgonians or (soft) corals (Pham *et al* 2013) may impede feeding and lead to broken parts, making the organisms more susceptible to infections possibly leading to death (Bavestrello *et al* 1997). Further, experimental feeding trials revealed that corals might mistake microplastics for food, with the impacts still being uncertain. Assuming only partial mortality of individual organisms by the introduction of litter, resilience has been recorded as *'Medium'* for *A. dissimilis* and *E. verrucosa, and 'High'* for *F. foliacea*, reflective of the greater capacity for regeneration in this species (Hymen 1959; Silén 1981; Tyler-Walters & Ballerstedt 2007).

Visual disturbance
None of the species within this group have the ability for visual perception and are therefore not able to detect visual disturbance. Tyler-Walters and Ballerstedt (2007) suggest that Bryozoa might react to very local shading effects, but that their visual acuity was probably extremely poor. Therefore the group was scored *'Not sensitive'* to visual disturbance.

Organic enrichment
The sensitivity assessment for this group was based upon the evidence available for *E. verrucosa*; the group was assessed as *'Not sensitive'*. Species within this group are attached to the seabed and as such are unable to use avoidance measures in response to this pressure.

E. verrucosa was the only species for which sufficient evidence was available regarding this pressure, and it was considered to be *'Not sensitive'*. *E. verrucosa* is an obligate heterotroph and has been shown to switch its diet seasonally from zooplankton in the winter months to sedimentary organic matter in the summer (Cocito *et al* 2013). Hiscock (2007) suggested that it is unlikely that organic enrichment will have a significant effect on *E. verrucosa* abundance and survival. Sea fans feed on planktonic organisms and, although abundance of those organisms might change as nutrient concentrations vary, the long term effects on food sources are not likely to be significant. However, algae colonize and may smother sea fans and may increase in abundance as a result of increase in organic concentrations (Hiscock *et al* 2005). The resistance of *E. verrucosa* to this pressure was recorded as *'High'*.

De-oxygenation
Evidence for this pressure was only available for *A. dissimilis* and *E. verrucosa*, so the sensitivity score of *'Medium'* assigned to the group is based on findings for these two species. Species within this group are attached to the seabed and as such are unable to use avoidance measures in response to this pressure. A lack of oxygen within the water column is likely to be an issue for any organisms which respire.

There was no species-specific information regarding the tolerance of *A. dissimilis* to de-oxygenation, however Cole *et al* (1999, in Tyler-Walters & Pizzola 2008) suggest possible adverse effects on marine species below 4mg/l and probable adverse effects below 2mg/l. Sponges rely on dissolved oxygen for respiration (Bell 2008), and the resistance has therefore been recorded as *'Medium'*. No information was available regarding the sponge's growth rates, reproduction or dispersal abilities of this species. However, most sponges tend to be slow growing and long-lived, therefore expert judgement was used to derive a score of '*Low*' resilience. There was no direct evidence available concerning the effects of de-oxygenation for *E. verrucosa*. However, Hiscock (2007) suggests that the species lives in fully oxygenated waters, and that intolerance to decreased oxygen levels was likely. Based on this information, a *'Medium'* resistance to de-oxygenation was recorded. According to Hiscock (2007), recovery will depend on recruitment which is likely to be very slow if surviving colonies are distant and even partial recovery may take more than ten years. The resilience was therefore recorded to be *'Low'*.

Introduction of other substances (solid, liquid or gas)
No evidence was available for the species in this group regarding 'Introduction of other substances (solid, liquid or gas)'.

Nutrient enrichment
The sensitivity assessment for this group was based upon the evidence available for *E. verrucosa;* no evidence existed for the other characterising species. The group was assigned an overall sensitivity score of *'Not sensitive'*, although species within this group are attached to the seabed and unable to use avoidance measures in response to this pressure.

E. verrucosa is an obligate heterotroph and has been shown to switch its diet seasonally from zooplankton in the winter months to sedimentary organic matter in the summer (Cocito *et al* 2013). Hiscock (2007) suggested that it is unlikely that nutrient enrichment will have a significant effect on *E. verrucosa* abundance and survival. Sea fans feed on planktonic organisms and, although abundance of those organisms might change as nutrient concentrations vary, the long term effects on food sources are not likely to be significant. However, algae colonize and may smother sea fans and may increase in abundance as a result of increase in nutrient concentrations (Hiscock *et al* 2005). The resistance of *E. verrucosa* to this pressure was recorded as *'High'*.

Hydrocarbon and PAH contamination – includes those priority substances listed in Annex II of Directive 2008/105/EC
The sensitivity assessment for this group was based upon the evidence available for *E. verrucosa;* no evidence could be sourced for other species in the group. The group was assessed as having a *'High'* sensitivity to hydrocarbon and PAH contamination. Species within this group are attached to the seabed and unable to avoid the impacts of hydrocarbon contamination where this occurs. The erect nature of the species may also enhance contact with contaminants through extension into the water column.

Etnoyer *et al (*2016) suggest that gorgonian corals such as *E. verrucosa* may be exposed to contaminants through the ingestion of contaminated plankton or suspended organic material. The authors assessed gorgonians affected by the Deepwater Horizon oil spill in the Northern Gulf of Mexico for health and condition in a before-after-control-impact (BACI) research design using still images. The study concluded that condition of gorgonians at sites near the oil spill declined significantly post-spill. Prior to the spill, injury was observed for 4–9% of large gorgonians. After the spill, injury was observed in 38–50% of large gorgonians. Resistance of *E. verrucosa* to hydrocarbon or PAH contamination was therefore recorded as '*Low*'. *E. verrucosa* is a long lived species (20-100 years), has slow growth rates (~10mm/year), and sporadic recruitment events (Hiscock 2007), and in case of death it will take the population a very long time to recover. Therefore its resilience was recorded as '*Low*'.

Radionuclide contamination
No evidence was available for the species in this group regarding 'Radionuclide contamination'.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The sensitivity assessment for this group was based upon the evidence available for *F. foliacea;* no evidence could be sourced for the other characterising species. The group was assessed as having a *'Low'* sensitivity to this pressure. Species within this group are attached to the seabed and unable to avoid the impacts of synthetic compound contamination where this occurs. The erect nature of the species may also enhance contact with contaminants through extension into the water column.

Evidence exists for both tolerance and intolerance of bryozoans to synthetic compound contamination. Tyler-Walters and Ballerstedt (2007) suggest that bryozoans are common members of the fouling community, and amongst those organisms most resistant to antifouling measures. On the other hand however Rees *et al* (2001) reported that the abundance of bryozoans had increased in the Crouch estuary in the five years since antifoul (TBT) was banned. The authors report that bryozoans may be at least inhibited by the presence of TBT. Hoare and Hiscock (1974, in Tyler-Walters & Ballerstedt 2007) reported that *F. foliacea* did not occur less than 165m from acidified halogenated effluents in Amlwch Bay. The resistance of *F. foliacea* to this pressure has therefore been recorded as *'Low'*, while the resilience is *'High'*.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been scored with '*Low*' sensitivity for this pressure. Group members are attached to the seabed and are unable to avoid the impacts of this pressure where it occurs. The erect nature of the species may also enhance contact with contaminants through extension into the water column.

F. foliacea is the only species from this group where information was available on the resistance to this pressure. Gibbs (1991) reported that there was little evidence regarding TBT toxicity in Bryozoa. On the other hand however Rees *et al (*2001) reported that the abundance of bryozoans had increased in the Crouch estuary in the five years since TBT was banned. The authors report that bryozoans may be at least inhibited by the presence of TBT. Hoare and Hiscock (1974) reported that *F. foliacea* did not occur less than 165m from acidified halogenated effluents in Amlwch Bay. The resistance of *F. foliacea* to this pressure has therefore been recorded as *'Low'*, while the resilience is *'High'*.

Genetic modification and translocation of indigenous species
No evidence was available for the species in this group regarding 'Genetic modification and translocation of indigenous species'.

Introduction of microbial pathogens
The individual species in this group demonstrated some disparity in tolerance to this pressure, therefore *F. foliacea* was considered separately from the rest of the group. No evidence was available for *A. dissimilis* and as such, assessments are made for the other two species with the overall group score being given is for the most conservative of these species scores. The combined group have been scored with '*High*' sensitivity and *F. foliacea* has been assessed as '*Not sensitive'*.

Combined group
The sensitivity of *E. verrucosa* to pathogens or disease vectors was recorded as *'High'*. Hall-Spencer *et al* (2007) reported that when stressed by high temperatures, *E. verrucosa*

becomes vulnerable to pathogenic activity by Vibro spp. Cerrano *et al* (2000) reported extensive gorgonian mortality during unusually warm water conditions in 1999, which Martin *et al* (2002) linked to infection by Vibrio spp. bacteria at elevated temperatures. Resistance of *E. verrucosa* to the instruction of microbial pathogens is therefore recorded as *'Low'*. *E. verrucosa* is a long lived species (20-100 years), has slow growth rates (~10mm/year), and recovery to a population with large individuals is likely to take more than 10 years (Hiscock 2007). Therefore its resilience was recorded as *'Low'*.

Flustra foliacea
This species was recorded *'Not sensitive'* to the introduction of microbial pathogens. Stebbing (1971a, in Tyler-Walters & Ballerstedt 2007) reported that encrusting epizoites reduced the growth rate of this species by approximately 50%. Also, the bryozoan Bugula flabellata produces stolons that grow in and through the zooids of *F. foliacea*, causing 'irreversible degeneration of the enclosed polypide (Stebbing 1971b, in Tyler-Walters & Ballerstedt 2007). Given the reduction of growth rate but no evidence for mortality of the species, Tyler-Walters and Ballerstedt (2007) recorded a *'High'* resistance to this pressure. It is noteworthy that no evidence is available about the species resistance to diseases, thus the result of the sensitivity assessment should be interpreted with caution.

Introduction or spread of non-indigenous species (INIS)
No evidence was available for the species in this group regarding 'Introduction or spread of non-indigenous species (INIS)'.

Removal of non-target species
No evidence was available for the species in this group regarding 'Removal of non-target species'.

Removal of target species
The sensitivity assessment for this group was based upon the evidence available for *E. verrucosa*; overall group sensitivity has been assigned as '*Medium'*. No evidence was found indicating that other species within the group have been targeted for commercial exploitation.

E. verrucosa has been exploited by the souvenir trade in localised areas since the late 1960's (Hiscock 2007). However, only large colonies were selected and so some of the population remained to grow and reproduce locally. A *'Medium'* resistance was therefore recorded. Hiscock (2007) suggest that the resilience of populations would be likely to be more rapid than if all had been removed, and resilience was recorded to be *'Medium'*.

4.9 Ecological group 6D: Attached robust species

The 'attached robust species' group comprises two widespread species: the calcareous tube-forming polychaete *Spirobranchus triqueter* and the acorn barnacle *Balanus crenatus.* These two species are likely to have similar sensitivities to pressures based upon their small body size and robust, encrusting nature amongst other similar biological traits such as resource capture method. *Spirobranchus triqueter* has not been grouped with other polychaetes in the tube-dwelling fauna group due to its encrusting nature. Unlike the sabellid and terebellid worms included in the project, *S. triqueter* does not project up from the seafloor, making it more robust and similar to *B. crenatus* when considering sensitivity response.

As the only two members of the ecological group, the representative species selected for the sensitivity assessments for this group are: *Balanus crenatus and Spirobranchus triqueter*.

Permanently attached species are inevitably exposed to biological, physical or chemical changes in their immediate environment and are therefore thought to be generally less resistant to such changes than mobile species.

Both species characterizing this group are active suspension feeders, typically feeding on zooplankton, phytoplankton and detritus (White 2004; Riley & Ballerstedt 2005). *S. triqueter* uses cilia action to induce a current flow enabling food transport towards its mouth (White 2004), while *B. crenatus* uses cirri to filter food particles from the water column (Riley & Ballerstedt 2005).

The relatively small sizes (<2.5cm) and compactness of the species characterizing this ecological group suggests they are more resistant to physical damage from abrasion than attached erect or attached soft-bodied species, whilst making them more susceptible to pressures through siltation. The group is further characterised by pelagic larval stages, and a range of pressures might affect the species' dispersal and settlement rates.

Due to the relatively short life spans of this group's species, the resilience of this ecological group is generally considered *'High'*. *Spirobranchus triqueter* has been reported to reach sexual maturity within four months (Hayward & Ryland 1995; Dons 1927), and to have longevity of up to four years (Riley & Ballerstedt 2005). Larvae are thought to be pelagic between two weeks in warmer summer months and up to eight weeks in colder winter months (Hayward & Ryland 1995), enabling wide dispersal (Riley & Ballerstedt 2005). With a growth rate of approximately 1.5mm per month, settled larvae can reach adult size range (10 – 25mm) within one to two years (Riley & Ballerstedt 2005), thus enabling full recovery within two years. Balanus crenatus reaches sexual maturity within four months (White, 2004) and has longevity of 18 months (Barnes & Powell 1953). While the growth rate is known to vary with current flow and siltation rates, it has been reported to be as high as 0.2mm per day in favourable conditions (Barnes & Bagenal 1951). As B. crenatus has a life span of less than two years, the species' resilience has also been scored as 'High'.

4.9.1 Sensitivity Assessments

Table 11. Group 6D Attached robust species and associated biotope in sublittoral rocky habitats (H = High; M = Medium; L = Low, VL = Very Low).

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Salinity changes - local	H	H	Not sensitive	M	H	M
Temperature changes - local	M	H	Low	L	H	L
Water flow (tidal current) changes - local	H	H	Not sensitive	M	H	H
Wave exposure changes - local	H	H	Not sensitive	H	H	M
Changes in suspended solids (water clarity)	H	H	Not sensitive	M	H	M
Abrasion/disturbance at the surface of the substratum	L	H	Low	M	H	M
Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)	None	H	Medium	M	H	M

Pressure	Resistance	Resilience	Sensitivity	Quality of evidence	Applicability of evidence	Degree of concordance
Physical loss (to land or freshwater habitat)	L	VL	High	H	H	H
Electromagnetic changes	No evidence					
Introduction of light	No evidence					
Litter	No evidence					
Visual disturbance	H	H	Not sensitive	M	H	M
Organic enrichment	H	H	Not sensitive	M	H	M
De-oxygenation	H	H	Not sensitive	H	H	M
Introduction of other substances (solid, liquid or gas)	H	H	Not sensitive	M	M	M
Nutrient enrichment	H	H	Not sensitive	M	H	M
Hydrocarbon & PAH contamination	H	H	Not sensitive	M	M	M
Radionuclide contamination	No evidence					
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals)	M	H	Low	L	H	M
Transition elements & organo-metal (e.g. TBT) contamination	M	H	Low	M	H	M
Genetic modification & translocation of indigenous species	H	H	Not sensitive	M	H	M
Introduction of microbial pathogens	No evidence					
Introduction or spread of non-indigenous species (INIS)	No evidence					
Removal of non-target species	No evidence					
Removal of target species	Not exposed					

Salinity changes - local

This group has been assessed as *'Not sensitive'* to changing salinity at the benchmark level. Being permanently attached, *Balanus crenatus* and *Spirobranchus triqueter* are inevitably exposed to changes in water chemistry. However, both species in this group are considered to be resistant to a salinity decrease at the benchmark level. *B. crenatus* can be found in a wide variety of salinities (<18psu to 40psu) (White 2004) and though *S. triqueter* does not generally inhabit estuarine or brackish conditions (Riley & Ballerstedt 2005), Dixon (1985, in Riley & Ballerstedt 2005) views the species as able to withstand significant reductions in salinity. Mature *Spirobranchus* sp. have been shown to survive at salinities as low as 3psu, but only when closed in their tube.

As marine organisms, the group members inhabit 30-40ppt conditions which is the highest salinity considered within the MNCR categories. As such, the sensitivity of the species in this group to hyper-salinity has not been considered as part of the assessment. However, it should be noted that increase in salinity causes abnormalities in *B. crenatus* embryos (Barnes & Barnes 1974). At >40psu abnormal development occurs and at >70psu, no development occurs. Assuming that *B. crenatus* inhabits the middle of its environmental range, it would be tolerant of this salinity but upon encountering hypersalinity it may suffer some abnormalities.

Temperature changes - local
The individual species in this group demonstrated some variable tolerances to this pressure. Therefore, a precautionary approach was taken and sensitivity was assessed as '*Low*', reflecting the more sensitive species within the group. The variation between species to this pressure is due to differences in physiology.

Being permanently attached, the species in this group are unable to relocate to areas of preferred environmental conditions, making them potentially susceptible to a change in temperature. However, *B. crenatus* is a Boreal species and was reported unaffected by temperatures during an extreme winter in 1962-63 (5-6°C lower for two months) (Crisp & Southward 1964). Conversely, when considering increasing water temperatures, *B. crenatus* is likely to demonstrate increased sensitivity. It has a peak rate of physiological function at 20°C and all activity ceases at 25°C (Southward 1955, in White 2004). As summer water temperatures in the UK may reach up to 20°C in some areas, a 5°C increase may be significant though little information is available on mortality rates

In contrast to *B. crenatus, S. triqueter* may undergo some negative effects as a result of decreasing water temperature by 5° for one month. Below a temperature of 7°C *S. triqueter* is unable to build calcareous tubes (Thomas 1940) though this would only affect the settling juvenile population as adult tubes are already formed. For a month this is not likely to lead to substantial losses to the population, thus a '*Medium*' resistance was assigned. As the distribution of *S. triqueter* ranges from the UK to the Mediterranean (Riley & Ballerstedt 2005), it is considered tolerant to an increase in temperature at the benchmark level.

Water flow (tidal current) changes - local, including sediment transport considerations
The group has been assessed as *'Not sensitive'* to a decrease in water flow. Due to the lack of mobility, species from this group are unable to relocate to areas of preferable water flow should the water flow regime change.

B. crenatus inhabits environments with a range of water speeds ranging from >3m/sec to <0.05m/sec (White 2004) and as such is considered tolerant to a decrease in water flow rate within the benchmark. A decrease in current speed may be accompanied by a decrease in food supply though the group is somewhat adapted to feed in a range of current speeds. *B. crenatus* copes with reduced water flow by rhythmically beating its cirri to feed in the absence of any current (Riley & Ballerstedt 2005). Barnes and Bagenal (1951) found that *B. crenatus* growth was considerably slower in high energy environments though no evidence of damage to the population was found and as such is also considered tolerant to an increase in water flow rate within the benchmark.

S. triqueter has been recorded in areas with very sheltered to exposed water flow rates (Price *et al* 1980, in Riley & Ballerstedt 2005) which illustrates the species' ability to withstand a decrease in flow rate. *S. triqueter* uses cilia action to induce a current flow enabling food transport towards its mouth (White 2004). Additionally, Wood (1988, in Riley

& Ballerstedt 2005) observed *Spirobranchus* sp. in strong tidal streams which demonstrates tolerance to the pressure. Both species are therefore considered resistant to this pressure.

Wave exposure changes - local, including sediment transport considerations
The group has been assessed as *'Not sensitive'* to this pressure. Due to the lack of mobility, species from this group are inevitably exposed to any changes in wave action. However, both species are found within a very wide range of wave conditions (White 2004; Riley & Ballerstedt 2005), suggesting resistance to a change in wave action. Barnacle growth is thought to be quickest at exposed locations (Crisp 1960) therefore a decrease in wave exposure may reduce growth rates but is unlikely to have an impact on the overall population. *S. triqueter* has been recorded in areas with variable wave action (Price *et al* 1980). Riley and Ballerstedt (2005) note that an increase in wave exposure over a period of a year could possibly affect the viability of a *S. triqueter* population, by reducing feeding and larval settlement. However mortality of organisms due to this pressure is unlikely. Thus both species are not thought to be affected by changes in wave exposure at the benchmark level.

Changes in suspended solids (water clarity)
Due their sessile nature, species in this group are unable to relocate to areas of differing water clarity. However, none of the species in this group are dependent on irradiance, primary production or vision for sourcing food, as such the group has been assessed as '*Not sensitive*' to this pressure. It's most likely that increased water clarity would increase energy supply to primary producers which in turn would stimulate the food chain and thus food supply to all filter feeders. Bacescu (1972, in Riley & Ballerstedt 2005) states that sabellids are accustomed to turbidity and silt, and *S. triqueter* is known to inhabit kelp beds where high and low levels of turbidity occur. This suggests that this group would also be tolerant to both an increase and a decrease in water clarity.

Abrasion/disturbance at the surface of the substratum
This group has been assessed with *'Low'* sensitivity to abrasion or disturbance at the surface of the substratum. Due to their lack of mobility, the species within this group are exposed to any potential physical damage due to abrasion or disturbance at the surface of the substratum. Their relative robustness and compact body shape however is likely to make them less sensitive to such damage when compared to erect or soft bodied attached species. The hard calcareous tube of *S. triqueter* for example is relative resistant to abrasion from sand, gravel and boulders (Wood 1988, in Riley & Ballerstedt 2005) that are mobilised by wave action. However, Riley and Ballerstedt (2005) suggest that *S. triqueter* may be removed from substrate in storms through abrasive action, though recovery of the population following this damage is thought to be quick, and a resistance of *'Medium'* was assigned to this pressure. *B. crenatus* has a rigid, inflexible shell, and White (2004) states that the species would probably be crushed by a heavy force, such as an anchor or dredging activity. However, it is compact and individuals in crevices in the substrate would probably survive. Kitching (1937) found that within one year after algae removal from rock surface *B. crenatus* had re-established as it is an important early coloniser. Off Chesil Bank, the epifaunal community dominated by *S. triqueter* and *B. crenatus* decreased in cover in the autumn, was scoured away in winter storms, and was recolonised by early summer (Warner 1985). This illustrates the high resilience of both of the species in this group to the pressure of abrasion.

Smothering and siltation rate changes (depth of vertical sediment overburden) (30cm)
The overall sensitivity of this group has been scored as *'Medium'*. As permanently attached species, this group are unable to avoid any degree of smothering or siltation and are therefore generally more exposed to this pressure than mobile species. *S. triqueter* and *B. crenatus* both grow to less than 5cm in height (White 2004; Riley & Ballerstedt 2005). Therefore smothering at the benchmark level would completely cover these species, impairing suspension feeding and respiration, eventually resulting in death of the populations. Sediment covering hard substrata would further impede larval settlement,

delaying new recruitment of both species. Thus a resistance of *'None*' was assigned. As resilience for both species is generally high, the group was assigned an overall '*Medium*' sensitivity to this pressure.

Physical loss (to land or freshwater habitat)
All marine habitats and benthic species are considered to have a resistance of *'Low'* to 'physical loss (to land or freshwater habitat)' and are unable to recover from a permanent loss of habitat (resilience is '*Very low*'). Sensitivity of this pressure is therefore *'High'*.

Electromagnetic changes
No evidence was available for the species in this group regarding 'Electromagnetic changes'.

Introduction of light
No evidence was available for the species in this group regarding 'Introduction of light'.

Litter
No evidence was available for the species in this group regarding 'Litter'.

Visual disturbance
The group has been assessed as *'Not sensitive'* to visual disturbance. Barnacles are unlikely to react to visual presence (White 2004) and as such, the resistance of *B. crenatus* is recorded as *'High'*. Movement and shadows detected by the photoreceptive surface of serpulid polychaetes may result in withdrawal of the worm back into its tube (Kinne 1970, in Hill 2007) though there is no evidence to suggest that this would affect the population of the worm in any way.

Organic enrichment
This group has been classified as *'Not sensitive'* to organic enrichment. Being permanently attached, species in this group are unable to avoid areas of organic enrichment. A slight increase in organic nutrient levels could promote growth of phytoplankton and therefore increase food supply for these suspension feeders (White 2004). Jakola and Gulliksen (1987) recorded *B. crenatus* as the dominant species on pier pilings which were prone to urban pollution, suggesting a tolerance of the species to this pressure. However, a substantial increase in nutrients could cause barnacles to be killed by the overgrowth of green algae (Holt *et al* 1995) though it is thought that this would require a larger degree of organic enrichment than is considered within the benchmark of this pressure. Gittenberger and van Loon (2011) suggest that *S. triqueter* is indifferent to organic enrichment though as with *B. crenatus*, it is likely that an increase in organic material may trigger an increase in food supply. Therefore both species are thought to be resistant to this pressure.

De-oxygenation
The sensitivity for the group to de-oxygenation has been assessed using the available evidence for *B. crenatus*, as no evidence could be sourced for *S. triqueter*. Being permanently attached, species in this group are unable to avoid areas of hypoxia or anoxia. However, the group is considered *'Not sensitive'* to de-oxygenation. Trials conducted by Barnes *et al (*1963) suggest that under anaerobic conditions the metabolic rate of *B. crenatus* are reduced but no other negative effects were observed. Barnacles can respire anaerobically so it is able to withstand a degree of oxygen depletion within the water (White 2004). Therefore the group has been assessed as having a *'High'* resistance to the pressure.

Introduction of other substances (solid, liquid or gas)
The species in this group have been assessed as *'Not sensitive'* to this pressure. The sensitivity for the group to the introduction of substances has been assessed using the little

available evidence for *B. crenatus*, as no evidence could be sourced for *S. triqueter*. *B. crenatus* was one of the species listed in an investigation conducted by Van Buuren (1984) who states that no lethal or sub-lethal effects were detected on the macrobenthic community following a gas leak (Hydrocarbons). Holt *et al (*1995) suggest that other littoral barnacles generally have a high tolerance to oil so it is suggested that *B. crenatus* also demonstrates a *'High'* tolerance.

Nutrient enrichment
The species in this group have been classified as *'Not sensitive'* to nutrient enrichment. Due to the lack of mobility, species from this group are unable to avoid areas of nutrient enrichment. A slight increase in nutrients could be beneficial for these suspension feeders, as it may promote growth of phytoplankton and therefore increasing food supply (White 2004). *B. crenatus* was recorded as the dominant species on pier pilings which were prone to urban pollution by Jakola and Gulliksen (1987) which suggests a tolerance to this pressure. A substantial increase in nutrients could cause barnacles to be killed by the overgrowth of green algae (Holt *et al* 1995) though it is thought that this would require a larger degree of organic enrichment than is considered within the benchmark of this pressure. Gittenberger and van Loon (2011) suggest that *S. triqueter* is indifferent to nutrient enrichment though as with *B. crenatus*, it is likely that an increase in organic material may trigger an increase in food supply. The lack of negative responses recorded for *S. triqueter* following enrichment suggests that the species is tolerant to this pressure. Therefore both species are thought to be resistant to this pressure.

Hydrocarbon and PAH contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been assessed as *'Not sensitive'* to this pressure. The sensitivity for the group to this pressure has been assessed using the available evidence for *B. crenatus* as no evidence could be sourced for *S. triqueter*. Due to the lack of mobility, species from this group are unable to avoid areas hydrocarbon or PAH contamination. The little evidence that was available for *B. crenatus* suggests that the group is *'Not sensitive'* to the introduction of other substances. *B. crenatus* was one of the species listed in an investigation conducted by Van Buuren (1984) who states that no lethal or sub-lethal effects were detected on the macrobenthic community following a gas leak (Hydrocarbons). Wharfe *et al (*1981) found that three months of chlorinated sewage discharge had no effect on macrofaunal communities including *B. crenatus*. Holt *et al (*1995) suggest that other littoral barnacles generally have a high tolerance to oil so it is suggested that *B. crenatus* demonstrates a *'High'* tolerance towards hydrocarbon contamination.

Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals) - includes those priority substances listed in Annex II of Directive 2008/105/EC
The species in this group have been classified with *'Low'* sensitivity. Due to the lack of mobility, species from this group are unable to avoid areas of synthetic compound contamination. Booij *et al (*2006) found that antifouling agents Iragol and Capsaicin had no effect on the extent of fouling when *B. crenatus* was one of the target species suggesting the species was resistant to contaminants used in the antifoulant. However, Holt *et al* (1995) concluded that barnacles are fairly sensitive to chemical pollution and have a low resilience to chemicals such as dispersants. In contrast, no lethal or sub-lethal effects were detected on the macrobenthic community including *B. crenatus* following a gas leak (Hydrocarbons) (Van Buuren 1984). Due to the seemingly mixed responses that *B. crenatus* has to various chemical contaminants, a resistance of *'Medium'* has been assigned. No evidence could be found in relation to *S. triqueter* for this pressure. As resilience of this ecological group is *'High'*, the overall sensitivity to synthetic compound contamination is *'Low'*.

Transition elements and organo-metal (e.g. TBT) contamination - includes those priority substances listed in Annex II of Directive 2008/105/EC
The sensitivity for the group to transition elements and organo-metal contamination has been assessed as *'Low'* using the available evidence for *B. crenatus.* No evidence could be sourced relating to *S. triqueter*. Due to the lack of mobility, species from this group are unable to avoid contaminated areas. Braithwaite *et al (*2007) found *B. crenatus* inhabiting control nets but avoiding copper nets suggesting that they have an aversion to copper, though the extent of resistance is unclear. White (2004) suggests that barnacles accumulate heavy metals and are generally tolerant of most heavy metals. Conversely, Pyefinch and Mott (1948) recorded a median lethal concentration of 0.19mg/l copper and 1.35mg/l mercury, for *B. crenatus* over 24 hours. Due to the seemingly mixed responses that *B. crenatus* has to these contaminants, a resistance of *'Medium'* has been assigned. As resilience of this ecological group is *'High'*, the overall sensitivity to synthetic compound contamination is *'Low'*.

Genetic modification and translocation of indigenous species
The sensitivity of the group to genetic modification and translocation of indigenous species has been assessed as *'Not sensitive'* using the available evidence for *S. triqueter*, as no evidence could be sourced relating to *B. crenatus*. Eno *et al* (1997) state that although several species of serpulid polychaetes have been introduced into British waters none are reported to compete with *S. triqueter*. It should be noted however that this source was published almost 20 years ago and new competitor species may have been introduced since.

Introduction of microbial pathogens
No evidence was available for the species in this group regarding 'Introduction of microbial pathogens'.

Introduction or spread of non-indigenous species (INIS)
No evidence was available for the species in this group regarding 'Introduction or spread of non-indigenous species (INIS)'.

Removal of non-target species
No evidence was available for the species in this group regarding 'Removal of non-target species'.

Removal of target species
B. crenatus and *S. triqueter* have been assessed as *'Not exposed'* to 'Removal of target species'.

5 Applications and limitations to sensitivity assessments

The sensitivity assessments undertaken as part of this project are subject to a number of applications and limitations, which are discussed in the following section.

An evaluation of the limitations inherent in the methods used to conduct the sensitivity assessments is provided in Tillin and Tyler-Walters (2014), with specific reference to the sublittoral sedimentary habitats which that study assessed. Similarly, an overview of the applications and limitations which are applicable to sublittoral rock habitats (assessed using the methods developed in Tillin & Tyler-Walters 2014) is presented below.

5.1 Observations

There were several outstanding points which were apparent throughout the course of this project which should be reflected upon when considering the sensitivity assessments in this report:

- The sensitivity assessments are not site-specific and assume that the population of a species is occurring in the middle of its environmental range with a stable benchmark population. However, a species may already exist at its upper limit relevant to a pressure, so when translating to management, feature specifics would need to be built in to the sensitivity assessments. Relevant literature regularly demonstrated that slow growing species recover at different rates depending on the location.

- The sensitivity assessments assume the population is healthy and in a steady state without the pressures being applied. It is recommended that the pre-assessment level should be taken in to account when using this method for habitat management. Should the populations being investigated inhabit an environment where it is at the upper/lower limit of a tolerance, pressure outcomes for ecological groups may be more/less extreme.

- The sensitivity scores are an indication of a response with pressures acting individually and not synergistically. Cumulative and combined risks are not taken in to account by sensitivity assessments and some pressures may be antagonistic, although this has not been accounted for in the methods applied.

- Sensitivity assessments are not absolute values, rather, they are relative to the scale, geographic extent and duration of the pressure being exerted by an activity. When applied to management of marine environments, this would need to be taken in to account as it would affect the outcome of the assessments.

- The maturity and scale of the features – i.e. the extent of the species assemblages present within the biotopes examined, is not taken into account by the sensitivity assessments. Should the methods used in this project be utilised as a management tool, the extent and age of the population should be carefully considered.

- The sensitivity scores stem from determining a species' resistance (tolerance) and resilience (recovery). The resilience score pre-supposes that the pressure has been removed and ceases to exist within a given timeframe. In practise, this is not likely to be the case and where one pressure is removed, another may remain which may continue to affect the populations resilience.

- There are limitations to the evidence available to fully inform the sensitivity assessments and the most robust assessments will be for species which are well researched. Literature for many widely distributed species in the UK is still extremely limited in terms of scientific evidence available.

5.2 Generalisations and assumptions of sensitivity assessments

The sensitivity assessments presented in this report assume that the pressures studied are being applied at the benchmark level. If a pressure were to be exerted at a lower or higher intensity in practice, a site specific assessment for that activity and location would need to be conducted as the result may alter significantly. However, this would still rely on the availability of information which may only be accessible for a particular benchmark level.

Often, the information that was accessed related to pressures being exerted at greater or less than the benchmark level. This required a degree of inference to determine how a species and concurrently a group were sensitive to a pressure. The frequency and magnitude of a pressure would also determine the outcome of a site specific assessment. Therefore, when applying a sensitivity approach for management practice, the degree of increase or decrease should be considered. Some assessments have been made based upon the combined sensitivities of increasing and decreasing benchmarks with the most conservative outcome being applied at the group level to reflect the most susceptible species within the group. In practice, it may be more efficient to consider increasing or decreasing pressures separately and to consider varying degrees of pressure application.

Ecological groups for sublittoral rock habitats were created using biological and habitat preference trait information. Conducting sensitivity assessments on ecological groups makes the assumption that all species will react similarly in terms of sensitivity based upon these traits. However, some factors which have bearing on resistance and resilience were not taken in to account when defining the original ecological groups. For example, growth rate and fecundity were particularly important biological traits used for determining resilience, and these were not considered when forming the ecological groups. This resulted in several sensitivity assessments being split by species in Phase 2 of the project. This issue was most evident in Group 6C (Attached erect species) which contained a sponge (*Axinella dissimilis*), a bryozoan (*Flustra foliacea*) and a gorgonian sea fan (*Eunicella verrucosa*). The bryozoan recovers much more quickly than the sponge and the gorgonian coral. This meant that resilience was routinely different between the three species in the group though the species are similar in terms of the niches they inhabit according to their general ecology. This outcome is important to note, as it illustrates the effectiveness of the assessments in accounting for differences in sensitivity, even for species which may initially be considered as similar in this regard. It is recommended that growth rate of features be taken in to account in any site level sensitivity assessments which may be conducted to assist in managing the marine environment.

Assigning an overall sensitivity score to a group of species where in-depth assessments have only been conducted for 2-4 species out of the group total may result in the sensitivity score being over- or under-cautious to risks associated with human activities. Though species have been carefully divided in to ecological groups (based upon biological and habitat preference traits), some variability between characterising species is inevitable, especially when considering up to 30 physical, chemical and biological pressures. Using ecological groups reduces the number of sensitivity assessments required and encourages management practice to examine the sensitivity of a range of species. However, individual variability should be contemplated. It should not be assumed that all species within a group will have the same sensitivity to all pressures and therefore it is recommended that a conservative approach to management when considering ecological groups should be taken.

The sensitivity assessments do not account for temporal or spatial variability. The method assumes that species exist in the middle of their environmental range and that the ecosystem is in a relatively steady state. However, temporal variation can have marked effects on the features examined in regards to sensitivity. Temperature and daylight for example vary significantly throughout the year in the UK and the sensitivity of a feature will subsequently change depending on their preferences. In winter for example, a species may demonstrate high resistance to a 5°C increase in temperature. In summer however, when water temperatures are higher, the feature may not be able to withstand an increase in 5°C without some mortality. Spatial scale is also not considered for sensitivity assessments and would need to be accounted for if the method was used at site level for management purposes. Abrasion for example could occur on a localised scale if the pressure is exerted by a single anchor but scallop dredging may lead to more widespread abrasion on a larger scale.

Additionally, the timescale over which the benchmark pressure is applied is not specified in the majority of pressures. The sensitivity of a benthic population is likely to be affected by the duration of the pressure and the timescale over which a pressure is introduced. Species may be more adaptive if a pressure (such as temperature decrease) is introduced gradually. Conversely, they may demonstrate a higher sensitivity if the pressure results in a short-term acute introduction of a different physical, chemical or biological condition.

The final sensitivity score stems from the ability of a species or ecological group to be resilient (recover) from any negative effects caused by a pressure. Firstly, this assumes that the pressure is removed which is unlikely to happen without the intervention of management. Secondly, the overall sensitivity scores may not accurately represent the susceptibility of a population to a pressure because of the scoring system. Even when a species' resistance to a pressure is *'Low'*, a final score of *'Low'* sensitivity can be derived if the resilience score is *'High'*. For a group where the resilience score has been assessed as '*Medium*', it is impossible using the scoring matrix to have an outcome of '*High*' sensitivity which in practise is very unlikely. This follows the assumption that when resistance is '*High*', resilience is also '*High*'. For example, the outcome for the sensitivity assessment for Group 6A to the pressure of smothering (30cm) was of '*Medium*' sensitivity as the resistance was considered to be '*Low*' and the group resilience score was '*Medium*'. Considering the assessment scale for resistance defines '*Low*' tolerance as a 25-75% mortality of the population, it was felt that the '*Medium*' sensitivity score did not seem to capture the vulnerability of the group to smothering. Therefore, the final sensitivity score may suggest that little or no action need be taken from a management perspective when in practice a feature could be at risk if no management practices are carried out. As was recommended by Tillin and Tyler-Walters (2014), ***'where resistance is '*****Low*****', the need for management measures should be considered, irrespective of the overall sensitivity assessment'.***

5.3 Limitations of scientific evidence

The sensitivity assessment method involved a detailed literature review exercise to ensure that the assessments were as informed as possible. However, expert judgement was regularly applied because the evidence base was incomplete, too general or not available for the features being assessed. There was often a lack of scientific evidence relating to even the most highly recorded and widely distributed species in the UK. Evidence regarding salinity and temperature was generally available for most characterising species but often, the information sources were dated. However, these sources (when peer reviewed) were considered to be good and were assessed with high confidence.

For some commercially important species such as *Cancer pagurus*, there was plentiful life history evidence to inform the sensitivity assessments. Conversely, for other species, such as *Pandalus montagui* (the pink shrimp), there was so little information available that the species had to be excluded from the species level sensitivity assessments. In general, there was a lack of basic information available for many of the species included within the scope of this project, even those with conservation importance. This had a direct effect on the overall confidence scores for the sensitivity assessments and entire pressures could not be assessed in some cases as there was not enough evidence. Resilience was often assessed on the basis of a species' ability to recolonise a habitat which required life history evidence. Information on population dynamics was sparse for some species included in the project and details regarding recruitment and reproduction for some species were not available which made it difficult to make assessments for resilience. Therefore, much of the recovery information has been based upon general information for high level groups such as for bivalves, sea urchins and sponges. Larval information was also used to infer resilience. Short-lived larvae with poor dispersal rates were considered to have *'Low'* resilience while species with a high larval dispersion potential were assessed as having a *'Medium'* or *'High'* resilience.

Though intertidal biotopes are not considered in the scope of this project, much of the evidence available for the species which were examined in this project was based upon intertidal and coastal populations. There was substantially less information for subtidal features not found directly adjacent to the shoreline and as such, some intertidal evidence has been used as a proxy for subtidal processes. For example, scarce material was available for some species' temperature preferences but if they were recorded in rock pools, expert judgement was applied to suggest that the species may have a tolerance for temperature increase as these environments are subjected to temperature fluctuations.

5.4 Pressure descriptions and benchmarks

The pressure descriptions were for some species, challenging to differentiate. In particular, the 'Pollution and other chemical changes' pressures overlapped in their descriptions of the pressures. As such, the evidence that was used for the pressure of 'Organic enrichment' was often the same for the pressure of 'Nutrient enrichment'. At times, the evidence available for one pressure was used for another as a proxy for another as the pressures were so closely related. Often though, the evidence required to assess one features' sensitivity to one pressure was directly applicable to the other. There were also numerous similarities between the evidence that could be sourced for the pressures: 'Introduction of solids, liquids and gases', 'Hydrocarbon and PAH contamination', 'Synthetic compound (incl. pesticides, antifoulants and pharmaceuticals) contamination' and 'Transition elements and organo-metal (e.g. TBT) contamination'. For example, both of the pressures 'Synthetic compound (incl. pesticides, antifoulants and pharmaceuticals) contamination' and 'Transition elements and organo-metal (e.g. TBT) contamination' require the assessment of TBT as it is mentioned in the title of the former pressure as an antifoulant and is referred to specifically in the latter pressure by name. Similarly, hydrocarbon contamination could also be considered to be covered by the pressure 'Introduction of solids, liquids and gases'.

Some pressure benchmarks were also very specific while others were less so. For example, the temperature benchmarks gave information of the duration and degree of the pressure: 'A 5°C decrease in temperature for one month period, or 2°C for one year'. This allowed information directly relating to the benchmark to be sourced. Other benchmarks such as that for litter were less exact: 'Introduction of man-made objects able to cause physical harm (surface, water column, sea floor, and/or strandline)'. This resulted in difficulty in finding information which was directly applicable to the assessments as extend and a timeframe were not precise.

5.5 Confidence assessments

The confidence assessments which have been conducted throughout the project are different to those completed during the literature review and the process was based on three assessment categories: quality of information, applicability of evidence and degree of concordance. The aim of the confidence assessments for the resistance, resilience and sensitivity assessments was to capture any uncertainty in the evidence being used and to record any applications of expert judgement. It should be noted that *'High'* quality evidence refers to the source and should not automatically be assumed to be directly relevant to the assessment. Though a matrix was provided by JNCC for the combined confidence assessment based on the Quality of Information, no guidelines were provided for applicability of evidence or degree of concordance when combining confidence.

The majority of the sensitivity assessment, approximately 56%, of rock habitats used medium quality evidence, with 13% of assessments being based on high quality evidence, and 11% on low quality evidence. The degree of concordance of evidence was also similar with 56% of the assessment using evidence of medium concordance, 10% using evidence of high concordance and 14% of evidence having a low concordance over all. Overall the majority of evidence, 60%, had high applicability, 18% had medium applicability and only 2% had low applicability. In total the majority of pressure and group combinations had evidence with 20% of the sensitivity assessment being scored with no evidence. On average, five pressures per group could not be assessed due to the lack of sufficient evidence. Most evidence was available for Group 4, bivalves and brachiopods, in which all but one pressures could be evaluated. The least evidence was available for Group 6D, attached robust species, in which 7 pressures could not be assessed.

The pressures electromagnetic changes, genetic modification and translocation of indigenous species and radionuclide contamination were particularly low in evidence for sublittoral rock habitats. Electromagentic changes were only assessed for mobile predators and scavengers, whilst genetic modification and translocation of indigenous species could only be assessed for bivalves and brachiopods and attached robust species, and radionuclide contamination could only be assessed for macroalgae and bivalves and brachiopods. These areas, both the groups with least evidence and the pressures with least evidence, could be considered in further work to improve the evidence base for the affects of pressures on sublittoral rock habitats and species.

6 Conclusions

The Tillin and Tyler-Walters (2014) sensitivity assessment method was used to examine the sensitivity of sublittoral rock species to human pressures. An in-depth literature review was compiled to gather information about the effects of anthropogenic activities on the benthic marine environment. The literature review targeted evidence which would facilitate scores for resistance, resilience and sensitivity to be made for species under physical, biological and chemical pressures. This literature formed the basis of a sensitivity assessment exercise for nine ecological groups defined in Phase 1 of this project (Maher *et al* 2016).

Following the completion of the sensitivity assessments, the following can be concluded:

- A substantial amount of literature relating to the effects of anthropogenic pressures on the sensitivity of marine species was reviewed and recorded for purposes of clarity.
- The resistance, resilience and sensitivity of nine ecological groups, representing 76 species, were assessed for 25-26 pressures.
- Each assessment of resistance, resilience and overall sensitivity of the species and combined group was accompanied by a confidence assessment which considered the quality of information, the applicability of evidence and degree of concordance to emphasize any uncertainty in the assessments.
- Limitations in the method and of the evidence available have been reviewed and are largely the same as those outlined by Tillin and Tyler-Walters (2014).

The results of the sensitivity assessments show:

Across sublittoral rock habitats as a whole six pressures were assessed to be not relevant: ‘Emergence regime changes - local, including tidal level change considerations’, ‘Habitat structure changes - removal of substratum (extraction)’, ‘Penetration and/or disturbance of the substratum below the surface, including abrasion’, ‘Physical change (to another substratum type)’, ‘Death by injury or collision’ and ‘Noise changes’. In adition, the pressure

‘Barrier to species movement’ was only relevant to the ecological groups ‘Non-Predatory Mobile Species’ and ‘Mobile Predators and Scavengers’, due to their mobility.

All of the ecological groupings were assessed as not sensitive to ‘Visual disturbance’, ‘Organic enrichment’ and ‘Nutrient enrichment’, with the exception of macroalgae, which were assessed as not exposed to ‘Visual disturbance’. In summary, nine pressures are not relevant or thought to cause immediate damage to sublittoral rock habitats (not considering frequency and duration of pressure).

Generally, few assessments resulted in *‘High’* sensitivity, a total of 10.8% across all groups and pressures. Groups 3 (mobile predators and scavengers) and 4 (bivalves and brachiopods) demonstrated ‘*High*’ sensitivity to four pressures each while 6C (attached erect species) displayed *‘High’* sensitivity towards five pressures. All groups were highly sensitive to the pressure ‘Physical loss (to land or freshwater habitat)’. The pressures ‘Smothering and siltation rate changes’ and ‘Introduction of microbial pathogens’ were also found to be particularly damaging to sublittoral rock habitats, especially Group 3 (mobile predators and scavengers), Group 4 (bivalves and brachipods) and sub-group 6C (permanently/temporarily attached, erect epifauna).

The tolerance of each ecological group was found to vary in response to different pressures, for example, although Group 6C (Attached erect species) demonstrated the highest sensitivity overall, the group was also tolerant of many pressures. Group 4 (bivalves and brachiopods) and Group 1 (macroalgae) showed the lowest sensitivities in general, with 25 and 24 pressures, respectively, being recorded as either *‘Not sensitive’* or with *‘Low’* sensitivity. Group 2 (Non-predatory mobile fauna) and Group 3 (Mobile predators and scavengers) each recorded 23 *‘Not sensitive’* or *‘Low’* sensitivity scores.

The majority of the sensitivity assessments were found to be either ‘*not sensitive’* (44.3%) or ‘*Low’* (28.6%), with a large proportion of the ‘*low*’ sensitivity scores attributed to the generally ‘*high*’ resilience of the groups. When a resilience score was *‘High’*, a final score of *‘Low’* sensitivity was derived even if the resistance to a pressure was *‘Low’*. As this may not capture the full vulnerability of the group, it is advised that where resistance is recorded as ‘*low*’, the need for management measures should be considered irrespective of the overall sensitivity assessment.

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8 Appendices

Appendix 1. Sensitivity Assessment Method

The full methods for the sensitivity assessment, scorings and confidence scales are described in Tillin *et al* (2014). A brief explanation of the details of the assessment are below.

The resistance and resilience of the characterising species are assessed against the pressure benchmark using the available evidence. The assessment scales used for resistance (tolerance) and resilience (recovery) are given in table 1 and 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 (Tillin *et al* 2014).

Table 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 physicochemical 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 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

The resistance and resilience scores can be combined, as follows, to give an overall sensitivity score as shown in Table 3.

Table 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):

Table 4. Category definitions for sensitivity assessment.

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.

Confidence scores are assigned to the individual assessments for resistance (tolerance) and resilience (recovery). 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 5.

Table 5. Confidence assessment categories for evidence.

Confidence level	Quality of information Sources	Applicability of evidence	Degree of Concordance
High (H)	Based on peer reviewed papers (observation or experimental) or grey literature reports by established agencies on the feature.	Assessment based on the same pressures acting on the same type of feature in the UK.	Agree on the direction and magnitude of impact.
Medium (M)	Based on some peer reviewed papers but relies heavuly on grey literature or expert judgement on feature or similar features.	Assessment based on similar pressures on the feature in other areas.	Agree on the direction but not magnitude.
Low (L)	Based on expert judgement.	Assessment based on proxies for pressures e.g. natural disturbance events.	Do not agree on concordance or magnitude.

Table 6. Combined confidence assessments (based on Quality of Informtaion Assessment only).

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

Intersessional Correspondence Group on Cumulative Effects – Amended 25th March 2011

Presented by the United Kingdom and the Netherlands on behalf of the Intersessional Correspondence Group Cumulative Effects

Pressure list and descriptions

This is an amended version of the document submitted to both EIHA and ICG-COBAM based on comments received from the Netherlands, Spain, Germany, France ICG-COBAM and the UK. Given the range of responses not all suggested revisions have been applied verbatim, however, it is believed that the spirit and intention of all the recommendations from Contracting Parties listed above have been included.

Pressure theme	Pressures	Code	Pressure Descriptor	MSFD Annex III Table 2
Hydrological changes (inshore/local)	Temperature changes - local	H1	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).	Significant changes in thermal regime (e.g. by outfalls from power stations)
Hydrological changes (inshore/local)	Salinity changes - local	H2	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.	Significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction)

Hydrological changes (inshore/local)	Water flow (tidal current) changes – local, including sediment transport considerations *[possibly split water flow & sediment transport, i.e. separate into 'Hydrological' & 'Physical']*	H3	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 &/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 substrate, 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.	X
Hydrological changes (inshore/local)	Emergence regime changes – local, including tidal level change considerations *[possibly split emergence regime & tidal level changes]*	H4	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 dependant on the position or height on the shore relative to the tide). The spatial and temporal extent of the pressure will be dependant 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	X

			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.	
Hydrological changes (inshore/local)	Wave exposure changes - local	H5	Local changes in wave length, height and frequency. Exposure on an open shore is dependant 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.	X
Pollution and other chemical changes	Transition elements & organo-metal (e.g. TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	P1	The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments the main elements of concern are Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead and Zinc Organo-metallic compounds such as the butyl tins (Tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs.	Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs)

Pollution and other chemical changes	Hydrocarbon & PAH contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	P2	Increases in the levels of these compounds compared with background concentrations. Naturally occurring compounds, complex mixtures of two basic molecular structures: - straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation) - multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation) These fall into three categories based on source (includes both aliphatics and polyaromatic hydrocarbons): - petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off) - pyrogenic hydrocarbons (from combustion of coal, woods and petroleum) - biogenic hydrocarbons (from plants & animals) Ecological consequences include tainting, some are acutely toxic, carcinomas, growth defects.	Introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs)
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.	P3	Increases in the levels of these compounds compared with background concentrations. Synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds include polychlorinated biphenols (PCBs), dichlor-diphenyl-trichloroethane (DDT) & 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD) are persistent and often very toxic. Pesticides vary greatly in structure, composition, environmental persistence and toxicity to non-target organisms. Includes: insecticides, herbicides, rodenticides & fungicides. Pharmaceuticals and Personal Care Products originate from veterinary and human applications compiling a variety of products including, Over the counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones. Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments they have become an emerging concern. Ecological	Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant to the marine environment such as pesticides, anti-foulants, pharmaceuticals, resulting, for example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances)

			consequences include physiological changes (e.g. growth defects, carcinomas).	
Pollution and other chemical changes	Introduction of other substances (solid, liquid or gas)	P4	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.	Introduction of other substances, whether solid, liquid or gas, in marine waters resulting from their systematic and/or international release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions
Pollution and other chemical changes	Radionuclide contamination	P5	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 ships crew is 10 µSv or less in a year; (ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum, then the material is deemed to contain de minimis levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 µSv/a. Ports and coastal sediments can be affected by the authorised discharge of both current and historical low-level radioactive wastes from coastal nuclear establishments.	Introduction of radio-nuclides
Pollution and other chemical changes	Nutrient enrichment	P6	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	Inputs of fertilisers and other nitrogen - and phosphorous-rich substances (e.g. from point and diffuse sources, including agriculture,

			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.	aquaculture, atmospheric deposition)
Pollution and other chemical changes	Organic enrichment	P7	Resulting from the degraded remains of dead biota & microbiota (land & sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of: sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural runoff. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication (see also nutrient enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.	Inputs of organic matter (e.g. sewers, mariculture, riverine inputs)
Pollution and other chemical changes	Deoxygenation	P8	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 substrate 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	X

			gases to kill non-indigenous species.	
Physical loss (Permanent Change)	Physical loss (to land or freshwater habitat)	L1	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.	Sealing (e.g. by permanent constructions)
Physical loss (Permanent Change)	Physical change (to another seabed type)	L2	The permanent change of one marine habitat type to another marine habitat type, through the change in substatum, 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 substrate habitats, removal of coarse substrate (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture i.e. mussel beds. Protection of pipes and cables using rock dumping and mattressing techniques. Placement of cuttings piles from oil & gas activities could fit this pressure type, however, there may be an additional 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.	Smothering (e.g. by man made structures, disposal of dredge spoil)
Physical damage (Reversible Change)	Habitat structure changes - removal of substratum (extraction)	D1	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 substrate) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine	Selective extraction (e.g. by exploration and exploitation of living and non-living resources on seabed and subsoil)

			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.	
Physical damage (Reversible Change)	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	D2	The disturbance of sediments where there is limited or no loss of substrate 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 & 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 & 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 substrate would adversely affect herring spawning grounds.	Abrasion (e.g. impact on the seabed of commercial fishing, boating, anhoring)
Physical damage (Reversible Change)	Changes in suspended solids (water clarity)	D3	Changes in water clarity from sediment & organic particulate matter concentrations. It is related to activities disturbing sediment and/or organic particulate matter and mobilising it into the water column. Could be 'natural' land run-off and riverine discharges or	X

			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 & 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.	
Physical damage (Reversible Change)	Siltation rate changes, including smothering (depth of vertical sediment overburden)	D4	When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. This accumulation of sediments is synonymous with "light" smothering, which relates to the depth of vertical overburden. "Light" smothering relates to the deposition of layers of sediment on the seabed. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the 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	Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal or dredge spoil)

			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 5-10 cm in open waters and the top 15 cm 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 and 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 5 cm (Chandrasekara & Frid, 1998) - H. ulvae maximum overburden 20 cm	

			mud or 9 cm sand (Bijerk, 1988) - S. shrubsolii maximum overburden 6 cm (Saila et al, 1972, cited by Hall 1994) - N. succinea maximum overburden 90 cm (Maurer et al 1982) - gastropod molluscs maximum overburden 15 cm (Roberts et al, 1998). Bolam, 2010 also reported when organic content was low: - H. ulvae maximum overburden 16 cm - T, benedii maximum overburden 6 cm - S. shrubsolii maximum overburden <6 cm - Tharyx sp.A. maximum overburden <6 cm	
Other physical pressures	Litter	O1	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).	Marine litter
Other physical pressures	Electromagnetic changes	O2	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).	X
Other physical pressures	Underwater noise changes	O3	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	Underwater noise (e.g. from shipping, underwater acoustic equipment)

			temporary or permanent hearing loss, discomfort & injury; response; masking and detection. In extreme cases noise pressures may lead to death. The physical or behavioural effects are dependant 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 greater than operational phases (i.e. shipping, operation of a wind farm).	
Other physical pressures	Introduction of light	O4	Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24 hour working; new tourist facilities, e.g. promenade or pier lighting, lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth.	X
Other physical pressures	Barrier to species movement	O5	The physical obstruction of species movements and including local movements (within & between roosting, breeding, feeding areas) and regional/global migrations (e.g. birds, eels, salmon, whales). Both include up river movements (where tidal barrages & devices or dams could obstruct movements) or movements across open waters (offshore wind farm, wave or tidal device arrays, mariculture infrastructure or fixed fishing gears). Species affected are mostly birds, fish, mammals.	X

Other physical pressures	Death or injury by collision	O6	Injury or mortality from collisions of biota with both static &/or moving structures. Examples include: Collision with rigs (e.g. birds) or screens in intake pipes (e.g. fish at power stations) (static) or collisions with wind turbine blades, fish & mammal collisions with tidal devices and shipping (moving). Activities increasing number of vessels transiting areas, e.g. new port development or construction works will influence the scale and intensity of this pressure.	X
Biological pressures	Visual disturbance	B1	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	X
Biological pressures	Genetic modification & translocation of indigenous species	B2	Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated with radionuclide contamination). Former related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, scallops if GM practices employed. Scale of pressure compounded if GM species "captured" and translocated in ballast water. Mutated organisms from the latter could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration. Movement of native species to new regions can also introduce different genetic stock.	X
Biological pressures	Introduction or spread of non-indigenous species	B3	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	Introduction of non-indigenous species and translocations

			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.	
Biological pressures	Introduction of microbial pathogens	B4	Untreated or insufficiently treated effluent discharges & run-off from terrestrial sources & vessels. It may also be a consequence of ballast water releases. In mussel or shellfisheries where seed stock are 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.	Introduction of microbial pathogens
Biological pressures	Removal of target species	B5	The commercial exploitation of fish & 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.	Selective extraction of species, … (e.g. by commercial and recreational fishing)
Biological pressures	Removal of non-target species	B6	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).	Selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing)