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Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities

Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes

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Summary

Human activities within the marine environment give rise to a number of pressures on seabed habitats. Improved understanding of the sensitivity of subtidal sedimentary habitats is required to underpin the management advice provided for Marine Protected Areas, as well as supporting other UK marine monitoring and assessment work. The sensitivity of marine sedimentary habitats to a range of pressures induced by human activities has previously been systematically assessed using approaches based on expert judgement for Defra Project MB0102 (Tillin *et al* 2010). This previous work assessed sensitivity at the level of the broadscale habitat and therefore the scores were typically expressed as a range due to underlying variation in the sensitivity of the constituent biotopes.

The objective of this project was to reduce the uncertainty around identifying the sensitivity of selected subtidal sedimentary habitats by assessing sensitivity, at a finer scale and incorporating information on the biological assemblage, for 33 Level 5 circalittoral and offshore biotopes taken from the Marine Habitat Classification of Britain and Ireland (Connor *et al* 2004). Two Level 6 sub-biotopes were also included in this project as these contain distinctive characterising species that differentiate them from the Level 5 parent biotope. Littoral, infralittoral, reduced and variable salinity sedimentary habitats were excluded from this project as the scope was set for assessment of circalittoral and offshore sedimentary communities.

This project consisted of three Phases.

- Phase 1 - define ecological groups based on similarities in the sensitivity of characterising species from the Level 5 and two Level 6 biotopes described above.
- Phase 2 - produce a literature review of information on the resilience and resistance of characterising species of the ecological groups to pressures associated with activities in the marine environment.
- Phase 3 - to produce sensitivity assessment 'proformas' based on the findings of Phase 2 for each ecological group.

This report outlines results of Phase 2.

The Tillin *et al* (2010) sensitivity assessment methodology was modified to use the best available scientific evidence that could be collated within the project timescale. An extensive literature review was compiled, for peer reviewed and grey literature, to examine current understanding about the effects of pressures from human activities on circalittoral and offshore sedimentary communities in UK continental shelf waters, together with information on factors that contribute to resilience (recovery) of marine species. This review formed the basis of an assessment of the sensitivity of the 16 ecological groups identified in Phase 1 of the project (Tillin & Tyler-Walters 2014).

As a result:

- the state of knowledge on the effects of each pressure on circalittoral and offshore benthos was reviewed;
- the resistance, resilience and, hence, sensitivity of sixteen ecological groups, representing 96 characteristic species, were assessed for eight separate pressures;
- each assessment was accompanied by a detailed review of the relevant evidence;

- knowledge gaps and sources of uncertainty were identified for each group;
- each assessment was accompanied by an assessment of the quality of the evidence, its applicability to the assessment and the degree of concordance (agreement) between the evidence, to highlight sources of uncertainty as an assessment of the overall confidence in the sensitivity assessment, and finally
- limitations in the methodology and the application of sensitivity assessments were outlined.

This process demonstrated that the ecological groups identified in Phase 1 (Tillin & Tyler-Walters 2014) were viable groups for sensitivity assessment, and could be used to represent the 33 circalittoral and offshore sediments biotopes identified at the beginning of the project.

The results of the sensitivity assessments show:

- the majority of species and hence ecological groups in sedimentary habitats are sensitive to physical change, especially loss of habitat and sediment extraction, and change in sediment type;
- most sedimentary species are sensitive to physical damage, e.g. abrasion and penetration, although deep burrowing species (e.g. the Dublin Bay prawn - *Nephrops norvegicus* and the sea cucumber - *Neopentadactyla mixta)* are able to avoid damaging effects to varying degrees, depending on the depth of penetration and time of year;
- changes in hydrography (wave climate, tidal streams and currents) can significantly affect sedimentary communities, depending on whether they are dominated by deposit, infaunal feeders or suspension feeders, and dependant on the nature of the sediment, which is itself modified by hydrography and depth;
- sedentary species and ecological groups that dominate the top-layer of the sediment (either shallow burrowing or epifaunal) remain the most sensitive to physical damage;
- mobile species (e.g. interstitial and burrowing amphipods, and perhaps cumaceans) are the least sensitive to physical change or damage, and hydrological change as they are already adapted to unstable, mobile substrata;
- sensitivity to changes in organic enrichment and hence oxygen levels, is variable between species and ecological groups, depending on the exact habitat preferences of the species in question, although most species have at least a medium sensitivity to acute deoxygenation;
- there is considerable evidence on the effects of bottom-contact fishing practices and aggregate dredging on sedimentary communities, although not all evidence is directly applicable to every ecological group;
- there is lack of detailed information on the physiological tolerances (e.g. to oxygenation, salinity, and temperature), habitat preferences, life history and population dynamics of many species, so that inferences has been made from related species, families, or even the same phylum;
- there was inadequate evidence to assess the effects of non-indigenous species on most ecological groups, and

- there was inadequate evidence to assess the effects of electromagnetic fields and litter on any ecological group.

The resultant report provides an up-to-date review of current knowledge about the effects of pressures resulting from human activities of circalittoral and offshore sedimentary communities. It provides an evidence base to facilitate and support the provision of management advice for Marine Protected Areas, development of UK marine monitoring and assessment, and conservation advice to offshore marine industries.

However, such a review will require at least annual updates to take advantage of new evidence and new research as it becomes available. Also further work is required to test how ecological group assessments are best combined in practice to advise on the sensitivity of a range of sedimentary biotopes, including the 33 that were originally examined.

Contents

1 Introduction

The Joint Nature Conservation Committee (JNCC) commissioned this project to generate an improved understanding of the sensitivities of circalittoral and offshore biotopes found in UK waters to pressures associated with human activities in the marine environment. This work will provide an evidence base that will facilitate and support the provision of management advice for Marine Protected Areas, development of UK marine monitoring and assessment, and conservation advice to offshore marine industries.

The sensitivity of marine sedimentary habitats to a range of pressures induced by human activities has previously been systematically assessed using approaches based on expert judgement for Defra Project MB0102 (Tillin *et al* 2010). This previous work assessed sensitivity at the level of the broadscale habitat and therefore the scores were typically expressed as a range due to underlying variation in the sensitivity of the constituent biotopes.

JNCC commissioned this project to reduce the uncertainty around identifying the sensitivity of selected subtidal sedimentary habitats by assessing sensitivity, at a finer scale and incorporating information on the biological assemblage, for 33 Level 5 circalittoral and offshore biotopes taken from the Marine Habitat Classification of Britain and Ireland (Connor *et al* 2004). Two Level 6 sub-biotopes were also included in this project as these contain distinctive characterising species that differentiate them from the Level 5 parent biotope. Littoral, infralittoral, reduced and variable salinity sedimentary habitats were excluded from this project as the scope was set for assessment of circalittoral and offshore sedimentary communities.

This project consists of three phases.

- Phase 1 - to define ecological groups based on similarities in the sensitivity of characterising species from the Level 5 and two Level 6 biotopes described above.

- Phase 2 - (this report) to produce a literature review of information on the resilience and resistance of characterising species of the ecological groups to pressures associated with activities in the marine environment.

- Phase 3 - to produce sensitivity assessment proformas based on the findings of Phase 2 for each ecological group.

Basing sensitivity assessments on all the species recorded as present within the target biotopes was considered unworkable due to the number of assessments required and the lack of information available for many species. Phase 1 of this project (Tillin & Tyler-Walters 2014) therefore reduced the number of assessments required by identifying ‘ecological groups’ of species to represent the species assemblages present in the biotopes that the subsequent sensitivity assessments (i.e. those presented in this report) are based on. The intention was that the ecological groups should not be species specific but rather consist of groups of ecologically similar species e.g. fragile erect epifauna on cobbles and boulders. This approach was intended to reduce the number of sensitivity assessments required while retaining, within the sensitivity assessments, information on different elements of the biological assemblage.

Sixteen ecological groups were proposed to represent the 96 characterising species identified from the target biotopes (see Tillin & Tyler-Walters 2014). These ecological groups were largely based on trait and habitat analyses but expert judgement was also used to group species. The ecological groups were not based on pre- defined sensitivities but on a combination of shared characteristics that have been identified as influencing sensitivity to pressures. Species placed in ecological groups based on some shared similarities may differ from each other in terms of other traits that also influence sensitivity. Therefore, within each ecological group that comprises more than a single species, the sensitivity of 2-5 species is reviewed in this report (Section 4) in order to best represent the overall sensitivity of the group. As some species are better studied than others we have selected, where possible, species with a good evidence base that represent the range of biological traits or habitat preferences expressed by species within each ecological group.

2 Key Concepts and Methodology

This section briefly describes the concepts of sensitivity, resistance, resilience and pressures resulting from human activities in the context of this report.

2.1 Definition of Sensitivity, Resistance and Resilience

The concepts of resistance and resilience introduced by Holling (1973) are widely used to assess sensitivity (Table 2.1). The UK Review of Marine Nature Conservation (Defra 2004) defined sensitivity as ‘dependent on the intolerance of a species or habitat to damage from an external factor [pressure] and the time taken for its subsequent recovery’.

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

Table 2.1. Definition of sensitivity and associated terms.

Term	Definition	Sources
Sensitivity	A measure of susceptibility to changes in environmental conditions, disturbance or stress which incorporates both resistance and resilience (recovery).	Holt *et al* (1995), McLeod (1996), Tyler-Walters *et al* (2001), Zacharias & Gregr (2005)
Resistance (Intolerance/tolerance)	A measure of the degree to which an element can absorb disturbance or stress without changing in character.	Holling (1973)
Resilience (Recoverability)	The ability of a system to recover from disturbance or stress.	Holling (1973)
Pressure	The mechanism through which an activity has an effect on any part of the ecosystem. The nature of the pressure is determined by activity type, intensity and distribution.	Robinson *et al* (2008)

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

Sensitivity can, therefore, be understood as a measure of the likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience). The detailed definitions used in this study are given on Appendix 1.

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

2.2 Sensitivity Assessment methodology

Tillin *et al* (2010) developed a method to assess the sensitivity of certain marine features, considered to be of conservation interest, against physical, chemical and biological pressures resulting from human activities. The sensitivity assessments made by Tillin *et al* (2010) were based on expert judgement. Therefore the methodology used in this report was modified to include a review of available evidence, rather than expert judgement alone, as the basis for sensitivity assessment. The methodology, definitions and terms are summarised in Appendix 1. The sensitivity assessments are based on an extensive review of relevant literature. The literature review methodology and aims are outlined in Appendix 2.

The sensitivity assessment method used (after Tillin *et al* 2010) involves the following stages, which are explained in Appendix 1.

A. Defining the key elements of the feature (addressed in Phase I; Tillin & Tyler-Walters 2014).
B. Assessing feature resistance (tolerance) to a defined intensity of pressure (the benchmark).
C. Assessing the resilience (recovery) of the feature to a defined intensity of pressure (the benchmark).
D. Combining resistance and resilience to derive an overall sensitivity score.
E. Assessing the level of confidence in the sensitivity assessment.
F. Providing a written audit trail.

The above steps ensure that the basis of the sensitivity assessment is transparent and repeatable and that the evidence base and justification for the sensitivity assessments is recorded. A complete and accurate account of the evidence used to make the assessments is presented for each sensitivity assessment in Section 4.

2.3 Human Activities and Pressures

A pressure is defined as ‘the mechanism through which an activity has an effect on any part of the ecosystem’ (Robinson *et al* 2008). Pressures can be physical (e.g. sub-surface abrasion), chemical (e.g. organic enrichment) or biological (e.g. introduction of non-native species).

An activity may give rise to more than one pressure. Therefore, rather than assessing the impact of activities as a single impact, the pressure-based approach supports clearer identification of the pathway(s) through which impacts on a feature may arise from the activity. Conversely, the same pressure can also be caused by a number of different activities. To be meaningful and consistent sensitivity to a pressure should be measured against a defined pressure benchmark.

Pressure definitions and an associated benchmark were supplied by JNCC for each of the pressures that were to be assessed (Appendix 2). The pressures JNCC supplied were a modified version of the Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR 2011). The ICG-C list contained a list of pressure definitions, but not benchmarks; as it was developed after the MB0102 project Tillin *et al* (2010). MB0102 has very similar pressures to the ICG-C list and therefore JNCC have taken the benchmarks from MB0102 and applied to the ICG-C list of pressures. The pressure themes and pressures assessed in this project are shown below in **Table 2.2**. A number of ICG-C pressures were scoped out of this contract.

Table 2.2. Pressure themes and related pressures assessed.

Pressure theme	ICG-C[2] Pressure
Hydrological changes	Salinity changes - local; Temperature changes - local; Water flow (tidal current) changes - local; Wave exposure changes - local
Pollution and other chemical changes	Organic enrichment
Physical loss (permanent change)	Physical change (to another seabed type)
Physical damage (reversible change)	Abrasion/disturbance of the substratum on the surface of the seabed; Penetration and/or disturbance of the substratum below the surface of the seabed; Changes in suspended solids (water clarity); Removal of substratum (extraction); Siltation rate changes, including smothering; Physical change (to another seabed type)
Biological pressures	Introduction or spread of non-indigenous species (NIS); Removal of non-target species; Removal of target species

[2] ICG-C (Intercessional Correspondence Group on Cumulative Effects)

3 Pressure review

3.1 Pressures with well-developed evidence base

3.1.1 Physical damage (reversible change)

I. Abrasion/disturbance of the substratum on the surface of the seabed

ICG-C Pressure description
The disturbance of sediments where there is limited or no loss of substratum from the system.

Benchmark
Damage to seabed surface features.

Description
Abrasion results in direct disturbance of the seabed and can lead to physical damage of organisms that are exposed to the impact. This pressure concerns abrasion at the surface only and deeply buried animals would avoid this pressure. Damage that leads to sub-surface disturbance is reviewed under the pressure 'penetration and/or disturbance of the substrate below the surface of the seabed'. The effects of abrasion at the surface and sub-surface damage from many fishing activities are difficult to separate and the combined effects of these activities are reviewed under the pressure 'penetration and/or disturbance of the seabed' (section 3.1.1.II).

Evidence for the effects of surface abrasion on subtidal habitats is poorly studied compared to penetration and disturbance of the sub-surface of the seabed. This is considered due to the lack of impacting activities which lead to surface abrasion alone and the difficulties inherent in studying this impact for subtidal habitats.

The sensitivity assessments for the abrasion pressure consider the likely direct, physical impact on individuals that are exposed to this pressure. Abrasion of the seabed may result in resuspension of fine sediments in muddy habitats, this indirect effect is reviewed under the changes in suspended solids (section 3.2.2.XII) and the siltation pressures' (section 3.1.1.III).

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

ICG-C Pressure description
The disturbance of sediments where there is limited or no loss of substratum from the system. Abrasion of the surface alone is considered specifically in a separate section (3.1.1.I). This section considers the impacts of sub-surface penetration and disturbance and abrasion of the surface of the seabed.

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

Description
The evidence base for substratum disturbance is most developed for fishing activities using towed gears in contact with the sediment. This is the most widespread human activity leading to this pressure. The main effect of sub-surface penetration and disturbance is the direct impact on organisms leading to damage or mortality. Sub-surface disturbance can also directly physically impact species by disturbing the sediment or displacing cobbles and other hard surfaces that individuals may be attached too. The effects of aggregate extraction

have also been well studied in UK shelf areas but this activity is considered specifically through the pressure 'Habitat structure changes - removal of substratum (extraction)'.

Substratum penetration and disturbance will directly impact organisms and may lead to damage that can be repaired or the contact may be lethal. Organisms, particularly small ones, may be moved within the sediment or pushed onto the surface either through direct contact or through movements of sediments, overturning of cobbles etc. Sub-surface damage operating over large spatial areas has the potential to directly alter the composition of the species assemblage and community structure (Kenchington *et al* 2007). Higher levels of sub-surface damage favour opportunistic, scavenging species (Blanchard *et al* 2004; Gaspar *et al* 2009) and robust, mobile and smaller species at the expense of large, fragile and slow-moving species (Bradshaw *et al* 2002). These changes may result in indirect effects on the species assemblage through changed trophic interactions and changes in resource availability such as increases in space for colonisation by opportunists, decreased provision of nursery and refugia through the loss of larger, structure forming species etc.

The sensitivity of species to sub-surface abrasion is influenced by a number of biological traits. Size influenced the degree of damage suffered by by-catch caught in otter trawl hauls from the Clyde Sea *Nephrops* fishery grounds but the results were not consistent between species groups (Bergman *et al* 2001). Larger starfish and brittle stars suffered more damage than smaller individuals presumed to be due to the potential for damage over a larger body surface. Conversely, smaller *Buccinum undatum* and *Liocarcinus holsatus* suffered more damage, as these were thinner shelled and therefore less protected than larger individuals (Bergman *et al* 2001). Smaller species are generally less directly impacted (Bergman & van Santbrink 2000b) as trawls and other sources of sub-surface abrasion mainly impact smaller species through sediment disturbance- with an effect similar to storms and other natural disturbances to which these species are adapted. Species adapted to more mobile sediments would therefore be expected to have higher resistance and higher resilience to abrasion and sub-surface damage while those found in more stable sediments will be more sensitive. Larger species are exposed to direct physical impact of the gear due to their greater body surface. The impact is not comparable to natural disturbances. Habitat preferences will not influence sensitivity but may mediate impact factors such as the depth of penetration of the gears.

For some ecological groups the effects of abrasion and sub-surface damage will be mediated by behaviour patterns that alter exposure (vulnerability) to the pressure. Such activity may be related to reproductive cycles. *Neptunea antiqua*, for example, when buried in sediments is relatively protected from this pressure, and is more vulnerable when forming breeding aggregations and laying eggs on hard surfaces. *Echinocardium cordatum* also experiences different levels of exposure seasonally; animals that have migrated closer to the sediment surface during the reproductive phases are more likely to suffer damage than deeper buried individuals. Behaviours that influence vulnerability may also change during different parts of the day, e.g. *Nephrops norvegicus* emerge from burrows at certain times of the day and are more vulnerable to being caught when on the surface. Similarly many cumaceans exhibit daily patterns of behaviours, swimming out of the sediments at night and burrowing into sediments in the day.

In summary, abrasion and sub-surface damage can directly affect sedimentary habitats through impacts on the habitat substratum, particularly reduction of surface topography and habitat complexity (Gilkinson *et al* 2003; Nilsson & Rosenberg 2003). The direct physical impacts of this pressure on the ecological groups are considered in the sensitivity assessment. Sediment disturbance may also lead to the re-suspension of solids (see changes in suspended solids) and subsequent deposition which can result in changes to the substratum type (sections 3.2.2.XII and 3.2.3.XIV). These indirect effects are not considered in the sensitivity assessments for this pressure which focus on the evidence for damage and mortality within the spatial footprint of the impacting activity.

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

ICG-C Pressure description
When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. 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 be assessed through the physical change pressures.

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

Description
Siltation resulting from human activities occurs at the pressure benchmark when large amounts of material are placed on the seabed as in the disposal of capital and maintenance dredging. The disposal of sewage sludge may also result in thick deposits on the seabed. Aggregate dredging accompanied by screening (the process of discharging unwanted grades of sediment) may also lead to the deposition of sediment layers although this is unlikely to reach the benchmark level. Some siltation may also result from activities that lead to abrasion or disturbance of the seabed and consequent re-suspension of sediments that are transported and re-deposited. The activities will typically result in deposits much thinner than the pressure benchmark. Deposition of suspended sediments has two impacts on the seabed. Animals living in or on the seabed can be immediately smothered and buried, while the habitat change alters the character of the associated benthic assemblage (considered under the pressure 'Physical change').

Most benthic organisms live in the top 10cm of the seabed and must maintain some connection to the sediment-water interface for ventilation and feeding (Miller *et al* 2002). Organisms have various capabilities for moving upward through newly deposited sediments, such as dredged material, to reoccupy positions relative to the sediment-water interface that are similar to those maintained prior to burial by the disposal activity. The level of effect is system specific as natural adaptations can determine sensitivity to smothering effects. The depth of siltation at the benchmark level is relatively high. Many species are adapted to re-surface from thin deposits but 30cm is a substantial deposit. The depth of sediment overburden that benthic biota can tolerate is both trophic group and particle size/sediment type dependant (Bolam *et al* 2010).

In high energy systems, the effects are relatively small as many of the species are capable of migrating up through the deposited sediments (Bijkerk 1988 cited in Essink 1999; Wilber *et al* 2007) as they are adapted to natural, high levels of background erosion and deposition. Relocation/disposal in high energy systems like tidal estuaries or coasts has less effect than relocation/disposal in low energy systems, for example lagoons. The effects are also mediated by the thickness of deposition and the intensity and frequency of deposition events, slower addition of thin layers has been shown to be better tolerated than the same thickness of sediment deposited in a single event. An analysis of data from 18 disposal sites (intertidal and subtidal), confirmed that long-term impacts were disposal site specific and varied according to the prevailing hydrodynamic regime, ecological condition and the disposal activity (mode, timing, quantity, frequency and type of material) (Bolam *et al* 2006). This variability means that it is difficult to predict generalised impacts (Bolam *et al* 2006).

Dredging may contain contaminants although levels will be monitored as part of licensing stages. This effect is not considered in this review. Similarly, sediments removed by dredging may be anoxic and this effect is also not considered within this section.

This literature review sought evidence for the sensitivity of each of the ecological groups to initial burial and their capacity to reposition within sediments through vertical migration. The trajectories of long-term change in response to sedimentation are community level responses and are site and habitat specific referring to recovery through lateral adult migration and particularly larval supply rather than resistance.

After the initial mortality that occurs immediately following deposition of sediments, initial recolonisation of the newly deposited dredged material begins via migration from surrounding areas (Richardson *et al* 1977; McLusky 1983), larval recruitment, and vertical migration (Maurer *et al* 1978; Maurer *et al* 1981b, 1981a, 1982). The first organisms to recolonise dredged material usually are not the same as those that originally occupied the site. They consist of opportunistic species whose environmental requirements are flexible enough to allow them to occupy the disturbed areas. Trends toward re-establishment of the original community are often noted within a year or two (Blanchard & Feder 2003). The general recolonisation pattern is often dependent upon the nature of the adjacent undisturbed community, which provides a pool of replacement organisms capable of recolonising the site by adult migration, passive advection, or larval recruitment.

Defaunation and mortality due to dredge material disposal was addressed by Maurer and his co-workers in laboratory deposition experiments on Delaware Bay benthos (Maurer *et al* 1978, 1981a, 1981b, 1982, 1985, 1986). Conclusions from these studies are summarised below:

- some degree of upward mobility and recolonisation of dredged material is expected from the vertical migration of buried organisms;

- vertical migration ability is greatest in dredged material similar to the existing substratum and is minimal in sediments of dissimilar particle-size distribution;

- benthic organisms with morphological and physiological adaptations for crawling through sediments are able to migrate vertically through several inches of overlying sediment;

- physiological status of the organism and environmental variables are of great importance to vertical migration ability;

- organisms of similar lifestyle and morphology react similarly when covered with an overburden, e.g. most surface-dwelling forms are generally killed if trapped under dredged material overburdens, while sub-surface dwellers migrate to varying degrees; and

- Cooper (2005) suggested that impacts would also be greater on animal assemblages in stable coarse sediments characterised by attached epifauna that cannot escape smothering, than finer sediments inhabited by burrowing infauna which are adapted to live in sandy sediments and cope with periodic natural disturbance.

Bijkerk (1988, cited in Essink 1999) compared results obtained at higher and lower temperatures (cf. summer and winter). At lower temperatures mortality among macrozoobenthos was lower and there was a higher tolerance of low oxygen conditions. The percentage of animals escaping from burial by crawling upward through the deposited sediment, however, was always lower at lower temperatures. These results are related to seasonal differences in metabolic activity.

The sensitivity assessments consider the immediate smothering effects resulting from the deposition of 30cm of overburden. The indirect effects of changes in suspended solids that accompany disposal and continue through resuspension of materials are assessed through changes in suspended solids (section 3.2.2.XII). Siltation may also change the character of the physical habitat where the disposed materials differ in character from the receiving environment (section 3.2.3.XIV).

3.1.2 Biological Pressures

IV. Introduction or spread of non-indigenous species (NIS)

ICG-C Pressure description
The direct or indirect introduction of non-indigenous species, e.g. Chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spreading and out-competing of native species.

Benchmark
A significant pathway exists for introduction of one or more invasive non-indigenous species (NIS) (e.g. aquaculture of NIS, untreated ballast water exchange, local port, terminal harbour or marina); creation of new colonisation space >1ha. One or more NIS has been recorded in the relevant habitat.

Description
The list of species considered was based on Marine Scotland's FEAST[3]. A number of non-indigenous species were not considered relevant to the ecological groups as their distribution does not overlap with the target biotopes. These include the Chinese mitten crab (*Eriocheir sinensis*), plants (cord grass *Spartina anglica* found in estuaries and on the upper parts of shores) and macroalgae (*Codium fragile* subsp. *tomentosoid*es, *Sargassum muticum* and *Undaria pinnatifida)*, which do not occur on subtidal sediments. The spionid *Marenzelleria viridis* and *Ficopomatus enigmaticus* are typically brackish water species and hence were also not considered relevant (Great British non-native species secretariat (GBNNSIP) register; Eno *et al* (1997)). *Styela clava* and *Corella eumyota* are also littoral to upper sublittoral species found down to 2m (Lützen 1998; Sewell *et al* 2008) with a preference for hard substrata; and were therefore not included in the review and assessments. *Botrylloides violaceus* is not considered to be present on fully open coasts (Sewell *et al* 2008). The

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[3] FEAST – Feature Activity Sensitivity Tool - http://www.scotland.gov.uk/Topics/marine/marine-environment/FEAST-Intro

Pacific oyster *Crassostrea gigas* can colonise upper sublittoral and littoral sediment, but suffers reduced recruitment and lower growth rates in the sublittoral than the littoral, and may even co-exist with mussels beds (its main competitor) in the upper sublittoral (Diederich 2005, 2006), so that its impacts are only likely to be significant in the littoral.

The invasive species that were reviewed include the ascidians *Perophora japonica* and *Didemnum vexillum*, the slipper limpet *Crepidula fornicata*, and the oyster drill *Urosalpinx cinerea*.

The sensitivity assessments are based on the evidence that non-indigenous species are affecting the ecological groups through competition or other pathways such as overgrowth and smothering.

V. Removal of target Species

ICG-C Pressure description
The commercial exploitation of fish and shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on sea bed communities are addressed by the 'abrasion' pressure (see 3.1.1.I), so this pressure addresses the direct removal / harvesting of biota. Ecological consequences include the sustainability of stocks of commercial species, impacting energy flows through food webs, changes to the abundance of seabed species that are food of target species and the size and age composition within fish stocks.

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

Description
The pressure reviews for this assessment identify whether the characterising species are either targeted by commercial fisheries, or whether the characterising species are dependent on any commercially targeted organisms. The assessment therefore identifies the effects of targeted removal on the ecological group that is being assessed through wider ecological dependencies and not the sensitivity of other species or species groups.

The sensitivity assessments for this pressure consider biological effects only (e.g. competition, predation, provision of biogenic habitats etc.) the direct physical effects resulting from physical removal are assessed through the abrasion and sub-surface penetration and disturbance pressures.

VI. Removal of non-target species

ICG-C Pressure description
By-catch associated with all fishing activities. The physical effects of fishing gear on sea bed communities are addressed by the 'abrasion' pressure type. The 'removal of non-target species' pressure addresses the direct removal of individuals associated with fishing/ harvesting. Ecological consequences include food web dependencies, population dynamics of fish, marine mammals, turtles and sea birds (including survival threats in extreme cases, e.g. harbour porpoise in Central and Eastern Baltic).

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

Description
The pressure reviews for this assessment identify whether species within the ecological group are dependent on any non-targeted organisms that may be removed by commercial fisheries. The assessment therefore identifies the effects of commercial fisheries on the ecological group that is being assessed, and the targeted removal of species outside of the ecological group which may through wider ecological dependencies effect the ecological group in question.

The sensitivity assessments for this pressure consider biological effects only (e.g. competition, predation, provision of biogenic habitats etc.) the direct physical effects resulting from physical removal are assessed through the abrasion and sub-surface penetration and disturbance pressures.

3.1.3 Pollution and other chemical changes

VII. Organic enrichment

ICG-C Pressure description
Resulting from the degraded remains of dead biota and microbiota (land and sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of: sewage material, domestic wastes, industrial wastes etc. Organic enrichment may lead to eutrophication. Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

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

Description
The impacts of this pressure will be altered by the magnitude and frequency of exposure. Adding 100gC in a single event may also lead to siltation impacts whereas chronic addition of smaller amounts may be readily absorbed by the habitat.

The response of benthic invertebrate communities to increasing inputs of organic material has been characterised by Pearson and Rosenberg (1978). There are two distinct phases in the response often referred to as organic enrichment and organic pollution.

Organic enrichment encourages the productivity of suspension and deposit feeding detritivores and allows other species to colonise the affected area to take advantage of the enhanced food supply. The benthic invertebrate community response is characterised by increasing numbers of species, total number of individuals and total biomass.

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

It was not clear how the pressure benchmark may compare to natural levels of sedimentation and thresholds for effect. Therefore, evidence was sought on background levels of organic carbon input in the environment and any potential effect thresholds identified directly from habitat exposed to this pressure or experimentally.

The Marine Ecosystems Research Laboratory studied the fate and effects of sewage solids added to mesocosms. Organic loading rates less than 36gC m^2/yr had little effect, rates between 36 and 365gC m^2/yr enriched the sediment community, and a loading over 548gC m^2/yr produced degraded conditions (Kelly & Nixon 1984; Frithsen *et al* 1987; Oviatt *et al* 1987; Maughan & Oviatt 1993, cited from Cromey *et al* 1998).

Eleftheriou *et al* (1982) showed that the addition of 767gC m^2/yr to an unpolluted sea loch enriched the sediment dwelling fauna whereas addition of 1498gC m^2/yr caused degraded conditions. These values are higher than the mesocosm values as it is likely that more organic matter was lost in the open water system.

Observations and applications of a depositional, particle tracking model called DEPOMOD around salmon farms in Scotland and British Columbia have also shown that proportions of benthic fauna feeding groups based on the infaunal trophic index (ITI) changed significantly when organic sedimentation rates increased above specific thresholds (Cromey *et al* 2002; Chamberlain & Stucchi 2007). ITI values >50 (which correspond to little effect) were associated with predicted organic carbon fluxes <1gC m^2/day (i.e. 365 gC m^2/yr) but ITI values decreased rapidly (<30, corresponding to an enriched community) as fluxes increased from 1 to 10gC m^2 /yr (i.e. 365-3650gC m^2/yr). The impact of adding organic matter will depend on the state of enrichment or pollution of the receiving environment and whether the additional loading leads to a tipping point. The results reported in Cromey *et al* (2002) and Eletheriou *et al* (1982) suggest that the addition of organic matter at the pressure benchmark may lead to slight enrichment effects, rather than gross organic pollution. For some ecological groups the AZTI Marine Biotic Index (AMBI) classification of disturbance effects, developed by Borja *et al* (2000) has been used as the basis for the assessment. There was greater confidence in assigning assessments of sensitivity for species that were indicated to be tolerant of organic enrichment. However, as the evidence underlying the assessment is not clear, there was less confidence in suggesting that the species indicated to be intolerant to organic enrichment according to the AMBI index would be sensitive at the pressure benchmark.

The sensitivity assessments for this pressure are based on evidence for organic enrichment tolerance of the ecological group. Increased organic matter inputs may also be accompanied by changes in suspended solids (see above 3.2.2.XII) and increases siltation (see above 3.1.1.III).

3.2 Pressures for which assessments are based on inferences from species traits, ecology and/or distribution

3.2.1 Hydrological changes, inshore/local

The hydrological pressures relate to environmental changes which impact populations by altering habitat suitability. Where direct evidence was not available these assessments were largely based on habitat distribution records as proxies to indicate the potential range of tolerance. The sensitivity assessment methodology (Tillin *et al* 2010) bases the assessment on a theoretical population of the species in the middle of its environmental range. As Holt *et al* (1995) have pointed out, organisms near the limits of their range are more sensitive to change, so that sensitivity assessments should concentrate on sensitivities of populations in 'mid-range' or typical habitats.

VIII. Salinity changes - local

ICG-C Pressure description
Events or activities increasing or decreasing local salinity. This relates to anthropogenic sources/causes that have the potential to be controlled, e.g. freshwater discharges from

pipelines that reduce salinity, or brine discharges from salt caverns washings that may increase salinity. This could also include hydromorphological modification, e.g. capital navigation dredging if this alters the halocline or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates. The pressure may be temporally and spatially delineated derived from the causal event/activity and local environment.

Benchmark
Increase from 35 to 38 units[4] for one year. Decrease in salinity by 4-10 units a year.

Description
Hypersaline conditions may form naturally in lagoons and other enclosed bodies with minimum water exchange where evaporation leads to an increasing concentration of salts. Some organisms including brine shrimps *Artemia* spp. and brine algae *Dunaliella* are adapted to these conditions. Desalination plants may also discharge brine waters into the marine environment with potentially damaging impacts on marine organisms. The salinity of the concentrate is largely a function of the plant recovery rate, which in turn depends on the salinity of the source water and the process configuration. Increased salinity from human activities is unlikely to impact circalittoral offshore sediments. The lack of exposure to this pressure also accounts for the lack of evidence for impacts for most species.

Decreased salinity can occur due to urban or storm runoff (especially in enclosed water bodies such as harbours, sea lochs and embayments). However, no evidence applicable to offshore or circalittoral communities was found, within the project timescale.

IX. Temperature changes - local

ICG-C Pressure description
Events or activities increasing or decreasing local water temperature. This is most likely from thermal discharges, e.g. the release of cooling waters from power stations. This could also relate to temperature changes in the vicinity of operational 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 change in temp for one month period, or 2°C for one year.

Description
This assessment is largely based on habitat distribution records supplemented by some activity specific information. Drawing inferences from distribution has some limitations as local populations are acclimated to the prevailing thermal regime and would be sensitive if exposed to temperatures experienced by populations in other parts of the global range.

Species are often categorised as eurythermal (wide range) or stenothermal (narrow range). The assessments presented are based on a change in temperature experienced by species at the middle of their range. Changes in temperature experienced by individuals that are close to the extreme high or low temperature range would lead to greater impacts. The main anthropogenic activity giving rise to this pressure is the discharge of heated effluents from power station, therefore the ‘change’ referred to in the sensitivity assessments is generally

[4] Salinity is a dimensionless quantity and is described in terms of ‘units’. In the past it has been described as practical salinity units (psu), units on the practical salinity scale (pps) or parts per thousand (ppt), and occasionally other units, e.g. chlorinity. As these units may not all by equivalent to each other, the units used in the original source text are quoted in the evidence given.

considered to be an increase in temperature (unless otherwise indicated). Exposure of circalittoral habitats to this pressure is limited and hence there is little empirical data to assess sensitivity to this pressure. The assessments are therefore based on distribution records as a proxy for resistance to temperature changes, species found at higher and lower latitudes to the UK are considered to be insensitive to a change (either increase or decrease). Where species have a northern distribution and populations reach their southern limit within the UK waters this is highlighted as a probable indicator of sensitivity to increased temperature.

X. Water flow (tidal current) changes - local

ICG-C Pressure description
Changes in water movement associated with tidal streams (the rise and fall of the tide, riverine flows), prevailing winds and ocean currents. The pressure is therefore associated with activities that have the potential to modify hydrological energy flows, e.g. tidal energy generation devices remove (convert) energy and such pressures could be manifested leeward of the device, capital dredging may deepen and widen a channel and therefore decrease the water flow, canalisation and/or structures may alter flow speed and direction; managed realignment (e.g. Wallasea, England). 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 tide flow speed of between 0.1m/s to 0.2m/s over an area >1km^2 or 50% if width of water body for more than 1 year.

Description
Changes in peak mean spring tide flow speed at the pressure benchmark may refer to an increase or decrease. The hydrodynamic regime, including flow rates, is an important factor determining the type of sediment present and mediates the supply and removal of organic and inorganic materials.

As a proxy indicator of resistance, evidence from the MNCR database for water flow categories experienced by the biotopes characterised by members of this ecological group was used. The categories were based on Hiscock (1996). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. However, it should be noted that a) not all biotopes were recorded with full habitat/site information, and b) the extraction only recorded the habitat conditions where the biotope was recorded and not the relevant species presence, abundance or biomass within each site. Therefore, this information represents the range of habitat conditions in which the biotopes can be found rather than identifying optimum habitats for species. This caveat applies to all assessments made using this data.

Changes in water flow have the potential to alter sediment composition. Fine sediments may be re-suspended and removed following increases in flow, while decreased flow may result in enhanced deposition (see siltation 3.1.1.III). Changes in sediment character are described in the physical changes to another seabed type pressure (see 3.2.3 XIV).

XI. Wave exposure changes - local

ICG-C Pressure description

Local changes in wave length, height and frequency. Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of winds. Exposure to wave action includes to swell waves which are generated away from the area affected and can have a very significant effect especially where the coast faces large expanses of sea. 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 nearshore significant wave height >3% but <5%.

Description

Changes in significant wave height at the pressure benchmark (change in height >3% but <5%) may reflect increases or decreases. Subtidal populations are not exposed to breaking waves but where the habitats these occur within the wave base they may be exposed to oscillatory water movements.

The evidence base for impacts of changes in wave height on subtidal populations is limited. As a proxy indicator of resistance, evidence from the MNCR database for the wave exposure categories experienced by biotopes characterised by members of this ecological group was used. These categories take account of the aspect of the coast (related to direction of prevailing or strong winds), the fetch (distance to nearest land), its openness (the degree of open water offshore) and its profile (the depth profile of water adjacent to the coast). The degree of wave exposure is understood to mediate wave heights experienced by the biotope due to differences in fetch (with shorter fetch associated with smaller wave heights), exposure to prevailing winds which reflects the energy of the wave (with exposure positively correlated with wave height) and factors such as the presence of deep water and offshore obstructions. The categories were based on Hiscock (1996).

- Extremely exposed - this category is for the few open coastlines which face into prevailing wind and receive oceanic swell without any offshore breaks (such as islands or shallows) for several thousand km and where deep water is close to the shore (50m depth contour within about 300m, e.g. Rockall).

- Very exposed - these are open coasts which face into prevailing winds and receive oceanic swell without any offshore breaks (such as islands or shallows) for several hundred km but where deep water is not close (>300m) to the shore. They can be adjacent to extremely exposed sites but face away from prevailing winds (where swell and wave action will refract towards these shores) or where, although facing away from prevailing winds, strong winds and swell often occur (for instance, the east coast of Fair Isle).

- Exposed - at these sites, prevailing wind is onshore although there is a degree of shelter because of extensive shallow areas offshore, offshore obstructions, a restricted (<90^{o}) window to open water. These sites will not generally be exposed to strong or regular swell. This can also include open coasts facing away from prevailing winds but where strong winds with a long fetch are frequent.

- Moderately exposed - these sites generally include open coasts facing away from prevailing winds and without a long fetch but where strong winds can be frequent.

- Sheltered - at these sites, there is a restricted fetch and/or open water window. Coasts can face prevailing winds but with a short fetch (say <20km) or extensive shallow areas offshore or may face away from prevailing winds.

- Very sheltered - these sites are unlikely to have a fetch greater than 20km (the exception being through a narrow (<30°) open water window, they face away from prevailing winds or have obstructions, such as reefs, offshore.

- Extremely sheltered - these sites are fully enclosed with fetch no greater than about 3km.

- Ultra sheltered - sites with fetch of a few tens or at most 100s of metres.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. However, it should be noted that a) not all biotopes were recorded with full habitat/site information, and b) the extraction only recorded the habitat conditions where the biotope was recorded and not the relevant species presence, abundance or biomass within each site. Therefore, this information represents the range of habitat conditions in which the biotopes can be found rather than identifying optimum habitats for species. This caveat applies to all assessments made using this data.

3.2.2 Physical Damage (reversible pressures)

XII. Changes in suspended solids (water clarity)

ICG-C 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 turbid for one year (**Table 3.1**).

Table 3.1. Water turbidity ranks (UKTAG 2014) based on mean concentration of suspended particulate matter mg/l.

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

Description
None of the ecological groups within this study are dependent on light penetration for photosynthesis although a pathway for impact exists for groups that feed on photosynthetic organisms such as phytoplankton and diatoms.

The main, relevant, environmental effects of increased turbidity levels from fishing and aquaculture operations are a reduction in penetration of light into the water column, suspended-sediment impacts on filter-feeding organisms and fish and increased deposition of particulates in low-energy environments. For most benthic deposit feeders, food is suggested to be a limiting factor for populations (Levinton 1979). Consequently, an increase in suspended particulates and subsequent increased deposition of organic matter in sheltered environments where sediments have high mud content will increase food resources to deposit feeders. This may lead to a shift in community structure with increased abundance of deposit feeders and a lower proportion of suspension feeders (as feeding is inhibited where suspended particulates are high and the sediment is destabilized by the activities of deposit feeders (Rhoads & Young 1970).

Fishing can directly alter the physical habitat by influencing re-suspension regimes (Thrush & Dayton 2002). For example, (Palanques *et al* 2001) showed that intense and continued trawling on muddy sediment had a noticeable effect on water turbidity with the average turbidity in the water column increasing by a factor of up to three, four to five days after trawling. Suspended sediment concentrations will be worse and last longer where the substratum has a high proportion of silt and clay and less, where sand concentrations are higher. Trawling can create suspended sediment plumes up to 10m above the bottom (Churchill 1989, cited in Clarke *et al* 2000). Shrimp trawlers in Texas have increased suspended sediment concentrations to between 100 and 550mg/l at 2m above the bottom and 100m astern of trawls (Schubel *et al* 1978, cited in Clarke *et al* 2000). The duration of sediment plumes resulting from hydraulic escalator dredging on water quality and benthic infauna were examined in an intertidal, mud flat habitat (<94% silt/clay before harvest) in Maine (Kyte *et al* 1975, summarised in Johnson 2002). Samples taken prior to, during, and ten months after dredging showed that turbidity plumes only lasted for a short time and often did not reach ambient seston (suspended particulate matter) levels. Although these effects would change water clarity at the pressure benchmark the duration would not match the benchmark unless the area was repeatedly trawled.

The pressure benchmark may also refer to a decrease in suspended solids. An example of biological control of suspended seston is demonstrated by bivalves which remove phytoplankton, bacteria and resuspended sediment and flocculated detrital particles from the water column when feeding. This bottom-up control of particulate matter may be beneficial in preventing eutrophication in estuaries where anthropogenic sources of dissolved nutrients stimulate phytoplankton production (Crawford 2003; Newell 2004). On a wider scale, at high levels of cultivation in enclosed areas, the removal of seston may lead to decreased deposition altering habitat sediment characteristics and the associated biological assemblage. Deposit feeders and tube builders rely on siltation of suspended sediment. A decrease in suspended sediment will reduce this supply and therefore may compromise growth and reproduction. Buchanan and Moore (1986) found that a decline in quantities of organic matter changed the infauna of a deposit feeding community which is essentially food limited. Decreases in suspended sediment/turbidity, may also enhance local rates of primary production enhancing food supply to deposit feeders.

Decreases in turbidity and impacts will be modified by a number of variables including the density of cultivated bivalves and natural populations, circulation patterns and water residence times, current speed and mixing processes. Particle depletion by wild and introduced shellfish populations is believed to be greatest in estuaries and inlets where water residence time is long and shellfish biomass is high (e.g. Dame 2011). In such areas, water depleted of particles by the cultured shellfish cannot be completely renewed by tidal exchange. These effects will be less relevant to subtidal populations in well-mixed or offshore areas.

The sensitivity assessments for this pressure assess the impact of increased or decreased levels of suspended solids in the water column. Indirect effects such as scour and increased sediment deposition are not assessed. Limited information was found of direct relevance to the pressure benchmark in the time available.

XIII. Habitat structure changes - removal of substratum (extraction)

ICG-C Pressure description
Unlike the "physical change" pressure type where there is a permanent change in sea bed type (e.g. sand to gravel, sediment to a hard artificial substratum) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonise; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.

Benchmark
Extraction of sediment to 30cm.

Description
The direct impact of sediment extraction on the benthic assemblage will be the removal of benthic organisms reducing the structure (abundance, biomass and diversity) of that habitat. Few benthic invertebrates are able to escape entrainment from aggregate dredging and research shows that under the path of an aggregate extraction draghead there is a 30-70% reduction in species diversity, a 40-95% reduction in the number of individuals and a similar reduction in biomass of benthic communities (Newell *et al* 1998). Some individuals may survive entrainment and be returned to the sea in the outwash or during screening although heavily shelled species such as bivalves, snails and crabs are more likely to be retained within the hopper and therefore would be lost with the cargo. The proportion of individuals that escape and their survival rates are not known, although evidence from the fishing industry has found that removal in fishing gears (as by-catch) leads to high mortality rates (Bergman & van Santbrink 2000a, 2000b). It is likely that high levels of fatal damage are suffered and this conclusion is supported by the fact that sediment plumes are rich in organic matter, most likely from fragments of dead or dying invertebrates (Newell *et al* 1998).

Exposure to removal may also vary according to other factors such as seasonality. For example, over-wintering crabs typically exhibit low levels of activity during winter and, as such, would be unlikely to be able to avoid a dredger drag-head (Royal Haskoning 2005, cited from Tillin *et al* 2011).

Recovery of many benthic invertebrate populations will depend on new juvenile recruits settling at the location in the form of larvae rather than the migration of adults. The settlement of many benthic species larvae has been demonstrated to be influenced by chemical cues from the same species or prey species or biofilms (Pawlik 1992; Rodriguez *et al* 1993). By removing surficial deposits, the dredging process is likely to remove these cues inhibiting settlement rates within the dredging zone.

Recovery of the benthic assemblage tends to be more rapid in unstable dynamic environments such as shallow water mobile sands, typically ranging from a few months to between 2-4 years. Conversely in deep water stable gravels recovery of some long lived species can take up to 15 years (Bellew & Drabble 2004). Random processes such as larval supply and the establishment of settlement cues as well as biological interactions between species such as competition for resources and predation play a role so that recovery rates are somewhat unpredictable.

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, and lead to changes in the topography of the area (Dernie *et al* 2003). Any remaining species, given their new position at the sediment / water interface, may be exposed to conditions to which they are not suited, i.e. unfavourable conditions. Newell *et al* (1998) stated that removal of 0.5m depth of sediment is likely to eliminate benthos from the affected area. Some epifaunal and swimming species may be able to avoid this pressure. Recovery of the habitat by sediment infilling will depend on local factors including the mobility of sediments, sediment supply, hydrodynamics and the spatial scale of the area affected.

The assessments for this pressure assess the direct risk that species will be removed by extraction of the sediment to 30cm and are largely based on information on the position of the species within the habitat and potential for escape. This pressure may result in other pressures which are assessed separately; these include physical change to sediment type where the sediments uncovered are different to those removed or recovery results in a different sediment type through, for example, differences in flow regime or sediment supply (see physical change to another seabed type). Sediment disturbance may also lead to re-suspension of sediments (see changes in suspended solids) and subsequent sediment deposition (see siltation rate changes).

3.2.3 Physical loss (permanent change)

XIV. Physical change (to another seabed type)

ICG-C Pressure description
The permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including to artificial (e.g. concrete). This therefore involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type.

Benchmark
Change in one Folk class for two years.

Description
This pressure represents a change in habitat type rather than a loss of habitat through land reclamation or construction of sea walls *etc*. Any change in the environmental factors that define a habitat at a location will alter the suitability of that location for some species and increase it for others. The expected effect of habitat changes is therefore a change in the species assemblage present, with some species lost and some gained and with further indirect effects on the assemblage ramifying through these changes e.g. the presence of predators may reduce the abundance of prey species. The magnitude, duration and spatial extent of habitat alteration will determine the effects on individual species and the concomitant effects on the assemblage structure e.g. species richness, diversity and biomass.

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

Although grain size and sediment preferences are frequently reported for benthic species there is little direct evidence of how changes in sediments may impact species. As a proxy indicator for resistance the range of sediment types that the species are found, in based on MNCR substratum records, was used. Where species were found in a range of substratum types corresponding to the simplified sediment classes (Long 2006) then the species was considered more resistant.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. However, it should be noted that a) not all biotopes were recorded with full substratum information, and b) the data extraction can only identify the substratum where the biotope was recorded and not the relevant species presence, abundance or biomass within each site. Therefore, this information indicates the range of habitat conditions in which the biotopes are found rather than identifying optimal habitats for species.

The pressure assessment considers sensitivity to a change in sediment type. The pressure assessment does not consider sensitivity to the pathways by which this change may occur. Changes in sediment type may occur through penetration and disturbance of the sediment (see 3.1.1 (II) and siltation (see 3.1.1 (III)).

There are a number of pathways through which this change can occur and human induced habitat type changes in the marine habitat can be categorised in the following ways:

Pathway 1 sedimentary to hard substrata

Hard materials may be placed on the seabed to install infrastructure including marinas, oil rigs, renewable energy device platforms, barriers, artificial reefs for habitat rehabilitation or recreation, coastal defence, fisheries mitigation, or to protect coastal areas or infrastructure, e.g. sea walls and scour protection for rigs and cables *etc*. The initial effect or placement of materials would be the smothering of the surficial habitats present within the footprint. The new materials will then be colonised. Changes to a hard substratum benefit species that can utilise the new habitat. The addition of hard materials to sedimentary habitats represents a profound change in habitat type.

Ashley *et al* (2013) conducted a systematic and comprehensive review of literature to evaluate the potential impacts of offshore wind farms on seabed biological assemblages This review included artificial structures constructed of similar materials and found in the same environments as offshore wind farm (OWF), including marinas, seawalls, artificial reefs and oil rigs. Twenty four studies on the effects of substratum changes on benthic biomass and/or diversity were identified and these papers were sourced where possible. The study found that the material used determined the degree to which the community was similar to natural reefs. Complex concrete or boulder reefs evolved assemblages that were relatively similar to natural reefs but steel structures supported assemblages that were distinct from surrounding natural hard or soft substrata (Ashley *et al* 2013).

Pathway 2 change from coarser to finer sediments

Aggregate extraction has the immediate effect of making seabed sediments finer through preferential removal of coarser sediment fractions. However, over time water currents may remove (winnow) these sediments so that the seabed will become coarser again. The extent to which this occurs depends on the prevailing hydrographic regime. It should be noted that in many areas where dredging occurs, sediment is also typically subject to some degree of natural mobility, with sand bed forms moving across the seabed (Tillin *et al* 2011).

The construction barrages, breakwaters, causeways and other artificial structures that reduce water flow or wave exposure will change sediment dynamics and promote the settling of finer sediments. Structures that reflect wave energy (e.g. artificial reefs) could also promote the settling of fine sediment in the lee of the structure itself.

Changes in the fine fraction of sediments will alter habitat characteristics. Any increase or decrease in grain size, silt content *etc*. will affect species numbers/richness but these should return to normal levels if the disturbance is temporary (Elliott *et al* 1998). Changes in the fine sediment fraction could alter sediment re-suspension rates as finer, organic particles are more easily suspended. This may favour populations of sediment re-working species such as bioturbating deposit feeders over suspension feeders that require more stable sediments, leading to changes in dominance of different groups of organisms. Consequently, an increase in the deposition of fine particles and organic matter in sheltered environments where sediments have high mud content will increase food resources to deposit feeders. This may lead to a shift in community structure with increased abundance of deposit feeders and a lower proportion of suspension feeders (as feeding is inhibited where suspended particulates are high and the sediment is destabilised by the activities of deposit feeders (Rhoads & Young 1970).

Pathway 3 change from finer to coarser sediments

Changes in substratum composition may occur where dredged material being deposited at a disposal site may not match the existing substratum distribution. Several studies have discussed the potential impacts to the benthic communities from these substratum changes (Richardson *et al* 1977; Maurer *et al* 1986; Flemer *et al* 1997; Miller *et al* 2002; Blanchard & Feder 2003)

Fishing activities can directly alter the physical habitat by influencing sediment particle size (Thrush & Dayton 2002 and references therein). Towed demersal gears have been shown to alter the sedimentary characteristics of subtidal muddy sand/mud habitats by penetration of the sediment (Ball *et al* 2000a, 2000b). Sediment disturbance can lead to re-suspension of fine sediments which are removed by water currents resulting in coarser sediments.

Pathway 4 addition of biological materials (cultch, bivalve relaying)

The addition of biological materials to the seabed is not assessed as a component of this pressure but is a vector of habitat change. Examples include the addition of bivalve shells as cultch to improve larval settlement rates and the addition of seed to sediments to create bivalve beds for later harvesting.

3.3 Pressures with no evidence available to support assessments (not included)

3.3.1 Electromagnetic changes

ICG-C Pressure description

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).

Benchmark

Local electric field of 1V m-1. Local magnetic field of 10µT 0.75 ± 0.01 mT.

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

In general, sessile species or those with low mobility may not have evolved sensitive electro or magneto receptors and may be unaffected by changes in these fields in terms of navigation and prey location. However these fields may have some physiological effects and some life stages e.g. larvae may be more sensitive than adults. Deleterious effects of superhigh and low frequency electromagnetic radiation have been recorded for sea urchins (Shkuratov *et al* 1998; Ravera *et al* 2006). Ravera *et al* (2006) found that threshold for formation of anomalous embryos was about 0.75 ± 0.01mT – which is lower than the pressure benchmark. Other physiological effects in animals exposed to magnetic fields include the induction of heat shock proteins in mussels (Suchanek 1978) and altered limb regeneration rates in fiddler crab (Lee & Weis 1980).

The evidence to assess these effects against the pressure benchmark is very limited and the impact of this pressure could not be assessed, based on available evidence for any of the ecological groups.

4 Sensitivity of subtidal sedimentary habitats to pressures associated with activities

We describe the characteristics of each of the ecological groups identified through the Phase 1 report (Tillin & Tyler-Waters 2014) in the sections that follow, providing an overview of the life histories of each of the characterising species researched to glean information on resistance and resilience to each of the pressures listed in section 3 as a means to assess sensitivity.

4.1 Ecological Group 1a Sea pens (erect, large, longer-lived epifaunal species with some flexibility)

4.1.1 Definition and characteristics of group including characteristic species

Sea pens are colonial cnidarians (Class Anthozoa; Subclass Octocorallia). The sea pens differ from other octocorals in their adaptation to life on soft muddy or sand sediments. There are three sea pens found in shelf seas in the UK (*Virgularia mirabilis*, *Funiculina quadrangularis* and *Pennatula phosphorea*) (Hughes 1998a) (**Table 4.1**). Hughes (1998) noted that another sea pen (*Halipterus christii*) has been recorded from the deep waters of the North Sea but no current records were found, so this species is not considered further. The sensitivity of all three sea pen species is assessed within this ecological group. Although there are some differences between species that influence sensitivity, particularly size differences, the sea pens are otherwise structurally and functionally similar.

Table 4.1. List of biotopes in which ecological group 1a species occur as characterising species.

Level 5 biotopes represented	Characterising species assessed
SS.SMu.CSaMu.VirOphPmax	*Virgularia mirabilis*
SS.SMu.CFiMu.SpnMeg (SS.SMu.CFiMu.SpnMeg.Fun)	*Pennatula phosphorea* *Virgularia mirabilis* *Funiculina quadrangularis*
SS.SMu.OMu.MyrPo	*Pennatula phosphorea*

4.1.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or are having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. Direct effects of static or mobile gears that are targeting other species are assessed in under abrasion and penetration of the seabed pressures (section 4.1.4). No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be '**Not Sensitive'** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability is ‘Not assessed’ – based on expert judgement.
Concordance is ‘Not assessed’ – based on expert judgement.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

III. Removal of Non-Target Species

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. The only species known to be have an obligate relationship with sea pens is the brittlestar *Asteronyx loveni*, which is a benthic and epizoic species often found encircling the sea pens such as *F. quadrangularis*, and is therefore, liable to damage or loss if the sea pen in removed or damaged. However, *A. loveni* uses *F. quadrangularis* as a substratum to gain height above the seafloor to suspension feed, and does not feed on the sea pen itself (Pedrotti 1993).

No obligate life-history or ecological associations were identified and this ecological group is considered have a **‘High Resistance**, and hence ‘**High’ Resilience** and ‘**Not Sensitive’.** This assessment is based on ecological and life history information rather than targeted studies.

Resistance

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability is ‘Not assessed’ – based on expert judgement.
Concordance is ‘Not assessed’ – based on expert judgement.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.1.3 Hydrological Changes (inshore/local)

Little species specific information was found, and the likely effects of change in hydrography were inferred from the geographical range (temperature) and habitat preferences (salinity, wave and water flow) of the characteristic species of this ecological group.

IV. Salinity changes - local

No information on the salinity tolerance of the three sea pens was found. Jones *et al* (2000) suggested that *Virgularia mirabilis* was more tolerant of reduced salinity due to its distribution in shallower waters. MNCR data recorded *V. mirabilis* and *P. phosphorea* species from biotopes (SS.SMu.IFiMu.PhiVir; SS.SMu.CFiMu.SpnMeg) that occur in full and variable salinity but *F. quadrangularis* was only recorded in biotopes at full salinity. Recent analysis of survey data by Greathead *et al* (2007) demonstrated that *V. mirabilis* was the most ubiquitous of all three of the sea pens in Scotland, found in habitats nearer coastal areas and inner sea lochs. For example, *V. mirabilis* is characteristic of the SS.SMu.IFiMu.PhiVir biotope, which can occur at depths of only 0-5m. Greathead *et al* (2007) suggested that *P. phosphorea* was found in areas further from coastal areas and inner sea lochs, except in Loch Broom. *F. quadrangularis* demonstrated a preference for deeper waters rather than any other physio-chemical factor (Greathead *et al* 2007).

Overall, the evidence suggests that *V. mirabilis* is the most likely of the three sea pens to be exposed to variable salinity and its presence in shallow water biotopes suggests that it can tolerate occasional reduced salinity, while *F. quadrangularis* is probably unexposed and hence intolerant to changes in salinity. *P. phosphorea* occurs in SS.SMu.CFiMu.SpnMeg at depths of >10m where it is probably unexposed and hence intolerant to changes in salinity. Therefore, *V. mirabilis* is probably resistant of variable salinity. But a decrease in 10 salinity units for a year (the benchmark) e.g. from 32-35 units to 22-25 units for a year is probably more extreme.

Therefore, *F. quadrangularis* and *P. phosphorea* probably have a **resistance** of **'None'** but the **Resistance** of *V. mirabilis* is probably **'Low'. Resilience** is likely to be at least **'Low'** and the resultant **sensitivity** is **'High'** for all three species**.**

Resistance

Quality of evidence is 'Medium' – based on grey literature and recorded habitat preferences.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (see section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

V. Temperature changes - local

No information on the temperature tolerance of the three sea pens was found. Jones *et al* (2000) suggested that biotopes containing *F. quadrangularis* and *P. phosphorea* required thermally stable conditions, probably thriving below thermoclines and occurring in waters where the annual variation in temperature is between 5 and 15°C. Jones *et al* (2000) went on to suggest that biotopes with *V. mirabilis* are shallow and probably exposed to greater temperate variation. Greathead *et al* (2007) noted that *V. mirabilis* occur in coastal areas on coarser muds than the other sea pen species, which may also suggest that it occurs in areas of higher energy, with more mixing and potential for changes in temperature.

Virgularia mirabilis is recorded widely in the North Atlantic from Norway and Iceland, south to the Mediterranean and west Africa , and occurs in the Gulf of Mexico (OBIS 2014). OBIS[5] (2014) provide a range of sea temperature from which the sea pen has been recorded, of -1.9 to 27.8°C. The majority of British records of *P. phosphorea* occur in Scotland but OBIS (2014) reports records from the northern North Sea south to the Mediterranean, occurring between sea temperatures of -1.39 to 27.9°C. All of the British records *of F. quadrangularis* occur in Scotland but it is recorded from the northern North Sea to the Mediterranean (OBIS, 2014). OBIS (2014) report *F. quadrangularis* records from sea temperatures ranging

[5] OBIS (Ocean Biogeographic Information System) - http://www.iobis.org/

between -1.2 to 28°C. It should be noted that there is uncertainty in how the OBIS temperature figures were obtained.

Overall, a long term chronic change in temperature is unlikely to adversely affect these three species as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. However, it should be noted that temperatures are more stable with increasing depth, especially in areas without strong currents or other sources of mixing, occupied by *P. phosphorea* and *F. quadrangularis*. *F. quadrangularis* in particular prefers greater depths than the other sea pen species, and may be less tolerant to short, acute changes in temperature than the others, while *V. mirabilis* is likely to be most tolerant. Therefore, a precautionary **resistance** of **'Low'** is suggested for ***P. phosphorea*** and ***F. quadrangularis***, with a **resilience** of **'Low'** resulting in an overall **sensitivity** of **'High'** for acute change (increase or decrease)**.** However, a **resistance** of **'Medium'** is suggested for ***V. mirabilis*,** which with a **resilience** of **'Low',** resulting in a **sensitivity** of **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on grey literature and recorded habitat preferences.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

VI. Water flow (tidal current) changes - local

Sea pen biotopes (e.g. SS.SMu.CFiMu.SpnMeg and SS.SMu.IFiMu.PhiVir) occur in low energy environments with weak (<0.5 m/s) to very weak tidal streams (Connor *et al* 2004) which are prerequisite for the fine mud sediments in which the sea pens occur (Hughes 1998a). Of the three sea pens, *V. mirabilis* occurs in coarser sandier muds with small stones and shell fragments e.g. SS.SMu.CSaMu.VirOphPmax (Hughes 1998a; Greathead *et al* 2007), and is probably more tolerant of current or wave induced flow than *F. quadrangularis* and *P. phosphorea* but the entire group is probably intolerant of increased flow.

For example, Hiscock (1983) examined the effects of water flow on *V. mirabilis*. As water flow rates increase, *V. mirabilis* first responds by swinging polyps around the axial rod to face away from the current, then polyps face downstream. With further increases the stalk bends over and the pinnae are pushed together to an increasing amount with increasing velocity of flow. Finally, tentacles retract and at water speeds greater than 0.5m/s (i.e. 1 knot) the stalk retracts into the mud (Hiscock 1983). If water speeds remain at this level or above the sea-pen will be unable to extend above the sediment, unable to feed and will die (Hill & Wilson 2000). *P. phosphorea* has a larger surface area due to its width, while *F. quadrangularis* is larger and less flexible, suggesting both species will be less tolerant of increased flow. In addition, long term increases in water flow are likely to modify the sediment, removing the fine sediments the sea pens require in favour of sandier, coarser sediments (see change in sediment type below).

Overall, an increase in water flow to 1-2m/s for a year would probably result in death and/or removal of *V. mirabilis*, and as the other sea pens are probably less tolerant of change, a

resistance of **'None'** is suggested, with a **resilience** of **'Low'**, resulting in a **sensitivity** of **'High'.**

Resistance

Quality of evidence is 'Medium' – based on directly applicable, peer reviewed evidence for *V. mirabilis,* and recorded habitat preferences for *P. phosphorea* and *F. quadrangularis*.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

VII. Wave exposure changes - local

Sea pen biotopes (e.g. SS.SMu.CFiMu.SpnMeg and SS.SMu.IFiMu.PhiVir) occur in low energy environments, extremely sheltered to sheltered from wave exposure (Connor *et al* 2004), a prerequisite for the fine mud sediments in which the sea pens occur (Hughes 1998a). While *V. mirabilis* occurs in coastal areas and inner sea lochs, these areas are still sheltered from wave action, and in sandier muds (e.g. the biotope SS.SMu.CSaMu.VirOphPmax) wave exposure was not recorded to be more than 'sheltered'. Therefore, it is likely that all of the sea pens characteristic of this ecological group are intolerant of increase in wave action. Again *V. mirabilis* is probably the most tolerant of the three species, while *F. quadrangularis* is probably the most intolerant as wave exposure is attenuated by depth.

A decrease in wave exposure is unlikely in the sheltered habitats they inhabit. But a decrease in wave exposure elsewhere may be beneficial by providing additional habitat for colonisation and hence and increase in their distribution.

Overall an increase in wave exposure is likely to adversely affect all three species, limiting or removing the shallower proportion of the population, and potentially modifying sediment and therefore habitat preferences in the longer-term. In some cases areas suitable for *P. phosphorea* and *F. quadrangularis* may become more suitable for *V. mirabilis*. **A resistance of 'Medium' is suggested (to represent the loss of the upper most part of the population), while resilience is probably 'Low', giving a sensitivity of 'Medium' to increased wave exposure. They are probably 'Not sensitive' to decreases in wave exposure.**

Resistance

Quality of evidence is 'Medium' – based on directly applicable, peer reviewed evidence for *V. mirabilis,* but recorded habitat preferences for *P. phosphorea* and *F. quadrangularis*.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

4.1.4 Physical Damage (Reversible Change)

Erect epifauna are considered to be amongst the most sensitive to physical disturbances (Auster 1998; Jennings & Kaiser 1998; Tillin *et al* 2006), but direct evidence on the effects on sea pen populations is mixed.

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

In experimental studies (Kinnear *et al* 1996; Eno *et al* 2001) sea pens were found to be largely resilient to smothering, dragging or uprooting by creels or pots. In both *P. phosphorea* and *F. quadrangularis*, the pressure wave caused by approaching pots/creels bent the sea pen away, so that they were laid flat before contact. Kinnear *et al* (1996) noted that *P. phosphorea* and *F. quadrangularis* were occasionally removed from the substratum by creels/pots. *V. mirabilis* withdrew very quickly into the sediment when exposed to pots or creels, and so it was difficult to determine their response. However, all sea pens recovered from being dragged over by pots or creels within 24-72 hours, with exception of one individual *F. quadrangularis*. Both *P. phosphorea* and *F. quadrangularis* were able to reinsert themselves into the sediment if removed as long as the peduncle remained in contact with the sediment surface, except in one specimen in which the peduncle was damaged. *P. phosphorea* and *F. quadrangularis* recovered with 72-96 hours after experimental smothering for 24 hours by pot or creel and after 96-144 hours of smothering for 48 hours (Kinnear *et al* 1996; Eno *et al* 2001).

Both *V. mirabilis* and *P. phosphorea* can withdraw into tubes in the sediment. In *V. mirabilis* withdrawal from physical stimulus is rapid (ca 30 seconds) (Hoare & Wilson 1977; Ambroso *et al* 2013). Birkland (1974) maintained that the only way to capture all of the sea pens in an area (quadrat) was to remove them slowly by hand until no more emerged. But several studies note that their ability to withdraw into the sediment in response to bottom towed or dropped gear (e.g. creels, pots, camera/video mounted towed sleds, experimental grab, trawl, or dredge) means that their abundance can be difficult to estimate (Birkeland 1974; Eno *et al* 2001; Greathead *et al* 2007; Greathead *et al* 2011). The ability to withdraw also suggests that sea pens can avoid approaching demersal trawls and fishing gear. This was suggested as the explanation for the similarity in the densities of *V. mirabilis* in trawled and untrawled sites in Loch Fyne, and the lack of change in sea pen density observed after experimental trawling (using modified rock hopper ground gear) over a 18 month period in Loch Gareloch (Howson & Davies 1991; Hughes 1998a; Tuck *et al* 1998). Kenchington *et al* (2011) estimated the gear efficiency of otter trawls for sea pens (*Anthoptilum* and *Pennatula*) to be in the range of 3.7–8.2%, based on estimates of sea pen biomass from (non-destructive) towed camera surveys However, species obtained by dredges were invariably damaged (Hoare & Wilson 1977). Note *F. quadrangularis* cannot withdraw into the sediment.

Hoare and Wilson (1977) noted that *V. mirabilis* was absent for areas of Holyhead Harbour disturbed by dragging or boat mooring, although no causal evidence was given (Hughes 1998). Sea pens are potentially vulnerable to long lining. Munoz *et al* (2011) noted that small numbers of Pennatulids (inc. *Pennatula* sp.) were retrieved form experimental long-lining around the Hatton Bank in the north east Atlantic, presumably either attached to hooks or wrapped in line as it passed across the sediment. Hixon and Tissot (2007) noted that sea pens (*Stylatula* sp.) were four times more abundant in untrawled areas relative to trawled areas in the Coquille Bank, Oregon, although no causal relationship was shown. Greathead *et al* (2011) noted that *F. quadrangularis* was largely absent from Fladen fishing grounds in northern North Sea, possibly due to its patchy distribution or fishing activities.

Overall, surface abrasion by pots and creels is unlikely to adversely affect the three sea pens. Towed gear is likely to remove a proportion of sea pens from the sediment, and if damaged they are likely to die, but if undamaged displaced and/or returned to suitable sediment they can recover relatively quickly. *V. mirabilis* and *P. phosphorea* can avoid abrasion by withdrawing into the sediment, but frequent disturbance will probably reduce feeding time and hence viability. However, *F. quadrangularis* cannot withdraw and is the tallest of all three of the sea pens (up to 2m) and is the most likely to be displaced or removed by surface abrasion and towed gear. Therefore, as bottom gears (e.g. otter trawls) may remove a proportion of the population a **resistance** of **'Medium'** is suggested for ***P. phosphorea*** and ***V. mirabilis*.** But as ***F. quadrangularis*** cannot withdraw and is more likely to be removed by bottom gears, a **resistance** of **'Low'** is suggested. As the entire group is given a **resilience** of **'Low',** the resultant **sensitivities** are **'Medium' for *P. phosphorea* and *V. mirabilis*** and **'High for *F. quadrangularis.***

Resistance

Quality of evidence is 'High' – based on directly applicable, peer reviewed targeted studies.
Applicability is 'High' – based on based on directly applicable, peer reviewed targeted studies.
Concordance is 'Low' – based on some disagreement between studies.

Resilience (section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

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

The relevant evidence and hence sensitivity assessment are the same as that presented under surface abrasion (VIII) above.

X. Change in suspended solids

The sea pen species assessed live in sheltered areas, in fine sediments, subject to high suspended sediment loads. The effect of increased deposition of fine silt is uncertain but it is possible that feeding structures may become clogged. When tested, *V. mirabilis* quickly seized and rejected inert particles (Hoare & Wilson 1977). Hiscock (1983) observed *V. mirabilis* secretes copious amounts of mucus which could keep the polyps clear of silt. Kinnear (1996) noted that another species of sea pen, *F. quadrangularis*, was quick to remove any adhering mud particles by the production of copious quantities of mucus. *V. mirabilis* is also likely to be able to self-clean (Hiscock 1983). No indication of the suspended sediment load was given in any evidence found.

If feeding is reduced by increases in siltation the viability of the population will be reduced. Once siltation levels return to normal, feeding will be resumed therefore recovery will be immediate. Overall, **resistance** is **probably 'High',** hence **resilience** is also **'High,** and the sea pens are **probably 'Not sensitive'** at the benchmark level.

Resistance

Quality of evidence is 'Medium' – based on the recorded habitat preferences of the species rather than targeted studies.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

XI. Habitat structure changes - removal of substratum (Extraction)

Benthic trawls (e.g. rock hopper ground gear, otter trawls) will remove and capture sea pens (Tuck *et al* 1998; Kenchington *et al* 2011), albeit with limited efficiency. Nevertheless, dredging and suction dredging penetrates to greater depth and are likely to remove sea pens. Although, *V. mirabilis* and *P. phosphorea* can withdraw into the sediment, they will not be able to avoid activities that penetrate into the sediment. Assuming their burrows are only deep enough to hold the entire animal, then *V. mirabilis* burrows are up to 40cm deep while *P. phosphorea* burrows are only up to 25cm deep (see Greathead *et al* 2007 for outline of sea pen size). *F. quadrangularis* cannot withdraw into a burrow.

Overall, extraction of sediment to 30cm (the benchmark) will remove most of the resident sea pens present. Hence, their **resistance** is probably **'None'** and their **resilience** is at least **'Low',** resulting in a **sensitivity** of **'High.**

Resistance

Quality of evidence is 'Medium' – based on ecology of the species and the effects of the pressure.
Applicability is 'Low' – based on the ecology of the species rather than pressure specific information.
Concordance is 'Medium' – based on agreement on direction but not magnitude.

Resilience (see section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

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

P. phosphorea and *F. quadrangularis* were found to recover within 72-96 hours after experimental smothering by pots or creels for 24 hours and after 96-144 hours after 48 hours of smothering by pots or creels (Kinnear *et al* 1996; Eno *et al* 2001). However, smothering by a pot or creel differs significantly from 30cm of fine sediment, which could clog feeding apparatus and exclude oxygen. Kinnear *et al* (1996) noted that *F. quadrangularis* was quick to remove any adhering mud particles by the production of copious quantities of mucus, once the source of smothering (in this case potting) was removed. Similarly, Hiscock (1983) observed *V. mirabilis* secretes copious amounts of mucus which could keep the polyps clear of silt and is also likely to be able to self-clean.

All three species occur in deep, sheltered muddy habitats where the accretion rates are potentially high. Both *P. phosphorea* and *V. mirabilis* can burrow and move into and out of their own burrows. It is probable therefore that deposition of 30cm of sediment will have little effect other than to temporarily suspend feeding and the energetic cost of burrowing. *F. quadrangularis* cannot withdraw into a burrow but can stand up to 2m above the substratum, and so will probably not be adversely affected. However, no direct evidence was found. Therefore, a **resistance** of **'High'** is suggested, resulting in a **resilience** of **'High'** and **sensitivity** of **'Not sensitive'.**

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.1.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

Virgularia mirabilis occurs in a number of biotopes, on substrata ranging from mud, sandy mud, and gravelly mud, with or without shell fragments or stones (Connor *et al* 2004). Greathead *et al* (2007) suggested that the muscular peduncle of *V. mirabilis* allowed it to occupy coarser muds than the other sea pens, and explained its presence in the Moray Firth and Firth of Forth, and its wider distribution in Scotland.

Greathead *et al* (2007) noted that *P. phosphorea* was absent in the North Minch, while *F. quadrangularis* and *V. mirabilis* were present, but that *P. phosphorea* was abundant in soft, adhesive mud with high silt-clay content in Loch Broom. This may suggest a preference for fine muds. The MNCR only recorded *P. phosphorea* from biotopes in 'mud'.

Greathead *et al* (2007) also noted that *F. quadrangularis* had the most restricted distribution, probably due to a preference of depth and soft deep muds of sheltered loch basins, where it was abundant. Again, the MNCR only recorded *F. quadrangularis* from biotopes in 'mud'. However, it was also recorded from areas of muddy sand in the South and North Minches and in the Fladen Grounds but in deep water.

A change in sediment type by one Folk class (the benchmark) will adversely affect the sea pens. Based on their reported distribution a change 'mud' to 'sandy mud or 'slightly gravelly mud' will probably exclude *P. phosphorea* and *F. quadrangularis* (except where *F. quadrangularis* occurs in deep basins) but not adversely affect *V. mirabilis*. Conversely, a change of sediment from coarse muds ('sandy mud', 'slightly gravelly muds') to mud will not affect *V. mirabilis* but may allow the other sea pens to colonise. Where, *V. mirabilis* already occurs in coarser muds and further change (e.g. from sandy mud to muddy sand) is probably detrimental. In all cases, a change in the sediment type is likely to change the associated community and result in loss of the sea pen population.

Overall, sea pens have narrow range of sediment type preferences, so their **resistance** to this pressure is **'Low'** for ***V. mirabilis*** and **'None' for the other sea pens,** and as **resilience** is probably **'Low', sensitivity** is therefore **'High'.**

Resistance

Quality of evidence is 'Medium' – based on grey literature and recorded habitat preferences.
Applicability is 'Low' – based on recorded habitat preferences rather than pressure specific information.
Concordance is 'Medium' – based agreement between recorded habitat preferences.

Resilience (see section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

4.1.6 Pollution

XIV. Organic enrichment

Hoare and Wilson (1977) noted that *Virgularia mirabilis* was absent from the part of Holyhead Harbour heavily affected by sewage pollution. However, the species was abundant near the head of Loch Harport, Skye, close to a distillery outfall discharging water enriched in malt and yeast residues and other soluble organic compounds (Nickell & Anderson 1977 in Hughes 1998a), where the organic content of the sediment was up to 5%. *V. mirabilis* was also present in Loch Sween in Scotland in sites where organic content was as high as 4.5% (Atkinson 1989). Wilding (2011) noted that the abundance of *P. phosphorea* was inversely correlated with predicted Infaunal Trophic Index (a predicted estimate of organic waste build up) around salmon farms in Scotland, but that the effect only extended for 50m from the cages.

Sublittoral muds may be expected to be high in organic nutrients, and the presence of *V. mirabilis* in areas of up to 4.5% organic carbon (Atkinson 1989) suggest resistance to organic enrichment. A precautionary **resistance** of **'Medium'** is suggested, with a resilience of **'Low'**, and **sensitivity** of **'Medium'**. However, *P. phosphorea*, and by inference *F. quadrangularis*, may be more sensitive.

Resistance

Quality of evidence is 'Medium' – based on peer reviewed and grey literature.
Applicability is 'Low' – based on anecdotal observations and studies that cannot be compared to the benchmark.
Concordance is 'Low' – based contradictory evidence.

Resilience (see section 4.1.7)

Quality of evidence is 'Medium' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species.
Applicability of evidence is 'Low' - based on the life history of the three sea pen species but not their population dynamics, or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

4.1.7 Review of likely rates of recovery based on the species present within the ecological group

Based on the evidence presented above, recovery from displacement and removal from the seabed is likely to be rapid for the characterising species in this group, *F. quadrangularis* and *P. phosphorea* have been shown to right themselves when dislodged, with all *P. phosphorea* individuals re-established and 50% of *F. quadrangularis* after 72 hours. *V. mirabilis* was found to withdraw into its burrow rapidly and could not be uprooted by dragged creels. *P. phosphorea* and *F. quadrangularis* recovered with 72-96 hours after experimental smothering for 24 hours by pot or creel and after 96-144 hours of smothering for 48 hours (Kinnear *et al* 1996; Eno *et al* 2001). In summary all three sea pen species have been found to recover rapidly from the effects of dragging, uprooting and smothering (Eno *et al* 2001).

Recovery from effects that remove a proportion of the sea pen population (e.g. bottom gears, hydrographic changes) will depend on recruitment processes and little is known about the reproduction, life history and population dynamics of sea pens (Hughes 1998a).

Recent studies of oogenesis in *F. quadrangularis* and *P. phosphorea* in Loch Linnhe, Scotland, demonstrated that they were dioecious, with 1:1 sex ratios, highly fecund, with continuous prolonged oocyte development and annual spawning (Edwards & Moore 2008, 2009). In *P. phosphorea*, oogenesis exceed 12 months in duration, with many small oocytes of typically 50 per polyp giving an overall fecundity of ca 40,000 in medium to large specimens, depending on size. However, <30% matured (synchronously) and were spawned in summer (July-August). Mature oocytes were large (>500µm) which suggested a lecithotrophic larval development (Edwards & Moore 2008). In *F. quadrangularis* fecundity was again high, expressed as 500-2000 per 1cm midsection, but not correlated with size, and again, only a small proportion of the oocytes (<10%) matured. Unlike *P. phosphorea*, annual spawning occurred in autumn or winter (between October and January). Also the mature oocytes were very large (>800µm), which suggested a lecithotrophic larval development (Edwards & Moore 2009). No similar studies were available for *V. mirabilis*, but Edwards and Moore (2009) noted that many sea pens exhibited similar characteristics. In a study of the intertidal *Virgularia juncea* fecundity varied with length (46,000 at 50cm and 87,000 at 70cm), oocytes reached a maximum size of 200-300µm in May and were presumed to be spawned between August and September (Soong 2005).

Birkland (1974) found the life span of *Ptilosarcus gurneyi* to be 15 years, reaching sexual maturity between the ages of 5 and 6 years; while Wilson *et al* (2002) noted that larger specimens of a tall sea pen (*Halipteris willemoesi*) in the Bering Sea were 44 years old, with a growth rate of 3.6 - 6.1cm/year.

Hughes (1998a) suggested that patchy recruitment, slow growth and long life-span were typical of sea pens. Larval settlement is likely to be patchy in space and highly episodic in time with no recruitment to the population taking place for some years. Greathead *et al* (2007) noted that patchy distribution is typical for sea pen populations. In Holyhead Harbour, for example, animals show a patchy distribution, probably related to larval settlement (Hoare & Wilson 1977). However, no information on larval development, settlement behaviour or dispersal was found.

Overall, where the adults survive impact undamaged, resistance is ‘High’ and recovery is rapid: a resilience of ‘High’ (<2 years). Where a proportion of the population is removed or killed, then the species has a high dispersal potential and long-lived benthic larvae, but larval recruitment is probably sporadic and patchy and growth is slow, suggesting that recovery will take many years: a resilience of ‘Low’ (>10 years). The assessment is based on literature on the life history of the three sea pen species but not their population dynamics, or inferred from information on other species. Therefore, the quality, applicability and concordance of the evidence are ‘Medium’.

4.1.8 Knowledge gaps

The effects of bottom trawling, especially for penetrative gear (scallop dredges), and dredging seem to be poorly recorded in the literature, and most studies make inferences from distribution rather than actual evidence, although sea pens are regularly captured in experimental or research trawls in suitable habitats (Tillin pers comm).

There is little information on the life history and population dynamics of the sea pens characterising this ecological group; as such it is difficult to estimate recovery rates with confidence. As with many benthic invertebrate species information on species specific responses to changes in physio-chemical conditions (temperature, salinity, oxygenation, turbidity, water flow and wave mediated oscillation), contaminants including litter, noise and vibration, and biological pressures, remain poorly studied. The resilience and resistance of species (and species populations) have to be inferred from their distribution or biology, rather than direct experimental or comparative studies.

4.2 Ecological Group 1b Erect, short-lived epifaunal species.

4.2.1 Definition and characteristics of the ecological group

The characterising species comprising this group are erect, relatively short-lived, attached epifaunal species. The characterising species from the target circalittoral and offshore sedimentary biotopes include hydroids (*Nemertesia* spp. *Sertularia* spp., *Hydrallmania falcata*) and the hydrozoan *Obelia longissima* (**Table 4.2**). The sensitivity assessment takes into account these and other similar species; specific assessments are made for *Nemertesia ramosa*, *Sertularia argentea* and *Obelia longissima*. There is little information on the biology of *Hydrallmania falcata* (although evidence is presented where found). These species are found in a range of habitats where there are suitable surfaces for attachment; this group is therefore based on trait similarities and is not specific to a biotope group.

Table 4.2. List of biotopes in which ecological group 1b species occur as characterising species.

Level 5 biotopes represented	Characterising species assessed
SS.SMu.CSaMu.AfilNten	*Obelia longissima* *Sertularia argentea*
SS.SMx.CMx.ClloMx.Nem	*Nemertesia ramosa*
SS.SMx.CMx.MysThyMx	Characterising species present in this ecological group were not selected for specific assessment.
SS.SMx.CMx.FluHyd	Characterising species present were not specifically assessed.

4.2.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

Perophora japonica has also been recorded growing on hydroids including *Nemertesia antennina* (Essink & Bos 1985) although no evidence to suggest a significant impact was found. There is no evidence that non-indigenous species are affecting species characterising this ecological group. Sensitivity is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group will be directly impacted by this pressure where it is targeted. *Sertularia* and other ('white weed') species have been harvested for use as decoration in flower arrangements, mainly in the 19th to the mid-20th century. Fisheries in the Wadden Sea ceased in the 1970s (Berghahn & Offermann 1999). These beds had been fished for decades but harvesting was not linked to the decline of the beds (Berghahn & Offermann 1999) which occurred after harvesting had ceased. It should be noted that in the Wadden Sea harvested beds were managed using a closed season to support long-term sustainability and this would have mediated the impact of this pressure.

Removal of this ecological group as a target species may have effects on other species. The ecological group provides a structurally complex habitat that acts as nursery habitat and refugia for other species including juvenile fish (Heidrich 1927, cited in Wagler *et al* 2009). This group may also provide food sources or settlement substrata for other animals, so their removal may have subsequent effects on community diversity (Bradshaw *et al* 2002). No direct, quantitative evidence for the effects of removal on other species were found and other species are not the focus of the sensitivity assessment.

Beds can be effectively targeted and removed (although demand for 'white weed' is now limited). No targeted fishery is currently taking place within UK waters and no obligate life-history or ecological associations were identified for this ecological group. The ecological group is therefore considered 'Not exposed'. Although members of this ecological group may grow on shellfish or macroalgae and be removed where these are targeted, their main habitat is hard substratum. **Resistance and resilience** are therefore assessed as **'High'** and this group is therefore assessed as '**Not Sensitive'** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability is 'Low' – based on general ecology rather than pressure specific information.
Concordance is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

III. Removal of Non-Target Species

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Although members of this ecological group may grow on animals or macroalgae and be removed alongside these, the main habitat is hard substratum. No obligate life-history or ecological associations were identified. Therefore, **resistance and resilience** are assessed as **'High'** and this group is assessed as '**Not Sensitive'** (to the ecological effects only) of removal of other species.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability is 'Low' – based on general ecology rather than pressure specific information.
Concordance is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.2.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No evidence was found to assess this pressure at the benchmark for this ecological group and sensitivity to this pressure is therefore **'No Evidence'** for this group.

V. Temperature

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

Nemertesia ramosa is found in the North Atlantic; from Iceland down to north-west Africa. In the Mediterranean: the Strait of Gibraltar, some parts of the Spanish coast, Israel and Italy. The species also occurs in the Indian Ocean; coasts of South Africa and Mozambique (Jackson 2004).

Stepanjants (1998) regarded *Obelia longissima* as a cold water species, with a bipolar distribution, while other authors regarded this species as probably cosmopolitan in distribution (Boero & Bouillon 1993; Cornelius 1995). Cornelius (1995) suggested that numerous records in the Indo-Pacific were probably attributable to *Obelia longissima*.

Berrill (1949) reported that growth in *Obelia commissularis* (syn. *longissima*) was temperature dependant but ceased at 27°C. Hydranths did not start to develop unless the temperature was less than 20°C and any hydranths under development would complete their development and rapidly regress at ca 25°C. Berrill (1948) reported that *Obelia* species were absent from a buoy in July and August during excessively high summer temperatures in Booth Bay Harbour, Maine, USA. Berrill (1948) reported that the abundance of *Obelia* species and other hydroids fluctuated greatly, disappearing and reappearing as temperatures rose and fell markedly above and below 20°C during this period. The upwelling of cold water (8-10°C colder than surface water) allowed colonies of *Obelia* sp. to form in large numbers. Berrill (1948) suggested that *Obelia longissima* grew vigorously in warm weather, although at temperatures above 20°C, growth of terminal stolons and branches was promoted but the formation of hydranths inhibited. Therefore, it would appear that *Obelia longissima* is intolerant of acute temperature change above 20°C.

Sertularia argentea is found in the North Sea, Bay of Fundy and France. OBIS (2014) report minimum and maximum sea temperatures as 0.23-22.19ºC respectively. It is not clear how these observations were derived.

Overall, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect this ecological group as the global distribution of the characterising species indicates they can potentially adapt to a wide range of temperatures. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from the geographic distribution, rather than empirical evidence.
Applicability is 'Low' – based on the geographic distribution as a proxy for pressure specific information.
Concordance is 'Not assessed' – based on the geographic distribution alone.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Tyler-Walters (2003) suggested that water movement was essential for hydroids to supply adequate food, remove metabolic waste products, prevent accumulation of sediment and disperse larvae or medusae. Hydroids are expected to be abundant where water movement is sufficient to supply adequate food but not cause damage (Hiscock 1983; Gili & Hughes 1995). Annulations at the base of branches in many species including *Obelia* sp. allow some flexibility so that individuals can bend to accommodate changes in water flow (Tyler-Walters 2003)

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for *biotopes* characterised by members of this ecological group as follows:

- *Hydrallmania falcata*: very weak to strong (negligible -3m/s);
- *Nemertesia antennina*: very weak to strong (negligible -3m/s);
- *Nemertesia ramosa*: very weak to strong (negligible -3m/s);
- *Obelia longissima*: (no information);
- *Sertularia argentea:* very weak to very strong (negligible - >3m/s), and
- *Sertularia cupressina*: very weak to strong (negligible -3m/s).

The range of flow speeds experienced by biotopes in which the species are found (from very weak to strong or very strong for selected species) suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. Colonies have some flexibility to allow them to bend in response to changes in water flow and growth form may be adapted to prevailing conditions. Therefore, **resistance** and **resilience** are therefore considered to be '**High'** and this group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from biotope records, rather than species records, of habitat preferences, rather than empirical evidence.
Applicability is 'Low' – based on habitat preferences as a proxy for pressure specific information.
Concordance is 'Not assessed' – based on the habitat preferences from a single source.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for *biotopes* characterised by members of this ecological group as follows:

- *Hydrallmania falcata*: very sheltered to exposed;
- *Nemertesia antennina*: extremely sheltered to very exposed;

- *Nemertesia ramosa*: very sheltered to very exposed;
- *Obelia longissima*: sheltered to moderately exposed;
- *Sertularia argentea*: sheltered to very exposed; and
- *Sertularia cupressina*: sheltered to exposed.

The records indicate that the species within this ecological group occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. Therefore, **resistance** and **resilience** are therefore considered to be '**High'** and this group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from biotope records, rather than species records, of habitat preferences, rather than empirical evidence.
Applicability is 'Low' – based on habitat preferences as a proxy for pressure specific information.
Concordance is 'Not assessed' – based on the habitat preferences from a single source.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.2.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

As erect epifauna, the growth form of members of this ecological group means they are exposed to direct physical damage from abrasion and sub-surface damage. Individuals may be directly knocked over, damaged or removed. Abrasion and sub-surface damage from activities such as fishing may move the boulders and cobbles that these species are attached to. If these are turned over species may die from physical damage or prevention of feeding. Direct evidence comes entirely from studies of fishing activities. No quantitative information was found for rates of damage and mortality; evidence for impacts is based largely on comparisons between areas with different levels of fishing activities or re-sampling of areas after exposure.

The available evidence indicates that attached epifauna, such as members of this ecological group, can be entangled and removed by abrasion. Drop down video surveys of Scottish reefs exposed to trawling showed that visual evidence of damage to bryozoans and hydroids on rock surfaces was generally limited and restricted to scrape scars on boulders (Boulcott & Howell 2011). The study showed that damage is incremental with damage increasing with frequency of trawls rather than a blanket effect occurring on the pass of the first trawls. The level of impact may be mediated by the rugosity of the attachment, surfaces with greater damage occurring over smooth terrains where the fishing gear can move unimpeded across a flat surface. Veale *et al* (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort.

Erect epifauna can be directly removed and brought to the surface in trawl hauls. De Groot (1984), for example, found that beam trawls with or without tickler chains removed the hydrozoan *Tubularia* spp. (mostly *Tubularia indivisa*). He suggested that nearly all individuals in the path of a beam trawl would be destroyed. This study was based on observations of species caught as by-catch and did not assess *in-situ* damage rates.

Re-sampling of grounds that were historically studied (from the 1930s) indicates that some upright species have increased in areas subject to scallop fishing (Bradshaw *et al* 2002). This study also found increases in the tough stemmed hydroids including *Nemertesia* spp., whose morphology may prevent excessive damage. Bradshaw *et al* (2002) suggested that as well as having high resistance to abrasion pressures, *Nemertesia* spp. have benthic larvae that could rapidly colonise disturbed areas with newly exposed substrata close to the adult.

Other population level effects have also been recorded. The scallop fishery has been implicated for altering genetic diversity within *Sertularia cupressina* populations on commercial scallop grounds in Atlantic Canada where increased damage rates have increased clonality from injury-induced fragmentation (Henry & Kenchington 2004). This means that genetic diversity in fished areas is lower than unfished areas. Similarly, Magorrian and Service (1998 and references therein) suggested that emergent epifauna were intolerant of trawling for queen scallops and reflected early signs of damage to horse mussels beds in Strangford Lough.

No specific information was available to assess the resistance of the selected species within this ecological group. But erect epifauna are directly exposed to abrasion and sub-surface penetration which would displace, damage and remove individuals (de Groot 1984; Magorrian & Service 1998; Veale *et al* 2001; Boulcott & Howell 2011). Therefore, **resistance** is assessed as **'Low'** (loss of 25-75% of individuals). Resistance has been demonstrated to vary with terrain (Boulcott & Howell 2011) and species specific traits including size, flexibility and fragility. Overall, **Resilience** within this ecological group following the removal of this pressure is assessed as **'High'** (due to occurring through repair, asexual reproduction and larval settlement) and **sensitivity** is therefore **'Low'.**

It should be noted that this pressure may be beneficial to some species within this ecological group by removing large and long-lived competitors for space, allowing species with opportunistic life-history strategies, such as hydroids, to colonise recently cleared substratum. This has been observed for *Nemertesia* spp. (Bradshaw *et al* 2002).

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability is 'Medium' – based on the effects of the pressure on similar species and other erect epifauna.
Concordance is 'Low' – based on differences in effect between species and studies.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on peer reviewed and grey literature.
Applicability of evidence is 'High' - based on peer reviewed and grey literature.
Concordance of evidence is 'High' - based on agreement in direction and magnitude across the group.

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

The relevant evidence and hence sensitivity assessment are the same as that presented under surface abrasion (4.2.4.VIII) above.

X. Change in suspended solids

No evidence was found to assess this pressure at the benchmark for this ecological group. Therefore, **'No Evidence'** is reported.

XI. Habitat structure changes - removal of substratum (Extraction)

This ecological group consists of attached species and within the extraction footprint all individuals would be removed and hence **resistance** is assessed as **'None'**. Species within this group are early colonisers of disturbed areas and recovery is predicted to be rapid although mediated by pressure impact and site-specific factors. Some species produce crawling planulae larvae and recovery would depend on some individuals remaining to re-populate the area. However as these are common species, **resilience** is predicted to be **High** (within 2 years). **Sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on expert judgement and inference on habitat position and life history from peer reviewed and grey literature.
Applicability is 'Low' – based on species traits used a proxy for resistance.
Concordance is 'Not assessed' – based on a proxy rather than direct evidence.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on peer reviewed and grey literature.
Applicability of evidence is 'High' - based on peer reviewed and grey literature.
Concordance of evidence is 'High' - based on agreement in direction and magnitude across the group.

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

No direct evidence was found to assess the impact of this pressure at the pressure benchmark. As the members of this ecological group are attached to the substratum and are usually shorter than 30cm (*Nemertesia ramosa* and *Sertularia argentea* are typically about 15cm in height; *Obelia longissima* is up to 20cm in length but may reach 35cm in British waters (Tyler-Walters 2003), this ecological group would be buried by the deposit and unable to migrate to the surface. Siltation by fine sediments would also prevent larval settlement by this ecological group which requires hard substratum (Berghahn & Offermann 1999). The intensity and duration of siltation will be mediated by site-specific hydrodynamic conditions, such as water-flow and wave action that determine the dispersal of deposits.

In general it appears that hydroids are sensitive to silting (Boero 1984; Gili & Hughes 1995) and decline in beds in the Wadden Sea has been linked to environmental changes including siltation. Round *et al* (1961) reported that the hydroid *Sertularia* (now *Amphisbetia*) *operculata* died when covered with a layer of silt after being transplanted to sheltered conditions. Boero (1984) suggested that deep water hydroid species develop upright, thin colonies that accumulate little sediment, while species in turbulent water movement were adequately cleaned of silt by water movement.

Based on expert judgement **resistance** to siltation is assessed as **'Low'** and **resilience** as **'High'** (when habitat conditions return to previous quality). **Sensitivity** is therefore assessed as **'Low'.**

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience (see section 4.2.7)

Quality of evidence is 'High' - based on peer reviewed and grey literature.
Applicability of evidence is 'High' - based on peer reviewed and grey literature.
Concordance of evidence is 'High' - based on agreement in direction and magnitude across the group.

4.2.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that this ecological group is able to colonise artificial substratum and an increase in available hard substratum is therefore thought to be beneficial to this ecological group (although differences in diversity and other structural characteristics of assemblages on hard and artificial substratum have been observed and artificial habitats may not provide a habitat of the same quality as natural rock reefs).

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Hydrallmania falcata*: mud; sandy mud; muddy gravelly sand with pebbles; medium to very fine sand; mixed sediment of sandy mud, cobble; pebble; boulders; bedrock.

- *Nemertesia antennina*: calcareous tubes mixed sediment of sandy mud; muddy sand with gravel pebbles and cobbles; mixed muddy sandy gravel; clean shell and stone gravel; very coarse sand with a finer sand fraction; sandy muddy gravel with surficial cobbles; clean stone gravel with pebbles, gravelly mud; shelly mud; sandy mud with stones or shells; bedrock; boulders; wrecks.

- *Nemertesia ramosa*: mud with a very significant sand to fine sand fraction; mixed sediment, mixed muddy sandy gravel; cobbles; boulders; bedrock, gravelly mud; shelly mud; sandy mud with stones or shells.

- *Obelia longissima*, peat; sandy mud; sand; gravels; cobbles.

- *Sertularia argentea*: *Modiolus* shells; sandy mud; gravel; pebbles; cobbles and pebbles; bedrock.

- *Sertularia cupressina*: muddy sand and gravel; medium to very fine sand; medium to fine sand with pebbles and cobbles.

A change in classification of one Folk class between coarse sediments, mixed sediments and sand and muddy sand (based on the Long 2006 simplification) is not predicted to negatively affect this ecological group which the MNCR records indicate is able to settle on hard substratum, including sand grains, in a range of sedimentary types. **Resistance** is therefore assessed as '**High'** and **resilience** as **'High'** as there is no impact to recover from. The ecological group is therefore assessed as **'Not Sensitive'**, but changes in habitat to a fine mud would negatively affect this group by preventing attachment.

As this pressure has not been the focus of targeted studies and the assessment is based on inferences made from biotope records, rather than species records, confidence in the quality of evidence for resistance is assessed as 'Medium'. Confidence in applicability is assessed as 'Low' as the assessment is based on a proxy. Confidence in the degree of concordance is not assessed as the evidence is based on a single source. The confidence in resilience is assessed as 'High, across all categories, based on the assessment of High resistance which suggests that there is no impact to recover from.

Resistance

Quality of evidence is 'Medium' – based on inferences from recorded biotope habitat preferences.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on a single source of evidence.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.2.6 Pollution

XIV. Organic enrichment

No direct evidence was found for the tolerance of this group. Empirical observations in the Weser estuary (Germany) found that *Obelia* species were more abundant in a sewage disposal area (with sedimentation of 1cm for more than 25 days), but *Sertularia cupressina* was significantly reduced in abundance when compared with unimpacted reference areas (Witt *et al* 2004).

Borja *et al* (2000) and Gittenberger and van Loon (2011) when developing the AZTI Marine Biotic Index AMBI I a biotic index to assess disturbance (including organic enrichment) both assigned *Obelia longissima* to AMBI Ecological Group II (Borja *et al* 2000; Gittenberger & van Loon 2011). The group definition is 'species considered indifferent to enrichment, always present in low densities with non-significant variations with time'. No AMBI categorisation has been made for other species in this group.

An increase in organic matter may increase food availability for these suspension feeders and the height above the seabed reduces sedimentation effects. This group is generally found in areas with some water movement and this will disperse organic matter reducing sedimentation. **Resistance** is therefore assessed as **'High'** (no significant effect) as is **resilience** (no effect to recover from). This ecological group is assessed as **'Not Sensitive'** to organic enrichment at the pressure benchmark.

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.2.7 Review of likely rates of recovery based on the species present within the ecological group

Members of this ecological group are considered to exhibit rapid rates of recovery through repair, asexual reproduction and larval colonisation, for example, each fragmented part of *Sertularia cupressina* can regenerate itself following damage (Berghahn & Offermann 1999).

Many hydroid species produce dormant, resting stages that are very resistant of environmental perturbation (Gili & Hughes 1995). Although colonies may be removed or destroyed, the resting stages may survive attached to the substratum. Rapid growth, budding and the formation of stolons allows hydroids to colonise space rapidly. Fragmentation may also provide another route for short distance dispersal. However, it has been suggested that rafting on floating debris as dormant stages or reproductive adults (or on ships hulls or in ship ballast water), together with their potentially long life span, may have allowed hydroids to disperse over a wide area in the long term and explain the near cosmopolitan distributions of many hydroid species (Cornelius 1992; Boero & Bouillon 1993; Gili & Hughes 1995). Therefore, recruitment potential is high.

Hydroids are often the first organisms to colonise available space in settlement experiments (Gili & Hughes 1995). For example, hydroids were reported to colonise an experimental artificial reef within less than 6 months becoming abundant in the following year (Jensen *et al* 1994). In similar studies, *Obelia* species recruited to the bases of reef slabs within three months and the slab surfaces within six months of the slabs being placed in the marine environment.

In a study of the long term effects of scallop dredging in the Irish Sea, Bradshaw *et al* (2002) noted that *Nemertesia* spp. increased in abundance, presumably because of their regeneration potential, good local recruitment and ability to colonise newly exposed substratum quickly. *Nemertesia* spp. has larvae that disperse locally by crawling away from the adult (Hughes 1977, 1979) thus, in a disturbed area, nearby newly exposed or disturbed substratum can be rapidly colonised. In *Nemertesia antennina*, reproduction occurs regularly, there being three generations per year. The presence of adults stimulates larval settlement, therefore, if any adults remain, reproduction is likely to result in local recruitment (Jackson 2004).

Based on the available evidence resilience is assessed as ‘High’ and confidence in the quality, applicability (although modified for some pressures) and degree of concordance is also ‘High’.

4.2.8 Knowledge gaps

Physical impacts on this group are relatively less studied than other groups as the coarse and hard substrata on which these are found are subject to less trawling effort (with the exception of scallop dredging) than soft sediments and have therefore been of lower priority. Gaps in information were recognised for hydrological changes (salinity, temperature, water flow). No direct information was found for organic enrichment or the direct effects of siltation. As impacts are poorly studied, it is also unsurprising that there is little evidence for resilience, which was inferred from life history traits and field observations rather than directly applicable evidence for recovery from the pressures. However, given that there is an abundance of evidence for repair, recovery and early colonisation for this ecological group (although patchy for some species) resilience was assessed as 'High' for this group with high confidence across all categories.

4.3 Ecological Group 1c soft-bodied or flexible epifaunal species

4.3.1 Definition and characteristics of the ecological group

This group comprises the bryozoan *Flustra foliacea*, the cnidarian *Alcyonium digitatum*, the tunicates *Ascidiella aspera* and *Styela gelatinosa* and the anemone *Urticina felina* (**Table 4.3**). The tunicate *Styela gelatinosa* has a restricted distribution and little information is available specific to this species. In order to ensure that the range of sensitivity of this group is represented, the bryozoan *Flustra foliacea*, the cnidarian *Alcyonium digitatum*, the anemone *Urticina felina* and the tunicate *Ascidiella aspera* are assessed for sensitivity. These species are found in a range of habitats where there are suitable surfaces for attachment; this group is therefore based on trait similarities rather than biotope group or taxonomic relatedness.

Table 4.3. List of biotopes in which ecological group 1c species occur as characterising species.

Level 5 biotopes represented	Characterising species assessed
SS.SMx.CMx.FluHyd	*Flustra foliacea* *Urticina felina*
SS.SMx.CMx.OphMx	*Alcyonium digitatum* *Urticina felina*
SS.SMu.OMu.StyPse	*Ascidiella aspera* *Styela gelatinosa*

4.3.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or are having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical impacts are assessed under abrasion and penetration of the seabed pressures (section 4.3.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified for this ecological group. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species**.**

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability is 'Low' – based on general ecology rather than pressure specific information.
Concordance is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.3.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Increased abundance of solitary ascidians under hydroid canopies has been documented in fouling studies; Dean and Hurd (1980) and Dean (1981) suggested that hydroids may facilitate settlement of ascidians. A canopy of the hydroid *Tubularia larynx* greatly enhanced settlement of the ascidians *Ascidiella aspera* and *Ciona intestinalis* (Schmidt 1983) for example. However, ascidians are not obligate associates of hydroids and therefore the removal of hydroids as a result of this pressure will not necessarily impact characterising species of this ecological group. No direct effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be ‘**Not Sensitive’.**

Resistance

Quality of evidence is ‘Medium’ – based on ecological and life history information rather than targeted studies.
Applicability is ‘Low’ – based on general ecology rather than pressure specific information.
Concordance is ‘Not assessed’ – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.3.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No evidence was available to assess the impact of an increase in salinity at the pressure benchmark for this ecological group. The sensitivity assessments therefore refer to a decrease in salinity. The available evidence indicates that tolerances to changes in salinity differ between the species within this ecological group.

Ascidiella aspera is found in estuaries and marine populations are therefore considered tolerant to a change in salinity at the pressure benchmark**, resistance** and **resilience** are assessed as **‘High’** and this species is therefore assessed as **‘Not Sensitive’.**

Resistance (Ascidiella aspersa)

Quality of evidence is ‘Low’ – based on expert judgement, ecological and life history information rather than targeted studies.
Applicability is ‘Not assessed’ – based on expert judgement.
Concordance is ‘Not assessed’ – based on expert judgement.

Resilience (Ascidiella aspersa)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

Alcyonium digitatum and *Flustra foliacea* appear to be restricted to areas with high salinity (Tyler-Walters & Ballerstedt 2007; Budd 2008b). Budd (2008b) reported that *Alcyonium digitatum* is found at the entries of German estuaries at salinities higher than 29.8 (Braber & Borghouts 1977) and does inhabit situations such as the entrances to sea lochs where low salinity may occasionally occur. However, its distribution and the depth at which it occurs suggest that *Alcyonium digitatum* is unlikely to survive significant dilution (Budd 2008). A decrease in salinity at the pressure benchmark is considered to reduce habitat suitability severely for *Flustra foliacea* and *Alcyonium digitatum* at the pressure benchmark. **Resistance** is therefore assessed as **'Low'** (a loss of 25-75% of the population). **Resilience** is assessed as **'Medium'** and sensitivity is therefore categorised as **'Medium'.**

Urticina felina occurs in estuaries e.g. the Thames estuary at Mucking (Jackson and Hiscock 2008) and the River Blackwater estuary (Davis 1967). Braber and Borghouts (1977) found that *Urticina* (as *Tealia*) *felina* penetrated to about the 11ppt chlorinity isohaline (corresponding to about 20psu based on conversion rates) at mid tide during average water discharge in the Westerschelde estuary suggesting that it would be tolerant of reduced salinity conditions. Intertidal and rock pool individuals will also be subject to variations in salinity because of precipitation on the shore; albeit for short periods on the lower shore. Therefore, the species seems to have a high tolerance to reduction in salinity but may have to retract tentacles and suffer reduced opportunity to feed (Jackson & Hiscock 2008). *Urticina felina* is considered to have **'Medium' resistance** as a change in salinity of 4-10psu may reduce habitat suitability. Due to the species long-lifespan and low reproduction, **resilience** is assessed as **'Medium** (2-10 years) and sensitivity is therefore assessed as **Medium'**.

Resistance (Urticina felina, Flustra foliacea, Alcyonium digitatum)

Quality of evidence is 'Medium' – based on inference from peer reviewed and grey literature on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience (Group 1c, section 4.3.7)

Quality of evidence is 'Medium' - based on inference from peer reviewed and grey literature on life history traits, and observations from the field.
Applicability of evidence is 'Low' – based on life history and observed recolonisation rates of the species in the group or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement in direction but not magnitude.

V. Temperature changes - local

Little information on temperature tolerances was found for members of this ecological group and the assessment is based largely on reported global distribution.

- *Alcyonium digitatum* is recorded from Iceland in the North, to Portugal in the South (Budd 2008b). *A. digitatum* was also reported to be apparently unaffected by the severe winter of 1962-1963 (Crisp 1964).

- *Ascidiella aspera* is native from Norway to the Mediterranean (Picton & Morrow 2010).

- *Flustra foliacea* is an amphiboreal species found in the Arctic Circle and south to the Bay of Biscay (Tyler-Walters & Ballerstedt 2007).

- *Urticina felina* has a boreal-arctic distribution and possibly a circumpolar distribution. It is found throughout Europe from northern Russia to the Bay of Biscay but not in the Mediterranean (Jackson & Hiscock 2008).

Overall, short term acute change in temperature and a long term chronic change in temperature at the pressure benchmark is unlikely to adversely affect these species as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'**. This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current changes) - local

Species within this ecological group are attached filter feeders reliant on some water movement to supply food, prevent accumulation of sediment and disperse larvae. In conditions of weak water flow, wave action may be a more important source of water movement (see section 4.3.3.VII).

The threshold tolerances for increases/decreases for each species are not clear. Within this ecological group *Alcyonium digitatum*, *Flustra foliacea* and *Urticina felina* reach highest abundances in areas of high water movement. The tunicate *Ascidiella aspera* is found in more sheltered areas with lower water movements and may be more sensitive to an increase in water flow at the pressure benchmark. Hiscock (1983) found that, for the solitary ascidian *Ascidia mentula*, siphons closed when current velocity rose above about 0.15m/s.

Alcyonium digitatum is common on hard substrata in areas of Lough Hyne on the south west coast of Ireland where current speeds reach 3m/s (Bell *et al* 2006). *Alcyonium digitatum* around Orkney and St Abbs (Scotland) experiences tidal currents of 3 and 4 knots (1.5-2m/s) during spring tides (De Kluijver 1993) and would not be sensitive to a change within this range.

Dyrynda (1994) suggested that mature fronded colonies of *Flustra foliacea* do not occur on unstable substratum due to the drag caused by their fronds, resulting in rafting of colonies on shells or the rolling of pebbles and cobbles, leading to destruction of the colony. Dyrynda (1994) reported that the distribution of *Flustra foliacea* in the current swept entrance to Poole Harbour was restricted to circalittoral boulders, on which it dominated as nearly mono-specific stands. The upper limits of tolerance for this group are therefore likely to be habitat specific and relate to the stability of the substratum.

Urticina felina favours areas with strong tidal currents (Holme & Wilson 1985; Migné & Davoult 1997) although it is also found in calmer and sheltered areas as well as deep water (Jackson & Hiscock, 2008).

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for *biotopes* characterised by members of this ecological group as follows:

- *Alcyonium digitatum*: moderately strong to very weak (negligible to 3m/s);
- *Ascidiella aspera*: moderately strong to very weak (negligible to 3m/s);
- *Flustra foliacea*: moderately strong to very weak (negligible to 3m/s), and
- *Urticina felina*: very strong to very weak (negligible) (negligible to >3m/s).

The range of flow speeds experienced by biotopes in which the species are found (from 0.5 - 3m/s for selected species) suggest that a change in the maximum water flow experienced by mid-range populations for the periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for *biotopes* characterised by members of this ecological group as follows:

- *Alcyonium digitatum*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed; extremely exposed;
- *Ascidiella aspera*: extremely sheltered, very sheltered; sheltered;
- *Flustra foliacea*: very sheltered; sheltered; exposed; moderately exposed; very exposed; extremely exposed; and
- *Urticina felina*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered **'High'** and as there is no impact, **resilience** is considered **'High'.** This group is therefore considered **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.3.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

This pressure refers to abrasion at the surface of the seabed only. The available evidence indicates that attached epifauna, such as members of this ecological group, can be entangled and removed by abrasion.

As erect epifauna, the growth form of members of this ecological group means they are exposed to direct physical damage from abrasion and sub-surface damage. Individuals may be directly displaced, damaged or removed as by-catch. Fishing may move the boulders and cobbles that these species are attached to. If these are turned over, species may die from physical damage or prevention of feeding. As suspension feeders, members of this ecological group may also be susceptible to resuspended sediment caused by disturbance (see changes in suspended solids). No quantitative information was found for rates of damage and mortality; evidence for impacts is based largely on comparisons between areas with different levels of fishing activities or re-sampling of areas after exposure. As suspension feeders, members of this ecological group may also be susceptible to resuspended sediment caused by disturbance (see change in suspended solids, section 4.3.4.X).

Magorrian and Service (1998 and references therein) reported that trawling for queen scallops resulted in removal of emergent epifauna from horse mussel beds in Strangford Lough. They suggested that the emergent epifauna such as *Alcyonium digitatum* were more intolerant than the horse mussels themselves and reflected early signs of damage (Budd 2008).

Veale *et al* (2000) reported that the abundance, biomass and production of epifaunal assemblages, including *Alcyonium digitatum*, decreased with increasing fishing effort. However (Bradshaw *et al* 2000) suggested that *Alcyonium digitatum* is more abundant on high fishing effort grounds. However, re-sampling of grounds that were historically studied (from the 1930s) indicates that some small upright species including *Ascidiella aspera* or ssp. have increased greatly in abundance in areas subject to long-term scallop fishing (Bradshaw *et al* 2002). Bradshaw *et al* (2002) suggested that *Ascidiella* species were probably able to survive by regeneration of damage and budding.

Drop down video surveys of Scottish reefs exposed to trawling show that damage to epifauna including *Alcyonium digitatum* is incremental with damage increasing with frequency of trawls rather than a blanket effect occurring on the pass of the first trawls. The level of impact may be mediated by the rugosity of the attachment surfaces, with greater damage occurring over smooth terrains where the dredge can move unimpeded across a flat surface (Boulcott & Howell 2011).

Activities that led to abrasion at the surface only would be predicted to remove entire individuals where some shear stress and dragging are involved. Direct impacts from this pressure may damage individuals that would recover through repair. Abrasion and penetration may also move and turnover boulders and cobbles that individuals are attached to which would lead to mortality. **Resistance** is considered to be **'Low'** (loss of 25-75% of individuals) as significant impacts on the population would be expected to result from surface abrasion and/or penetration. The **resilience of *A. aspersa* is 'High'** (within 2 years) following either repair of damage or settlement and recovery. Recovery will be mediated by the footprint of the activity and whether some individuals are present either inside or outside the footprint to provide propagules for species where larval dispersal is low. Hence, **sensitivity** is assessed as **'Low'.** However, ***A. digitatum*, *F. foliacea* and *U. felina*** are likely to take longer to recover, so a **resilience** of **'Medium'** (2-10 years) is recorded, resulting in a **sensitivity** of **'Medium'**.

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'High' – based on directly relevant evidence.
Concordance is 'Medium' – based on the agreement in direction but not magnitude.

Resilience (section 4.3.7)

Quality of evidence is 'Medium' - based on inference from peer reviewed and grey literature on life history traits, and observations from the field.
Applicability of evidence is 'Low' – based on life history and observed recolonisation rates of the species in the group or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement in direction but not magnitude.

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

The relevant evidence and hence sensitivity assessment are the same as that presented under surface abrasion (4.3.4.VIII) above.

X. Change in suspended solids

An increase in turbidity could be beneficial for this ecological group if the suspended particles are composed of organic matter, however high levels of suspended solids with increased inorganic particles may reduce filter feeding efficiencies.

Budd (2008b) assessed the sensitivity of *Alcyonium digitatum* to increased suspended sediment and considered that this species was tolerant. Hill *et al* (1997) reported that in areas with high siltation *A. digitatum* sloughed off settled particles with a large amount of mucus. The sea squirt *A. aspersa* is found in estuaries, where suspended sediment levels can be extremely high (g/l rather than mg/l), so that it unlikely to be sensitive at the benchmark level.

Tyler-Walters and Ballerstedt (2007) suggested that *Flustra foliacea* is tolerant to increased and decreased suspended sediment based on its occurrence in areas of high suspended sediment e.g. abundant in turbid, fast flowing waters of the Menai Straits (Moore 1977). Communities dominated by *F. foliacea*, with *U. felina* were described on tide swept seabed, were exposed to high levels of suspended sediment and sediment scour in the English Channel (Holme & Wilson 1985). *F. foliacea* and *U. felina* dominate sediment-scoured, silty rock communities CR.HCR.XFa.FluCoAs and CR.MCR.EcCr.UrtScr (Connor *et al* 2004).

Based on the available evidence, **resistance** to a change in turbidity of one rank is assessed as **'High'**. **Resilience** is assessed as **'High'** and sensitivity of this group is therefore assessed as **'Not sensitive'** at the benchmark level. The available information does not relate to the pressure benchmark and hence the resistance assessment is based on expert judgement.

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

XI. Habitat structure changes-removal of substratum (Extraction)

The process of extraction will remove all members of this ecological group. **Resistance** is therefore assessed as **'None'** based on expert judgment but supported by the literature relating to the position of these species on or within the seabed. The exposed sediments are considered to be suitable for colonisation almost immediately following extraction (levels of suspended sediments which may rise after extraction will subside rapidly (see 4.3.4.X). **Resilience** of members of this ecological group following the removal of this pressure are assessed as **'Medium-High'** (see section 4.3.7; resilience of *Ascidiella aspera* is assessed as 'High; *F. foliacea*, *A. digitatum* and *U. felina* as 'Medium'). Sensitivity is therefore **'Medium'** overall.

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience (section 4.3.7)

Quality of evidence is 'Medium' - based on inference from peer reviewed and grey literature on life history traits, and observations from the field.
Applicability of evidence is 'Low' – based on life history and observed recolonisation rates of the species in the group or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement in direction but not magnitude.

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

The complete disappearance of the sea squirt *Ascidiella aspera* biocoenosis and associated sponges in the Black Sea near the Kerch Strait was attributed to siltation (Terent'ev 2008). This ecological group is considered likely to express little resistance to this pressure as individuals are attached to the substratum and are likely to exhibit no or little vertical mobility. Similarly, *Alcyonium digitatum* is unable to move and is likely to be smothered by 30cm of sediment.

Tyler-Walters and Ballerstedt (2007) suggested that *Flustra foliacea* is tolerant to increased and decreased suspended sediment based on its occurrence in areas of high suspended sediment e.g. abundant in turbid, fast flowing waters of the Menai Straits (Moore 1977). Communities dominated by *F. foliacea*, with *U. felina* were described on tide swept seabed, exposed to high levels of suspended sediment, sediment scour and to periodic smothering by thin layers of sand, up to ca 5cm in the central English Channel (Holme & Wilson 1985). *F. foliacea* and *U. felina* dominate sediment-scoured, silty rock communities CR.HCR.XFa.FluCoAs and CR.MCR.EcCr.UrtScr (Connor *et al* 2004).

Laboratory experiments have shown that another anemone *Sagartiogeton laceratus* is able to survive under sediments for 16 days and to be capable of re-emerging under shallow (2cm) burial (Last *et al* 2011). The percentage mortality increased with both depth and increasingly finer sediment fraction. Last *et al* (2011) also tested burial tolerances of the sea squirt *Ciona intestinalis*. This species was highly intolerant of burial events with 100% mortality of all individuals buried for at least two days. The species demonstrated no ability to re-emerge from burial and no significant difference was found in sediment fraction effect. This species is not a characterising species but is relevant to this ecological group. Bijkerk (1988, results cited from Essink (1999) indicated that the maximal overburden through which the anemone *Sagartia elegans* could migrate was <10cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

The effect of smothering by 30cm of sediment (as a single event) will be mediated by time taken for the deposited sediment to be dispersed. The biotopes (CMX.FluHyd and CMX.OphMx) that the species in this group can dominate are high to moderate energy and hence the deposited sediment is unlikely to remain more than a few days (expert judgment). But in low energy conditions, where the sediment remains for prolonged periods, the resistance will be lower.

Therefore, **resistance** to smothering by 30cm of fine sediment was assessed as **'Low'** (loss of 25-75% of abundance, extent or density) for ***A. aspera*** and ***A. digitatum*** **but 'Medium'** for ***F. foliacea*** and ***U. felina*****.** **Resilience** is assessed as **'High'** for ***A. aspera*** and **'Medium'** (2-10 years) for ***A. digitatum*****,** ***F. foliacea*** and ***U. felina*****.** **Sensitivity** is therefore assessed as **'Medium'** for all species except *A. aspersa* which is considered to have **'Low' sensitivity** based on 'High' resilience.

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience (section 4.3.7)

Quality of evidence is 'Medium' - based on inference from peer reviewed and grey literature on life history traits, and observations from the field.

Applicability of evidence is 'Low' – based on life history and observed recolonisation rates of the species in the group or inference from other species or pressures.
Concordance of evidence is 'Medium' - based on agreement in direction but not magnitude.

4.3.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that this ecological group is able to colonise artificial substratum. An increase in availability of hard substratum is therefore thought to be beneficial to this ecological group (although differences in diversity and other structural characteristics of assemblages on hard and artificial substratum have been observed and artificial habitats may not provide a habitat of the same quality as natural rock reefs).

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Alcyonium digitatum*: muddy sand, sandy muds, gravel and pebbles; mixed sediment (with stones and shells); mixed muddy sandy gravel; pebble, gravel and shells on sandy mud sediments; medium-coarse sands with gravel, shell, pebbles and cobbles; clean stone gravel with pebbles; bedrock; boulders; artificial, wrecks; cobbles, pebbles and *Modiolus* shells; Stones or shells on muddy sediment; and mixed sediment.

- *Ascidiella aspera*; mud with a fine to very fine sand fraction; mud with terrigenous debris; mud or muddy sand with shells, gravel or pebbles; mud occasionally with small stones; sandy mud; sandy mud with some shells and occasionally gravel; sandy muddy gravel; pebble, calcareous tubes; mixed sediment; pebbles; shells; gravel on sandy mud; gravel and shells on sandy mud sediments stony sediment; bedrock; boulders and cobbles; artificial, and other.

- *Flustra foliacea*: medium-coarse sands with gravel, shell, pebbles and cobbles; mixed muddy sediment; muddy gravelly sand with pebbles; mixed sediment of sandy mud, muddy sand with gravel pebbles and cobbles; bedrock; boulders; artificial, and wrecks.

- *Urticina felina*: mixed sediment of sandy mud, muddy sand with gravel pebbles and cobbles; medium-coarse sands with gravel, shell, pebbles and cobbles; medium to fine sand with pebbles and cobbles; mixed sediment (with stones and shells) medium to very fine sand; mixed sediment; muddy gravelly sand with pebbles; cobbles, pebbles and *Modiolus* shells; muddy sand, sandy muds, gravel and pebbles; stony sediment; bedrock, boulders; artificial, and other.

A change in classification of one Folk class between coarse sediments, mixed sediments and sands and muddy sands (based on the Long 2006 simplification) is not predicted to negatively affect this ecological group which the MNCR records indicate is found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). **Sensitivity** is therefore assessed as **'Not Sensitive'.** Changes in habitat to a fine mud would negatively affect this group by preventing attachment although if there were some pebbles and cobbles remaining this group may be able to colonise the habitat. *Urticina felina*, for example, has been found in mud habitats attached to buried pebbles and shells and the species also occurs on mud overlying stone covered dikes (Braber & Borghouts 1977).

Resistance

Quality of evidence is 'Medium' – based on inference from on habitat preferences (ecology and distribution) information rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on the habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.3.6 Pollution and other chemical changes

XIV. Organic enrichment

No directly applicable evidence was available to assess this pressure at the benchmark for members of this ecological group.

Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of an AMBI index to assess disturbance (including organic enrichment) have assigned *Alcyonium digitatum*, *Ascidiella aspera* and *Urticina felina* to AMBI categories based on their tolerance to organic enrichment. Each species differs in the category it was assigned to:

- *Alcyonium digitatum* was assigned to AMBI Group I (Species very sensitive to organic enrichment and present under unpolluted conditions (initial state) (Gittenberger & van Loon 2011).

- *Ascidiella aspera* was assigned to AMBI Group III (Species tolerant to excess organic matter enrichment). These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations) (Borja *et al* 2000; Gittenberger & van Loon 2011).

- *Urticina felina* was assigned to AMBI Group II (Species indifferent to enrichment, always present in low densities with non-significant variations with time) (from initial state, to slight unbalance) (Gittenberger & van Loon 2011).

It is not clear whether the pressure benchmark would lead to enrichment effects in the dynamic habitats these species generally favour. High water movements in areas of tidal flow would remove organic matter particles mitigating the effect of this pressure. *Ascidiella aspera* in more sheltered environments would be able to utilise the additional organic matter as food and may benefit from an increase in supply. Although members of this group may be sensitive to gross organic pollution resulting from sewage disposal and aquaculture they are considered to have **'High' resistance** to the pressure benchmark which represents organic enrichment and therefore **'High' resilience.** The group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on peer reviewed AMBI score although the evidence supporting the AMBI score is unclear.
Applicability is 'Low' – based on AMBI scores but evidence and assumptions are unknown.
Concordance is 'Low' – based on AMBI scores but evidence and assumptions are unknown.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.3.7 Review of likely rates of recovery based on the species assemblages present within the ecological group

Recovery rates between species within this ecological group vary. The tunicate *Ascidiella aspera* has the greatest resilience as it expresses life-history traits typical of opportunistic species that can rapidly colonise newly cleared spaces via planktonic larvae. It likely to recolonise rapidly following impacts as long as habitats are suitable. Resilience for this species is therefore assessed as ‘High’.

Little information is available for life-history and reproductive strategies to inform a recovery assessment for *Urticina felina.* Recovery is likely to be slow in populations where nearby individuals do not exist. The large size, slow growth rate and evidence from aquarium populations suggest that *Urticina felina* is long lived (Jackson & Hiscock 2008). Although it probably breeds each year there is no information regarding fecundity. Breeding probably does not occur until the anemone is at least 1.5 years old (Jackson & Hiscock 2008). Dispersal ability is considered to be poor in the similar species *Urticina eques* (Solé-Cava *et al* 1994, cited in Jackson & Hiscock, 2008). Adults can detach from the substratum and relocate but locomotive ability is very limited. Impacts that remove large proportions of the population over a wide area will effectively reduce the availability of colonists. However, the species colonised ex-HMS *Scylla* in the fourth year of the vessel being on the seabed (Sköld *et al* 2001). Resilience is assessed as ‘Medium’.

Budd (2008) suggested that *Alcyonium digitatum* had a high recovery potential. The combination of spawning in winter and larvae with a long pelagic life allows widespread dispersal and means that newly settled *Alcyonium digitatum* will consequently be able to take advantage of an abundant food resource in spring and be well developed before the appearance of other forms which may compete for the same substrata.

Silen (1981) reported that *Flustra foliacea* could repair physical damage to its fronds within 5-10 days. The brooded, lecithotrophic larvae of bryozoans have a short pelagic life time of several hours to about 12 hours (Ryland 1976). Even in the presence of available substratum, Ryland (1976) noted that significant recruitment in bryozoans only occurred in the proximity of breeding colonies. For example, Keough and Chernoff (1987) reported that a population of another bryozoan *Bugula neritina* demonstrated spatial variation over very small scales, and populations were sometimes absent even when substantial populations were <100m away.

Flustra foliacea colonies are perennial, and potentially highly fecund when large. Once settled, new colonies take at least one year to develop erect growth and 1-2 years to reach maturity, depending on environmental conditions. Four years after sinking, the wreck of a small coaster, the M.V. Robert, off Lundy was found to be colonised by erect bryozoans and hydroids, including occasional *Flustra foliacea* (Hiscock 1981). The wreck was several hundreds of metres from any significant hard substrata, and hence a considerable distance from potential parent colonies (Hiscock 1981 and pers comm, cited in Tyler-Walters & Ballerstedt 2007).

Recovery rates are predicted to be relatively longer for *Flustra foliacea* and *Alcyonium digitatum* where the population is removed or significantly impacted. Resilience is therefore assessed as ‘Medium’ for these species. The magnitude of the impact and the footprint will partially determine recovery rates.

Overall, **resilience** of *F. foliacea, A. digitatum,* and *U. felina* and probably **'Medium'** (2-10 years), while the resilience of the rapid colonising sea squirt *A. aspersa* is probably **'High'**. The assessments are based on inference from peer reviewed and grey literature on life history traits, and observations from the field. Therefore, the quality of the evidence is regarded as 'Medium'. Confidence in applicability and the degree of concordance is assessed as ‘Medium’.

4.3.8 Knowledge gaps

In general the sensitivity of this ecological group has not been extensively studied. The species are not of particular conservation or commercial interest to stimulate interest although the conspicuous members of the group, *Alcyonium digitatum* and *Flustra foliacea* are frequently recorded in surveys. The occurrence of these species on hard substratum and tide-swept areas means they are less amenable to sampling than soft sediment infauna.

The information available to assess species resistance and resilience varied between species within this ecological group and between pressures. No evidence was found for non-indigenous species although it was not clear if this represents a lack of overlap or a lack of evidence.

Little evidence to support the hydrological change assessments was found and these pressures were assessed based on distribution records rather than direct evidence. Little evidence was found for other pressures that potentially change habitat quality including physical change in substratum and changes in suspended solids and organic enrichment.

Information on the physical damage pressures was also more limited than for other groups and this may be due in some instances to a lack of overlap with impacting activities but is most likely driven by the lower study effort in coarse and hard bottom habitats.

The anemone *Urticina felina* is poorly studied and little information was found to assess resilience.

4.4 Ecological Group 1d Small epifaunal species with robust, hard or protected bodies

4.4.1 Definition and characteristics of the ecological group

This group comprises small, attached species that have protected bodies. These species include the barnacles *Balanus balanus*, *Balanus crenatus*, and the tube worm *Pomatoceros triqueter* (**Table 4.4**). Bryozoan crusts (indeterminate) are also included in this ecological group. This ecological group is found attached to hard surfaces from bedrock to stones within mixed sediments in exposed and unstable environments, as well as deeper and more stable mixed sediments with suitable attachment surfaces where *Pomatoceros triqueter* is dominant.

The characteristic species tend to dominate in disturbed and/or mobile coarse sediments subject to periodic storm damage or regular scour and wave action.

Table 4.4. List of biotopes in which ecological group 1d species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.PomB	*Balanus crenatus* *Pomatoceros triqueter*
SS.SMx.CMx.ClloModHo	*Pomatoceros triqueter*
SS.SMx.CMx.OphMx	*Pomatoceros triqueter*

4.4.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No Evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.4.4). No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be 'Not Exposed' to targeted removal.

Members of this ecological group are usually found on hard substratum but in some cases living animals will provide suitable settlement surfaces. *Pomatoceros triqueter* for example, may colonise bivalve shells and macroalgae, including kelp, and the removal of these target species will remove associated living individuals and remove the availability of suitable habitats. Similarly *Balanus crenatus* has been found inhabiting the hard carapace of crustaceans, including *Nephrops norvegicus*. A managed fishery will not remove all targeted individuals, and as the epizootic proportion of the population is probably fairly small compared to the epilithic, this pressure is not considered to significantly impact populations. It should be noted that the assessments refer to a species in their typical range (Holt *et al* 1995). This group is therefore considered to be **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species**.**

Resistance

Quality of evidence is ‘Medium’ – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability is ‘Low’ – based on species traits as a proxy for resistance.
Concordance is ‘Not assessed’ – based on species traits alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.4.4). Although members of this ecological group may grow on bivalve shells, crustaceans or macroalgae and be removed alongside these, the main habitat is hard substratum. No further obligate life history or ecological associations were identified for this ecological group. No direct effects on this ecological group are therefore predicted to arise from this pressure and **resistance** and **resilience** are therefore assessed as **‘High’** and this group is considered to be **‘Not Sensitive’**.

Resistance

Quality of evidence is ‘Medium’ – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability is ‘Low’ – based on species traits as a proxy for resistance.
Concordance is ‘Not assessed’ – based on species traits alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.4.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

The available evidence indicates that tolerances to changes in salinity differ between the species within this ecological group.

When subjected to sudden changes in salinity *Balanus crenatus* closes its opercular valves so that the blood is maintained temporarily at a constant osmotic concentration (White 2004). *B. crenatus* can tolerate salinities down to 14psu if given time to acclimate (Foster 1970). At salinities below 6psu motor activity ceases, respiration falls and the animal falls in to a "salt sleep". In this state the animals may survive in fresh water for 3 weeks, enabling them to withstand changes in salinity over moderately long periods (Barnes & Powell 1953).

Therefore, ***Balanus crenatus*** is considered to have **‘High’ resistance** to a decrease in salinity at the pressure benchmark. **Resilience** is therefore assessed as **‘High’** (no effect to recover from) and the species is considered to be **‘Not Sensitive’.**

Resistance

Quality of evidence is 'High' – based on peer reviewed targeted studies.
Applicability is 'High' – based on the effect of directly relevant pressure.
Concordance is 'High' – based on agreement in direction and magnitude.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

Pomatoceros triqueter has not been recorded from brackish or estuarine waters. Therefore, it is likely that the species will be very intolerant of a decrease in salinity. However, Dixon (1985, cited in Riley & Ballerstedt 2005) views the species as able to withstand significant reductions in salinity. The degree of reduction in salinity and time that the species could tolerate those levels were not recorded. Therefore, there is insufficient information available to assess the intolerance of *P. triqueter* to a reduction in salinity. No evidence was available to assess the impact of an increase in salinity at the pressure benchmark.

Due to the lack of records from estuarine and brackish waters (Riley & Ballerstedt, 2005), ***Pomatoceros triqueter*** is considered to have a **resistance** of **'None'** to decreases in salinity. **Resilience** is assessed as **'High'** based on the evidence available (within 2 years following habitat recovery) and **sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on inference from distribution rather than targeted studies.
Applicability is 'Low' – based on distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on distribution alone.

Resilience (section 4.4.7)

Quality of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Applicability of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

However, **'No evidence'** was found to assess the sensitivity to an increase in salinity.

V. Temperature changes-local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

In Queens Dock, Swansea where the water was on average 10°C higher than average due to the effects of a condenser effluent, *Balanus crenatus* was replaced by the subtropical barnacle *Balanus amphitrite*. After the water temperature cooled *B. crenatus* returned (Naylor 1965). It has a peak rate of cirral beating at 20°C and all spontaneous activity ceases at about 25°C (Southward 1955). The increased water temperature in Queens Dock is greater than an increase at the pressure benchmark (2-5°C). The species is more tolerant of lower temperatures. *B. crenatus* was unaffected during the severe winter of 1962-63, when average temperatures were 5 to 6°C below normal (Crisp 1964). Thomas (1940) noted that *P. triqueter* could not form tubes below 7°C.

Global distribution

- *Balanus crenatus*: northeast Atlantic from the Arctic to the west coast of France as far south as Bordeaux; east and west coasts of North America and Japan.

- *Pomatoceros triqueter* occurs from the coasts of northwest Europe to the Mediterranean (Riley & Ballerstedt 2005).

Overall, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect these species as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'.** This group is therefore considered to be '**Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from distribution rather than targeted studies.
Applicability is 'Low' – based on distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on distribution alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

The threshold tolerances for increases/decreases in water flow for each species are not clear. White (2004) reports that *Balanus crenatus* is found in a very wide range of water flows and can adapt feeding behaviour according to follow rates. In the absence of any current, the barnacle rhythmically beats its cirri to create a current to collect zooplankton.

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for biotopes characterised by members of this ecological group as follows.

- *Balanus crenatus*: very strong to very weak (negligible - >3m/s).

- *Pomatoceros triqueter*: moderately strong to very weak (negligible - >1.5m/s).

The range of flow speeds experienced by biotopes in which the species are found (from negligible - >3m/s for selected species) suggest that a change in the maximum water flow experienced by mid-range populations for the periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from habitat preferences rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

VII. Wave exposure changes - local

This pressure and the assumptions regarding wave height and exposure are described in more detail in Section 3.2.1. Changes in significant wave height at the pressure benchmark (change in height >3% but <5%) may reflect an increase or decrease in wave height.

No information was found on the effects of changes in wave height on this ecological group. As a proxy indicator of resistance, evidence from the MNCR database for the wave exposure categories (see section 3.2.1 for descriptions) experienced by biotopes characterised by members of this ecological group was used. The degree of wave exposure is understood to mediate wave heights experienced by the biotope due to differences in fetch (with shorter fetch associated with smaller wave heights), exposure to prevailing winds which reflects the energy of the wave (with exposure positively correlated with wave height) and factors such as the presence of deep water and offshore obstructions. Records from the MNCR database indicate the wave exposure levels experienced by biotopes characterised by members of this ecological group follow.

- *Balanus crenatus*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed.

- *Pomatoceros triqueter*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed; extremely exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **‘High’** and as there is no impact, **resilience** is considered to be **‘High’.** This group is therefore considered to be **‘Not Sensitive’.**

Resistance

Quality of evidence is ‘Low’ – based on inference from habitat preferences that do not compare directly with the benchmark, rather than targeted studies.
Applicability is ‘Low’ – based on habitat preferences as a proxy for resistance.
Concordance is ‘Not assessed’ – based on habitat preferences alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.4.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

Attached epifauna can be damaged and removed by abrasion although evidence to assess this pressure is limited. Evidence was found for natural abrasion rather than human induced disturbance, although this evidence is considered applicable to this pressure.

Hiscock (1983) noted that a community, under conditions of scour and abrasion from stones and boulders moved by storms, developed into a community consisting of fast growing species such as *Pomatoceros triqueter*. Off Chesil Bank, the epifaunal community dominated by *P. triqueter*, *Balanus crenatus* and *Electra pilosa* (an encrusting bryozoan), decreased in cover in October as it was scoured away in winter storms, but recolonised in May to June (Gorzula 1977). Warner (1985) reported that the community did not contain any persistent individuals, being dominated by rapidly colonising organisms. Recruitment was sufficiently predictable to result in a dynamic stability and a similar community (dominated by *P. triqueter*, *Balanus crenatus* and *Electra pilosa*) was present in 1979, 1980 and 1983 (Riley & Ballerstedt 2005).

Both *B. crenatus* and *P. triqueter* are protected from abrasion by hard, calcareous tubes or plates and encrusting bryozoans are relatively robust. However natural scour has been observed to remove individuals (Warner 1985). Where individuals are attached to mobile pebbles, cobbles and boulders rather than bedrock, surfaces can be displaced and turned over preventing feeding and leading to smothering**.**

Re-sampling of grounds that were historically studied (from the 1930s) indicated that some encrusting species including serpulid worms and several species of barnacles and encrusting bryozoans had decreased in abundance in gravel substrata subject to long-term scallop fishing (Bradshaw *et al* 2002). These may have been adversely affected by the disturbance of the stones and dead shells on to which they attach (Bradshaw *et al* 2002).

Bradshaw *et al* (2002) found that serpulid worm abundance had decreased in fished grounds compared to areas that were less exposed to trawling. This observation is supported by experimental trawling, carried out in shallow, wave disturbed areas using a toothed, clam dredge, which found that *Pomatoceros* sp. decreased in intensively dredged areas over monitoring period (Constantino *et al* 2009). In contrast, a study of *Pomatoceros* spp. aggregations found that the tube heads formed were not significantly affected by biannual beam trawling in the eastern Irish Sea (Kaiser *et al* 1999). No changes in the number or size of serpulid tube heads was apparent throughout the course of the study, and no significant changes were detectable in the composition of the tube head fauna that could be attributed to fishing disturbance (Kaiser *et al* 1999). Subsequent laboratory experiments on collected tube heads found that these were unlikely to resettle on the seabed in an orientation similar to that prior to disturbance (Kaiser *et al* 1999). This may lead to the death of the resident serpulids and sessile associated fauna.

Members of this ecological group are directly exposed to abrasion and sub-surface penetration which would displace, damage and remove individuals. **Resistance** is assessed as **'Low'** (loss of 25-75% of individuals). Evidence from Warner (1985) indicates that colonisation is rapid and transitory communities are annual, **resilience** is therefore assessed as **'High'. Sensitivity** is therefore assessed as **'Low'.**

Resistance

Quality of evidence is 'Medium' – based on by-catch studies, comparisons of areas that are subject to different levels of trawling disturbance and samples collected from areas that are known to be trawled.
Applicability is 'High' – based on studies on relevant activities for *Pomatoceros triqueter* and both species (*P. triqueter* and *Balanus crenatus*) dominance of physically disturbed habitats.
Concordance is 'Medium' – based on agreement on direction not magnitude consistent.

Resilience (section 4.4.7)

Quality of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Applicability of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

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

The relevant evidence and hence sensitivity assessment are the same as that presented under surface abrasion (4.4.4.VIII) above.

X. Change in suspended solids

An increase in turbidity could be beneficial for this ecological group if the suspended particles are composed of organic matter, however high levels of suspended solids with increased inorganic particles may reduce filter feeding efficiencies. A reduction in light penetration could also reduce growth rate of phytoplankton and so limit zooplankton levels, which form the majority of barnacle diets. However, light penetration itself is unlikely to be an important factor as both *Balanus crenatus* and *Pomatoceros triqueter* are recorded from the lower eulittoral or the lower circalittoral.

Barnes and Bagenal (1951) found that growth rate of *B. crenatus* epizoic on *Nephrops norvegicus* was considerably slower than animals on raft exposed panels. This was attributed to reduced currents and increased silt loading of water in the immediate vicinity of *Nephrops norvegicus*.

Available evidence indicates that *Pomatoceros triqueter* is tolerant of a wide range of suspended sediment concentrations (Riley & Ballerstedt 2005). Stubbings and Houghton (1964) recorded *P. triqueter* in Chichester harbour, which is a muddy environment. However *P. triqueter* has been noted to occur in areas where there is little or no silt present (Price *et al* 1980).

Based on the available evidence, **resistance** to a change in turbidity of one rank is assessed **as 'Medium'**. **Resilience** is assessed as **'High'** and the **sensitivity** of this group is therefore assessed as '**Low'.**

Resistance

Quality of evidence is 'Low' – based on expert judgement, albeit inferred from limited evidence.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience (section 4.4.7)

Quality of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Applicability of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

XI. Habitat structure changes - removal of substratum (Extraction)

The process of extraction will remove all members of this ecological group as they are permanently attached and live on the surface or shallowly buried. The sediments exposed by extraction are considered to be suitable for recolonisation almost immediately following extraction as levels of suspended sediments which may rise after extraction will subside rapidly (see changes in water clarity, section 4.4.4.X). Recovery will be mediated by the scale of the disturbance and the suitability of the sedimentary habitat. **Resistance** is assessed as **'None'** and **resilience** as **'High'** (occurring through larval settlement). This results in a **sensitivity** score of **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on inference from ecology rather than targeted studies.
Applicability is 'Low' – based on ecology as a proxy for resistance.
Concordance is 'Not assessed' – based on ecology alone.

Resilience (section 4.4.7)

Quality of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Applicability of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

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

As small, sessile species attached to the substratum siltation and smothering would bury these species and probably destroy the community. Holme and Wilson (1985) described a *Pomatoceros-Balanus* assemblage on 'hard surfaces subjected to periodic sever scour and 'deep submergence by sand or gravel' in the English Channel. They inferred that the *Pomatoceros-Balanus* assemblage was restricted to fast-growing settlers able to establish themselves in short periods of stability during summer months (Holme & Wilson 1985), as all fauna were removed in the winter months.

Resistance is therefore assessed as **'None'**. Recovery would require habitat restoration but would be expected to be rapid if this was achieved. **Resilience** is therefore assessed as **'High'** and **sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on inferences from peer reviewed observations.
Applicability is 'Low' – based on natural disturbance as a proxy for this pressure.
Concordance is 'Not assessed' – based on a single source.

Resilience (section 4.4.7)

Quality of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Applicability of evidence is 'High' - based on the ecology and life history of the species, together with peer reviewed reports and observations.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

4.4.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that this ecological group is able to colonise artificial substratum. An increase in available hard substratum is therefore thought to be beneficial to this ecological group (although differences in diversity and other structural characteristics of assemblages on hard and artificial substratum have been observed and artificial habitats may not provide a habitat of the same quality as natural rock reefs).

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The records indicate the following substratum types for biotopes characterised by members of this ecological group.

- *Balanus crenatus*: mud; muddy sand; sandy muds; sandy mud with some shells and occasionally gravel; sandy mud and gravel; medium to very fine sand; medium to fine sand with pebbles and cobbles; mixed sediment (with stones and shells); cobble; stony sediment; gravel and pebbles; boulders; boulders, cobbles and pebbles on muddy sediments; cobbles, pebbles and *Modiolus* shells; small boulders; bedrock.

- *Pomatoceros triqueter*: mud with a significant fine to very fine sand fraction; muddy sand, sandy muds, gravel and pebbles; muddy gravelly sand with pebbles; sandy mud with some shells and occasionally gravel; mixed muddy sediment; *Maerl*; shell gravel; stones and coarse sediment; coarse sand and gravel with a minor finer sand fraction; gravels, clean sands; pebble, gravel and shells on sandy mud sediments; boulders, cobbles and shells on muddy sediment; cobbles, pebbles and *Modiolus* shells; bedrock, boulders, cobbles, pebbles, gravel, sand.

A change in classification of one Folk class between coarse sediments, mixed sediments and sand and muddy sand (based on the Long 2006 simplification) is not predicted to negatively affect this ecological group which the MNCR records indicate is able to settle on hard substratum e.g. stones and shells, in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). The group is therefore considered **'Not Sensitive'.** Changes in habitat to a fine mud would negatively affect this group by preventing attachment although if there were some pebbles and cobbles remaining this group may be able to colonise the habitat.

Resistance

Quality of evidence is 'Medium' – based on inference from habitat preferences rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.4.6 Pollution

XIV. Organic enrichment

No directly applicable evidence was available to assess this pressure at the benchmark for members of this ecological group at the pressure benchmark. In the development of the AZTI Marine Biotic Index AMBI pollution indicator, supported by a recent review of evidence, *Pomatoceros triqueter* and *Balanus crenatus* were characterised as AMBI Group II: Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers (Borja *et al* 2000; Gittenberger & van Loon 2011).

Based on the AMBI categorisation (Borja *et al* 2000; Gittenberger & van Loon 2011), this ecological group is assessed as **'Not Sensitive'** to this pressure based on **'High' resistance** and **'High' resilience** as there is no impact to recover from.

Resistance

Quality of evidence is 'Medium' – based on peer reviewed AMBI score although the evidence supporting the AMBI score is unclear.
Applicability is 'Low' – based on AMBI scores but evidence and assumptions are unknown.
Concordance is 'Low' – based on AMBI scores but evidence and assumptions are unknown.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.4.7 Review of likely rates of recovery based on the species present within the ecological group

Some attachment surfaces used by this ecological group are unstable and members of this ecological group are adapted to rapidly colonise available space. These relatively short-lived species mature rapidly and have long reproductive seasons with a spring maxima from March-April for *Pomatoceros triqueter* although breeding can occur throughout the year. *Balanus crenatus* produce larvae from February and September, with peaks in April and late summer when phytoplankton levels are highest (White 2004). Both stages have relatively long planktonic larval phases. There is therefore a good larval supply available. *B. crenatus* has a life span of 18 months (Barnes & Powell 1953) although *P. triqueter* lives for 2 to 4 years (Dons 1927; Castric-Fey 1983; Hayward & Ryland 1995) and matures at 4 months (Hayward & Ryland 1995; Dons 1927). Barnacles grow rapidly except in winter. April-settled individuals may release larvae the same July and reach full size before their first winter. Individuals that settled later reach maximum size by the end of spring the following year (Rainbow 1984).

Members of this group can utilise a variety of substrata including artificial and natural hard substratum, bivalves and other animals. The life history traits and broad habitat preferences mean that populations of these species can recover rapidly. *P. triqueter* is considered to be a primary fouling organism (Crisp 1965) colonising artificial commercially important structures such as buoys, ships hulls, docks and offshore oil rigs (OECD 1967). *P. triqueter* are commonly the initial recruits to new substrata (Sebens 1985, 1986; Hatcher 1998). For example, *P. triqueter* colonized artificial reefs soon after deployment in summer (Jensen *et al* 1994) and settlement plates within 2-3.5 months and dominated spring recruitment (Hatcher 1998).

Balanus crenatus is an important early coloniser of sublittoral rock surfaces (Kitching 1937) and it heavily colonised a site that was dredged for gravel within 7 months (Kenny & Rees 1994). *Balanus crenatus* also colonized settlement plates or artificial reefs within 1-3 months of deployment in summer, and became abundant on settlement plates shortly afterwards (Brault & Bourget 1985; Hatcher 1998).

Hiscock (1983) noted that a community, under conditions of scour and abrasion from stones and boulders moved by storms, developed into a community consisting of fast growing species such as *P. triqueter*. Off Chesil Bank, the epifaunal community dominated by *P. triqueter*, *B. crenatus* and *Electra pilosa*, decreased in cover in October as it was scoured away in winter storms, and was recolonised in May to June (Warner 1985). Warner (1985) reported that the community did not contain any persistent individuals, being dominated by rapidly colonising organisms such as *P. triqueter* and *B. crenatus*. While larval recruitment was patchy and varied between the years studied, recruitment was sufficiently predictable to result in a dynamic stability and a similar community was present in 1979, 1980 and 1983. Holme and Wilson (1985) suggested that the fauna of the *Balanus-Pomatoceros* assemblage in the central English Channel was restricted to rapid growing colonizers able to settle rapidly and utilize space in short periods of stability in the summer months.

Both species are rapid colonisers and likely to recover quickly, probably within months. Therefore, resilience is assessed as 'High. The assessment is based on the ecology and life history of the species, together with peer reviewed reports and observations. Therefore, confidence in the quality, applicability and concordance is 'High'.

4.4.8 Knowledge gaps

The life cycles of these common, widespread species are relatively well understood and good examples of recovery were provided by natural proxies for disturbance (storm driven abrasion and sediment disturbance). However little, direct information was available to assess responses to pressures although impacts could be inferred from life history traits and habitat distribution (e.g. for siltation, physical change and extraction). No direct evidence was found to assess the hydrological change pressures at the pressure benchmarks and these assessments were based on recorded distribution.

No evidence was found for the resistance of *B. crenatus* to physical damage pressures from human activities directly, although some evidence was available for *Pomatoceros* spp. with regard to fishing activities.

4.5 Ecological Group 2 Temporary or permanently attached surface dwelling or shallowly buried larger bivalves.

4.5.1 Definition and characteristics of the ecological group

Members of this ecological group are the scallops *Pecten maximus*, *Pseudamussium septemradiatum*, the horse mussel *Modiolus modiolus* and *Limatula auriculata* (**Table 4.5**). The species have some disparate characteristics in terms of attachment, position within sediment and mobility and are considered to vary in sensitivity. The bivalve *P. maximus* for example lives on the surface of coarse sediments and can 'swim' to escape predators whereas the horse mussel *M. modiolus* lives shallowly buried in soft sediments and may form reefs. This group was based on taxonomy (bivalves), the surface or interface habit and suspension feeding. To adequately assess sensitivity *P. maximus* and *M. modiolus* are specifically reviewed as little is known about *P. septemradiatum* or *L. auriculata*. *P. maximus* characterises coarse sediment and sandy mud biotopes and *M. modiolus* is found in mixed sediment biotopes. As these species do not overlap in distribution the relevant species sensitivity assessment can be applied where appropriate. The sensitivity assessments developed in this section are based on *M. modiolus* occurring in low densities within circalittoral and offshore biotopes rather than the dense beds that characterise the reef biotopes.

Table 4.5. List of biotopes in which ecological group 2 species occur as characterising species.

Level 5 biotopes represented	Characterising species assessed
SS.SCS.CCS.Nmix	*Pecten maximus*
SS.SMu.CSaMu.VirOphPmax	*Pecten maximus*
SS.SMx.CMx.ClloMx.Nem	*Modiolus modiolus*
SS.SMx.CMx.ClloModHo	*Modiolus modiolus*
SS.SMu.OMu.StyPse	Characterising species present were not specifically assessed.

4.5.2 Biological Pressures

XV. Introduction or spread of non-indigenous species (NIS)

Castric-Fey *et al* (1993) report that scallops, *Placopecten magellanicus*, overgrown with the invasive tunicate *Didemnum vexillem* show changes in escape potential. Scallops covered by *D. vexillum* became exhausted more quickly, and were not able to swim as far in either the horizontal or vertical direction as the control sea scallops without *D. vexillum* encrustation. The authors conclude that the expansion of *D. vexillum* into scallop habitat may increase the vulnerability of sea scallops to predation and limit their ability to access food rich habitats. No evidence was available to quantify the potential effect on *Pecten maximus*. There may also be a potential beneficial effect through camouflage as (Hay & Luckens 1987) found that overgrowth reduced predation rates by *Carcinus maenas* on *Mytilus edulis* beds but this aspect was not assessed.

The slipper limpet *Crepidula fornicata* was reported to alter the substratum due to build-up of its pseudofaeces and faeces, and spatially compete with and lower recruitment of *P. maximus* and *Aequipecten opercularis* in the Bay of Brest, France (Frésard & Boncoeur 2006). Although adult scallops that settle amongst *C. fornicata* beds are not affected, juveniles cannot settle in areas of high *C. fornicata* density (Chauvaud *et al* 2003, cited in Frésard & Boncoeur 2006), and the *C. fornicata* beds threatened the sustainability of the ongoing scallop restocking program in the area.

No evidence was available to quantify the potential effect on *Pecten maximus*. However, evidence that *C. fornicata* had an adverse effect on scallop beds in France suggests the potential for impact in the UK. Therefore, a precautionary **resistance** of **'Medium'** is recorded**. Resilience** is probably **'Medium'** resulting in a sensitivity of **'Medium'**. However, **'No evidence'** of the effect of NIS on *M. modiolus* was found.

Resistance (P. maximus)

Quality of evidence is 'Medium' – based on inference peer reviewed literature and expert judgment.
Applicability is 'Medium' – based on the effects of the pressure outside the UK.
Concordance is 'Medium' – based on agreement on direction but not magnitude.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

XVI. Removal of Target Species

Within this ecological group *Pecten maximus* is targeted by extensive commercial fisheries. Holt *et al* (1998) reported that, although there was no large scale *Modiolus* fishery in the United Kingdom, there have been small scale local fisheries in Scotland for food or bait and that horse mussels were occasionally seen on markets in Lancashire. The other species within this ecological group that are not specifically assessed are not targeted for harvesting. All members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts are assessed in section 4.5.4 (abrasion and penetration of the seabed pressures). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group.

The catching efficiency of scallop dredges has been found to vary between size classes (Fifas & Berthou 1999). In the case of spring-loaded dredges used in the Western English Channel, (Dare *et al* 1993) indicated efficiencies ranging from 6% for rough ground to 41% on smooth muddy gravel bottom for scallops greater than 90mm (legal size). Capture by a scallop dredge can cause damage to the scallop shells and in particular to the growing edge. (Ansell *et al* 1991) stated that up to 19% of the scallops left behind by a dredge are affected to some extent. Individuals with damaged shells are more prone to predation. In addition, the energy budget would be altered so that energy previously reserved for spawning would be allocated to new shell growth and therefore reduce the viability of the population. However, (Jenkins *et al* 2001) reported that, during dredging, more than 90% of *Pecten maximus* that came into contact with a dredge (including those landed, discarded and left behind by the dredge) were in good condition overall and showed little or no shell damage.

Laboratory studies of simulated dredging showed that swimming escape responses in *Pecten maximus* were reduced after an experimentally simulated dredge haul, most likely due to exhaustion after swimming while in the net (Jenkins & Brand 2001). This suggests that discarded scallops, such as undersize specimens, will be less active for hours after being returned to the seabed and less able to escape predators and scavengers. Both *Asterias rubens* and the crab *Cancer pagurus* (Brand 1991) are abundant at scallop grounds and are attracted to high scallop densities, for example, in areas of juvenile reseeding (Wilson 1994) and to simulated by-catch discards (Veale *et al* 2000). Undamaged, discarded scallops that are returned to the seabed along with large quantities of damaged invertebrate by-catch will be subjected to high levels of predator activity which they will be less able to escape from (Jenkins & Brand 2001).

Where directly targeted the **resistance** of *Pecten maximus* is assessed as **'Medium'** as scallop dredge efficiency is relatively low (Dare *et al* 1993). Blyth *et al* (2004), when comparing sites that were trawled for scallops to those that were untrawled or previously trawled (but not in the 18-24 months prior to the study) found that significantly fewer scallops were caught in the trawled sites. They suggested that at least a two year period was necessary for the benthic community to recover to a state that was indistinguishable from non-trawled areas. **Resilience** is therefore assessed as **'Medium'.** Overall, **sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed studies.
Applicability is 'High' – based on peer reviewed studies of the effects of this pressure.
Concordance is 'High' – based on agreement in both magnitude and direction.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

Modiolus modiolus is not directly targeted in the UK (Holt *et al* 1998) and hence **'Not exposed'.** While removal of targeted species (scallops) will reduce species richness there is no obligate relationship between the two species, and loss of scallops itself is unlikely to adversely affect the resident *M. modiolus* population. The physical effects of dredging for scallops are discussed under abrasion and penetration pressures below (section 4.5.4).

XVII. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. This direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.5.4).

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Species within this group live on or shallowly buried within sediments and feed on suspended particles transported in the water column. They are not considered dependent on other species for habitat or food (Marshall & Wilson 2009). Removal of predators as by-catch may generate a beneficial, indirect effect for this ecological group. No obligate life-history or ecological associations were identified and this ecological group is considered to be '**Not Sensitive'** (**resistance** and **resilience** are assessed as **'High'**).

Resistance

Quality of evidence is 'Medium' – based on inference from species ecology rather than targeted studies.
Applicability is 'Low' – based on ecology as a proxy for resistance.
Concordance is 'Not assessed' – based on ecology alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.5.3 Hydrological Changes (inshore/local)

XVIII. Salinity changes - local

No evidence for tolerance to hypersaline conditions was found. Tolerances to hyposaline conditions of *Pecten maximus* and *Modiolus modiolus* have been relatively well studied through field observations and laboratory experiments.

For *Pecten maximus* Christophersen and Strand (2003) found that in the laboratory, the shells of spat held in water with a low salinity (20ppt) became thin and easily damaged which ultimately led to a negative shell growth rate. The scallops made fewer foot movements and retracted the mantle from the shell margin. Laing (2002) found that between 13-21°C the growth rate was significantly lower at 26psu than at 28-30psu.

For *Modiolus modiolus,* Holt *et al* (1998) reported that dense populations of very young *M. modiolus* do occasionally seem to occur sub tidally in estuaries, but the species is more poorly adapted to fluctuating salinity than many other mussel species (Bayne 1976) and dense populations of adults are not found in low salinity areas. Pierce (1970) exposed *Modiolus* sp. to a range of salinities between 1.5 and 54psu and reported that *M. modiolus* survived for 21 days (the duration of the experiment) between 27 and 41psu. Davenport and Kjørsvik (1982) reported the presence of large horse mussels in rock pools at 16psu in Norway, subject to freshwater inflow, and noted that they were probably exposed to lower salinities. Shumway (1977) reported that *M. modiolus* survived for ten days exposed to either gradual or sudden cyclic changes in salinity between 50 or 100% seawater. After a winter and spring of extremely high rainfall, populations of *M. modiolus* at the entrance to Loch Leven (near Fort William) were found dead, almost certainly due to low salinity outflow (K. Hiscock pers. comm., cited from Tyler-Walters 2007).

Based on the available information both *Pecten maximus* and *Modiolus modiolus* are considered to tolerate a decrease in salinity at the pressure benchmark. Although most of the effects would be sub-lethal **resistance** has been assessed as **‘Medium’** (loss of <25%) as some mortality may occur**. Resilience** is assessed as **‘Medium’** for ***P. maximus*** and **‘Low’ for *M. modiolus*. Sensitivity** is therefore assessed as **‘Medium’**.

Resistance

Quality of evidence is ‘High’ – based on peer reviewed studies.
Applicability is ‘Low’ – based on laboratory experiments and proxies for reduced salinity, rather than this pressure.
Concordance is ‘High’ – based on agreement in both magnitude and direction.

Resilience (section 4.5.7)

Quality of evidence is ‘Medium’ - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is ‘Medium’ - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is ‘Medium’ - based on agreement on direction but not magnitude.

XIX. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

Pecten maximus occurs along the European Atlantic coast from northern Norway, south to the Iberian Peninsula and has also been reported off West Africa, the Azores, Canary Islands and Madeira (Marshall & Wilson 2009). Temperature is considered by many to be the primary trigger in spawning among Pectinidae (Marshall & Wilson 2009) and there is some evidence to suggest that there may be a critical range (Barber & Blake 1991). In the Bay of Brest and the Bay of St Brieuc in France, for instance, the critical temperature range for spawning is thought to be between 15.5 -16°C (Paulet *et al* 1988).

No information was available on an upper threshold of temperature tolerance for adult *P. maximus* although Gruffydd and Beaumont (1972) observed high larval mortality above 20°C. Therefore, a short term, acute increase in temperature of 5°C may lead to the death of some individuals at the upper extreme of their temperature range but it is not thought to affect the majority of *P. maximus* in the long term (Marshall & Wilson 2009). Crisp (1964) reported mortalities approaching 100% of *P. maximus* from several areas around the British coast in the severe winter of 1962-1963 where the average sea temperature fell by approximately 4°C.

Overall, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect *Pecten maximus* as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. For ***P. maximus,* resistance** is therefore assessed as **'High'** and resilience as **'High'** and is, therefore, considered to be **'Not Sensitive'**.

Resistance (P. maximus)

Quality of evidence is 'Medium' – based on inference from geographic distribution rather than targeted studies.
Applicability is 'Low' – based on geographic distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on geographic distribution alone.

Resilience (P. maximus)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

Modiolus modiolus is a boreal species reaching its southern limit in British waters (Holt *et al* 1998). Davenport and Kjørsvik (1982) suggested that its inability to tolerate temperature change was a factor preventing the horse mussel from colonising the intertidal in the UK. Intertidal specimens were more common on northern Norwegian shores (Davenport & Kjørsvik 1982). Little information on temperature tolerance in *M. modiolus* was found, however, its upper lethal temperature is lower than that for *Mytilus edulis* (Bayne 1976) by about 4°C (Henderson 1929, cited in Davenport & Kjørsvik 1982). Subtidal populations are protected from major, short term changes in temperature by their depth. However, Holt *et al* (1998) suggested that because *Modiolus modiolus* reaches its southern limit in British waters it may be susceptible to long term increases in summer water temperatures.

M. modiolus is a boreal species, and the fact that dense aggregations seem to reach their southerly limit around British shores suggests a possible susceptibility to a long-term rise in summer water temperatures. Little published information was found on which to make an informed judgement at the pressure benchmark. For ***M. modiolus***, **Resistance** to either a chronic increase or a short term acute increase in temperature is assessed as **'Low'. Resilience** (following habitat recovery) is assessed as **'Low'** (10-25 years). **Sensitivity** is therefore assessed as **'High'.**

Resistance (M. modiolus)

Quality of evidence is 'Medium' – based on inference from geographic distribution rather than targeted studies.
Applicability is 'Low' – based on geographic distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on geographic distribution alone.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

XX. Water flow (tidal current) changes - local

Pecten maximus lives embedded in recesses in the seabed usually with the upper valve flush with the sediment surface. This position can facilitate feeding by bringing the inhalant current near to the seabed therefore increasing the intake of detritus (Mason 1983). It can also reduce the vulnerability of the scallop to dislodgment through increased water flow rate and wave action. Growth rates of scallops are generally faster in areas of relatively strong currents and reduced growth rates can occur in areas of low current speeds due to food limitation. However, excessive particle enrichment, commonly associated with areas of high water flow rate, may reduce the effectiveness of the feeding apparatus and reduce ingestion rates (Gibson 1956).

A reduction in water flow rate as set in the benchmark may reduce the availability of food particles but it is not likely that this reduction would adversely affect the growth and general condition of the scallop. Bricelj and Shumway (1991) suggested that scallops can compensate for short-term changes in the availability of food by adjusting the clearance rate of food particles.

Wildish *et al* (2000) examined suspension feeding in *M. modiolus* in a flume and noted that they kept the exhalent and inhalant siphons open over the range of flow rates studied, 0.12-0.63m/s. However, the inhalant siphon closed by about 20% in currents above 0.5m/s. Comely (1978) suggested that areas exposed to strong currents required an increase in byssus production, at energetic cost, and resulted in lower growth rates. Populations in strong tidal streams may be more intolerant of an increase in water flow. Fouling by epifauna and algae may also increase the population's intolerance to increased water flow. Witman (1984, cited in Suchanek 1985) found that over 11 months in New England, 84% of fouled mussels were dislodged in comparison with 0% of unfouled individuals.

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for biotopes characterised by members of this ecological group as follows:

- *Modiolus modiolus*: moderately strong to very weak: (negligible – 1.5m/s);

- *Pecten maximus*: moderately strong to very weak: (negligible – 1.5m/s).

Holt *et al* (1998) suggested water movement was important in the development of dense reefs and beds of *M. modiolus*. In addition, the dense beds or reefs of *M. modiolus* occur in stronger water flow than the biotopes examined in this report, for example SS.SBR.SMusModT and SS.SBR.SMus.ModCvar. *P. maximus* is a potentially mobile species, so that an increase above the upper limit of their preferred range is likely to result in an increase in dislodgment from the sediment, so that the population may be displaced, probably without any associated mortality. It should be noted that although no mortality in the population is expected, loss of the population from any given site/habitat may constitute a 'loss' of a habitat component but that such a 'loss' is not part of the assessment. Therefore, the range of flow speeds experienced by biotopes in which the species are found suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group.

Resistance and **resilience** is therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from recorded habitat preferences rather than targeted studies.
Applicability is 'Low' – based on inference from recorded habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based inference from recorded habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

XXI. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for biotopes characterised by members of this ecological group as follows:

- *Modiolus modiolus*: extremely sheltered, very sheltered; sheltered; moderately exposed;

- *Pecten maximus*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **'High'** and as there is no impact, **resilience** is considered to be **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from recorded habitat preferences rather than targeted studies.

Applicability is ‘Low’ – based on inference from recorded habitat preferences as a proxy for resistance.
Concordance is ‘Not assessed’ – based inference from recorded habitat preferences alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.5.4 Physical Damage (Reversible Change)

XXII. Abrasion/disturbance of the substratum on the surface of the seabed

This ecological group represents larger epifaunal bivalves or those that are shallowly buried with part of the shell projecting above the surface. This group is therefore directly exposed to abrasion and sub-surface damage. Evidence to assess the sensitivity of this ecological group is provided by studies on catch efficiency and by-catch damage, comparisons between areas with different levels of fishing activities or re-sampling of areas after exposure. The available evidence suggests that the resistance of *Pecten maximus* and *Modiolus modiolus* to sub-surface penetration and disturbance varies.

Pecten maximus

The scallop *Pecten maximus* is the target of commercial fisheries and hence gears have been developed to capture this species. By-catch studies suggest that due to their robust shells captured *P. maximus* suffer low rates of damage. Jenkins *et al* (2001) found that less than 10% of scallops encountering dredges showed any signs of external physical damage on a scallop fishing ground in the north Irish Sea. Undamaged *P. maximus* captured using dredges, show low levels (-5%). of mortality in the laboratory (Jenkins unpublished data, described in Jenkins *et al* 2001). Similarly (Bergman *et al* 2001) found that most (98%) of queen scallops *Aequipecten opercularis* were undamaged when retained in otter trawl hauls in the Clyde Seas *Nephrops* fishery. Damage was restricted to chipping of the outer shell. Ansell *et al* (1991) however, stated that up to 19% of the scallops left behind by a dredge are affected to some extent. Individuals with damaged shells are more prone to predation. However, Jenkins *et al* (2001) reported that, during dredging, more than 90% of *P. maximus* that came into contact with a dredge (including those landed, discarded and left behind by the dredge) were in good condition overall and showed little or no shell damage. The differences between reported rates of effect may be due to different classification systems used to score impacts.

Blyth *et al* (2004), when comparing sites that were trawled for scallops to those that were untrawled or previously trawled (but not in the 18-24 months prior to the study) found that significantly fewer scallops were caught in the trawled sites. They suggested that at least a two year period was necessary for the benthic community to recover to state that was indistinguishable from non-trawled areas.

Where directly targeted the **resistance** of ***Pecten maximus*** is assessed as **‘Medium’** as scallop dredge efficiency is relatively low (Dare *et al* 1993). **Resilience** is assessed as **‘Medium’.** Overall, **sensitivity** is assessed as **‘Medium’.**

Resistance

Quality of evidence is 'High' – based on peer reviewed studies.
Applicability is 'High' – based on peer reviewed studies of the effects of this pressure.
Concordance is 'High' – based on agreement in both magnitude and direction.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

Modiolus modiolus

Holt *et al* (1998) suggested that horse mussels beds were not particularly fragile, even when epifaunal, with semi-infaunal and infaunal population being less vulnerable to physical disturbance. However, impacts from towed fishing gear (e.g. scallop dredges) are known to flatten clumps and aggregations, and may break off sections of raised reefs and probably damage individual mussels (Holt *et al* 1998). Older specimens can be very brittle due to infestations of the boring sponge *Cliona celata* (Comely 1978; Holt *et al* 1998). It was suggested that scallop dredging on areas adjacent to beds in the south east of the Isle of Man had become less dense and more scattered (Holt *et al* 1998). Holt *et al* (1998) suggested that damage by whelk potting was not likely to be severe but noted that epifaunal populations may be more intolerant.

Magorrian and Service (1998) suggested that horse mussel beds in Stragford Lough were being damaged by bottom trawling, especially for scallops. Magorrian and Service (1998) reported that queen scallop trawling resulted in flattening of horse mussel beds and disruption of clumps of horse mussels and removal of emergent epifauna in Strangford Lough. They suggested that the emergent epifauna were more intolerant than the horse mussels themselves but were able to identify different levels of impact, from impacted but largely intact to few *Modiolus modiolus* intact with lots of shell debris (Service & Magorrian 1997; Magorrian & Service 1998). Recent comparison of dive survey data sets collected in 1975-1983 and 2005-2007, demonstrated declines in *M. modiolus, Aequipecten irregularis* and *Chlamys varia* and some erect sessile fauna between the survey periods (Strain et al 2012). Strain *et al* (2012) concluded that the epifaunal assemblage in Strangford Lough had shifted due to the period of intensive fishing for the queen scallop (*A. irregularis*) between 1985 and 1995. They also noted a significant increase in *P. maximus* but concluded that the increase was due to a closure of its fishery and a reseeding program in the 1990s. Strain *et al* (2012) noted that although all mobile fishing gear was banned in 20004, there were no detectable differences in epifaunal communities between 2003 and 2007 surveys, seven years after the period of intensive fishing for queen scallops.

Cook *et al* (2013) examined the effects of a single pass by an otter trawl on *M. modiolus* beds off the Llyn Peninsula and a scallop dredge on the northeast of the Isle of Man. The trawl resulted in a 90% reduction in the number of epifauna and total number of *M. modiolus*, while the scallop dredge resulted in a 59% reduction. They noted that the single pass of fishing gear was sufficient to flatten the horse mussel reef. No evidence of recovery was recorded at the Isle of Man site a year after impact was first recorded.

While horse mussel reefs are reported to be adversely affected, Kenchington *et al* (2006) examined the effects of experimental otter trawling on benthic communities on Western Bank, northwest Atlantic. The community was dominated (76%) by *M. modiolus* attached to rocks, embedded in the seabed or in small groups but not a reef. The transect was trawled 12-14 times, on three occasions over a 20 month period. As a result, the epifauna was reduced from a 90% to a 77% contribution to the community. But the most marked decline was in *M. modiolus*, which declined by ca 80% to 60% of the community, (a reduction in biomass from 2752.9g before trawling in 1997 to 987.4g after trawling in 1999) due to direct damage from the trawl and subsequent consumption by predators and scavengers. All of the impacts observed were short-lived, persisting for less than a year, except the decrease in *M. modiolus* biomass.

Therefore, **resistance** is assessed as **'Low'** (loss of 25-75%) and **resilience** is assessed as **'Low'**. **Sensitivity** is therefore assessed as **'High'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed studies.
Applicability is 'High' – based on peer reviewed studies of the effects of this pressure.
Concordance is 'Medium' – based on agreement in direction but variation in magnitude depending on the gear used and the nature of the horse mussel bed.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

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

The relevant evidence and hence sensitivity assessment are the same as that presented under surface abrasion (4.5.4.XXII) above.

XXIV. Change in suspended solids

No direct evidence was found relating to the sensitivity of this ecological group to this pressure and the assessment is based on inference from related species and expert judgement.

Increases in turbidity through increased inorganic particulate matter may reduce filter feeding efficiency for this ecological group. Growth rates of adult *Pecten maximus* are adversely affected by increases in suspended sediments concentrations (Bricelj & Shumway 1991) and excessive particle bombardment may threaten the viability of the feeding apparatus (Gibson 1956), thereby potentially decreasing ingestion rates. However, *Modiolus modiolus* is found in a variety of turbid and clear water conditions (Holt *et al* 1998; Connor *et al* 2004). Bivalves may compensate for increased turbidity from suspended inorganic particles by increasing the rate of pseudofaeces. Where the pressure results from an increase in suspended organic matter this would be beneficial to this ecological group by providing increased food material (and perhaps local stimulation of phytoplankton abundance where nutrients are recycled back to the water column).

Last *et al* (2011) tested the response of two species similar to members of this ecological group *Mytilus edulis* and *Aequipecten opercularis* to two levels of suspended particulate matter (SPM) (high SPM (~71mg/l) and low SPM (~12mg/l). The high SPM treatment is comparable to SPM conditions that might be expected within only a few hundred meters distance of a primary aggregate extraction site impact area, whilst the low SPM treatment is comparable to a much wider footprint encompassing the secondary impact area and probably extending up to a few kilometres.

Last *et al* (2011) reported that there were no mortalities in response to changes in SPM. *Mytilus edulis* displayed an overt nocturnal shell gape cycle under both SPM and no SPM conditions. However, shell gape cycles were significantly reduced under high SPM compared with the control condition, a change in circadian clock expression that may have consequences on fitness (Last *et al* 2011). *Aequipecten opercularis* does not display nocturnal shell gape cycles. However, shell closure events were significantly increased under both low and high SPM when compared to control conditions and is likely to be a reflection of increased efforts to clear the mantle of sediment. Significantly more ‘claps’ (considered an escape response) and ‘coughs’ (thought to be a mechanism for the expulsion of sediment) were also recorded in animals under high SPM when compared to control conditions. All three behaviours: shell closure events, clapping and coughing will confer energetic cost (Last *et al* 2011).

Szostek *et al* (2013) examined the effects of increased SPM and burial on juvenile *P. maximus*. The scallops were exposed to low (50-100 mg/l SPM) and high (200-700mg/l SPM) conditions for 18 days in pVORT systems. Shell claps and movements were significantly higher under high rather than low SPM or control (no SPM) but growth rates (over the 18 days) were significantly lower under both low and high SPM than under control conditions. The result indicated that *P. maximus* was keep the mantle clear of sediment, more effectively than A. *opercularis.* The energetic cost resulted in lower growth rates in both species (Szostek *et al* 2013). Szostek *et al* (2013) noted that while the short term survival (over the 18 day experiment) of *P. maximus* was not affected by SPM levels but that longer term survival required further investigation.

Overall, elevated SPM can result in increased energy expenditure (Last *et al* 2011; Szostek *et al* 2013). Hence, an increase in turbidity, from clear to turbid over the course of a year, (greater than the SPM concentrations measured by Last et al 2011, but similar to the ‘high SPM’ studied by Szostek *et al* 2013) could result in some mortality of the population of either member of the ecological group. **Resistance** is therefore assessed as **‘Medium’. Resilience** is assessed as **‘Medium’ for *P. maximus*** and **‘Low’ for *M. modiolus*,** hence **sensitivity** is therefore assessed as **‘Medium’.**

Resistance (Pecten maximus)

Quality of evidence is ‘High’ – based on peer reviewed and grey literature.
Applicability is ‘Medium’– based on directly applicable studies, although limited in duration compared to the pressure benchmark.
Concordance is ‘Medium’ – based on one short study of *P. maximus* and comparable studies of a similar species.

Resistance (Modiolus modiolus)

Quality of evidence is ‘Low’ – based on inference from limited evidence.
Applicability is ‘Not assessed’ – based on expert judgement.
Concordance is ‘Not assessed’ – based on expert judgement.

Resilience (section 4.5.7)

Quality of evidence is ‘Medium’ - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is ‘Medium’ - based on inferences from studies of the ecology and

population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

XXV. Habitat structure changes - removal of substratum (Extraction)

The process of extraction is considered to remove all members of this ecological group as *Modiolus modiolus* are sessile and *Pecten maximus* can 'swim' for a limited distance only. **Resistance** is therefore assessed as **'None'** based on expert judgment but supported by the literature relating to the position of these species on or within the seabed. The exposed sediments are considered to be suitable for recolonisation almost immediately following extraction (levels of suspended sediments which may rise after extraction will subside rapidly (see section 4.5.4.XXIV above). Recovery will be mediated by the scale of the disturbance and the suitability of the sedimentary habitat. Local migration of adults would re-populate small defaunated patches and passive transport of adults via water movements may occur. **Resilience** is considered to be **'Medium' for *P. maximus*** but **'Low for *M. modiolus***. **Sensitivity** is therefore categorised as **'Medium' for *P. maximus*** but **'High' for *M. modiolus.***

Resistance

Quality of evidence is 'Low' – based on expert judgement, inferred from limited evidence.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

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

Information from laboratory studies on similar species (Last *et al* 2011) and *Pecten maximus* (Szostek *et al* 2013) were used in this assessment. As the members of this ecological group are shallowly buried this ecological group would be buried by the deposit. The intensity and duration of siltation will be mediated by site-specific hydrodynamic conditions, such as water-flow and wave action that determine the dispersal of deposits.

Last *et al* (2011) found that the blue mussel *Mytilus edulis* is relatively tolerant of short term (≤ 32 day) burial events, with less than 15% mortality of all buried specimens. Animals showed a limited ability to re-emerge from a shallow (2cm) burial depth and burial tolerance was largely a reflection of survival under sediment. Percentage mortality increased with progressively finer sediment fractions, and was significantly higher when the burials were conducted under higher temperatures. Preliminary findings (reported previously in Condie (2009) suggest *M. edulis* is also tolerant of repeated burial events.

Last *et al* (2011) found that *Aequipecten opercularis* was highly intolerant of burial events, with the loss of over 70% of buried specimens after 2 days burial (20/27 individuals). The species demonstrated some ability to re-emerge from sediment but this was limited in its extent (14/162 individuals) and restricted to shallow (2cm) burial. Percentage mortality was similar under burial with coarse and medium sediment, but there was a marked increase under the fine sediment fraction. Last *et al* (2011) noted that *A. opercularis* has an effective swimming response and its vulnerability to burial is considered to be low as a result of its avoidance ability. If suddenly buried, however, the species' ability to escape is limited to very shallow sediment and their overall tolerance is exceedingly low, possibly due to a relatively high metabolism particularly for a mollusc (Guderley & Portner 2010).

But Szostek *et al* (2013) noted that *P. maximus* was more tolerant of burial than *A. opercularis*. Szostek *et al* (2013) examined a variety of burial duration (1-8 days), depth of burial (0 to 5cm) and size fraction of the sediment (fine: 0.1-0.3mm, medium fine: 0.4-0.8mm and coarse: 1.2-2mm diameter). Emergence was higher at shallow depth and in coarse to medium sediment. At shallow depths scallops emerged almost immediately or within 1 day except for fine sediments where no scallops emerged from under 3 or 5cm of burial. Mortality was low under coarse and medium sediment and was unrelated to depth as only 4 of the 27 that remained buried died. But mortality was under fine sediment increased with depth, as 15 out of 27 scallops that remained buried died, and with increased duration 100% mortality was observed after 4 and 8 days of burial.

Based on the laboratory studies by Last *et al* (2011) and Szostek *et al* 2013, this ecological group was considered to be unable to vertically migrate through a layer of overburden at the pressure benchmark level, that is, 30cm of fine material. If comparable to *Mytilus edulis*, *Modiolus modiolus* may be able to survive burial for some time although in areas of high water movement the overburden may be removed before animals succumb. However, as the tolerance for burial is not clear, **Resistance** for both species was assessed as **'None'. Resilience** is considered to be **'Medium' for *P. maximus*** but **'Low for *M. modiolus***. **Sensitivity** is therefore categorised as **'Medium' for *P. maximus*** but **'High' for *M. modiolus.***

Resistance

Quality of evidence is 'Low' – based on expert judgement, inferred from limited evidence.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience (section 4.5.7)

Quality of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature.
Applicability of evidence is 'Medium' - based on inferences from studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* from similar pressures.
Concordance of evidence is 'Medium' - based on agreement on direction but not magnitude.

4.5.5 Physical Loss (Permanent Change)

XXVII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that *Modiolus modiolus* is able to colonise artificial substrata including oil rigs (Holt *et al* 1998).

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The substratum types recorded for biotopes characterised by members of this ecological group follow.

- *Pecten maximus*: mud; mud with a significant fine to very fine sand fraction; muddy sand with shells, gravel or pebbles; sandy mud; shelly and gravelly mud; mixed sediment (with stones and shells); muddy gravelly mixed sediment; sandy muddy gravel; sand with some gravel; clean fine sands; very coarse sand with a finer sand fraction; clean shell and stone gravel.

- *Modiolus modiolus*: muddy sand, sandy muds, gravelly sand and muddy mixed sediment; pebble, gravel and shells on sandy mud sediments; mixed muddy sandy gravel; mixed sediment (with stones and shells); stony mixed sediment; bedrock; boulders and cobbles.

A change in classification of one Folk class (based on Long 2006) is not predicted to negatively affect this ecological group which the MNCR records indicate occurs in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (as there is no impact to recover from). The group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from recorded habitat preferences rather than targeted studies.
Applicability is 'Low' – based on inference from recorded habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based inference from recorded habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.5.6 Pollution

XXVIII. Organic enrichment

'No evidence' was found to assess this pressure at the benchmark for this ecological group and these species have not been assigned to AMBI groups. Sensitivity to this pressure is therefore not assessed for this group.

4.5.7 Review of recovery based on the species assemblages present within the ecological group

Recovery of *Pecten maximus* populations may occur through adult migration over small scales or through recolonisation by larvae. *Pecten maximus* can swim for short periods by clapping the valves together. Swimming is limited in terms of distance and endurance and is primarily reserved for escape reactions given the high energy expenditure involved. Tagging experiments in Loch Creran, western Scotland, found that the vast majority of tagged *Pecten maximus* adults were within 30m of the release point after 18 months (Howell & Fraser 1984, cited in Marshall & Wilson 2009).

Recovery following a significant decline of the population will rely on larval recruitment. The timing of spawning may be influenced by both internal and external factors such as genetic adaptation (Ansell *et al* 1991) age and temperature respectively (Barber & Blake 1991). In general, mature scallops spawn over the summer months from April or May to September. Dispersal potential in *Pecten maximus* is high given that the length of the pelagic larval stage exceeds one month (Marshall & Wilson 2009).

Self-recruiting populations are dependent on successful recruitment from within the parent bed. In St Brieuc, France, entire populations of scallops have been shown to spawn within just a few days (Paulet *et al* 1988). Anything that has the potential to disrupt the success of this mass spawning will adversely affect recruitment to the stock. In addition, *Pecten maximus* are generally said to have a low population turnover (Rees & Dare 1993) and scallop stock recruitment is highly variable (Beukers-Stewart *et al* 2003).

Therefore, providing a certain proportion of the population remains after exploitation, a good spawning episode occurs and suitable environmental conditions prevail after exploitation for the larval, veliger and juvenile stages including a suitable substratum and temperature regime, there is the potential for a strong recruitment and recovery. Generation time for this species is between two and a half and three years. Under certain environmental conditions however, recovery could take significantly longer. If none of the population remained and the population was thought to be self-recruiting, it is possible that the population may never fully recover. Overall, *P. maximus* populations have the potential to recover within ca 2-10 years, a resilience is assessed as 'Medium', depending on local recruitment.

Recruitment in *Modiolus modiolus* is sporadic and highly variable seasonally, annually or with location (geographic and depth) (Holt *et al* 1998). Some areas may have received little or no recruitment for several years. Even in areas of regular recruitment, such as enclosed areas, recruitment is low in comparison with other mytilids such as *Mytilus edulis*. For instance, in Strangford Lough, small horse mussels (<10mm) represented <10% of the population, with peaks of 20-30% in good years (Brown & Seed 1977). In open areas with free water movement larvae are probably swept away from the adult population, and such populations are probably not self-recruiting but dependant on recruitment from other areas, which is in turn dependant on the local hydrographic regime. In addition, surviving recruits take several to many years to reach maturity (3-8 years) (Holt *et al* 1998). However, colonisation on new structures such as the legs of oil rigs can occur within a few years (K. Hiscock pers. comm., cited from Holt *et al* 1998).

Holt *et al* (1998) point out that the time required for small breaks in beds to close up due to growth of surrounding clumps, and the survival of clumps torn from the bed is not known. Witman (1984, cited in Suchanek 1985) cleared 115cm^2 patches in a New England *Modiolus modiolus* bed. None of the patches were recolonised by the horse mussel after 2 years, 47% of the area being colonised by laminarian kelps instead (Witman pers. comm., cited in Suchanek 1985). No details on longer term studies were found.

Translocation of horse mussels *Modiolus modiolus*, to areas of 'cultch' (broken scallop shells) in Strangford Lough, Northern Ireland as part of a programme of work to restore populations destroyed by scallop dredging, indicated that settlement of *M. modiolus* larvae was directly enhanced by the presence of adults on the sea floor (Davoult *et al* 1990). Translocation seemed essential and, as a part of the same study, Elsäßer *et al* (2013) concluded that remnant populations of *M. modiolus* are largely self-recruiting with little connectivity between them and with populations outside the lough. They suggested that the best approach to accelerate the recovery and restoration of *M. modiolus* biogenic reefs in Strangford Lough is to provide total protection of all remaining larval sources and establish additional patches of mussels in areas where models predicted certain larval densities to ensure that restoration sites are located where recovery has the highest likelihood of success.

Therefore, the available evidence for *M. modiolus* suggests that recovery could be protracted and the resilience is assessed as 'Low' (10 to 25 years).

The confidence in the quality of evidence, applicability and degree of concordance in this assessment is 'Medium' based on studies of the ecology and population dynamics of *P. maximus* and *M. modiolus* in peer reviewed and grey literature which demonstrate that recovery can be variable in *P. maximus* and both variable and protracted in *M. modiolus*.

4.5.8 Knowledge gaps

Large species that are visible or readily captured and widely distributed are more likely to be recorded and studied than smaller cryptic species and therefore the two larger species in this ecological group have been better studied. As a commercially targeted species there has been greater impetus to understand the ecology and lifecycle of *Pecten maximus* and this species is better studied than many other representatives of ecological groups. The horse mussel *Modiolus modiolus* as a large and visible species that forms biogenic reefs is of conservation importance has also been the focus of specific studies as well as incidental recording and reporting (Tyler-Walters 2007).

There is good evidence for the effects of fishing and physical disturbance on these species. But recovery rates in *M. modiolus* remain uncertain. Recent work on populations in Strangford Lough (Strain *et al* 2013; Elsäßer *et al* 2013) demonstrates that recovery is prolonged, but on constant surveillance in Strangford Lough has the potential to provide the evidence required by managers.

There is surprisingly little direct evidence on the effects of changes in hydrography, and organic enrichment. The effects of hydrographic (water flow and wave energy) have been inferred from habitat preferences and proxies for direct evidence.

4.6 Ecological Group 3 Mobile epifauna, mobile predators and scavengers

4.6.1 Definition and characteristics of the ecological group

This group is comprised of the mobile scavenging and predatory crab *Pagurus bernhardus* and the common starfish *Asterias rubens* and *Astropecten irregularis* (**Table 4.6**). These species are found in a wide range of habitats and are robust and mobile. The sensitivity of each of these species is assessed.

Table 4.6. List of biotopes in which ecological group 3 species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.PomB	*Asterias rubens*
SS.SCS.CCS.MedLumVen	*Asterias rubens* *Pagurus bernhardus*
SS.SCS.CCS.Nmix	*Asterias rubens*
SS.SSa.CMuSa.AalbNuc	*Asterias rubens*
SS.SSA.CMuSa.AbraAirr	*Asterias rubens* *Pagurus bernhardus* *Astropecten irregularis*
SS.SMu.CSaMu.AfilMysAnit	*Asterias rubens* *Pagurus bernhardus*
SS.SMu.CSaMu.VirOphPmax	*Pagurus bernhardus*
SS.SMu.CFiMu.SpnMeg	*Asterias rubens*
SS.SMx.CMx.ClloMx	*Asterias rubens* *Pagurus bernhardus*
SS.SMx.CMx.ClloMx.Nem	*Asterias rubens* *Pagurus bernhardus*
SS.SMx.CMx.ClloModHo	*Asterias rubens* *Pagurus bernhardus*
SS.SMx.CMx.FluHyd	*Asterias rubens*
SS.SMu.OMu.StyPse	*Asterias rubens*

4.6.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

In field experiments, Thieltges (2005) found that the presence of *Crepidula fornicata* on mussels led to a three-fold decrease in predation by *Asterias rubens* in laboratory experiments. It was thought that the cover provided by settled limpets made it more difficult for the starfish to prey on the mussels (Thieltges 2005). In choice experiments, the dominant predators on mussel beds in the Sylt-Rømø basin (shore crabs *Carcinus maenas*, and *A. rubens*) fed preferentially on the blue mussel (*Mytilus edulis*) over *C. fornicata* (Thieltges 2005). The presence of slipper limpets on mussel beds and other biogenic and sedimentary habitats may have a negative impact on *A. rubens* and other predators by reducing the availability of their preferred food source.

Dense beds of *C. fornicata* may reduce feeding rates for this ecological group. It is unclear from the evidence what population level effects may occur. The species within this ecological group feed on a wide range of prey items and may switch to feeding on *C.*

fornicata. As the effects are considered to be sub-lethal **resistance** was assessed as **'High'** and resilience as **'High'**. This group is therefore considered to be **'Not Sensitive'**.

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

II. Removal of Target Species

The species selected to represent this ecological group are not targeted by commercial fisheries and, hence, not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.6.4). Commercial fisheries may result in discarding of undersized or damaged target species. This will increase the available food supply to this ecological group which are active, mobile predators and scavengers. Overall commercial fisheries would be considered to have a beneficial impact on populations of species within this ecological group.

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be **'Not Exposed'** to targeted removal of the ecological group and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species (**resistance** and **resilience** are therefore assessed as **'High'**).

Resistance

Quality of evidence is 'Medium' – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability is 'Low' – based on species traits as a proxy for resistance.
Concordance is 'Not assessed' – based on species traits alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.6.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. The members of this ecological group are habitat generalists feeding on a range of food sources but primarily scavenging and preying on a wide range of species. Commercial fisheries may result in discarding of undersized or damaged non-target species.

This will increase the available food supply to this ecological group which are active, mobile predators and scavengers. Evidence for these indirect effects is described in more detail under abrasion and penetration of the seabed. Overall commercial fisheries would be considered to have a beneficial impact on populations of species within this ecological group. No obligate life-history or ecological associations were identified and resistance is therefore assessed as 'High'. **Resilience** is assessed as **'High'** and this ecological group is considered to be '**Not Sensitive'**

Resistance

Quality of evidence is 'Medium' - based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' - based on general ecology rather than pressure specific information.
Concordance is 'Not assessed' - as no specific evidence is drawn on for this assessment.

Resilience

Quality - Assessed as 'High' based on no impact to recover from.
Applicability - Assessed as 'High' based on no impact to recover from.
Concordance - Assessed as 'High' based on no impact to recover from.

4.6.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

Echinoderms are restricted to the marine environment and one of the only stenohaline phyla in the animal kingdom (Russell 2013), owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulation. The inability of echinoderms to osmoregulate extracellularly causes body fluid volume to increase or decrease when individuals are transferred to lower or higher external salinity respectively, e.g. a sudden inflow of river water into an inshore coastal area caused mass mortality of the conspecific species *Asterias vulgaris* at Prince Edward Island, Canada (Smith 1940, cited in Lawrence 1996). However, some echinoderms are capable of surviving in hypersaline and hyposaline conditions, although the exact mechanisms on salinity tolerance are unknown (Russell 2013).

Asterias rubens has been reported from areas of reduced salinity, e.g. Loch Etive, Scotland (16‰) and the Baltic Sea (8‰), and (reported as *A. vulgaris*) the east coast of N. America (18‰), The Netherlands (18‰) and Maine (27.4‰) (Russell 2013). Binyon (1961) demonstrated all specimens exposed to 18‰ for one week died, while those exposed to 25‰ for the same period all survived. Binyon (1961) determined that their LD_{50}[6] was between 22-24‰. He also noted that the Baltic specimens tolerated 8‰ and were probably a 'physiological' race; that is, adapted to low salinity. Russell (2013) reviewed additional experimental studies in which *A. rubens* was reported to experience mortality at 26‰, 22‰ or 12‰, and tolerate 27.4‰ and 14‰. The results suggest local or regional variation in tolerance. Echinoderm larvae have a narrow range of salinity tolerance and will develop abnormally and die if exposed to reduced or increased salinity.

Davenport (1972) found that the ability to osmoregulate varies between size classes of *Pagurus bernhardus*. Larger species found subtidally were less tolerant of 60% seawater and increase in weight by about 15% in the first hour and continue to increase in weight,

[6] LD_{50} = lethal dose, 50 percentile.

since urine output is not sufficient to cope with the water load. Davenport (1972) concluded that the intolerance of larger species to decreased salinity excluded them from intertidal zones.

The larger *P. bernhardus* typical of the offshore and circalittoral biotopes that are the target of these sensitivity assessments are relatively stenohaline. Similarly, the *A. rubens* characteristic of circalittoral habitat may not be physiological adapted to reduced salinity and would probably not tolerate decreased or increased salinity for a year. **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of individuals). **Resilience** (following the removal of this pressure) is assessed as **'Medium'** (2-10 years), as some rapid recolonisation by adults may be expected through passive water transport or migration from adjacent populations. **Sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on inferences from peer reviewed papers.
Applicability of evidence is 'Low' - based on limited information for *P. bernhardus*.
Concordance of evidence is 'Low' - based on a range of values for *A. rubens* and limited information for *P. bernhardus*.

Resilience (section 4.6.7)

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

V. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

Asterias rubens is abundant throughout the north-east Atlantic, from Arctic Norway, along Atlantic coasts to Senegal, and only found occasionally in the Mediterranean (Mortensen 1927). The geographic range of *Asterias rubens* illustrates that the species is tolerant of a range of temperatures and probably becomes locally adapted (Budd 2008a). *Asterias rubens* was reported to be unaffected by the severe winter of 1962-1963 in Britain when anomalously low temperatures persisted for two months (Crisp 1964).

- *Astropecten irregularis* is found from Norway, the North Atlantic Ocean, the coasts of Europe and the Mediterranean to the Moroccan coasts (WoRMS[7]).

- *Pagurus bernhardus* is found from Norway, the North Atlantic Ocean, the coasts of Europe and the Mediterranean basin (WoRMS).

The geographic range suggests that these species are tolerant to a range of temperatures and a long term chronic change of 2°C or short-term acute change is unlikely to have adverse effects on populations and some migration away from unsuitable habitats is possible. **Resistance** and **resilience** are therefore assessed as **'High'** and the group is considered to be **'Not Sensitive'.**

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[7] WoRMS (World Register of Marine Species), www.marinespecies.org

Resistance

Quality of evidence is 'Medium' - based on inferences made from geographical distribution, rather than targeted studies.
Applicability of evidence is 'Low' - based on geographical distribution as a proxy for the pressure specific information.
Concordance is 'Not assessed' - based on geographical distribution alone.

Resilience

Quality - Assessed as 'High' based on no impact to recover from.
Applicability - Assessed as 'High' based on no impact to recover from.
Concordance - Assessed as 'High' based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for biotopes characterised by members of this ecological group as follows:

- *Asterias rubens*: very weak to strong (negligible - >3m/s);
- *Astropecten irregularis*: very weak to moderately strong (negligible -1.5m/s; (based on two biotope records)); and
- *Pagurus bernhardus*: very weak to strong (negligible - >3m/s).

The range of flow speeds experienced by biotopes in which the species are found (from very weak to strong) suggest that a change in the maximum water flow experienced by mid-range populations would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' - based on inferences made from habitat preferences, rather than species records or targeted studies.
Applicability of evidence is 'Low' - based on habitat preferences as a proxy for the pressure specific information.
Concordance is 'Not assessed' - based on habitat preferences alone.

Resilience

Quality - Assessed as 'High' based on no impact to recover from.
Applicability - Assessed as 'High' based on no impact to recover from.
Concordance - Assessed as 'High' based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for biotopes characterised by members of this ecological group as follows:

- *Asterias rubens*: extremely sheltered; very sheltered; sheltered; exposed; moderately exposed; very exposed;

- *Astropecten irregularis*: very sheltered; sheltered; moderately exposed (2 biotope records); and

- *Pagurus bernhardus*: extremely sheltered, very sheltered; sheltered; moderately exposed, exposed, very exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered **'High'** and as there is no impact, **resilience** is considered **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' - based on inferences made from habitat preferences, rather than species records or targeted studies.
Applicability of evidence is 'Low' - based on habitat preferences as a proxy for the pressure specific information.
Concordance is 'Not assessed' - based on habitat preferences alone.

Resilience

Quality - Assessed as 'High' based on no impact to recover from.
Applicability - Assessed as 'High' based on no impact to recover from.
Concordance - Assessed as 'High' based on no impact to recover from.

4.6.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

The constituent species of this ecological group are generally found on the surface of sediments and hard surfaces and therefore are directly exposed to physical damage from abrasion. This assessment is largely based on the evidence presented for the penetration and sub-surface disturbance presented below as no evidence was found for surface abrasion only (see section 4.6.4.IX).

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

Members of this ecological group are ubiquitous in many different habitat types. The constituent species are generally found on the surface of sediments and hard substrata and therefore are directly exposed to physical damage from abrasion and sub-surface damage. This ecological group is relatively robust compared to some other groups. As mobile scavengers and predators, members of this ecological group will benefit from the opportunity to feed on exposed, damaged and dead individuals following this pressure. Asch and Collie (2008) for example found higher abundances of scavengers including *Pagurus* spp. at shallow (40-50m) and deep disturbed sites.

Individuals can be directly impacted *in-situ*. In field experiments, *Astropecten irregularis* in silty sediments were estimated to suffer direct mortality (percentage of the initial density in trawled tracks) of 12% and 18% from a 12m beam trawl with tickler chains and a 4m beam trawl fitted with tickler chains respectively (Bergman & van Santbrink 2000a). Lindeboom and de Groot (1998) estimated direct mortality (percentage; proportion of initial density in the trawl track) of *Astropecten irregularis* as 45% in sand and 22% in silty sediments after an average trawling frequency of 1.5 passes. A meta-analysis of fishing impacts using regression tree analysis based on 56 papers predicted that trawling has a relatively lower level of impact on Asteroidea, compared with other groups, with a predicted reduction in abundance of 21% (Collie *et al* 2000).

Bergman *et al* (2001) found that up to 14% of *Pagurus bernhardus* and 50% of the sand star *Astropecten irregularis* were damaged in *Nephrops* trawl hauls. The common starfish *Asterias rubens* was more robust with 31% of individuals damaged with loss of one arm (16%) and puncture wounds (9%) as the most common injuries. De Groot (1984) found that the number of starfish caught (*Asterias* and *Astropecten*) increased rapidly when using beam trawl fitted with ticklers. The percentage of damaged specimens was about 3%. There was about a 3-fold increase in the catch when the number of tickler chains was increased to four. The same study found that the use of tickler chains with beam trawls enhanced the catch of *Pagurus* spp. by 1.6 times but damage rates were generally low (de Groot 1984). This study was based on observations of species caught as by-catch and did not assess in-situ damage rates.

Re-sampling of grounds that were historically studied (from the 1930s) indicates that some robust scavengers including *Asterias rubens* and *Pagurus* spp. have increased in abundance in areas subject to long-term scallop fishing (Bradshaw *et al* 2002).

Abrasion and penetration provides a food subsidy to this ecological group by exposing infaunal species and providing a supply of damaged and dead organisms. Evidence suggests that this has been beneficial to this ecological group with population increases observed in fished areas. This indirect effect is not assessed and resistance and resilience of members of this ecological group to direct physical impacts is considered. In general this group is more robust than some species. The evidence from by-catch studies and direct mortality estimates suggest that **resistance** is **'Medium-Low'** as the level of observed damage varies between species (Lindeboom & de Groot 1998; Bergman & van Santbrink 2000a; Bergman *et al* 2001). Recovery is considered to take place through active migration from adjacent populations stimulated by the presence of damaged and dead species. **Resilience** is therefore assessed as **'High-Medium'** and **sensitivity** is **'Low to Medium'**. But the evidence also suggests that these species can benefit (increase in abundance) from physical disturbance related to fishing activities. **Therefore, a sensitivity of 'Low' is reported.**

Resistance

Quality of evidence is 'High' – based on peer reviewed evidence.
Applicability of evidence is 'High' - based directly relevant evidence.
Concordance of evidence is 'Medium' - based on agreement in direction but variation in reported magnitude.

Resilience (section 4.6.7)

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

X. Change in suspended solids

Asterias rubens appears able to flourish in naturally turbid conditions, such as the north-east coast of England (P.G. Moore, personal observation) and River Crouch (Mistakidis 1951, in

Moore 1977). Greve and Kinne (1971, citied in Moore 1977) noted that *Asterias rubens* would cleanse itself of adhering mud particles by secreting mucus. However, Zafiriou *et al* (1972, cited in Budd 2008a) suggested that the behaviour of starfish may be modified by variations in suspended material. They found an apparent lessening in intensity of approach response of *Asterias rubens* to soluble oyster homogenate in turbid water.

Astropecten irregularis buries within sediments limiting exposure to suspended solids in the water column. No evidence was found to assess the sensitivity of *Pagurus bernhardus*.

No members of the group are likely to be affected by changes in water clarity, while the starfish are either tolerant of turbid conditions or burrowers in sediment. *P. bernhardus* is found in a wide range of conditions, on sedimentary and rocky shores and rock pools, so probably also tolerant. Therefore, a **resistance** of **'High'** is suggested**. Resilience** is therefore also **'High'** and the group is probably **'Not sensitive'.**

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability is 'Not assessed' – based on expert judgement.
Concordance is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

XI. Habitat structure changes-removal of substratum (Extraction)

The process of extraction is considered to remove all members of this ecological group which occur on or close to the sediment surface. Mobility is limited to crawling rather than rapid escape mechanisms. **Resistance** is therefore assessed as **'None'** based on expert judgment but supported by the literature relating to the position of these species on or within the seabed. The exposed sediments are considered suitable almost immediately following extraction, as levels of suspended sediments that may rise after extraction will subside rapidly (see section 4.6.4.X). These species are common and present in most habitats and local migration of adults would re-populate areas. In some cases individuals of the assessed species may be attracted to adjacent areas if dead or moribund animals are present as a food source and starfish are attracted to recently trawled areas to feed on exposed, dead and damaged individuals and discards (Kaiser & Spencer 1994; Ramsay *et al* 1998; Groenewold & Fonds 2000; Bergmann *et al* 2002). **Resilience** is therefore considered **'Medium'. Sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' - based on inferences from species traits and habitat, rather than targeted studies.
Applicability of evidence is 'Low' - based on species traits and habitat as a proxy for the pressure specific information.
Concordance is 'Not assessed' - based on species traits and habitat alone.

Resilience (section 4.6.7)

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

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

Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which *Astropecten* spp. could migrate was <10cm in sand. However, Christensen (1970, cited in Freeman *et al* 2001) found that this species were unable to re-surface once it had been buried beneath 4cm of sediment. *Asterias* however was able to reach the surface though 60cm of sand (Bijkerk 1988, results cited from Essink 1999). No further information was available on the rates of survivorship or the time taken to reach the surface. No evidence could be found for the impact of siltation on *Pagurus bernhardus*.

Members of this ecological group show varying sensitivity to this pressure. Although reported evidence suggests that *Asterias* is able to surface from a great depth (60cm) of overburden, there was no information available regarding the basis of this assessment. The result relates to sand rather than mud and it is not clear what proportion of individuals could migrate through a 30cm layer of fine sediments (the pressure benchmark). No assessment was made for *Asterias rubens*, or *Pagurus bernhardus* due to **'No evidence'**.

Based on the available evidence, (Bijkerk 1988, cited from Essink 1999) and Christensen (1970, cited in Freeman *et al* 2001), *Astropecten irregularis* is considered to have **'No' resistance** to this pressure, **resilience** is assessed as **'Medium'** and **sensitivity** is categorised as **'Medium'.**

Resistance

Quality of evidence is 'High' - based on peer reviewed literature.
Applicability of evidence is 'Medium' - based on laboratory experiments rather than the impact of the pressure.
Concordance is 'High' - based on agreement between both studies cited.

Resilience (section 4.6.7)

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

4.6.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that *Asterias rubens* and *Pagurus bernhardus* are found on hard substratum including bedrock and boulders and would not be excluded by an increase artificial substratum although it should be noted that artificial habitats may not provide a habitat of the same quality as natural rock reefs.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The records indicate the substratum types for biotopes characterised by members of this ecological group as follows.

- *Asterias rubens*: mud; gravelly mud; shelly mud; fine muddy sands; sandy mud; medium to very fine sand with some silt; clean fine sands; mixed sediment; sandy muddy gravel; muddy gravel with shell; muddy maerl gravel; coarse sand and gravel with a minor finer sand fraction; clean stone gravel with pebbles; maerl; stony sediment; bedrock; boulders; cobble; calcareous tubes; pebbles; shells.

- *Astropecten irregularis*: fine to very fine muddy sand; medium to fine sand; slightly muddy sand (based on three records).

- *Pagurus bernhardus*: mud; fine to very fine muddy sand; sandy mud; sandy muddy gravel; mixed muddy sand with gravel, pebbles and cobbles; fine to very fine sand with a fine silt fraction; medium to very fine sand; medium to coarse sand and gravelly sand; mixed muddy sediment; stony mixed sediment; muddy maerl gravel; maerl; shell gravel; stones and coarse sediment; clean stone gravel with pebbles; bedrock, boulders, cobble; calcareous tubes.

Although the information above suggests that *Astropecten irregularis* is found in a more restricted range of sediments than *Pagurus bernhardus* and *Asterias rubens*. Freeman et al (2001) report that *A. irregularis* is found from mud to gravel although it prefers sand (Freeman *et al* 2001 and references therein). Members of this ecological group are therefore habitat generalists and occur within a wide range of sediment types.

A change in classification of one folk class (based on Long 2006 simplification) is not predicted to negatively affect this ecological group which the MNCR records indicate is able to settle on hard substratum, including sand grains, in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High' (**no impact to recover from). The group is assessed as **'Not Sensitive'**

Resistance

Quality of evidence is 'Medium' - based on inferences made from habitat preferences, rather than species records or targeted studies.
Applicability of evidence is 'Low' - based on habitat preferences as a proxy for the pressure specific information.
Concordance is 'Not assessed' - based on habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.6.6 Pollution

XIV. Organic enrichment

Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), both assigned *Asterias rubens* to their ecological group III of species that are 'tolerant to excess organic matter enrichment'. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). *Pagurus bernhardus* was assigned to Ecological Group II, 'species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance)'. The basis of the assessment was not clear. However, the tolerance of these species to high levels of organic matter is confirmed by field observations. Hall-Spencer *et al* (2006) observed a much higher abundance (10-100 times higher abundance) of *Pagurus bernhardus* and *Asterias rubens* beneath salmon farms where organic enrichment had led to a visible build-up of wastes compared to reference areas. No evidence was found for *Astropecten irregularis* and the assessment is based on the other characterising species of this ecological group.

Based on the AMBI categorisation and field observations (Hall-Spencer *et al* 2006), this ecological group is assessed as '**Not Sensitive'** to this pressure based on **'High' resistance** and **'High' resilience** (no impact to recover from).

Resistance

Quality of evidence is 'Medium' – based on peer reviewed AMBI score (although the evidence supporting the AMBI score is unclear) and peer reviewed paper (Hall-Spencer *et al* 2006).
Applicability is 'Low' – based on AMBI scores but evidence and assumptions are unknown.
Concordance is 'Low' – based on AMBI scores but evidence and assumptions are unknown.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.6.7 Review of recovery based on the species assemblages present within the ecological group

Previous sensitivity assessments (Budd 2008a) have considered that the resilience of UK *Asterias rubens* is 'High' (full recovery within five years). Individuals that are damaged can regenerate missing arms and repair damage. Some recovery of populations through horizontal migration is possible as these species are mobile and are attracted to areas where there are dead and damaged animals. This species is widespread throughout shallow areas of the North Atlantic and recovery from more severe impacts over wider areas will occur through larval colonisation. Reproduction is annual and large numbers of eggs are produced (>1.5 million eggs per female). The pelagic larva is long lived (>80 days), allowing dispersal over a wide area.

Little information was found to assess the resilience of *Astropecten irregularis*. Arm regeneration can occur after physical injury and this species is also migratory (Freeman *et al* 2001) so that populations may recover through repair of surviving individuals and horizontal migration. Recovery from more severe impacts over wide spatial scales will require larval colonisation.

Previous sensitivity assessments (MES 2010) suggest that *Pagurus spp*. is widespread and common species have high recovery potential. Sexual maturity is reached after only six months and the females release large numbers of eggs (12,000-15,000). The planktotrophic zoea larvae remain in the plankton for up to 4 weeks.

Members of this ecological group are attracted to recently fished areas to feed, (Kaiser & Spencer 1994; Ramsay *et al* 1998; Groenewold & Fonds 2000; Bergmann *et al* 2002).

Pagurus bernhardus and *Asterias rubens* were the most frequently recorded mobile scavengers caught in baited traps (Groenewold & Fonds 2000).

Recovery rates of this ecological group will be influenced by the character of the impact, including the spatial footprint. Very small disturbed patches surrounded by abundant populations of the same species may be rapidly infilled by adult migration. All the species within this group are mobile and hence recovery by horizontal migration is assumed where resistance is ‘Medium’ (less than 25% mortality). Members of this group may feed on conspecifics so the presence of dead individuals may enhance recovery.

Resilience is therefore assessed as **‘High’** where resistance is ‘Medium’. This assessment is based on peer reviewed observations of mobility (e.g. Freeman *et al* 2001) and the attraction of scavengers to recently disturbed areas (Kaiser & Spencer 1994; Ramsay *et al* 1998; Groenewold & Fonds 2000; Bergmann *et al* 2002). Confidence in the quality of evidence for this assessment is ‘High’ as it is based on peer reviewed evidence. As the increase in abundance of this ecological group relates to a pressure (penetration and sub-surface disturbance) applicability is assessed as ‘High’ and, based on the weight of peer reviewed evidence, concordance is assessed as ‘High’.

Where populations are removed or significantly reduced (resistance is ‘Low’ or ‘None’) over large areas then recovery will be through larval recolonisation and will depend on the supply of new larvae. Successful recruitment may be episodic and recovery of adult biomass may take more than two years. **Resilience** is therefore assessed as **‘Medium’** where resistance is ‘None’ or ‘Low’. This assessment was based on expert judgement and therefore confidence in the quality of evidence is assessed as ‘Low’ and applicability and degree of concordance are not assessed as these categories are not relevant to assessments based on expert judgement.

4.6.8 Knowledge gaps

This group consists of common, widespread species. *Pagurus bernhardus* and *Asterias rubens* are conspicuous members of the epifauna and some life history traits and sensitivities are well-studied. *Astropecten irregularis* is a burrowing species and less information was available to assess this species in most cases (although evidence for siltation sensitivity was only available for this species).

As is the case for most ecological groups changes in hydrological pressures and other pressures (e.g. physical change) were assessed using habitat distribution as a proxy as no other direct sources of evidence were found.

When direct evidence was lacking proxies were used to develop the assessment based on taxonomic group (e.g. the salinity assessments for the starfish were based on general echinoderm sensitivity) or life history traits (e.g. habitat position for extraction). In some instances however sensitivity could not be inferred from life history traits, distribution or other taxonomic groups. For example, the sensitivity of *Pagurus bernhardus* to changes in suspended solids and siltation could not be assessed.

4.7 Ecological Group 4 Infaunal very small to medium sized suspension and/or deposit feeding bivalves

4.7.1 Definition and characteristics of the ecological group

This group consists of bivalves that are deposit or suspension feeders or can switch between these feeding methods (**Table 4.7**). These species are typically positioned at the sediment-water interface or are shallowly buried, to allow extension of the feeding parts into the water column or to capture surface detritus. These species are typically present in silty sediments which are relatively stable, although some members may be found in coarse sediments (e.g. *Moerella* spp., *Spisula* spp.). To capture the sensitivity range of this group the largest and most mobile member of this group, *Phaxas pellucidus*, will be assessed for sensitivity, together with *Abra* spp., *Thyasira flexuosa* and *Timoclea ovata*. These suggested species capture a range of genera, biological traits and habitat preferences. As these species do not generally overlap in distribution (based on circalittoral biotopes) the relevant species sensitivity assessment can be applied where appropriate.

Table 4.7. List of biotopes in which ecological group 4 species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.OCS.GlapThyAmy	*Thyasira flexuosa*
SS.SCS.OCS.HeloPkef	Characterising species present were not specifically assessed.
SS.SSa.CFiSa.ApriBatPo	*Abra prismatica (as Abra spp.)*
SS.SSa.CFiSa.EpusOborApri	*Abra prismatica (as Abra spp.)* *Timoclea ovata*
SS.SSa.CMuSa.AalbNuc	*Abra alba (as Abra spp.)*
SS.SSA.CMuSa.AbraAirr	*Abra alba (as Abra spp.)*
SS.SSa.OSa.MalEdef	Characterising species present were not specifically assessed.
SS.SMu.CSaMu.AfilMysAnit	*Abra nitida (as Abra spp.)*
SS.SMu.CSaMu.ThyNten	*Abra alba (as Abra spp.)* *Thyasira fluxuosa*
SS.SMu.CSaMu.AfilNten	Characterising species present were not specifically assessed.
SS.SMu.CSaMu.LkorPpel	*Abra alba (as Abra spp.)* *Phaxas pellucidus*
SS.SMx.CMx.MysThyMx	*Thyasira flexuosa*
SS.SMx.OMx.PoVen	*Timoclea ovata*
SS.SMu.OMu.StyPse	*Abra alba (as Abra spp.)*
SS.SMu.OMu.AfalPova	Characterising species present were not specifically assessed.
SS.SMu.OMu.ForThy	*Thyasira flexuosa*
SS.SMu.OMu.PjefThyAfil	*Thyasira flexuosa*
SS.SMu.OMu.MyrPo	*Abra nitida (as Abra spp.)*

4.7.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.7.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. Although *Mysella bidentata* (which is not specifically assessed), may be commensal with other burrowing species it also occurs alone. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be 'Not Exposed' to targeted removal of the ecological group and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is 'Medium' – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability is 'Low' – based on general ecology as a proxy for resistance.
Concordance is 'Not assessed' – based on general ecology alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.7.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Species within this group live on or shallowly buried within sediments and feed on suspended particles transported in the water column or organic matter deposited on or within sediments. They are not considered dependent on other species for habitat or food. As no obligate life-history or ecological associations were identified this ecological group is considered to be '**Not Sensitive'.** By default, **resistance** and **resilience** are therefore assessed as **'High'**.

Resistance

Quality of evidence is 'Medium' – based on inference from ecology and life history characteristics rather than targeted studies.

Applicability is ‘Low’ – based on general ecology as a proxy for resistance.
Concordance is ‘Not assessed’ – based on general ecology alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.7.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No direct evidence was found to assess changes in salinity and OBIS data (OBIS 2014) was used as the basis of the assessment. The minimum and maximum range of salinities is as follows.

- *Abra alba*: 30.16-38.55pps.
- *Phaxas pellucidus*: no information.
- *Thyasira flexuosa*: 31.8-39.05pps.
- *Timoclea ovata*: 33.97-39.03pps.

This evidence suggests that that this ecological group may be tolerant of increases in salinity (35-38 units for one year) and is assessed as ‘**Not Sensitive’** (**resistance** and **resilience** are both considered **‘High’**).

However, this ecological group may be more sensitive to a decrease in salinity at the pressure benchmark of 4-10psu for a year. **Resistance** is assessed as **‘Low’** as a change toward the upper end (10psu) may severely impact populations. **Resilience** is assessed as **‘High’** for *Abra alba* (**Sensitivity** is **‘Low’**) and **‘Medium’** (**Sensitivity** is **‘Medium’**) for the other members of this ecological group 4).

Resistance

Quality of evidence is ‘Low’ – based on habitat distribution and OBIS values rather than targeted studies.
Applicability is ‘Low’ – based on habitat distribution and OBIS values as a proxy for resistance.
Concordance is ‘Not assessed’ – based on habitat distribution alone.

Resilience (section 4.7.7)

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

V. Temperature changes - local

No information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

- *Abra alba*: distributed from the Norwegian Sea and the Baltic, south to the Iberian Peninsula, into the Mediterranean and Black Seas, and south along the coast of Africa to Senegal (Budd 2007).

- *Phaxas pellucidus*: distributed from Norway to north-west Africa.

- *Thyasira flexuosa*: not in the southernmost part of the North Sea but distributed from Norway to the Azores, and extends into the Mediterranean.

- *Timoclea ovata*: sheltered; widespread in the North Sea; distributed from Norway to the Mediterranean and Cape Verde Islands (de Kluijve *et al* 2000).

Overall, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect these species as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from geographic distribution rather than targeted studies.
Applicability is 'Low' – based on geographic distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on geographic distribution alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded water flow categories for biotopes characterised by members of this ecological group follow.

- *Abra alba*: moderately strong to very weak (negligible -1.5m/s).

- *Phaxas pellucidus*: moderately strong to very weak (negligible -1.5m/s).

- *Thyasira flexuosa*: moderately strong to very weak (negligible -1.5m/s).

- *Timoclea ovata*: moderately strong (1.5m/s; based on one biotope record).

The range of flow speeds experienced by biotopes in which the species are found (from <0.5-1.5m/s for selected species) suggest that a change in the maximum water flow experienced by mid-range populations, for the periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inference from habitat preferences rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded wave exposure categories for biotopes characterised by members of this ecological group follow.

- *Abra* spp.: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; extremely exposed; very exposed.
- *Phaxas pellucidus*: very sheltered; sheltered; moderately exposed.
- *Thyasira flexuosa*: extremely sheltered; very sheltered; sheltered; moderately exposed.
- *Timoclea ovata*: sheltered; moderately exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **'High'** and as there is no impact, **resilience** is considered to be **'High'.** This group is therefore considered to be **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inference from habitat preferences rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.7.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

The constituent species of this ecological group are infauna found close to the sediment surface. This life habit provides some protection from abrasion at the surface only. Abrasion and sub-seabed penetration is assessed below. No specific evidence to assess sensitivity to abrasion was found for this ecological group.

No evidence was found on depth of burial for *Phaxas pellucidus*. Razor clams are able to burrow rapidly into sediments making them difficult to capture, although their short siphons indicate that their usual position in the sediment is close to the surface. Due to this mobility, it is assumed that this species could escape from surface abrasion, however due to fragility and environmental position it is considered likely that a small proportion of the population would be damaged and killed.

Similarly for the small bivalves *Abra* spp. *Thyasira flexuosa* and *Timoclea ovata* it was considered that surface abrasion may damage and kill a proportion of the population although some protection may be conferred by shallow burial and the shells.

Resistance was therefore assessed as **'Medium'** (<25% mortality) and recovery may be very rapid where the spatial footprint of the impact is small due to adult migration from adjacent populations. Recovery by *in-situ* reproduction of surviving adults would be complete within 2 years based on life-history characteristics. **Resilience i**s assessed as **'High'** for *Abra alba,* generally considered to be an annual species **(Sensitivity** is **'Low')** and **'Medium'** (**Sensitivity** is **Medium'**) for the other members of this Ecological Group (see section 4.7.7).

Resistance

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

Resilience (section 4.7.7)

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

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

Members of this ecological group are buried close to the surface and will be directly impacted by penetration and disturbance of the substratum below the surface. Diver observations of fauna dislodged by a hydraulic dredge used to catch *Ensis* spp. found small numbers of small bivalves in the trawl tracks that had been dislodged, including the venerid clams *Dosinia exoleta*, *Chamelea striatula* and the hatchet shell *Lucinoma borealis*. These were usually intact (Hauton *et al* 2003a). In general, the small size of members of this ecological group will confer some level of resistance. Gilkinson *et al* (1998) simulated the physical interaction of otter trawl doors with the seabed in a laboratory test tank using a full-scale otter trawl door model. Between 58% and 70% of the bivalves in the scour path that were originally buried were completely or partially exposed at the test bed surface. However, only two out of a total of 42 specimens showed major damage. The pressure wave associated with the otter door pushes small bivalves out of the way without damaging them. Where species can rapidly burrow and reposition (typically within species occurring in unstable habitats) before predation mortality rates will be relatively low.

Ball *et al* (2000) found that members of this ecological group, *Thyasira flexuosa*, *Phaxas pellucidus* and *Myrtea spinifera*, were present at a wreck site that prevented fishing disturbance but were absent from adjacent *Nephrops* trawling grounds, indicating that these species may be sensitive to fishing impacts. Duineveld *et al* (2007) also found abundances of *P. pellucidus* and other fragile bivalves were higher in areas where fishing was excluded. Examination of historical and recent samples suggest that the spatial presence of *P. pellucidus* in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al* 2007). Sparks-McConkey and Watling (2001) found that trawler disturbance resulted in a decline of *Thyasira flexuosa* in Penobscot Bay, Maine. However, the population recovered after 3.5 months.

Ball *et al* (2000b) estimated that the direct mortality (percentage of initial density) of small bivalve species relevant to this ecological group as *Abra* sp. 6-20%, *Thyasira flexuosa* 0-28%, *Nuculoma tenuis* 59% and *Mysella bidentata* 72% (based on samples taken with a Day grab before and 24 hours after trawling). These estimates of direct mortality generally concur with estimates (Bergman & van Santbrink 2000a) where a single pass of a beam trawl on sandy and silty sediments resulted in a range of estimated direct mortality of infaunal bivalves:

- *Abra alba* in silty sediments were estimated as suffering direct mortality (percentage of the initial density in trawled tracks) of 18% and 38% from a 12m beam trawl with tickler chains and a 4m beam trawl fitted with ticklers respectively (Bergman & van Santbrink 2000a).

- *Phaxas pellucidus* suffered an estimated mortality of 27% (12m beam trawl with ticklers) 29% and 33% (4m beam trawl fitted with ticklers in silty and sandy sediments respectively) and 32% (otter trawl). Lindeboom and de Groot (1998) estimated direct mortality (percentage; proportion of initial density in the trawl track) of *Phaxas pellucidus* as 15% in sand and 38% in silty sediments after an average trawling frequency of 1.5 passes.

The available evidence, particularly the estimates of direct mortality (Lindeboom & de Groot 1998; Ball *et al* 2000b; Bergman & van Santbrink 2000a) suggest that **resistance** ranges from **'Low- Medium'**, with the effect depending on the type of impact and mediated by the sediment type (penetration from fishing gears is deeper in siltier sediments). **Resilience** is assessed as **'High'** for *Abra alba* which is generally accepted to be an annual species **(Sensitivity** is **'Low')** and **'Medium' (Sensitivity** is **Medium')** for the other members of this Ecological Group (see section 4.7.7).

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability is 'High' – based on directly applicable peer reviewed literature.
Concordance is 'Medium' – based on agreement on direction but variation in magnitude.

Resilience (section 4.7.7)

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

X. Change in suspended solids

This ecological group does not require light and therefore the effects of increased or decreased turbidity on light attenuation are not directly relevant. An increase in turbidity may affect primary production in the water column and therefore indirectly reduce the availability of phytoplankton food available to species in filter feeding mode. However, phytoplankton will also be transported from distant areas and so the effect of increased turbidity may be mitigated to some extent. According to Widdows *et al* (1979) growth of filter-feeding bivalves may be impaired at suspended particulate matter (SPM) concentrations >250mg/l.

Abra alba can switch between deposit and filter feeding if the level of suspended sediment becomes so high as to risk clogging the feeding structures (Budd 2007). However, a sustained increase in suspended sediment levels would be expected to have a detrimental effect. For instance, the abundance of *A. alba* declined over two years within 1km of an outfall pipe discharging fine-grained mineral waste from the china clay industry at a rate of 450,000 tons per year to Mevagissey Bay, Cornwall. However, it was argued that persistent sediment instability was the more significant source of stress to the predominantly deposit-feeding community than the suspended sediment concentration (Probert 1981).

The dominance of *Phaxas pellucidus* in areas subject to dredge soil dumping and subsequent further deposition (Rees *et al* 1992) suggest that this species would not be sensitive to increased turbidity, to either increased seston or subsequent deposition following re-suspension of sediments.

As *Thyasira flexuosa* are buried within the sediment and are fed by symbiotic bacteria they were considered insensitive to a change in suspended solids. No evidence was found to assess impacts on *Timoclea ovata.*

This ecological group is not predicted to be sensitive to acute changes in turbidity. However at the pressure benchmark the change is chronic and sustained for a year. This is predicted to have negative impacts on growth and fecundity by reducing filter feeding efficiency and imposing costs on clearing and producing pseudofaeces for the filter feeders *Timoclea ovata* and *Phaxas pellucidus*. **Resistance** is therefore assessed as **'Medium'** and **resilience** is assessed as **'High'** for *Abra alba* **(Sensitivity** is **'Low')** and **'Medium' (Sensitivity** is **Medium')** for the other members of this Ecological Group (see section 4.7.7).

Resistance

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

Resilience (section 4.7.7)

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

XI. Habitat structure changes-removal of substratum (Extraction)

This ecological group consists of shallowly buried species. Within the extraction footprint all individuals would be removed and hence **resistance** is assessed as **'None'**. **Resilience** is assessed as **'High'** for *Abra alba* (an annual species) and **'Medium'** for the other members of this Ecological Group (see section 4.7.7). Therefore **Sensitivity** is **'Medium'.**

Resistance

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

Resilience (section 4.7.7)

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

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

Little direct evidence was found to assess the impact of this pressure at the pressure benchmark. As the members of this ecological group are shallowly buried this ecological group would be buried by the deposit. The intensity and duration of siltation will be mediated by site-specific hydrodynamic conditions, such as water-flow and wave action that determine the dispersal of deposits.

Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which small bivalves could migrate was 20cm in sand for *Donax* and approximately 40cm in mud for *Tellina* sp and approximately 50cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

Powilleit *et al* (2009) studied responses to smothering for three bivalves; *Arctica islandica*, *Macoma balthica* and *Mya arenaria*. These successfully burrowed to the surface of a 32 – 41cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. These high escape potentials could partly be explained by the heterogeneous texture of the till and sand/till mixture with ‘voids’. In comparison to a thick coverage, thin covering layers (i.e. 15-16cm and 20cm) increased the chance of the organisms to reach the sediment surface after burial. While crawling upward to the new sediment surfaces burrowing velocities of up to 8 cm/day were observed for the bivalves

Rees *et al* (1992 from Connor *et al* 2004) report that *Phaxas pellucidus* can become dominant in areas where dredge spoil is dumped. However, it is not clear whether this relates to vertical migration and survivability or an increase in habitat suitability enhancing post-dredging colonisation (as seems more likely).

The character of the overburden is an important factor determining the degree of vertical migration of buried bivalves. Individuals are more likely to escape from a covering similar to the sediments in which the species is found than a different type. **Resistance** is assessed as **‘Low’. Resilience** is assessed as **‘High’** for *Abra alba* (an annual species) (**Sensitivity** is **‘Low’)** and **‘Medium’ (Sensitivity is Medium’)** for the other members of this Ecological Group (see section 4.7.7).

Resistance

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

Resilience (section 4.7.7)

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

4.7.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to a change in one Folk class of the sedimentary classification). This ecological group would be highly sensitive to a change to hard substratum as this would result in the loss of suitable habitat for this ecological group.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. Records from the MNCR database indicate the substratum types for biotopes characterised by members of this ecological group as follows.

- *Abra alba*: mud with terrigenous debris; muddy sands and sandy muds; medium to very fine sand with some silt; clean sand; sand with some gravel; fine muddy sands occasionally with small gravel content; mixed muddy sediment; muddy gravelly mixed sediment with stones and shells; gravel with coarse to medium sand; mixed sediment of sandy mud, muddy sand with gravel pebbles and cobbles; sand with gravel, pebbles and/or shingle.

- *Phaxas pellucidus*: mud with a significant fine to very fine sand fraction; sandy mud; medium to very fine sand with some silt; muddy sand and gravel; mud occasionally with scattered shells or gravel; mixed sediment (with stones and shells).

- *Thyasira flexuosa*: soft mud; mud with a fine to very fine sand fraction; muddy sand; sandy mud; muddy sand and gravel; clean sand; mixed sediment (with stones and shells).

- *Timoclea ovata*: mud and sandy muddy mixed sediments; muddy gravel and sand, with shells and stones; medium to coarse sand and gravelly sand.

A change in classification of one Folk class (based on Long 2006 simplification) between mud and sandy mud, sand and muddy sand and mixed sediments is not predicted to negatively affect this ecological group which is found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). The ecological group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from habitat preferences rather than targeted studies.
Applicability is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.7.6 Pollution

XIV. Organic enrichment

Abra alba is typically found in organically enriched sediments where it may be present in high densities (Harger & Landenberger 1971). In a sewage dumping region of the North Sea, a great increase in the abundance of *A. alba* occurred in much of the dumping area because the ecological adaptations of the species enabled it to exploit the greatly increased supply of nutrients (Caspers 1981). *A. alba* also dominated harbour sediments in Ceuta, North Africa where 'very high' levels of organic matter (5-13% of sediment) and heavy metals were found (Guerra-García & García-Gómez 2004). Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI) a biotic index to assess disturbance (including organic enrichment) both assigned *A. alba* to their Ecological Group III (defined as 'species tolerant to excess organic matter enrichment). These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations)(Borja *et al* 2000; Gittenberger & van Loon 2011).

Thyasira flexuosa has been identified as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski 1975, cited in Gray 1979). *Thyasira* spp. are characteristic of organically enriched off-shore sediments with *Capitella capitata* (Connor *et al* 2004). López-Jamar *et al* (1987) stated that *Thyasira flexuosa* is adapted to living in reduced sediments and also is found in organically enriched sediments, Borja *et al* (2000) and Gittenberger and van Loon (2011), in the development of the AMBI index to assess disturbance (including organic enrichment) both assigned *Thyasira flexuosa* to their Ecological Group III (defined as 'species tolerant to excess organic matter enrichment). These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations)(Borja *et al* 2000; Gittenberger & van Loon 2011).

Simboura and Zenetos (2002) assigned *Timoclea ovata* to their Ecological Group 2 (GII) category for the biotic index that they developed called BENTIX Ecological Group II is defined as 'species tolerant to disturbance or stress whose populations may respond to enrichment or other source of pollution by an increase of densities (slight unbalanced situations).

Based on the AMBI index scores and observations of increased densities in organically enriched areas, this ecological group is assessed as **'Not Sensitive'** to organic enrichment at the pressure benchmark **resistance** is assessed as '**High'** and **resilience** as '**High'**.

Resistance

Quality of evidence is 'Medium' – peer reviewed based evidence is not available for all species and the type of evidence supporting the AMBI score is unclear, however AMBI assessments are reported in peer reviewed literature, widely used and are considered credible.
Applicability is 'Low' – based on unknown underlying evidence and assumptions for AMBI/BENTIX.
Concordance is 'Low' – based on unknown underlying evidence and assumptions for AMBI/BENTIX.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.7.7 Review of likely rates of recovery based on the species a present within the ecological group

Abra spp. are opportunistic species capable of exploiting newly disturbed substratum through larval recruitment, secondary settlement of post-metamorphosis juveniles, or re-distribution of adults (Rees & Dare 1993, cited by Budd 2007). *Abra alba* spawns at least twice a year over a protracted breeding period, during which time an average sized animal of 11 mm can produce between 15,000 to 17,000 eggs. Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month (Dauvin & Gentil 1989, cited in Budd 2007), allowing high potential dispersal. In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting (Sigurdsson *et al* 1976) and probably bed load transport (Emerson & Grant 1991).

Diaz-Castaneda *et al* (1989) investigated recolonisation sequences of benthic associations over a period of one year, following defaunation of the sediment. Recovery of the *A. alba* community was rapid; recruitment occurring from surrounding populations via planktonic supply. The experimental data suggested that *A. alba* would colonise available sediments within the year following environmental perturbation. Summer settled recruits may grow very rapidly and spawn in the autumn, whilst autumn recruits experience delayed growth and may not reach maturity until the following spring/summer. In the worst instance, a breeding population may take up to two years to fully establish and so resilience has been assessed to be ‘High’. However, recovery may be very high in instances where a proportion of the adult population survives (Budd 2007).

The recovery potential of *Phaxas pellucidus* is difficult to judge as no information on reproduction or longevity were found in the literature. Previous intensive searches have also been unable to find evidence (Tillin *et al* 2008).

Other members of the Pharidae, the razor shells, are long-lived and reach sexual maturity after 3-5 years. *P. pellucidus* can be locally abundant and can dominate disturbed sediments suggesting that it has some opportunistic traits (Rees *et al* 1992). The planktonic larvae are found in autumn and winter in the water column (Lebour 1938), which suggest that wide spatial dissemination is possible for this species. Resilience of a population from significant mortality (loss of 25-75% of the population) is considered likely to be ‘Medium’ (2-10 years).

Little information was available for *Thyasira flexuosa.* The larval development of the congener *Thyasira equalis* is lecithotrophic and the pelagic stage is very short or suppressed. This agrees with the reproduction of other *Thyasira* sp., and in some cases (e.g. *Thyasira gouldi*) no pelagic stage occurs at all (Thorson 1946, 1950). This means that larval dispersal is limited. If mortality of *Thyasira* sp. occurs, there would have to be nearby populations for recovery to occur. Where some individuals survive, due to the fact that larvae spend little or no time in the water column, post-settlement survival may be higher, and the population may be able to recover. It is also possible that adults could be brought into the area by bed load transport, enabling colonisation for example (Riley 2002). Sparks-McConkey and Watling (2001) found that a population of *Thyasira flexuosa* in Penobscot Bay, Maine recovered rapidly (within 3.5 months) following trawler disturbance that resulted in a decrease in the population. Benthic reproduction allows recolonisation of nearby disturbed sediment and leads to rapid recovery where a large proportion of the population remains to repopulate the habitat.

Timoclea ovata has a life span of about 4-6 years and reaches reproductive maturity at 1 year. The sexes are separate and there is an annual episodic breeding event between March-September. Little is known of the fecundity of this genus but the fertilised eggs develop into lecithotrophic veliger larvae that settle to the seabed after a period of about 30 days in the plankton. This genus probably has a relatively high dispersal potential based on the length of the larval phase. Restoration of the biomass by growth of the colonising individuals is likely to take several years (MES 2010).

Overall, information on recovery is best-studied for *Abra* spp., which are generally considered to be an annual species with high levels of mortality each year. Recovery from a severe decline (e.g. loss of 25-75% of the population) is considered to be 'High' (within 2 years). Less information is available for the other species although the high recovery of *Thyasira flexuosa* (Sparks-McConkey & Watling 2001) is noted. Recovery from a significant decline for *Phaxas pellucidus*, *Timoclea ovata* and *Thyasira flexuosa* is assessed as 'Medium' although it is suggested that the lower end of the medium scale applies, e.g. within 5 years rather than 10 years. This assessment is largely based on expert judgement, confidence in quality of evidence is therefore 'Low' and confidence in the applicability and degree of concordance is not assessed as these categories are not relevant when assessments are based on expert judgement.

4.7.8 Knowledge gaps

The evidence available to assess the pressures and to infer resilience varies between species within this ecological group. Of the species the life history of *Abra alba* is best understood. Very little or no information was available to assess the population dynamics and recovery potential of *Phaxas pellucidus* and *Timoclea ovata* from pressure impacts or natural disturbance. The resilience assessments for this ecological group are therefore largely based on expert judgement.

As these species are not of commercial or conservation interest there has been little impetus to study sensitivity. However, as these species are present in soft-sediments that can be sampled with grabs; assessments of the impacts from fishing activities have been recorded and quantified. The evidence base to assess the sub-surface and surface abrasion pressure was therefore the most developed.

As is the case for most ecological groups changes in hydrological pressures and other pressures (e.g. physical change) were assessed using habitat distribution and other life-history traits as a proxy as no other direct sources of evidence were found.

4.8 Ecological Group 5 Small-medium suspension and/or deposit feeding polychaetes

4.8.1 Definition and characteristics of the ecological group

This ecological group is represented by a number of polychaetes that are deposit or suspension feeders or can switch between these feeding methods (**Table 4.8**). This ecological group is based on taxonomy and feeding type and the species share some other trait similarities. The species within this group are typically positioned at the sediment-water interface or are shallowly buried to extend the feeding parts into the water column or to capture surface detritus. This large group encompasses a range of species with varying biological traits and life histories that will influence resistance to pressures and subsequent recovery. It is therefore suggested that the following species sub-groups are assessed to ensure a range of species with different sensitivities are captured.

- **Medium-large, sessile species in relatively robust tubes**, e.g. rigid tubes made of sediment particles rather than mucus, in a range of sediment types but generally preferring coarser and sandy sediments. These species are predominantly suspension feeders and the sensitivity of *Lanice conchilega* is assessed to represent this sub-group.

- **Medium-sized, longer-lived species**, in a range of sediment types and free-living within a burrow system. These species are predominantly deposit feeders and the sensitivity of *Scoloplos armiger* is assessed to represent this sub-group.

- **Small and small-medium, surface deposit feeders in fragile tubes** that are found in coarse sands, muddy sands and sandy muds. The sensitivity of *Caulleriella zetlandica* and *Ampharete falcata* is assessed to represent this sub-group. *Caulleriella zetlandica* is found in coarse sediments and mixed sediments while *Ampharete falcata* is found in offshore muds.

- **Fragile, suspension/deposit feeders** living 1-2 years. The sensitivity of *Polydora caulleryi* is assessed to represent this sub-group.

Table 4.8. List of biotopes in which ecological group 5 species occur as characterising species (continued overleaf).

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.MedLumVen	*Lanice conchilega*
SS.SCS.CCS.Pkef	*Caulleriella zetlandica*
SS.SCS.CCS.Nmix	*Lanice conchilega*
SS.SCS.CCS.Blan	Characterising species present were not specifically assessed.
SS.SSa.CFiSa.ApriBatPo	*Scoloplos armiger*
SS.SSa.CFiSa.EpusOborApri	Characterising species present were not specifically assessed.
SS.SSa.CMuSa.AalbNuc	*Lanice conchilega* *Scoloplos armiger*
SS.SSa.OSa.MalEdef	*Scoloplos armiger*
SS.SSa.OSa.OfusAfil	Characterising species present were not specifically assessed.
SS.SMu.CSaMu.LkorPpel	*Lanice conchilega*

Level 5 biotopes represented	Key or characterising species assessed
SS.SMu.CFiMu.MegMax	Characterising species present were not specifically assessed.
SS.SMx.CMx.MysThyMx	*Scoloplos armiger*
SS.SMx.OMx.PoVen	*Caulleriella zetlandica* *Polydora caulleryi*
SS.SMu.OMu.StyPse	Characterising species present were not specifically assessed.
SS.SMu.OMu.AfalPova	*Ampharete falcata*
SS.SMu.OMu.LevHet	Characterising species present were not specifically assessed.
SS.SMu.OMu.MyrPo	Characterising species present were not specifically assessed.

4.8.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or have an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **‘No evidence’**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical impacts are assessed under abrasion and penetration of the seabed pressures (section 4.8.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. Species within this group live on or shallowly buried within sediments and feed on suspended particles transported in the water column or deposits of organic matter on or within sediments. They are not considered dependent on other species for habitat or food. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered ‘Not Exposed’ to targeted removal of the ecological group and **‘Not Sensitive’** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is ‘Medium’ – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability is ‘Low’ – based on general ecology as a proxy for resistance.
Concordance is ‘Not assessed’ – based on general ecology alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.8.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Species within this group live on or shallowly buried within sediments and feed on suspended particles transported in the water column or deposits of organic matter on or within sediments. They are not considered dependent on other species for habitat or food. As no obligate life-history or ecological associations were identified this ecological group is considered to be '**Not Sensitive'.** By default, **resistance** and **resilience** are therefore assessed as **'High'**.

Resistance

Quality of evidence is 'Medium' – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology as a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on general ecology alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.8.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No direct evidence was found to assess changes in salinity and OBIS data (OBIS, 2014) was used as the basis of the assessment. The minimum and maximum range of salinities is as follows.

- *Ampharete falcata*: 33.837 - 38.174pps
- *Caulleriella zetlandica*: 32.629 - 35.982pps
- *Lanice conchilega*: 31.982 - 36.315pps
- *Polydora caulleryi*: 32.853 - 34.892pps
- *Scoloplos armiger*: 30.381 - 35.201pps

This evidence suggests that that this ecological group may be tolerant of increases in salinity (35-38 units for one year) and is assessed as '**Not Sensitive'** (**resistance** and **resilience** are both considered to be **'High'**). However, this ecological group may be more sensitive to a decrease in salinity at the pressure benchmark of 4-10psu for a year. **Resistance** is assessed as **'Low'** as a change of up to 10psu may severely impact populations. **Resilience** is assessed as **'High'** for *Polydora* spp. (**Sensitivity** is **'Low'**) and **'Medium'** (**Sensitivity** is **'Medium'**) for the other members of ecological group 5.

Resistance

Quality of evidence is 'Low' – based on habitat distribution and OBIS values rather than targeted studies.
Applicability is 'Low' – based on habitat distribution and OBIS values as a proxy for resistance.
Concordance is 'Not assessed' – based on habitat distribution alone.

Resilience (L. conchilega) (section 4.8.7)

Quality of evidence is 'High' - based peer reviewed evidence.
Applicability of evidence is 'Medium' - based on peer reviewed evidence on a variety of pressures.
Concordance of evidence is 'High' - based on agreement on magnitude and direction.

Resilience (others) (section 4.8.7)

Quality of evidence is 'Low' - based on largely on life-history traits but also uses expert judgement.
Applicability of evidence is 'Not assessed' - based on expert judgement.
Concordance of evidence is 'Not assessed' - based on expert judgement.

V. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

- *Ampharete falcata*: Swedish west coast, Skagerrak, Kattegat, Norway, North Sea, Irish Sea (Marine Species Identification Portal[8])

- *Caulleriella zetlandica*: northeast North Sea, Shetland, south to the English Channel and Celtic Sea, Greece in the Mediterranean, and the Gulf of Mexico (OBIS 2014).

- *Lanice conchilega*: is found from the Arctic to the Mediterranean, in the Arabian Gulf and the Pacific (Ager 2008)

- *Polydora caulleryi*: Northern North Sea, Skagerrak, Kattegat, Öresund, English Channel, North Atlantic, North Pacific, Black Sea, Arctic (Marine Species Identification Portal)

- *Scoloplos armiger*: found from the Arctic and northwest Europe to the Indian Ocean, the Pacific and the Antarctic (MarLIN).

In addition, the genus *Caulleriella* is found in the discharge channels where heated effluents from power stations are discharged, indicating a tolerance for chronic exposure to increased temperatures (Bamber & Spencer 1984).

Ampharete falcata seem to reach their southerly limit in UK waters suggesting a possible susceptibility to a long-term rise in summer water temperatures. No published information was found on which to make an informed judgement at the pressure benchmark. **Resistance** to either a chronic increase or a short term acute increase is assessed as **'Low'**.

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[8] http://species-identification.org/

Resilience (following habitat recovery) is assessed as **'Medium'** (2-10 years). **Sensitivity** is therefore assessed as **'Medium'**.

Resistance (*A. falcata*)

Quality of evidence is 'Medium' – based on inference from biotope records rather than targeted studies.
Applicability is 'Low' – based on geographic distribution as a proxy for resistance.
Concordance is 'Not assessed' – evidence is based on a single source.

Resilience (*A. falcata*)

Quality of evidence is 'Low' - based on expert judgment.
Applicability of evidence is 'Not assessed' –based on expert judgment.
Concordance of evidence is 'Not assessed' - based on expert judgment.

However, based on the global distribution or evidence for tolerance, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect *L. conchilega*, *C. zetlandica*, *P. caulleryi* and *S. armiger* as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'.** Therefore, the other members of the group are considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from geographical distribution rather than targeted studies.
Applicability is 'Low' – based on geographical distribution as a proxy for resistance.
Concordance is 'Not assessed' – based on geographical distribution alone.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for biotopes characterised by members of this ecological group as follows:

- *Ampharete falcata*: weak (<0.5m/s, based on one biotope record)
- *Caulleriella zetlandica*: moderately strong to very weak (negligible -1.5m/s)
- *Lanice conchilega*: strong to very weak (negligible –3m/s)
- *Polydora caulleryi*: no information
- *Scoloplos armiger*: moderately strong to very weak (negligible -1.5m/s)

The range of flow speeds experienced by biotopes in which the species are found suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inference from biotope records rather than targeted studies.
Applicability is 'Low' – based on MNCR database records as a proxy for resistance.
Concordance is 'Not assessed' – evidence is based on a single source.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded the wave exposure categories for biotopes characterised by members of this ecological group follow.

- *Ampharete falcata*: extremely sheltered; very sheltered; sheltered.
- *Caulleriella zetlandica*: extremely sheltered; very sheltered; sheltered; moderately exposed.
- *Lanice conchilega*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed.
- *Polydora caulleryi*: moderately exposed (based on one biotope record).
- *Scoloplos armiger*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed, very exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **'High'** and as there is no impact to recover from, **resilience** is considered to be **'High'.** This group considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inference from biotope records rather than targeted studies.
Applicability is 'Low' – based on MNCR database records as a proxy for resistance.
Concordance is 'Not assessed' – evidence is based on a single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from

4.8.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

Infaunal species within this ecological group are considered to be relatively protected from surface abrasion. Abrasion may damage species where parts of an animal project above the surface.

Lanice conchilega

Species such as *Lanice conchilega* inhabit tough, flexible tubes which afford some protection from surface abrasion. This hypothesis is supported by experimental trawling in an intertidal area using a small beam trawl that did not lead to any significant effects on *Lanice conchilega* that was present in dense patches (Rabaut *et al* 2008). Tubes can be rapidly repaired as observed by Ferns (2000) who investigated the effect of mechanical cockle harvesting. Therefore, this species is considered to have **’High’ resistance** to a single event of surface abrasion. **Resilience** is therefore assessed as **‘High’** (no, or very limited, effect to recover from). This species is therefore assessed as **‘Not Sensitive’.**

Resistance (L. conchilega)

Quality of evidence is ‘High’ – based on peer reviewed literature.
Applicability is ‘High – based on evidence directly relevant to the pressure.
Concordance is ‘High’ – based on agreement between the two sources.

Resilience (L. conchilega)

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

Polydora caulleryi and *Caulleriella zetlandica*

No evidence was found to assess *Polydora caulleryi* and *Caulleriella zetlandica*. **Resistance** was assessed as **‘Medium**’ as surface abrasion may inflict some damage on these species which feed at the surface. **Resilience** is assessed as **‘Medium’ for *C. zetlandica*** and **sensitivity** is as **‘Medium’**, but **‘High’ for the opportunistic *Polydora* spp.** and **sensitivity** as **‘Low’.**

Resistance (P. caulleryi and *C. zetlandica)*

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability of evidence is ‘Not assessed’ – assessment based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (P. caulleryi and *C. zetlandica) (section 4.8.7)*

Quality of evidence is ‘Low’ - based on largely on life-history traits but also uses expert judgement.

Applicability of evidence is ‘Not assessed’ - based on expert judgement.
Concordance of evidence is ‘Not assessed’ - based on expert judgement.

Ampharete falcata

The tube dwelling polychaete *Ampharete falcata* is considered particularly sensitive to surface abrasion which would likely damage and remove the fragile tubes. **Resistance** is therefore assessed as **‘Low’** and **resilience** as **‘Medium’.** The **sensitivity** of this species is therefore assessed as **‘Medium’.**

Resistance (A. falcata)

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (A. falcata) (section 4.8.7)

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability of evidence is ‘Not assessed’ - based on expert judgment.
Concordance of evidence is ‘Not assessed’ - based on expert judgment.

Scoloplos armiger

Juveniles and adults of *S. armiger* stay permanently below the sediment surface, and freely move without establishing burrows. While juveniles are only found a few millimetres below the sediment surface, adults may retreat to 10cm depth or more (Reise 1979; Kruse *et al* 2004). The egg cocoons are laid on the surface and hatching time is 2-3 weeks during which these are vulnerable to surface abrasion. Based on species traits (environmental position and flexibility), adults of *S. armiger* were judged to have ‘**High’ resistance** to surface abrasion, the lack of effect means that **resilience** is judged as **‘High’** and hence this species is assessed as **‘Not Sensitive’**.

Resistance (S. armiger)

Quality of evidence is ‘Medium’ – based on expert judgment with supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is ‘Low’ – species traits are used as proxy.
Concordance of evidence is ‘Not assessed’ – based on proxy rather than direct evidence.

Resilience (S. armiger)

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

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

Members of this ecological group are either shallowly buried (*Cauleriella zetlandica*, *Polydora caulleryi*) or project above the surface (*Ampharete falcata* and *Lanice conchilega*) and will be directly impacted by penetration and disturbance of the substratum below the surface. This ecological group is therefore considered sensitive to direct physical impacts from activities that lead to penetration and disturbance of the seabed although the sensitivity is predicted to vary between members of the group.

Very little evidence was found to assess the sensitivity of *Ampharete falcata*. The species was present at a wreck site that prevented fishing disturbance and were absent from fished sites in the Irish Sea (Ball *et al* 2000a).

Lanice conchilega can retract quickly into its tube to avoid abrasion and shallow sediment disturbance. This is supported by experimental trawling in an intertidal area where the passage of a small beam trawl did not lead to any significant effects on *Lanice conchilega* that was present in dense patches (Rabaut *et al* 2008). Rabaut *et al* (2008) also studied the direct mortality of *L. conchilega* as a consequence of sustained physical disturbance at varying frequencies to reflect the effect of beam trawl fisheries. Research was based on a laboratory experiment in which four different disturbance regimes were applied (disturbance every other 12, 24 and 48 h and no fishing disturbance as a control). Survival dropped significantly after 10 and 18 days (with a disturbance frequency of every 12 and 24h respectively). The results indicate that *L. conchilega* is relatively resistant to physical disturbance but that reef systems can potentially collapse under continuous high frequency disturbance.

However, de Groot (1984) found that the tube dwelling polychaetes *Pectinaria* spp. and *L. conchilega* were particularly vulnerable (amongst annelids) to being caught in beam trawls fitted with tickler chains and damaged. This study was based on observations of species caught as by-catch and did not assess *in-situ* damage rates.

Direct mortality (percentage of initial density) of *Scoloplos armiger* from a single pass of a beam trawl was estimated from experimental studies on sandy and silty grounds as 18% (Bergman & van Santbrink 2000a). *Scoloplos armiger* was more abundant in samples from Algarve coastal areas subject to greater fishing effort (clam and razor clam dredges) than areas that were not known to be fished. Experimental intertidal dredging for cockles reduced the abundance of *Scoloplos armiger* in disturbed plots compared to control sites. These differences persisted for 56 days (Hall and Harding 1997).

Based on the above evidence, *L. conchilega and S. armiger* are considered to have **'Medium' resistance** to a single event of shallow disturbance and **'High' resilience** (based on field observations). The **sensitivity** of these species is therefore assessed as **'Low'.** Repeated disturbances will lead to greater effects.

Resistance (L. conchilega)

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on relevant activities.
Concordance of evidence is 'High' – based on agreement between sources on the direction and magnitude of impact.

Resilience (L. conchilega)

Quality of evidence is 'High' – based on expert judgement.
Applicability of evidence is 'High' – based on relevant activities.
Concordance of evidence is 'High' – based on agreement between sources on the direction and magnitude of recovery.

No direct evidence was found to assess the sensitivity of *A. falcata*, *C. zetlandica* and *P. caulleryi*. Based on expert judgement **resistance** is assessed as **'Low'** and **resilience** as **'Medium'**. The **sensitivity** of these species is therefore assessed as **'Medium'.** Confidence in the quality of supporting evidence for resistance and resilience is assessed as 'Low' as the assessments are based on expert judgement. Confidence in the applicability and degree of concordance is not assessed as these categories are not relevant when assessments are based on expert judgement.

Resistance (*A. falcata*, *C. zetlandica* and *P. caulleryi)*

Quality of evidence is ‘Low’ – based on expert judgement.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (*A. falcata*, *C. zetlandica* and *P. caulleryi)*

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

X. Change in suspended solids

‘No evidence’ was found to assess this pressure and therefore sensitivity is ‘Not assessed’.

XI. Habitat structure changes-removal of substratum (Extraction)

Extraction would remove all individuals within the extraction footprint and hence **resistance** is assessed as **‘None’**. **Resilience** is predicted to be **‘Medium’** (recovery within 2 years) for all species within this ecological group except for *P. caulleryi* (**resistance** is **‘High’**) and *C. zetlandica* (**resistance** is **‘Low’)**. **Sensitivity** is therefore assessed as **‘Medium’** for all species in the group except *C. zetlandica* whose sensitivity is assessed as **‘High’.**

Resistance

Quality of evidence is ‘Medium’ – based on expert judgement and supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is ‘Low’ – based on species traits as a proxy.
Concordance of evidence is ‘Not assessed’ – based on proxy rather than direct evidence.

Resilience

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

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

As the members of this ecological group are shallowly buried this ecological group would be buried by the deposit. The intensity and duration of siltation will be mediated by site-specific hydrodynamic conditions, such as water-flow and wave action that determine the dispersal of deposits.

Bolam (2011) conducted field experiments to investigate the vertical migratory capability of macroinvertebrate species. The cirratulid polychaete worms *Tharyx* sp. and the spionid *Streblospio shrubsolii* showed poor vertical migration with only 6cm of sediment overburden.

Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which *Scoloplos* could migrate was 50cm in sand and mud. No further information was available on the rates of survivorship or the time taken to reach the surface.

Warner (1971) simulated the effects of dredge disposal of different thicknesses on animals in aquaria or plastic cores for 2 weeks. In core experiments at temperatures ranging from 14 to 18°C and 20 to 21°C, there was a relationship between vertical migration distance and sediment depth for the congener *Scoloplos fragilis*. This species could vertically migrate through 30cm of sand. In other core experiments in silt-clay at temperatures of 17^{o}C to 18^{o}C, there was a suggestion of reduced efficiency of burrowing in finer grained sediment where even the smallest amount of silt-clay proportion tested (20%) affected the burrowing ability of this species.

As a general rule, Richardson *et al* (1977) reported that the species most affected by dredged material disposal were tube-dwelling polychaetes. Therefore, within this ecological group the tube dwelling polychaetes *Lanice conchilega*, *Ampharete falcata*, *Polydora caulleryi* and *Caulleriella zetlandica* were considered to have a **resistance** of **'None'. Resilience** (following habitat recovery) is assessed as **'Medium'** for *L. conchilega*, and *A. falcata,* and **sensitivity** is assessed as **'Medium'**. **Resilience** of the opportunistic *P. caulleryi* is assessed as **'High'** and sensitivity is categorised as **'Low'**, while the resilience of *C. zetlandica* is assessed as **'Low'**, and **sensitivity** is therefore, **'High'***.*

Resistance (*L. conchilega*, *A. falcata*, *P. caulleryi* and *C. zetlandica*)

Quality of evidence is 'High' – based on limited vertical migration of spionids and cirratulids taken from peer reviewed literature.
Applicability of evidence is 'High' – based on evidence directly relevant to this pressure.
Concordance of evidence is 'High' – based on agreement in direction and magnitude.

Resilience (*L. conchilega*, *A. falcata*, *P. caulleryi* and *C. zetlandica*) (section 4.8.7)

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

Although *Scoloplos armiger* is considered to be able to migrate vertically, this may be limited where the overburden consists of fine sediments (based on Maurer 1978), **resistance** is assessed as **'Low'**. **Resilience** is assessed as **'Medium'** and **sensitivity** is **'Medium'**.

Resistance (*S. armiger)*

Quality of evidence is 'Low' – based on a congener.
Applicability of evidence is 'Low' – based on a congener response to this pressure.
Concordance of evidence is 'Low' – based on a single source.

Resilience (*S. armiger)*

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

4.8.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (a change in one Folk class). This ecological group would be highly sensitive to a change to hard substratum as this would result in the loss of suitable habitat for this ecological group.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Ampharete falcata*: cohesive sandy mud (one biotope record only).

- *Caulleriella zetlandica*: mud and sandy muddy mixed sediments; sandy gravelly muddy mixed sediment; medium to coarse sand with some gravel or shell, and a fine sand or mud fraction; mixed sediment of sandy mud, muddy sand with gravel pebbles and cobbles; coarse sand and gravel with a minor finer sand fraction.

- *Lanice conchilega*: peat; clay sandy mud; fine muddy sands occasionally with small gravel content; medium to fine muddy sand; clean fine sands; mixed sediment; sandy gravelly muddy mixed sediment; fine to very fine sand and muddy sand; sandy muddy gravel with surficial cobbles, pebbles and shells; medium-coarse sands with gravel, shell, pebbles and cobbles; boulders, cobbles and pebbles on muddy sediments; clean stone gravel with pebbles; stony sediment; sand with some gravel; boulders, cobbles, pebbles and gravel; muddy gravel; bedrock, cobble, sand; clean shell and stone gravel; very coarse sand with a finer sand fraction.

- *Polydora caulleryi*: mud and sandy muddy mixed sediments; gravelly sand and muddy mixed sediment.

- *Scoloplos armiger*: cohesive mud; fine sand or muddy sand; sandy gravelly muddy mixed sediment; mixed muddy sediment; medium to very fine sand with gravel and pebbles; sand with some gravel; mixed sediment; muddy sand and gravel; mixed sediment, shell debris; medium to coarse sand with some gravel or shell, coarse sand and gravel with a minor finer sand fraction; sand with gravel, pebbles and/or shingle.

A change in classification of one Folk class is not predicted to negatively affect this ecological group which is found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). The group is considered **'Not Sensitive'.**

Resistance

Quality of evidence is ‘Medium’ – based on inferences made from biotope records rather than species records.
Applicability of evidence is ’Low’ – data based on a proxy for the pressure.
Concordance of evidence is ‘Not assessed’ – based on a single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.8.6 Pollution

XIV. Organic enrichment

Borja *et al* (2000) and Gittenberger and van Loon (2011) for the development of the AZTI Marine Biotic Index (AMBI) biotic index to assess disturbance (including organic enrichment) assigned the congener of *Ampharete falcata*, *A. acutifrons*, *Lanice conchilega* and *Scoloplos armiger* to either Ecological Group II or III. These are defined as either 'species indifferent to enrichment' (Ecological Group II), or 'species tolerant to excess organic matter' (Ecological Group III). No AMBI group assessments were found for *Polydora caulleryi* and *Caulleriella zetlandica*.

Based on the AMBI categories this group was considered to have '**High' resistance** to organic enrichment (at the pressure benchmark) and **'High' resilience** (no impact to recover from'. This group is therefore considered to be **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – type of evidence supporting the AMBI score are unclear, however these assessments are reported in peer reviewed literature, are widely used and are considered credible.
Applicability of evidence is 'Low' – based on unknown underlying evidence and assumptions.
Concordance of evidence is 'Low' – based on unknown underlying evidence and assumptions.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.8.7 Review of recovery based on the species assemblage present within the ecological group

The recovery characteristics of the group members vary.

Lanice conchilega

The recovery of *Lanice conchilega* was assessed previously by Ager (2008) and Callaway *et al* (2010). This species is sessile and larval recolonisation is therefore the most important recovery mechanism. However, adults intact in their tubes have been observed after storms and this represents a potential, if random, colonisation mechanism. The tube itself can be rapidly repaired or rebuilt following damage (Warner & Woodley 1975).

The larvae spend up to 60 days in the plankton and therefore have a wide dispersal potential. Larvae preferentially settle on either the tubes of *L. conchilega* or other suitable settlement surfaces including artificial tubes (Heuers & Jaklin 1999) or bivalve shells (Herlyn *et al* 2008). Strasser and Pielouth (2001) reported that larvae were seen to settle in areas where there were no adults (but took 3 years to re-establish the population) The duration of recovery, appears to range between one and four years (Beukema 1990; Heuers 1998; Zühlke 2001; Callaway *et al* 2010).

The recovery of *L. conchilega* populations will therefore be enhanced by the presence of adults that survive impacts (e.g. where resistance is 'Medium' or 'Low'). *L. conchilega* resilience is assessed as 'High' (Ager 2008) where resistance is 'Medium' but assessed as 'Medium', where resistance is 'Low' or 'None'. The assessment is based on peer reviewed evidence and hence confidence in the quality of evidence is 'High', applicability is 'Medium' and degree of concordance is 'High'.

Scoloplos armiger and *Caulleriella zetlandica*

The resilience of *Scoloplos armiger* was reviewed by MES (2010). *S. armiger* has a life-span of about four years and reaches maturity at two years. The sexes are separate and as many as 100-5000 eggs of about 0.25mm are fertilised externally between February-April. The eggs are attached to the seabed in a gelatinous mass and emerge after three weeks and burrow near the site of release. There may be a very short lecithotrophic pelagic phase in subtidal populations but dispersal is very limited. This genus has a low dispersal potential (MES 2010).

MES (2010) have also recently reviewed the recoverability of *Caulleriella* (genus rather than specific species). There is little available evidence but the review suggests that restoration of the biomass following colonisation may take 3-5yrs as *Caulleriella spp*. are thought to have a lifespan of 3-5yrs, reaching maturity by the second year. The review indicates that it is not known whether the larvae of *Caulleriella* have a planktotrophic phase although there is some evidence that they are brooded and undergo direct development. Therefore, recolonisation may be slow if the dispersal potential is low.

Where individuals remain to re-populate sediments, species with direct development stages rather than planktonic larvae are able to rapidly recolonise adjacent disturbed sediments. Where resistance is ‘Low’ or ‘Medium’, the resilience of *Caulleriella zetlandica* and *Scoloplos armiger* is assessed as ‘Medium’ and may be towards the lower end of this scale, e.g. five years rather than ten. Where resistance is ‘None’, recovery may be more protracted and take up to 10 years or more, a resilience of ‘Low’.

Ampharete spp.

There is little life-history information for *Ampharete* spp. (MES 2010). The genus is known to take three years to reach sexual maturity indicating a low reproductive potential. MES (2010) suggest that the slow growth to reproductive maturity means that restoration of the biomass may take several years after initial colonisation of disturbed sediments and that, coupled with the low dispersion and mobility, the genus has a low recovery potential. Resilience is therefore assessed as ‘Medium’ (2-10 years) and may be nearer ten years.

Polydora spp.

The genus *Polydora* has life-history traits that suggest this species is an opportunist that can colonise disturbed areas rapidly. The life span for *Polydora* is estimated to be 1-2 years and sexual maturity is achieved within the first year (MES 2010). Adult dispersal can be up to 1000m, while larval potential dispersal can be of hundreds of kilometres (MES 2010). MES (2010) suggest that recovery should be achieved in a limited period of time, provided there is the presence of suitable substratum. Based on this evidence available resilience is assessed as ‘High’.

Confidence in the quality of supporting evidence for the resilience assessment for *Scoloplos armiger, Caulleriella zetlandica, Polydora* spp. and *Ampharete* spp. is assessed as ‘Low’ as the assessment is based largely on life-history traits but also uses expert judgement. Confidence in the applicability and degree of concordance is not assessed as these categories are not relevant when assessments are based on expert judgement.

4.8.8 Knowledge gaps

The evidence available to assess the pressures and to infer resilience varies between species within this ecological group. Very little or no information was available to assess the population dynamics and recovery potential or sensitivities of *Ampharete falcata*, *Caulleriella* *zetlandica* and *Polydora caulleryi*. Studies sometimes recorded the occurrence of these species in samples but no reviews or focussed studies on ecology and responses were found.

As is the case for most ecological groups changes in hydrological pressures and other pressures (e.g. physical change) were assessed using habitat distribution and other life-history traits (where known) as a proxy as no other direct sources of evidence were found.

The more common and widespread species *Scoloplos armiger* and *Lanice conchilega* were better studied. *Lanice conchilega* is a conspicuous species, is of interest as a habitat engineer and occurs intertidally and in the shallow subtidal so is accessible for collection and amenable to experimental manipulation which may explain this.

4.9 Ecological Group 6 Predatory polychaetes

4.9.1 Definition and characteristics of the ecological group

This group consists of polychaetes that are primarily scavengers or predators (**Table 4.9**). This ecological group is based on taxonomy and feeding type and the species share some other trait similarities. These species are generally distinct from deposit or suspension feeding polychaetes in terms of mobility and may, in some cases, be larger and longer-lived than typical tubicolous, sessile suspension and deposit feeders. In order to capture the range of sensitivities the following species will be specifically assessed:

- **Small (<1cm) short-lived (1-2 years) species** living in sands and other coarser sediments - *Paramphinome jeffreysii*.

- **Small (1-2cm) short-lived species (1-2 years)** living in mixed and silty sediments - *Protodorvillea kefersteini*.

- **Medium (11-20cm) species living 3-10 years** - *Nephtys hombergii* and *Glycera lapidum*.

Table 4.9. List of biotopes in which ecological group 6 species occur as characterising species

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.MedLumVen	*Protodorvillea kefersteini*
SS.SCS.CCS.Pkef	*Glycera lapidum* *Protodorvillea kefersteini*
SS.SCS.CCS.Blan	*Glycera lapidum*
SS.SCS.OCS.GlapThyAmy	*Glycera lapidum*
SS.SCS.OCS.HeloPkef	*Protodorvillea kefersteini*
SS.SSa.CFiSa.EpusOborApri	*Glycera lapidum*
SS.SSa.CMuSa.AalbNuc	*Nephtys hombergii*
SS.SMu.CSaMu.LkorPpel	Characterising species present were not specifically assessed.
SS.SMu.CFiMu.MegMax	Characterising species present were not specifically assessed.
SS.SMx.CMx.MysThyMx	*Nephtys hombergii*
SS.SMx.OMx.PoVen	*Glycera lapidum*
SS.SMu.OMu.LevHet	*Paramphinome jeffreysii*
SS.SMu.OMu.PjefThyAfil	*Paramphinome jeffreysii*
SS.SMu.OMu.MyrPo	*Paramphinome jeffreysii*

4.9.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.9.4). Commercial fisheries may result in discarding of undersized or damaged target species. This will increase the available food supply to this ecological group which are active, mobile predators and scavengers. Evidence for these indirect effects is described in more detail under the pressures abrasion and penetration of the seabed. Overall commercial fisheries would be considered to have a beneficial impact on populations of species within this ecological group.

The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be ‘Not Exposed’ to targeted removal of the ecological group and **‘Not Sensitive’** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is ‘Medium’ – based on inference from ecology and life history characteristics rather than targeted studies.
Applicability of evidence is ‘Low’ – based on general ecology as a proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on general ecology alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.9.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. The members of this ecological group feed on a range of food sources but primarily scavenge and prey on a wide range of species. Commercial fisheries may result in discarding of non-target species. This will increase the available food supply to this ecological group which are active, mobile predators and scavengers. No obligate life-history or ecological associations were identified and this ecological group is considered to be ‘**Not Sensitive’.** By default, **resistance** and **resilience** are therefore assessed as **‘High’**.

Resistance

Quality of evidence is ‘Medium’ – based on ecological and life history information rather than targeted studies.
Applicability of evidence is ‘Low’ – based on general ecology as a proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on general ecology alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.9.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

Little evidence was found to assess this pressure. OBIS (2014) provided the following salinity ranges for the species in this ecological group.

- *Glycera lapidum*: 33.631 - 39.023pps
- *Nephtys hombergii*: 17.095 - 39.051pps
- *Paramphinome jeffreysii*: 32.326 - 38.597pps
- *Protodorvillea kefersteini*: 32.279 - 38.884pps

Most of the species are limited to fully saline conditions, except *N. hombergii* which also occurs in variable salinity environment, e.g. lagoons and estuaries.

This evidence suggests that that this ecological group may be tolerant of increases in salinity (35-38 units for one year) and is assessed as ‘**Not Sensitive’** (**resistance** and **resilience** are both considered to be **‘High’**). However, this ecological group (except *N. hombergii*) may be more sensitive to a decrease in salinity at the pressure benchmark of 4-10psu for a year. **Resistance** is assessed as **‘Low’** as a change of up to 10psu may severely impact populations. **Resilience** is assessed as **‘Medium’ for *Glycera* sp**, resulting in a **sensitivity** of **‘Medium’**. However, resistance is **‘High’ for *P. kefersteini* and *N. hombergii*,** resulting in a sensitivity of **‘Low’.**

Resistance

Quality of evidence is ‘Low’ – based on habitat distribution and OBIS values rather than targeted studies.
Applicability is ‘Low’ – based on habitat distribution and OBIS values as a proxy for resistance.
Concordance is ‘Not assessed’ – based on habitat distribution alone.

Resilience (section 4.9.7)

Quality of evidence is ‘Medium’ - based on supporting information from the grey literature and expert judgement.
Applicability of evidence is ‘Low’ - based on life history traits as a proxy for pressures.
Concordance of evidence is ‘Not assessed’ - based on a single source.

V. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

- *Glycera lapidum*: North eastern Atlantic, Mediterranean, North Sea, Skagerrak and Kattegat (Marine Species Identification Portal).

- *Nephtys hombergii*: Found from the northern Atlantic, from such areas as the Barents Sea, the Baltic and the North Sea, to the Mediterranean. *Nephtys hombergii* has been reported from as far south as South Africa (George & Warwick 1985).

- *Paramphinome jeffreysii*: A widespread species in North Atlantic waters, found from northern parts of the North Sea to Skagerrak and Kattegat (Marine Species Identification Portal).

- *Protodorvillea kefersteini*: North Atlantic to North Sea and English Channel, Mediterranean and Black Sea (Marine Species Identification Portal).

P. jeffreysii seems to reach its southerly limit in UK waters suggesting a possible susceptibility to a long-term rise in summer water temperatures. No published information was found on which to make an informed judgement at the pressure benchmark. Therefore, its **resistance** to either a chronic increase or a short term acute increase is assessed as **'Low'. Resilience** (following habitat recovery) is assessed as **'Medium'** (2-10 years). **Sensitivity** is therefore assessed as **'Medium'**.

Resistance (P. jeffreysii)

Quality of evidence is 'Medium' – based on inferences made from biotope records rather than species records.
Applicability of evidence is 'Low' – data used is a proxy for the pressure.
Concordance of evidence is 'Not assessed' – based on a single source.

Resilience (P. jeffreysii)

Quality of evidence is 'Low' - based on expert judgment.
Applicability of evidence is 'Not assessed' – based on expert judgment.
Concordance of evidence is 'Not assessed' - based on expert judgement.

However, the remaining members of the group are considered unlikely to adversely affected as they can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'**. This group is therefore considered to be **'Not Sensitive'**.

Resistance (others)

Quality of evidence is 'Medium' – based on inferences made from biotope records rather than species records.
Applicability of evidence is 'Low' – data used is a proxy for the pressure.
Concordance of evidence is 'Not assessed' – based on a single source.

Resilience (others)

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the

MNCR data. The recorded water flow categories for biotopes characterised by members of this ecological group follow.

- *Glycera lapidum*: moderately strong to weak (<0.5-1.5m/s).
- *Nephtys hombergii*: strong to very weak (negligible -3m/s).
- *Paramphinome jeffreysii*: no evidence
- *Protodorvillea kefersteini*: weak to very weak (negligible -<0.5m/s)

The range of flow speeds experienced by biotopes in which the species are found suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on biotope records rather than species records.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on single source.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded wave exposure categories for biotopes characterised by members of this ecological group follow.

- *Glycera lapidum*: very sheltered; sheltered; moderately exposed.
- *Nephtys hombergii*: very sheltered; extremely sheltered; sheltered; moderately exposed, exposed; very exposed; extremely exposed.
- *Paramphinome jeffreysii*: (no information).
- *Protodorvillea kefersteini*: extremely sheltered; very sheltered; moderately exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **'High'** and as there is no impact, **resilience** is considered to be **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is ‘Medium’ – based on inferences made from biotope records rather than species records.
Applicability of evidence is ‘Low’ – based on proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.9.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

The constituent species of this ecological group are infauna found close to the sediment surface. This life habit provides some protection from abrasion at the surface only. Abrasion and sub-seabed penetration is assessed below. No specific evidence to assess sensitivity to abrasion was found for this ecological group. **Resistance** was therefore assessed as **‘High’** as they are infaunal and **resilience** as **‘High’** (no effect to recover from). This group is therefore considered to be ‘**Not Sensitive’**.

Resistance

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

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

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

The abundance of *Protodorvillea kefersteini* increased greatly in samples following high intensity clam dredging at a previously undisturbed site in the Mediterranean. Abundance remained high over the 35 day sampling period following the disturbance (Constantino *et al* 2009). The passage of the dredge across the sediment floor will kill or injure some organisms that will then be exposed to potential predators/scavengers (Frid *et al* 2000; Veale *et al* 2000) providing a food source to mobile scavengers including these species. Similarly, *P. kefersteini* showed a rapid increase in abundance at 21 days after disturbance (creation of pits, approximately 30cm in diameter and 10cm deep) in a coarse gravelly substratum exposed to high current velocities (Thrush 1986).

Nephtys hombergii was present at a wreck site that prevented fishing disturbance and were absent from fished sites in the Irish Sea (Ball *et al* 2000b). Sensitivity to immediate disturbance was demonstrated by studies in the intertidal. Rostron (1995, cited in Gubbay 1999) undertook experimental dredging of sand flats with a mechanical cockle dredger. The distribution of *Nephtys hombergii* was disturbed by dredging with recovery after six months. Ferns *et al* (2000) recorded significant losses of infaunal polychaetes from areas of intertidal muddy sand sediment worked with a tractor-towed cockle harvester: The population of *Nephtys hombergii* were depleted for over 50 days.

No direct evidence was found for the sensitivity of *Glycera* sp.

The evidence suggests that this pressure will impact individuals; however, the food subsidy provided by this pressure also rapidly attracts mobile adults to the impacted area. Results are therefore short-lived**.** **Resistance** is therefore assessed as **'Low'** and **resilience** as **'High'** so that **sensitivity** is assessed as **'Low'.** Confidence in resistance and resilience is assessed as 'High' for quality of evidence and applicability based on the peer reviewed papers for fishing impacts. Degree of concordance is assessed as 'High' due to the general agreement in impact and recovery patterns between *P. kefersteini* and *N. hombergii*.

Resistance

Quality of evidence is 'High' - based on peer reviewed literature on fishing impacts.
Applicability of evidence is 'High - based on directly relevant peer reviewed literature on this pressure.
Concordance of evidence is 'High' - based on the agreement in impact patterns.

Resilience

Quality of evidence is 'High' - based on peer reviewed literature on fishing impact.
Applicability of evidence is 'High' - based on directly relevant peer reviewed literature on this pressure.
Concordance of evidence is 'High' - based on the agreement in recovery patterns.

X. Change in suspended solids

This pressure and benchmark is described in more detail in Section 3.2.2. Increased organic suspended solids may lead to organic enrichment and siltation and sensitivity to these pressures is described in section 4.9.4. XII and 4.9.6, below. No direct evidence was found relating to the sensitivity of this ecological group to this pressure and the assessment is based on expert judgement. Members of this ecological group live beneath the sediment surface and are not directly exposed to changes in suspended seston. Increased organic matter in suspension that is deposited may become incorporated into sediments via bioturbation and may enhance food supply to this group. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no effect to recover from). This group is therefore considered to be **'Not Sensitive'.**

Resistance

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

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

XI. Habitat structure changes-removal of substratum (Extraction)

This ecological group consists of shallowly buried species and all individuals within the extraction footprint would be removed and hence **resistance** is assessed as **'None'.** Sarda *et al* (2000) reported that shallow soft bottoms (10 to 30m depth) off the Tordera River were dredged for beach nourishment. After two years, the abundance of *P. kefersteini* and *Glycera* spp., were still clearly reduced (Sarda *et al* 2000). **Resilience** is predicted to be **'Medium'** (within 2-10 years) for *Glycera* spp. and *P. kefersteini*, while the **resilience of *N. hombergii*** is assessed as **'High'. Sensitivity** is therefore assessed as **'Medium'**.

Resistance

Quality of evidence is 'Medium' - based on expert judgment and supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as a proxy for resistance.
Concordance of evidence is 'Not assessed' - based on proxy rather than direct evidence.

Resilience (section 4.9.7)

Quality of evidence is 'Medium' - based on supporting information from the grey literature and observation in peer reviewed literature for *Glycera* spp. and *P. kefersteini*.
Applicability of evidence is 'Medium' - based on life history traits as a proxy for pressures in *Nephtys* but peer reviewed literature for *Glycera* spp. and *P. kefersteini*.
Concordance of evidence is 'Low' - based on a single source for *Nephtys* but peer reviewed literature for *Glycera* spp. and *P. kefersteini*.

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

Little direct evidence was found to assess the impact of this pressure at the benchmark level. Powilleit *et al* (2009) studied the response of the polychaete *Nephtys hombergii* to smothering. This species successfully migrated to the surface of 32 – 41cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. The high escape potential could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. While crawling upward to the new sediment surfaces burrowing velocities of up to 20cm/day were recorded for *N. hombergii*.

Similarly, Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which species could migrate was 60cm through mud for *Nephtys* and 90cm through sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

'No evidence' was found for siltation impacts on the other species within this ecological group**.**

Based on the available evidence *Nephtys hombergii* is considered to have **'Medium' resistance** to siltation at the pressure benchmark (as some individuals may be unable to vertically migrate). **Resilience** is assessed as **'High'** and **sensitivity** is therefore assessed as **'Low'.**

Resistance

Quality of evidence is 'High' - based on supporting information from peer reviewed literature and grey literature.
Applicability of evidence is Low' - based on evidence from laboratory experiments rather than activities resulting in this pressure.
Concordance of evidence is 'High' - available evidence agrees on direction and magnitude of resistance.

Resilience (section 4.9.7)

Quality of evidence is 'Medium' - based on supporting information from the grey literature.
Applicability of evidence is 'Low' - based on life history traits as a proxy for pressures.
Concordance of evidence is 'Not assessed' - based on a single source of information.

4.9.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to a change in one Folk class of the sedimentary classification), this ecological group would be highly sensitive to a change to hard substratum as this would result in the loss of suitable habitat for this ecological group.

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Paramphinome jeffreysii*: no MNCR information.

- *Protodorvillea kefersteini*: muddy *maerl* gravel; gravel with coarse to medium sand; medium to coarse sand with some gravel or shell, and a fine sand or mud fraction; mixed sediment of sandy mud, muddy sand with gravel pebbles and cobbles; coarse sand and gravel with a minor finer sand fraction; muddy gravel; muddy sand.

- *Nephtys hombergii*: cohesive mud; sandy mud; medium to fine muddy sand; mixed sediment; cohesive mud and sandy mud; medium to very fine sand; medium to very fine sand with some silt possibly with shell debris and stones; fine to very fine muddy sand; sandy mud; sandy gravelly muddy mixed sediment; mixed muddy sediment; muddy sand and gravel; sand with gravel, pebbles and/or shingle.

- *Glycera lapidum*: mud and sandy muddy mixed sediments; medium to very coarse sand; medium to coarse sand with some gravel or shell gravel; muddy *maerl* gravel; gravel with coarse to medium sand; muddy gravel and sand, with shells and stones; sand with gravel, pebbles and/or shingle.

A change in classification of one Folk class is not predicted to negatively affect this ecological group which is found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). This results in an assessment of **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' - based on inferences made from biotope records rather than species records.
Applicability of evidence is 'Low' - based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.9.6 Pollution

XIV. Organic enrichment

Protodorvillea kefersteini has been identified as a ‘progressive’ species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski 1975, cited in Gray *et al* 1979; Hiscock *et al* 2005). *P. kefersteini* can become very plentiful in organically enriched habitats (Hill 2001) and this species was very abundant in the vicinity of a sewage outfall at Kircaldy (S.C. Hull pers. comm). *P. kefersteini* was the dominant species in muddy, organically enriched sediments (organic content approximately 25%) located about 100 and 500m from fish farm cages, in a bay in Corsica, France (Terlizzi *et al* 2010).

Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), both assigned *Nephtys hombergii* and *Glycera lapidum* to their Ecological Group II. This group is defined as ‘species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance)’.

Based on the AMBI index scores and observations of increased densities of *P. kefersteini* in organically enriched areas (Leppakoski 1975, cited in Gray *et al* 1979) this ecological group is assessed as **‘Not Sensitive’** to organic enrichment at the pressure benchmark. **Resistance** is assessed as **‘High’** and **resilience** as **‘High’**.

Resistance

Quality of evidence is ‘Medium’ – peer reviewed evidence is not available for all species and the type of evidence supporting the AMBI score is unclear, however the assessments are reported in peer reviewed literature, are widely used and are considered credible.
Applicability of evidence is ‘Low’ - based on unknown underlying evidence and assumptions.
Concordance of evidence is ‘Low’ – based on unknown underlying evidence and assumptions.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.9.7 Review of recovery based on the species assemblages present within the ecological group

The recovery potential, and hence resilience, of the members of this group vary.

Glycera sp.

Recovery potential of the genus *Glycer*a was assessed as intermediate by MES (2010) based on a high potential rate of recolonisation of sediments, mediated the relatively slow growth-rate and long-life span suggesting that recovery of biomass following initial recolonisation by post-larvae is likely to take several years (MES 2010). The genus has a relatively long life-span of five years. Reproductive maturity occurs at three years. The larvae are planktotrophic and spend 11-30 days in the water column. Therefore, the resilience of *G. lapidum* is assessed as **'Medium'** where resistance is 'None' to 'Medium'.

Protodorvillea kefersteini

The recovery potential of *Protodorvillea kefersteini* was assessed by MES (2010) who suggested that this genus had a high recovery potential based on short life-span, relatively rapid growth rate and larval dispersal phase. The life-span of this genus is about one year and sexual maturity is at about 4-6 months. There is little information on the breeding season or fecundity. After fertilisation, the embryos are brooded before release as planktotrophic larvae and juveniles (MES 2010). Therefore, the resilience of *P. kefersteini* is assessed as **'High'** where resistance is 'None' to 'Medium'.

Nephtys hombergii

Dittman *et al* (1999) observed that *Nephtys hombergii* was amongst the macrofauna that colonised experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment. *Nephtys* is a relatively long-lived polychaete genus with a life-span of six to possibly as much as nine years (MES 2010). It matures at 1 year and the females release over 10,000 (and up to 80,000 depending on species) eggs of 0.11-0.12mm from April through to March. These develop into an early lecithotrophic larva and a later planktotrophic larva which spends as much as 12 months in the water column before settling from July-September. The genus has a relatively high reproductive capacity and widespread dispersion during the lengthy larval phase. It is therefore likely to have a high recovery potential following disturbance (MES 2010). Therefore, the resilience of *N. hombergii* is assessed as **'High'** where resistance is 'None' to 'Medium'.

Overall, confidence in the quality of evidence is assessed as 'Medium' as this assessment is based on supporting information from the grey literature and expert judgement. Confidence in the applicability is 'Low' as life history traits are used as proxy for pressures. Confidence in degree of concordance is 'not assessed' single only a single source of information was available.

4.9.8 Knowledge gaps

No evidence was found to support assessments for *Paramphinome jeffreysii*. The ecology and life history traits were better understood for *Protodorvillea kefersteini* and *Nephtys hombergii* within this ecological group. Some evidence was available for *Glycera lapidum* but this was more limited.

As is the case for most ecological groups changes in hydrological pressures and other pressures (e.g. physical change) were assessed using habitat distribution and other life-history traits (where known) as a proxy as no other direct sources of evidence were found.

Pressure specific information relevant to the benchmark was found for the siltation pressure (although based on laboratory studies rather than human activities giving rise to this pressure). Direct evidence for the tolerance of *P. kefersteini* was available for organic enrichment but the studies did not record the level of the pressure so relating this to the benchmark was problematic.

4.10 Ecological Group 7 Very small to small, short lived (<2 years) free-living species defined on size and feeding type

4.10.1 Definition and characteristics of the ecological group

The small free-living amphipod, *Bathyporeia elegans* and the cumaceans *Diastylis bradyi, Eudorellopsis deformis* and *Iphinoe trispinosa* characterise the group (**Table 4.10**). The sensitivity assessment is based on *Bathyporeia elegans* and *Eudorellopsis deformis* (as a representative of other cumaceans).

Table 4.10. List of biotopes in which ecological group 7 species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.Pkef	Characterising species present were not specifically assessed.
SS.SSa.CFiSa.ApriBatPo	*Bathyporeia elegans* *Eudorellopsis deformis*
SS.SSa.OSa.MalEdef	*Eudorellopsis deformis*
SS.CMuSa.AalbNuc	Characterising species present were not specifically assessed.
SS.SMu.CSaMu.LkorPpel	*Iphinoe trispinosa* (NB – present but not assessed).

4.10.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical impacts are assessed under abrasion and penetration of the seabed pressures (section 4.10.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. Species within this group live shallowly buried within sediments and feed on organic matter and algae in the water column (cumaceans) or are epistatic feeders feeding on organic matter and algae coating sand grains (some cumaceans and *B. pelagica*). No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be **'Not Exposed'** to targeted removal of the ecological group and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species. By default, **resistance** and **resilience** are therefore assessed as **'High'**.

Resistance

Quality of evidence is 'Medium' – the assessment is based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – the assessment is based on general ecology rather than pressure specific information.

Concordance of evidence is ‘Not assessed’ – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.10.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Species within this group live shallowly buried within sediments and feed on organic matter and algae in the water column (cumaceans) or are epistatic feeders feeding on organic matter and algae coating sand grains (some cumaceans and *B. pelagica*). This ecological group is therefore not considered dependent on other species for habitat or food. As no obligate life-history or ecological associations were identified (although removal of predators may be beneficial) this ecological group is considered to be ‘**Not Sensitive’** to the ecological effects of the removal of non-target species**.** By default, **resistance** and **resilience** are therefore assessed as **‘High’**.

Resistance

Quality of evidence is ‘Medium’ – the assessment is based on ecological and life history information rather than targeted studies.
Applicability of evidence is ‘Low’ – the assessment is based on general ecology rather than pressure specific information.
Concordance of evidence is ‘Not assessed’ – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

4.10.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

Bathyporeia pelagica is able to migrate and avoid conditions of depressed salinity. Fish and Preece (1970), Ladle (1975) and Fish and Fish (1978) reported both the re-distribution of populations down the shore during spring and summer on open coasts, and the migration of *B. pelagica* from sandy estuarine beaches to sites on the open coast. These authors recorded *B. pelagica* in the sandy flats at the mouths of estuaries (west Wales and Northumberland) from September through to April, after which time the species disappeared, a pattern which was observed in each subsequent year. Fish and Fish (1978) concluded that the migration pattern was controlled by the combined effects of salinity and temperature, the species being better able to tolerate conditions of reduced salinity at cooler temperatures. Furthermore, although the extent of penetration by *B. pelagica* into estuarine sand flats is ultimately limited by its salinity tolerance, populations that do so are able to exploit the food resources of the estuary. Fish and Fish (1978) found that in the population of *B. pelagica* that over-wintered in the Dovey Estuary, the reproductive output was greater and specimens were larger.

Cumaceans are marine species with a few exceptions found in brackish water. Therefore, changes in salinity may be detrimental, although no specific information for *Eudorellopsis deformis* or other species was found to develop a sensitivity assessment.

Overall, this group is only likely to be exposed to changes in salinity due to hypo/hypersaline effluents, as all the represented biotopes occur in full salinity conditions. *B. pelagica* is likely to avoid changes in salinity (reduction by 4-10 units), especially reduced salinity, by migration to other areas. Although no information was found for *Eudorellopsis deformis* or other cumaceans, these are also mobile and could potentially move away from adverse conditions. Therefore a **resistance of 'High'** is suggested, with a **resilience** of **'High'**, and the ecological group is considered to be **'Not sensitive'.**

Resistance

Quality of evidence is 'Low' – although 'High' quality information is available for *B. pelagica*, the evidence for cumaceans is of uncertain provenance, so the ecological group assessment is largely based on expert judgement and confidence is therefore 'Low'.
Applicability of evidence is 'Not assessed' – based on expert judgment.
Concordance of evidence is 'Not assessed' – based on expert judgment.

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

V. Temperature changes - local

Bathyporeia pelagica is found from the Shetland Isles, south to the Bay of Biscay at the coast of Denmark and is also an intertidal species, potentially exposed to a range of temperatures. For example, Khayrallah and Jones (1980) reported the temperature range of sand at a depth of 1cm during neap tide periods, to be from -2°C in February 1973 to a maximum of 25°C in July 1977. While Crisp (1964) reported that other interstitial species of amphipod and isopods seemed to be unharmed by the severe winter of 1962-1963.

OBIS (2014) record *Eudorellopsis deformis* between a temperature range of -1.3 and 28.9°C (although it is unclear how these values are determined). It is distributed from Norway, the northern and southern North Sea, the Skagerrak, Greenland to Long Island USA, Japan and Okhotsk Seas in the Pacific, so unlikely to be affected by chronic temperature (see benchmark). No information on the temperature tolerance of cumaceans was found but given their subtidal, interstitial habit, they are unlikely to be exposed and therefore adapted to rapidly changing temperature, so that an acute change (e.g. by 5°C) is probably detrimental.

Overall, exposure of hypo/hyperthermal effluents may be detrimental to cumacean species (although no evidence was found for *Eudorellopsis deformis* or other cumacean species) but *B. pelagica* is unlikely to be adversely affected. This ecological group is considered to have **'High' resistance** (based on *B. elegans*), **resilience** is potentially **'High'** (due to mobility), resulting in a **sensitivity** of **'Not Sensitive'**. The limitations of the evidence base to develop this assessment are recognised.

Resistance

Quality of evidence is ‘Low’ – although ‘High’ quality information is available for *B. pelagica*, the evidence for cumaceans is of uncertain provenance for resistance, so the assessment is based on expert judgement and confidence is ‘Low’.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the water flow categories for biotopes characterised by *Bathyporeia pelagica* range from very low (negligible) to strong (1.5-3m/s). There were no records for *Eudorellopsis deformis* in this database.

The range of flow speeds experienced by biotopes in which *B. pelagica* are found suggest that a change in the maximum water flow experienced by mid-range populations would not have negative effects on this species. **Resistance** and **resilience** are therefore considered to be **‘High’** and this group is assessed as **‘Not Sensitive’**. This assessment is based on *B. pelagica* only as evidence was not found for cumacean species. Cumaceans would also probably be unaffected, although the most abundant species may change for example *Iphinoe trispinosa* replacing *Eudorellopsis deformis* in muddier sediments, although no direct evidence was found.

Resistance

Quality of evidence is ‘Medium’ – as the assessment is based on biotope records rather than species records.
Applicability of evidence is ‘Low’ – based on a proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on a single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for *biotopes* characterised by *Bathyporeia pelagica* range from very sheltered to exposed.

As the available evidence indicates that *B. pelagica* occurs within a range of wave exposure categories an increase or decrease in wave height at the pressure benchmark is considered to fall within the natural range of conditions experienced by this ecological group.

Resistance is therefore considered to be **'High'** and as there is no impact, **resilience** is considered to be **'High'.** This group is therefore considered to be **'Not Sensitive'.** This assessment is based on *B. pelagica* only as no evidence was found for cumacean species.

Resistance

Quality of evidence is 'Medium' – based on inferences made from biotope records rather than species records.
Applicability of evidence is 'Low' – based on proxy for resistance.
Concordance of evidence is 'Not assessed' – based on single source.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.10.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

Bathyporeia spp. and the cumaceans considered are infaunal and protected within sediments when not swimming. They can also migrate to avoid disturbance and are therefore considered to have '**High' resistance** to abrasion of the surface only and to have **'High' resilience** based on the suggested lack of impact. The ecological group is therefore considered to be **'Not Sensitive'.**

Resistance

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

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

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

The cumacean *Diastylis lyrifera* was present at a wreck site that prevented fishing disturbance and absent from fished sites in the Irish Sea (Ball *et al* 2000b), suggesting indirectly that these species may be sensitive to activities that lead to subsurface disturbance. Ball *et al* (2000b) estimated that the direct mortality of small species relevant to this ecological group including tanaids, copepods and amphipods from a trawl (based on samples taken with a Day grab before and 24 hours after trawling) as between approximately 60% and 100%. Samples were taken in the Irish Sea in an inshore trawling ground for *Nephrops*.

Direct mortality (percentage of initial density) of cumaceans and gammarids from a single pass of a beam trawl was estimated from experimental studies on sandy and silty grounds as 22% and 28% respectively.

The available information is limited and the estimated mortalities are not species specific, but based on Ball *et al* (2000b) and Bergman and van Santbrink (2000a), **resistance** of the ecological group is assessed as **'Low'** (loss of 25-75% of exposed individuals). Based on the observations of Bergman and van Santbrink (2000a) the more severe mortality estimate of Ball *et al* (2000b) of 100% mortality was rejected. **Resilience** is assessed as **'High'** (within 2 years) and is considered likely to occur through active adult migration given the mobility of adult amphipods and cumaceans, water transport and recolonisation through local reproduction by surviving adults. The resilience assessment is based largely on the reported life-history traits for the genus *Bathyporeia* as described in section 4.10.7 and the presence of this genus in disturbed sediments. *Bathyporeia* species reach sexual maturity rapidly and have multiple broods annually this supports rapid local recolonisation of disturbed sediments where some of the adult population remains. **Sensitivity** is therefore assessed as **'Low'**.

Resistance

Quality of evidence is 'High' - based on peer reviewed literature.
Applicability of evidence is 'High' – based on directly applicable literature.
Concordance of evidence is 'Medium' – studies agree on direction of change but not magnitude.

Resilience

Quality of evidence is 'Medium' – as the assessment for the ecological group is based on expert judgement supported by life history traits for the *Bathyporeia* genus.
Applicability of evidence is 'Low' – as the assessment is based largely on life-history traits and habitat preferences of *B. pelagica*.
Concordance of evidence is 'Not assessed' – as the assessment is based on species traits rather than direct evidence.

X. Change in suspended solids

Budd and Curtis (2007) assessed the congener *Bathyporeia pelagica* as not sensitive to this pressure as it is a regular swimmer in the surf plankton, where the concentration of suspended particles would be expected to be high (Fincham 1970, cited in Budd and Curtis 2007). Furthermore, during the winter, when the species often extends its distribution into the mouths of estuaries, *B. pelagica* may encounter concentrations of suspended sediment measurable in grams per litre (benchmark is mg/l) (Cole *et al* 1999).

Based on the above evidence and their presence in areas subject to frequent disturbance where sediments are mobilised, *Bathyporeia spp.* are considered to have a **'High' resistance** and **'High' resilience** and are therefore considered **'Not Sensitive'.** No evidence was found to assess the sensitivity of *Eudorellopsis deformis* or other cumaceans.

Resistance

Quality of evidence is 'Medium' – based on the distribution and habitat preferences and inferred from peer reviewed and grey literature for *B. pelagica* alone.
Applicability of evidence is 'Low' – based on habitat preferences of *B. pelagica* as a proxy for resistance.
Concordance of evidence is 'Not assessed' - based on distribution of *B. pelagica* as a proxy rather than direct evidence.

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

XI. Habitat structure changes - removal of substratum (Extraction)

This ecological group consists of species that are either shallowly buried or present on the surface or in the water column. Within the extraction footprint all individuals would be removed and hence **resistance** is assessed as **'None'** (loss of ≥75% of exposed individuals). Species within this group are early colonisers of disturbed areas and recovery is predicted to be rapid although mediated by pressure impact and site-specific factors. **Resilience** is predicted to be **'High'** (within 2 years) and is considered likely to occur through active adult migration given the mobility of adult amphipods and cumaceans, water transport and recolonisation through local reproduction by surviving adults. The resilience assessment is based largely on the reported life-history traits for the genus *Bathyporeia* as described in section 4.10.7 and the presence of this genus in disturbed sediments. *Bathyporeia* species reach sexual maturity rapidly and have multiple broods annually this supports rapid local recolonisation of disturbed sediments where some of the adult population remains. **Sensitivity** is assessed as **'Low'.**

Resistance

Quality of evidence is 'Medium' - uses expert judgement but is based on supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' - based on species traits as a proxy rather that direct evidence.

Resilience

Quality of evidence is 'Medium' – as the assessment for the ecological group is based on expert judgement and life history traits for the *Bathyporeia* genus.
Applicability of evidence is 'Low' – as the assessment is based largely on life-history traits and habitat preferences of *B. pelagica*.
Concordance of evidence is 'Not assessed' – the assessment is based on species traits as a proxy rather than direct evidence.

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

This pressure and benchmark are described further in section 3.1.1.iii. Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which *Bathyporeia* could migrate was approximately 20cm in mud and 40cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

As the pressure benchmark relates to fine sediments, **resistance** to this pressure was assessed as **'None'** (loss of ≥75% of exposed individuals) for *Bathyporeia elegans* as (based on Essink 1999) the overburden exceeds vertical migration capacity. **Resilience,** following habitat recovery, is assessed as **'High'** (recovery within 2 years). **Sensitivity** is therefore assessed as **'Low'**. No evidence was found to assess the sensitivity of *Eudorellopsis deformis* or other cumaceans.

Resistance

Quality of evidence is ‘Medium’ - based on *B. pelagica* alone and inferred from peer reviewed and grey literature.
Applicability of evidence is ‘Low’ - based on evidence from laboratory experiments rather than activities resulting in this pressure.
Concordance of evidence is ‘Not assessed’ – the assessment is based on a single source (Bijkerk 1988, results cited from Essink 1999).

Resilience

Quality of evidence is ’Medium’ – as the assessment for the ecological group is based on expert judgement and life history traits for the *Bathyporeia* genus.
Applicability of evidence is ‘Low’ – as the assessment is based largely on life-history traits of *B. pelagica*.
Concordance of evidence is ‘Not assessed’ – as the assessment is based on species traits as a proxy rather than direct evidence.

4.10.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

Bathyporeia elegans occurs in areas of sand with some silt fraction. An increase in silts would alter habitat suitability through changes in food availability (*Bathyporeia* spp. are epistatic feeders, removing algae from sand grains). Where areas become muddy and sediments are more stable, bivalve populations may develop, out-competing *Bathyporeia spp*. for space. Where sediments become coarser burrowing may be altered and feeding rates impacted through a lack of suitable grains.

Resistance to this pressure is therefore assessed as **‘Low’** (loss of 25-75% of exposed individuals) for *Bathyporeia elegans,* **resilience** is assessed as **‘High’** (within 2 years following habitat recovery). **Sensitivity** is therefore assessed as **‘Low’**. No evidence was found to assess the sensitivity of *Eudorellopsis deformis* or other cumaceans to this pressure.

Resistance

Quality of evidence is ‘Medium’ – based on the distribution and habitat preferences of *B. pelagica* alone.
Applicability of evidence is ‘Low’ – based on habitat preferences of *B. pelagica* as a proxy for resistance.
Concordance of evidence is ‘Not assessed’ - based on distribution of *B. pelagica* as a proxy rather than direct evidence.

Resilience

Quality of evidence is ’Medium’ – as the assessment for the ecological group is based on expert judgement supported by life history traits for the *Bathyporeia* genus.
Applicability of evidence is ‘Low – as the assessment is based largely on life-history traits of *B. pelagica*.
Concordance of evidence is ‘Not assessed’ – as the assessment is based on species traits as a proxy rather than direct evidence.

4.10.6 Pollution

XIV. Organic enrichment

No specific evidence for response to organic enrichment was found for this ecological group. Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), assigned *Bathyporeia* spp. to either Ecological Group I (Borja *et al* 2000) or Ecological Group II (Gittenberger & van Loon 2011). These are defined as either, species very sensitive to organic enrichment and present under unpolluted conditions (Ecological Group I), or ‘species indifferent to enrichment’ (Ecological Group II).

‘No evidence’ was found to assess this pressure at the benchmark for this ecological group. *Bathyporeia* spp. were assigned to different AMBI groups by Borja *et al* (2000) and Gittenberger and van Loon (2011). The basis for this categorisation and relation to the pressure benchmark is unclear and no judgement regarding sensitivity could be made using these contradictory scores. Sensitivity to this pressure is therefore not assessed for this group.

4.10.7 Review of recovery based on the species assemblages present within the ecological group

Bathyporeia spp. occur in biotopes such as SS.SSa.IFiSa.NCirBat that are found in sediments subject to physical disturbance, as a result of wave action (and occasionally strong tidal streams) and where the diversity of species is generally low due to sediment instability. This species is therefore tolerant of disturbed environments and can recover quickly.

This genus is short lived, reaching sexual maturity within 6 months with 6-15 eggs per brood, depending on species. Reproduction is continuous with one set of embryos developing in the brood pouch whilst the next set of eggs is developing in the ovaries. There is no opportunity for larval dispersal as they are brooded. The adults are, however, highly mobile in the water column and recolonisation by the adults is likely to be significant in sediments that have been disturbed by dredging. Fast growth and development means that biomass could also be expected to recover quickly (MES 2010). The life history traits of rapid sexual maturation and production of multiple broods annually support rapid local recolonisation of disturbed sediments where some of the adult population remains.

No direct information was found to assess recovery within the cumaceans.

A resilience of ‘High’ is suggested due to the mobility of the amphipods and presumed mobility of cumaceans. The assessment for the cumaceans is based on expert judgement and, although evidence for *B. pelagica* is good (based on life-history traits and habitat preferences) the overall confidence in the resilience assessment is ‘Low’.

4.10.8 Knowledge gaps

This ecological group is poorly studied; the species are small, cryptic and do not have economic or conservation importance to stimulate research. This group may however be functionally important to benthic habitats due to high abundance and productivity. The evidence base to assess the sensitivity of the amphipod representative of this group, *Bathyporeia pelagica*, was better developed than that for cumaceans, although little direct information was available to assess resistance to pressures. No targeted studies were found regarding the resistance and subsequent resilience of populations represented by this ecological group in response to pressures other than some limited information regarding resistance to trawling activities that lead to sub-surface penetration. The sensitivity assessments developed for this species are based almost entirely on information regarding habitat preferences (based on distribution records) and species traits. Information on the basic biology, life history, and population dynamics of *Eudorellopsis deformis* and other cumaceans is lacking.

4.11 Ecological Group 8a Echinoderms - sub-surface urchins

4.11.1 Definition and characteristics of the ecological group

The infaunal sea urchins (*Echinocardium cordatum*, *Brissopsis lyrifera*, *Echinocyamus pusillus*) form a distinct group due to body form, fragility and mobility (**Table 4.11**). The sensitivity of the three urchins is assessed to capture the range of sensitivities between the larger species and the smallest (*Echinocyamus pusillus*).

Table 4.11. List of biotopes in which ecological group 8a species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.MedLumVen	*Echinocyamus pusillus*
SS.SCS.CCS.Blan	*Echinocyamus pusillus*
SS.SSa.CFiSa.EpusOborApri	*Echinocyamus pusillus*
SS.SMu.CSaMu.AfilNten	*Echinocardium cordatum*
SS.SMu.CFiMu.BlyrAchi	*Brissopsis lyrifera*

4.11.2 Biological Pressures

I. Introduction of Non-native species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.11.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be **'Not Exposed'** to targeted removal of the ecological group and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is 'Medium' - based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.11.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Members of this ecological group live buried within sediments feeding on organic detritus, diatoms and foraminiferans. They are not considered dependent on other species for habitat or food. As no obligate life-history or ecological associations were identified this ecological group is considered to be '**Not Sensitive'.** By default, **resistance** and **resilience** are therefore assessed as **'High'**.

Resistance

Quality of evidence is 'Medium' - based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.11.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

As members of this ecological group are present in fully marine waters they are not considered sensitive to increases in salinity at the pressure benchmark. Echinoderms are stenohaline species owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl 1987; Russell 2013). This means that they are unable to tolerate wide fluctuations in salinity and are considered sensitive to a decrease in salinity at the pressure benchmark.

In the recent review by Russell (2013), *Echinocardium cordatum* was reported to occur at 27‰ in The Netherlands, and in experiments to tolerate a salinity of 28‰ but experience mortality at 24‰. But *Echinocyamus pusillus* was reported to occur in environments at 14.8‰ in the Sado estuary, Portugal. No information concerning the specific tolerance of *B. lyrifera* was found. Echinoderm larvae have a narrow range of salinity tolerance and will develop abnormally and die if exposed to reduced or increased salinity.

Overall, a reduction is salinity by up to 10 units for a year (the benchmark) is likely to adversely affect *E. cordatum* and especially *B. lyrifera*. **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of individuals). **Resilience** (following the removal of this pressure) is assessed as **'Medium'** (2-10 years) as some rapid recolonisation by adults may be expected through passive water transport or migration from adjacent populations but establishing full age-structured populations is predicted to take up to 10 years. The resilience assessment is largely based on the species traits information sourced from MES (2010) as described in the recovery section (4.11.7). **Sensitivity** is assessed as **'Medium'.**

Resistance (*Echinocardium cordatum* and *Brissopsis lyrifera*)

Quality of evidence is ‘Medium’ - based on inferences made from taxonomic group for *B. lyrifera* and peer reviewed literature for *E. cordatum*.
Applicability of evidence is ‘Medium’ – based on the effects of this pressure outside the UK.
Concordance of evidence is ‘Low’ – based on inferences made from taxonomic group for *B. lyrifera* and peer reviewed literature for *E. cordatum*.

Resistance (*Echinocyamus pusillus)*

Quality of evidence is ‘High’ - based on a single peer reviewed source.
Applicability of evidence is ‘Low’ – based on inference from a single distribution record.
Concordance of evidence is ‘Low’ – based on inference from a single distribution record.

Resilience (section 4.11.7)

Quality of evidence is ‘Medium’ - based on expert judgment but is based on supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is ‘Low’ - based on species traits as proxy for resilience.
Concordance of evidence is ‘Not assessed’ - based on a proxy rather than direct evidence.

V. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

Brissopsis lyrifera has a wide distribution and may be found in offshore or inshore stable sediments from Norway and Iceland to South Africa and the Mediterranean. They are also present on the east coast of North America but not Greenland (Budd 2004).

Echinocardium cordatum has a relatively wide degree of tolerance to temperature (Higgins 1974) in accordance with its cosmopolitan distribution. The species is found from Norway to South Africa, Mediterranean, Australasia and Japan. Very low water temperature can cause mass mortalities of *Echinocardium cordatum*. During the severe winter of 1963 the species was almost completely eliminated from the German Bight to a depth of about 20m (Lawrence 1996) and very heavy mortality was observed in the English Channel and North Sea (Crisp, 1964). High temperatures can also cause a suffocation effect: there can be mass mortality of *Echinocardium cordatum* on sandy shores following oxygen depletion during extreme low water tides on hot days (Nichols pers comm, cited in Hill 2008).

Echinocyamus pusillus has a wide distribution and is reported from the North East Atlantic, Kattegat, Iceland, Norway, Mediterranean, and south and west coasts of Africa among others (WoRMS). OBIS (2014) report maximum and minimum sea water temperatures as 19.21^{o}C and 6.81^{o}C but the derivation of these temperatures is not clear.

The geographic range of the species assessed suggests that these species are tolerant to a range of temperatures and a long term chronic change of 2°C or a short term acute change is unlikely to have adverse effects on populations. **Resistance** and **resilience** are therefore assessed as **‘High’** and the group is considered to be **‘Not Sensitive’**.

Resistance

Quality of evidence is ‘Medium’ - based on inferences made from distribution records.
Applicability of evidence is ‘Low’ – based on a proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on a single source.

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded water flow categories for biotopes characterised by members of this ecological group follow.

- *Brissopsis lyrifera*: weak (<0.5m/s; based on two biotope records).

- *Echinocardium cordatum*: strong to very weak (negligible -3m/s).

- *Echinocyamus pusillus:* moderately strong (0.5-1.5m/s; based on one biotope record).

The range of flow speeds experienced by biotopes in which the *E. cordatum* and *E. pusillus* species are found suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. **Resistance** and **resilience** are therefore considered to be **'High'** and this group is assessed as **'Not Sensitive'**.

Resistance (E. cordatum and *E. pusillus)*

Quality of evidence is 'Medium' - based on inferences made from biotope records, rather than species records.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a single source.

Resilience (E. cordatum and *E. pusillus)*

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

However, *B. lyrifera* is only found in mud and muddy sand in weak tidal streams, therefore, an increase at the benchmark level might result in an reduction in the extent of suitable habitat, and hence the population. Therefore, a precautionary **resistance** of **'Medium'** (<25% loss) is suggested. **Resilience** is assessed as medium based on life history characteristics and **sensitivity** is therefore, **'Medium'**.

Resistance (B. lyrifera)

Quality of evidence is 'Medium' - based on inferences made from biotope records, rather than species records.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a single source.

Resilience (B. lyrifera) (section 4.11.7)

Quality of evidence is ‘Medium’ - based on expert judgment but with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is ‘Low’ – based on species traits as proxy for resilience.
Concordance of evidence is ‘Not assessed’ - based on a proxy (species traits) rather than direct evidence.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The recorded wave exposure categories for biotopes characterised by members of this ecological group follow.

- *Brissopsis lyrifera*: (no information).

- *Echinocardium cordatum*: extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed.

- *Echinocyamus pusillus*: sheltered; moderately exposed.

The records indicate that the species occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **‘High’** and as there is no impact, **resistance** is considered to be **‘High’.** This group is therefore considered to be **‘Not Sensitive’.**

Resistance

Quality of evidence is ‘Medium’ - based on inferences made from biotope records, rather than species records.
Applicability of evidence is ‘Low’ – based on a proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on a single source.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.11.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

The constituent species of this ecological group are infauna found close to the sediment surface. This life habit provides some protection from abrasion at the surface only. No evidence for sensitivity to abrasion was found for this ecological group. The infaunal position provides some protection but species have fragile tests and surface abrasion may therefore damage a proportion of the population. Based on expert judgement, **Resistance** is assessed as **‘Medium’** (loss of <25% of individuals) and **Resilience** is assessed as **‘High’** as an impacted population would be expected to recover through migration of adults and larval recolonisation. **Sensitivity** is assessed as **‘Low’.**

Resistance

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

Resilience

Quality of evidence is ‘Low’ - based on expert judgment.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ - based on expert judgement.

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

This ecological group represents infaunal sea urchins that are shallowly buried. *Brissopsis lyrifera* lives buried about 2cm below the surface (Buchanan 1966). Similarly *Echinocardium cordatum* lives in a permanent burrow buried about 2cm deep (to 15cm) in offshore sediments (Buchanan 1966).

The fragility of the tests means that these species have little protection from abrasion that is coupled with penetration and disturbance of the seabed. Evidence to assess the sensitivity of this ecological group is provided by studies on by-catch damage, comparisons between areas with different levels of fishing activities and re-sampling of areas after exposure to directly estimate mortality. No evidence was found for impacts on *Echinocyamus pusillus.* This species may be too small to be retained as by-catch and *in-situ* assessments have not been carried out.

Echinocardium cordatum in silty sediments were estimated from field experiments as suffering direct mortality (percentage of the initial density in trawled tracks) of 40% and 35% from a 12m beam trawl with tickler chains and a 4m beam trawl fitted with tickler chains respectively (Bergman & van Santbrink 2000a). Mortality from a lighter otter trawl was estimated as 26%. In sandy sediments penetration of the trawls was less and mortalities were estimated as 14% and 12% (12 and 4m beam trawls) and 16% (otter trawl). This value was corrected for the proportion of the population that was estimated (based on mean burrow depths) to be too deep to be sampled. Bergman and van Santbrink (2000a) suggested that mortality may increase to 90% in summer when individuals migrate to the surface of the sediment during their short reproductive season. Bergman and van Santbrink (2000a) also suggested that *E. cordatum* was one of the most vulnerable species to trawling.

De Groot (1984) found that *E. cordatum* were heavily damaged when beam trawls fitted with tickler chains were used. The number of damaged *E. cordatum* increased with the number of ticklers used. There was an increase of about 3.4 times in the catch when the number of tickler chains was increased to four. This study assessed damage from by-catch; *in situ* damage was not studied.

A substantial reduction in the numbers of *E. cordatum* due to physical damage from scallop dredging was observed by Eleftheriou and Robertson (1992). Smaller size classes of the heart urchin are found near the surface of the sediment and are therefore likely to be more vulnerable to physical damage (Jennings & Kaiser 1998).

Echinocardium cordatum were the dominant by-catch species, representing 60% (by wet weight) of the total discard in a hydraulic dredge fishery for *Ensis* spp. (Hauton *et al* 2003a). Between 60% and 70% were found to be undamaged. In terms of wet weight, the heart urchin *E. cordatum* dominated the megafauna dislodged by the hydraulic dredge (based on diver observations in the trawl tracks). Of these, 20-30% suffered severe damage many being completely smashed by the dredge. Divers observed that approximately 85% of urchins dislodged by the dredge but not brought to the surface and subjected to aerial exposure had completely reburied within 25 minutes. The high survival rate of *E. cordatum* was considered to be a function of the slow towing speed of the dredge in combination with the large volumes of water used to fluidise the sand, which would have pushed many of the urchins away from the blade of the dredge. These results may not reflect damage rates from other gear types which disturb and penetrate the sediment.

The sensitivity of *Brissopsis lyrifera* and *Echinocardium cordatum* to seabed disturbance resulting from trawling is demonstrated indirectly by distribution patterns. Both species were present at a wreck site that prevented fishing disturbance and were absent from fished sites in the Irish Sea (Ball *et al* 2000b). In particular, large specimens of some of *B. lyrifera* and *E. cordatum* were quite common along transects. By contrast, while juveniles of some of these species were occasionally taken at the offshore trawling station, large specimens were never found.

Examination of historical and recent samples suggest that the spatial presence of *Brissopsis lyrifera* in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al* 2007). However, a >100% increase in spatial presence was found for *Echinocardium cordatum*.

Based on the available evidence **resistance** to this pressure is assessed as **'Low'** (loss of 25-75% of exposed individuals) although the effect will depend on the type of impact and mediated by the sediment type (penetration from fishing gears is deeper in siltier sediments). **Resilience** is assessed as **'Medium'** (recovery within 2-10 years) as a proportion of the adult population is expected to survive to provide larvae and adult migration may also occur into an impacted area, this assessment is based on the life-history data from MES (2010) see section 4.11.4. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance

Quality of evidence is 'High' - based on peer reviewed literature.
Applicability of evidence is 'High'– based on literature directly applicable to the pressure.
Concordance of evidence is 'High' - based on general agreement of direction and magnitude of impact.

Resilience (section 4.11.7)

Quality of evidence is 'Medium' - based on expert judgment but with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is 'Low' – based on species traits as proxy for resilience.
Concordance of evidence is 'Not assessed' - based on a proxy (species traits) rather than direct evidence.

X. Change in suspended solids

Members of this ecological group live beneath the sediment surface and are not directly exposed to changes in suspended solids. Increased organic matter in suspension that is deposited may become incorporated into sediments via bioturbation and may enhance food supply to this group. **Resistance** is assessed as **'High'** and **resilience** as **'High'** (no impact to recover from)**.** This group is therefore assessed as **'Not Sensitive'**

Resistance

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

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' –based on no impact to recover from.

XI. Habitat structure changes - removal of substratum (Extraction)

This ecological group consists of shallowly buried species. *Brissopsis lyrifera* lives buried about 2cm below the surface (Hollertz & Duchêne 2001). *Echinocardium cordatum* lives in a permanent burrow buried about 2cm deep (to 15cm) in offshore sediments (Buchanan 1966). Within the extraction footprint all individuals would be removed and hence **resistance** is assessed as **'None'. Resilience** is predicted to be **'Medium'** (within 2-10 years) and to occur largely through larval recolonisation. This assessment is based on the life-history traits described by MES (2010) and outlined in section 4.11.7. **Sensitivity** is therefore assessed as **'Medium'**.

Resistance

Quality of evidence is 'Medium' - based on expert judgment but with supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' - based on proxy rather than direct evidence.

Resilience (section 4.11.7

Quality of evidence is 'Medium' – based on expert judgment with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is 'Low' – based on species traits as proxy for resilience.
Concordance of evidence is 'Not assessed' – based on life-history traits as a proxy rather than direct evidence.

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

Little evidence was found to assess the impacts of this pressure on this ecological group. Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which *Echinocardium* could migrate was approximately 30cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. No information was found regarding the sensitivity of *Brissopsis lyrifera* or *Echinocyamus pusillus*.

All urchins within this group are burrowers and adapted to life within sediments. These species are therefore likely to be able to move within sediments although the character of the overburden will determine some degree of the impact. *Echinocardium* and *Echinocyamus pusillus* are adapted to coarse sediments and members of this ecological group have low tolerances for de-oxygenation. Although some individuals may reposition within sediment**, resistance** is assessed as **'Low'** (loss of 25-75% of exposed individuals) at the pressure benchmark due to the depth of the overburden**. Resilience** based on significant mortality is assessed as **'Medium'** (recovery within 2-10 years) based on life-history date from MES (2010) as described in section 4.11.7. **Sensitivity** is therefore categorised as **'Medium'.**

Resistance

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

Resilience (section 4.11.7)

Quality of evidence is 'Medium' – based on expert judgment with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is 'Low' – based on species traits as proxy for resilience.
Concordance of evidence is 'High' – based on a proxy rather than direct evidence.

4.11.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that this ecological group is not able to colonise artificial hard substratum and the introduction of this would reduce the extent of suitable habitat.

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Brissopsis lyrifera*: cohesive sandy mud; silty mud (two biotope records only).

- *Echinocardium cordatum*: fine to very fine muddy sand; sandy mud; fine to very fine sand with a fine silt fraction; medium to fine sand; slightly muddy sand; sand with some gravel; sand with gravel, pebbles and/or shingle.

- *Echinocyamus pusillus*: muddy gravel and sand, with shells and stones; medium to coarse sand with some gravel or shell gravel; gravel with coarse to medium sand.

Telford *et al* (1983) report that in the Firth of Lorne, Scotland, *Echinocyamus pusillus* was found most abundantly in highly variable, poorly sorted substrata but absent in fine sediments in sheltered areas. Wolff (1968, cited in Telford *et al* 1983) reported that *E. pusillus* was abundant in the North Sea in relatively coarse sands with a median grain size of 210-460µm.

The environmental requirements of the selected species vary but each appears to occur in a relatively restricted range of sediment types, related to burrowing, feeding and other characteristics. The species are therefore considered to have **'Low' resistance** to a change in sediment type of 1 Folk class for a year. **Resilience** is assessed as **'Medium' Resilience** based on significant mortality is assessed as **'Medium'** (recovery within 2-10 years) based on life-history date from MES (2010) as described in section 4.11.7. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance

Quality of evidence is ‘Medium’ - based on inferences made from biotope records, rather than species records.
Applicability of evidence is ‘Low’ – based on proxy for resistance.
Concordance of evidence is ‘Not assessed’ - based on single source.

Resilience (section 4.11.7)

Quality of evidence is ‘Medium’ – based on expert judgment with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is ‘Low’ – based on species traits as proxy for resilience.
Concordance of evidence is ‘High’ – based on a proxy rather than direct evidence.

4.11.6 Pollution

XIV. Organic enrichment

This group feeds on organic matter within sediments. *Brissopsis lyrifera* feeds on organic matter adhering to sediment particles. The species is also capable of filter feeding although ventilation rates are not high enough to sustain the animal on filter feeding alone (Hollertz 2002).

Echinocardium cordatum is generally found in sediments with low organic content and the species appears to be intolerant of increases in nutrient concentration (Hill 2008). Growth levels have been observed to be lower in sediments with high organic content although it is suggested that this may be due to higher levels of intraspecific competition (Duineveld & Jenness 1984). The species was absent from an area in the southern North Sea into which large quantities of sewage sludge from Hamburg had been dumped and the species was never seen to settle in the area (Caspers 1980). No evidence was available but the organic input from the sewage probably exceeded the pressure benchmark. Pearson and Rosenberg (1978) describe the changes in fauna along a gradient of increasing organic enrichment by pulp fibre where *Echinocardium cordatum* is absent from all but distant sediments with low organic input. Osinga *et al* (1997) assessed the effects of sub-surface bacterial production on *Echinocardium cordatum* by adding up to 90gC/m^2 in one event to sediment surfaces in experimental mesocosms. No detrimental effects on *E. cordatum* individuals were reported.

Borja *et al* (2000) and Gittenberger and van Loon (2011), in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), assigned *E. cordatum* to different Ecological Groups. Borja *et al* (2000) considered that *E. cordatum* belonged to Ecological Group I ‘species very sensitive to organic enrichment and present under unpolluted conditions’. However Gittenberger and van Loon (2011) considered this species belonged to Ecological Group II ‘species indifferent to enrichment, always present in low densities with non-significant variations with time’.

Brissopsis lyrifera is a non-selective deposit feeder so an increase in the suspended matter settling out from the water column to the substratum will be used by *B. lyrifera* as a food resource. Although characteristically a sub-surface deposit feeder, *B. lyrifera* has been observed to increase its surface feeding (apical tuft becomes visible) activity after addition of organic matter to the sediment surface and used the material for growth (Dare *et al* 1993; Hollertz *et al* 1998). Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of an AMBI index to assess disturbance (including organic enrichment) both assigned *B. lyrifera* to their Ecological Group I ‘species very sensitive to organic enrichment and present under unpolluted conditions' (Borja *et al* 2000 and Gittenberger & van Loon 2011).

No direct evidence was found for *Echinocyamus pusillus*. However, this species lives in areas of high water movement and wave action, so that excess matter silted on the surface is considered to be rapidly removed. Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of an AMBI index to assess disturbance (including organic enrichment) both assigned *E. pusillus* to their Ecological Group I 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)' (Borja *et al* 2000; Gittenberger & van Loon 2011).

The available evidence on the effects of organic enrichment could not be compared directly with the benchmark, which probably represents a lower increase in enrichment, than sewage sludge dumping or pulp fibre effluents. But as the AMBI assessments conclude that all three species are 'very sensitive to organic enrichment' a precautionary **resistance** of **'Low'** is suggested. **Resilience** is assessed as **'Medium'** and **sensitivity** is considered to be **'Medium'**.

Resistance

Quality of evidence is 'Medium' – as peer reviewed evidence is not available for all species and the type of evidence supporting the AMBI score is unclear, however the assessments are reported in peer reviewed literature, are widely used and are considered credible.
Applicability of evidence is Low' - based on unknown underlying evidence and assumptions.
Concordance of evidence is 'Low' – based on unknown underlying evidence and assumptions.

Resilience (section 4.11.7)

Quality of evidence is 'Medium' – based on expert judgment with supporting information from the grey literature (MES 2010) on life-history traits.
Applicability of evidence is 'Low' – based on species traits as proxy for resilience.
Concordance of evidence is 'High' – based on a proxy rather than direct evidence.

4.11.7 Review of likely rates of recovery based on the species assemblages present within the ecological group.

Relatively little information of recovery of members of this ecological group was found. But their life history characteristics were recently reviewed by MES (2010).

- *Brissopsis lyrifera* is a fast growing and highly productive echinoderm with a high dispersal potential, and life span of 3-5 years (MES 2010).

- *Echinocardium cordatum* has a very high fecundity and high dispersal potential. *Echinocardium* grows quickly in the first 2 years until it reaches sexual maturity at 2-3 years. Individual or species longevity is as much as 10 years with relatively slow growth after sexual maturity.

- *Echinocyamus* lives for 1-3 years, reaching sexual maturity after one year. There is little information available on its fecundity. Reproduction is external and the echinopluteus larvae are of about 0.5mm long. These planktotrophic larvae occur in the plankton from March to September indicating a high dispersal potential. Once the sediment has been colonised, the abundance and the biomass of *Echinocyamus* could be expected to recover within three years.

As a group, echinoderms are highly fecund; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability. For example, the heart urchin *Echinocardium cordatum* recruitment was recorded as sporadic, only occurring in 3 years out of a 10 year period (Buchanan 1967). Millport populations of *E. esculentus* showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980 and 1981 (Nichols 1984). Bishop and Earll (1984) suggested that the population of *E. esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years.

Based on the above information, resilience is assessed as ‘Medium’ (2-10 years). Confidence in the quality of evidence is assessed as ‘Medium’ as this assessment uses expert judgement but is based on supporting information from the grey literature (MES 2010) on habitat position. Confidence in applicability is assessed as ‘Low as the species traits are used a proxy for resistance. Degree of concordance is not assessed as the resistance assessment is based on a proxy rather than direct evidence.

4.11.8 Knowledge gaps

As with most echinoderms, information of recruitment, population dynamics, and hence recovery is lacking. Most of the information available relates to *Echinocardium cordatum* and *Brissopsis lyrifera* but very little was found for *Echinocyamu*s *pusillus*.

As with many benthic invertebrate species information on species specific responses to changes in physio-chemical conditions (temperature, salinity, oxygenation, turbidity, water flow and wave mediated oscillation), and biological pressures, remain poorly studied. The resilience and resistance of species (and species populations) have to be inferred from their distribution or biology, rather than direct experimental or comparative studies.

4.12 Ecological Group 8b Echinoderms - surface urchins

4.12.1 Definition and characteristics of the ecological group

The free-living, epifaunal urchin *Echinus esculentus* (edible European sea urchin or common sea urchin) was assigned to its own ecological group as its mobility, body form and fragility meant that it was distinct from the other epifaunal species assessed as Ecological Group 1 (a-d) (**Table 4.12**). *E. esculentus* is a grazer, commonly associated with kelp zones of rocky subtidal on a variety of hard substratum from ca 5m (below chart datum) to 100m but recorded as deep a 200m (Nichols 1984; Tyler-Walters 2008). It can occasionally occur on mixed sediments, but is included due to its presence very coarse sediments, e.g. cobbles, pebbles (Table 4.12). It may also be considered an ecological engineer species as grazing on macroalgae can have a large influence on habitats. It was therefore considered appropriate that this species was included as a distinct group.

Table 4.12. List of biotopes in which ecological group 8b species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.PomB	*Echinus esculentus*

4.12.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

Echinus esculentus was harvested commercially (Nichols 1979; Barber & Blake 1991) initially for marketing as souvenirs for the tourist trade, and subsequently for human consumption, mainly for the Japanese market (Comely & Ansell 1988). Nichols (1981, 1984) examined the Cornish sea urchin fishery. They noted that most commercial divers were inefficient at collecting the sea urchin, as many were obscured by weeds and other debris, or undersides of rocks, so that commercial divers probably leave behind a 'fair proportion' of the population. Intensive collecting did remove all urchins down to 15m from part of Lamora Cove, Cornwall in 1978. But the subsequent diving survey in 1979, showed that the urchins had returned (although no abundance was given), due to migration from deeper waters (Nichols 1981, 1984).

At the time of the study (ca 1978-1984) about 0.5 million sea-urchins (*Echinus*) were collected annually. Nichols (1984) concluded that the fishery was sustainable, based on the few years studied. However, he cautioned against complete clearance due to the adverse effects on habitats. Also natural fluctuations in *Echinus* populations meant that it was not possible to determine an acceptable level of catch. He advised that population densities should not be allowed to fall below $0.2/m^2$, as this population density had been stable at Shallow Tinker Shoal, Plymouth for 24 years (Nichols 1984).

Commercial harvesting by divers may be relatively inefficient, but at high intensities can remove 100% of the population (within the area impacted) **resistance** is assessed as **'Low'** (significant mortality, 25-75% loss) and **resilience** is assessed as **'High'**. **Sensitivity** is therefore considered to be **'Low'**.

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on directly relevant literature on this pressure.
Concordance of evidence is 'Medium' – based on agreement in direction but not magnitude.

Resilience (section 4.12.7)

Quality of evidence is 'High' – based on based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

III. Removal of Non-Target Species

Echinus esculentus may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (see 4.12.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. No obligate life history or ecological associations were identified and this ecological group is considered to be **'Not Sensitive'.** By default, **resistance** and **resilience** are therefore assessed as **'High'**.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.12.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

Echinoderms are stenohaline species owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl 1987; Russell 2013). At low salinity, sea urchins gain weight, and the epidermis loses its pigment as patches are destroyed; prolonged exposure is fatal. Echinoderm larvae have a narrow range of salinity tolerance and will develop abnormally and die if exposed to reduced or increased salinity. The coelomic fluid of *Echinus esculentus* is isotonic with seawater (Stickle & Diehl 1987). Populations in the sublittoral fringe probably encounter reduced salinity due to low water and fresh water runoff or heavy rain and may tolerate low salinity for short periods.

No information concerning the specific tolerance of *Echinus esculentus* was found although echinoderms in general are considered stenohaline with limited tolerance for decreased salinity. **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of individuals). **Resilience** (following the removal of this pressure) is assessed as **'High'** (<2 years). **Sensitivity** is assessed as **'Low'.**

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – as no specific evidence is drawn on for this assessment.

Resilience (section 4.12.7)

Quality of evidence is 'High' – based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

V. Temperature changes - local

Echinus esculentus was recorded at temperatures between 0 -18°C in the Limfjord, Denmark (Ursin 1960). Bishop (1985) noted that gametogenesis proceeded at temperatures between 11 - 19°C, although continued exposure to 1°C destroyed synchronicity of gametogenesis between individuals. Embryos and larvae developed abnormally after up to 24hrs at 15°C (Tyler & Young 1998) but normally at the other temperatures tested (4, 7 and 11°C at 1 atmosphere). Tyler and Young (1998) concluded that embryos and larvae were more tolerant of depth and temperature than adults. Bishop (1985) suggested that this species could not tolerate high temperatures for prolonged periods due to increased respiration rate and resultant metabolic stress. Therefore, *Echinus esculentus* is likely to exhibit a 'low' tolerance to chronic long term temperature change but would probably be more tolerant of sudden or short term acute change (e.g. 5°C for 3 days) in temperature. **Resistance** is assessed as **'Low'** and **resilience** is assessed as **'High'. Sensitivity** is assessed as **'Low'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed evidence.
Applicability of evidence is 'High' - based on directly relevant evidence.
Concordance of evidence is 'High' - based on agreement in direction and magnitude.

Resilience (section 4.12.7)

Quality of evidence is 'High' – based on based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

VI. Water flow (tidal current) changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. *Echinus esculentus* was recorded in biotopes from moderately strong (0.5-1.5m/s) to very weak (negligible) tidal streams, predominately in rock, mixed or very coarse sediment. *E. esculentus* is known to be removed from kelp stipes by wave action, when rolled by strong currents and displaced by storms (Tyler-Walters 2008). However, they exhibit positive geotaxis and move up the shore towards shallower waters when displaced, which is probably adaptation to displacement to deeper waters by wave action (Lewis & Nichols 1979). Therefore, increased water flow is unlikely to kill individuals but may displace the population. However, once conditions return to prior condition, the species would probably migrate back from the surrounding area.

Therefore, an increase in water flow of 0.1-.02m/s for a year is unlikely to adversely affect the population. **Resistance** is therefore considered **'High'** and**,** as there is no impact, **resilience** is considered **'High'.** This species is therefore **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inferences made from biotope records rather than species records.
Applicability of evidence is 'Low' – based on proxy for resistance.
Concordance of evidence is 'Not assessed' – based on single source.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group (see section 3.2.1 for further information and caveats). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. *Echinus esculentus* was recorded in biotopes from extremely sheltered; very sheltered; sheltered; moderately exposed; exposed, very exposed; extremely exposed habitats.

The records indicate that *Echinus esculentus* can occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. *E. esculentus* is known to be removed from kelp stipes by wave action, rolled by strong currents and displaced by storms (Tyler-Walters 2008). However, they exhibit positive geotaxis and move up the shore towards shallower waters when displaced, which is probably adaptation to displacement to deeper waters by wave action (Lewis & Nichols 1979). Therefore, increased water flow is unlikely to kill individuals but may displace the population. However, once conditions return to prior condition, the species would probably migrate back from the surrounding area.

Resistance is therefore considered to be **'High'** and**,** as there is no impact, **resilience** is considered to be **'High'.** This species is therefore considered to be **'Not Sensitive'**.

Resistance

Quality of evidence is ‘Medium’ – based on inferences made from biotope records rather than species records.
Applicability of evidence is ‘Low’ – based on proxy for resistance.
Concordance of evidence is ‘Not assessed’ – based on single source.

Resilience

Quality of evidence is ‘High’ – no impact to recover from.
Applicability of evidence is ‘High’ – no impact to recover from.
Concordance of evidence is ‘High’ – no impact to recover from.

4.12.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

MacDonald *et al* (1996) assessed benthic species sensitivity to fishing disturbance by ‘scoring’ each species ability to withstand the physical impact of a single fishing disturbance and recovery potential assuming no further fishing disturbance occurred. These authors classified the slow growing epifaunal species *Echinus esculentus* as being ‘very fragile’ and having ‘moderate’ recovery potential, based on life history characteristics.

Kaiser *et al* (2000) reported that *E. esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. This species was reported to suffer badly as a result of impact with passing scallop or queen scallop dredges (Bradshaw *et al* 2000; Hall-Spencer & Moore 2000a) Based on epifaunal position, size and fragility and the available evidence *E. esculentus* is assessed as having **‘Low’ resistance** to abrasion. **Resilience** is assessed as **‘High’** and therefore **sensitivity** is assessed as **‘Low’.**

Resistance

Quality of evidence is ‘Medium’ – based on expert judgement with supporting information from peer reviewed and grey literature on life history traits.
Applicability of evidence is ‘High’ – based on species traits which are a useful proxy for resistance and the assessment is supported by peer reviewed literature.
Concordance of evidence is ‘High’ – based on agreement in direction and magnitude.

Resilience (section 4.12.7)

Quality of evidence is ‘High’ – based on based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is ‘High’ – based on literature that addresses population dynamics directly.
Concordance of evidence is ‘Medium’ – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

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

The relevant evidence and hence sensitivity assessment are the same as those presented under surface abrasion (4.12.4.VIII) above.

X. Change in suspended solids

No evidence was found to assess this pressure. Sensitivity is therefore ‘Not assessed’.

XI. Habitat structure changes-removal of substratum (Extraction)

The process of extraction is considered to remove all *Echinus esculentus* within the extraction footprint as this group is epifaunal and has slow mobility. Hence, **resistance** is assessed as **'None'. Resilience** is predicted to be **'High'** (within 2 years). **Sensitivity is** therefore assessed as **'Medium'**.

Resistance

Quality of evidence is 'Medium' – based on expert judgement with supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

Resilience (section 4.12.7)

Quality of evidence is 'High' – based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

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

No direct evidence was found to support this assessment. This species is likely to be able to tolerate small quantities of sediment deposition (MES 2010). Comely and Ansell (1988) recorded large *Echinus esculentus* from kelp beds on the west coast of Scotland in which the substratum was seasonally covered with 'high levels' of silt.

Last *et al* (2011) found that a smaller epifaunal urchin *Psammechinus miliaris* is moderately tolerant of shorter term (12 days) burial events, with less than 25% mortality of all buried specimens. Survivorship was partly due to the re-emergence of many specimens, even from depths of up to 7cm, particularly when buried under coarse sediment. After 12 days of burial, mortality in the specimens that remained buried was high. Percentage mortality increased with progressively finer sediment fractions.

No evidence was found for the length of time *Echinus esculentus* could survive being buried under 30cm of sediment. In areas of high water flow, dispersion of fine sediments may be rapid and this will mitigate the magnitude of this pressure by reducing the time exposed and the depth of over burden that the species must crawl through. **Resistance** was assessed as **'None'** due to the depth of overburden and the predicted low level of vertical migration. **Resilience** was assessed as **'Medium'** (2-10 years) to take into account a delay in recolonisation of the affected area due to the presence of the deposit of fine sediment. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on expert judgement with supporting information from peer reviewed and grey literature on similar species.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

Resilience (section 4.12.7)

Quality of evidence is 'High' – based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

4.12.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that *Echinus esculentus* is predominantly found on hard substratum and is able to colonise artificial substratum. An increase in the available hard substratum is therefore thought to be beneficial to this species (although differences in diversity and other structural characteristics of assemblages on hard and artificial substratum have been observed and artificial habitats may not provide a habitat of the same quality as natural rock reefs). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data.

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). *E. esculentus* is recorded from biotopes on: muddy sand; sandy muds, shelly and gravelly mud; gravel and pebbles; mixed sediment (with stones and shells); mixed muddy sand with gravel, pebbles and cobbles; coarse sand and gravel with a minor finer sand fraction; sand with some gravel; sandy muddy gravel with surficial cobbles; clean shell and stone gravel; very coarse sand with a finer sand fraction; pebbles and shells; maerl; shell gravel; stones and coarse sediment; cobbles; bedrock and boulders. However, most authors note that *E. esculentus* is only found in abundance on hard, rocky reef habitats rather than on sedimentary habitats (Hiscock pers comm.), although it can occur on sedimentary habitats in small numbers.

A change in classification of one Folk class (e.g. from coarse cobbles and pebbles, or mixed sediments with cobbles and pebbles, to gravel, sands or muds) is unlikely to kill individuals but rather to reduce their abundance by excluding them from the affected area together with their preferred food species (faunal turfs and macroalgae). **Resistance** is therefore assessed as **'Low'** (reducing in abundance of 25-75%) and **resilience** as **'High'**. **Sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on inferences made from biotope records and habitat preferences.
Applicability of evidence is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on habitat preferences alone.

Quality of evidence is 'High' – based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*.
Applicability of evidence is 'High' – based on literature that addresses population dynamics directly.
Concordance of evidence is 'Medium' – based on recovery rates (recolonisation vs recruitment) that vary between studies and sites.

4.12.6 Pollution

XIV. Organic enrichment

Lawrence (1975) reported that sea urchins had persisted over 13 years on barren grounds near sewage outfalls, presumably feeding on dissolved organic material, detritus, plankton and microalgae, although individuals died at an early age. The ability to absorb dissolved organic material was suggested by Comely and Ansell (1988).

Based on the available evidence **Resistance** is assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). This group is therefore assessed as '**Not Sensitive'**.

Resistance

Quality of evidence is 'Low' – based on expert judgement.
Applicability of evidence is 'Not assessed' – based on expert judgement.
Concordance of evidence is 'Not assessed' – based on expert judgement.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.12.7 Review of likely rates of recovery based on the species present within the ecological group

As a group, echinoderms are highly fecund; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability.

Recovery of populations may occur through repair of non-lethal damage, adult migration into impacted areas or larval colonisation. Lewis and Nichols (1979; cited in Tyler-Walters 2008) found that adults were able to colonise an artificial reef in small numbers within three months and the population steadily grew over the following year. Similarly, Nichols (1981, 1984) reported that a site where all sea urchins were removed in 1978, the species had returned by a subsequent survey in 1979 (although no abundance was given).

Recruitment is sporadic or annual depending on locality and factors affecting larval pre-settlement and post-settlement survival (Tyler-Walters 2008). For example, the heart urchin *Echinocardium cordatum* recruitment only occurred in 3 years out of a 10 year period (Buchanan 1967). Millport populations of *E. esculentus* showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980 and 1981 (Nichols 1984). Bishop and Earll (1984) suggested that the population of *E. esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years. Also, *Echinus* is slow to mature and it would take up to 8 years for adult biomass to be restored (MES 2010).

Therefore, it is possible for *Echinus* to recolonize areas from which it is lost quickly by migration, where there is a large resident population in the surrounding area, such as on rocky or hard substrata. However, recruitment is more variable, annual in some cases or prolonged in others. Therefore, as *Echinus esculentus* is widespread and abundant around the coasts of the UK, a local population is likely to recover via migration from the surrounding area, and a **resilience of 'High'** (<2 years) is suggested, however it should be **noted** that in isolated areas dependent on recruitment alone, resilience would likely be **'Medium'** (2-10 years).

Confidence in the quality of evidence is assessed as 'High' as this assessment is based on supporting information from peer reviewed and grey literature on the populations of *Echinus esculentus*. Confidence in applicability is assessed as 'High' as the literature addresses population dynamics directly. Degree of concordance is 'Medium' as the recovery rates (recolonisation vs recruitment) vary between studies and sites.

4.12.8 Knowledge gaps

There was little information on the effects of suspended sediment on *Echinus esculentus.* As with many benthic invertebrate species information on species specific responses to changes in physio-chemical conditions (salinity, oxygenation, turbidity, water flow and wave mediated oscillation), and biological pressures, remain poorly studied. The resilience and resistance of species (and species populations) have to be inferred from their distribution or biology, rather than direct experimental or comparative studies.

4.13 Ecological Group 8c Ophiuroids (free-living interface suspension/deposit feeders)

4.13.1 Definition and characteristics of the ecological group

The ophiuroids are a large group and the following species were identified as characteristic of the biotopes examined: *Amphipholis squamata, Amphiura brachiata, Amphiura chiajei, Amphiura filiformis, Ophiocomina nigra, Ophiothrix fragilis, Ophiura albida* and *Ophiura ophiura* (**Table 4.13**). These species differ in feeding type and habit with suspension or deposit feeding predominating and the species being found, typically, in different habitats and different positions relative to the sediment or substratum. Examples of different genera (*Amphiura filiformis, Ophiocomina nigra, Ophiothrix fragilis* and *Ophiura spp.* (based on *Ophiura ophiura* and *Ophiura albida* depending on data availability) have been primarily used in considering sensitivity of biotopes associated with this ecological group, but evidence is also presented for other species in this group where available.

Table 4.13. List of biotopes in which ecological group 8c species occur as characterising species.

Level 5 biotopes relevant to ecological group	Key or characterising species assessed
SS.SCS.CCS.Nmix	*Ophiura albida*
SS.SSa.CMuSa.AalbNuc	*Ophiura albida*
SS.SSA.CMuSa.AbraAirr	Characterising species present were not specifically assessed due to a lack of evidence available.
SS.SSa.OSa.MalEdef	*Amphiura filiformis*
SS.SSa.OSa.OfusAfil	*Amphiura filiformis*
SS.SMu.CSaMu.AfilMysAnit	*Amphiura filiformis*
SS.SMu.CSaMu.AfilNten	*Amphiura filiformis* *Ophiura albida*
SS.SMu.CSaMu.VirOphPmax	Characterising species present were not specifically assessed due to a lack of evidence available.
SS.SMu.CSaMu.LkorPpel	*Ophiura albida*
SS.SMu.CFiMu.MegMax	Characterising species present were not specifically assessed due to a lack of evidence available.
SS.SMu.CFiMu.BlyrAchi	*Amphiura filiformis*
SS.SMx.CMx.OphMx	*Ophiocomina nigra* *Ophiothrix fragilis*
SS.SMx.OMx.PoVen	Characterising species present were not specifically assessed due to a lack of evidence available.
SS.SMu.OMu.PjefThyAfil	*Amphiura filiformis*

4.13.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical impacts are assessed under abrasion and penetration of the seabed pressures (section 4.13.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial as brittlestar beds are restricted to areas with low predation. Commercial fisheries may result in discarding of damaged or undersized target species. This will increase the available food supply to scavenging brittlestars but may also attract mobile predators and scavengers including fish and crustaceans to habitats supporting brittlestars, which may alter predation rates. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be ‘Not Exposed’ to targeted removal of the ecological group and **‘Not Sensitive’** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is ‘Medium’ – based on ecological and life history information rather than targeted studies.
Applicability of evidence is ‘Low’ – based on general ecology rather than pressure specific information.
Concordance of evidence is ‘Not assessed’ – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – no impact to recover from.
Applicability of evidence is ‘High’ – no impact to recover from.
Concordance of evidence is ‘High’ – no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.13.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. Commercial fisheries may result in discarding of damaged or dead non-target species. This will increase the available food supply to scavenging brittle stars but may also attract mobile predators and scavengers including fish and crustaceans to habitats supporting brittlestars which may alter predation rates. (Hughes 1998b) and the relevant MarLIN records (Budd 2006; Hill & Wilson 2008; Jackson 2008) state that there are no known examples of species that are obligate or specialist associates of brittlestar beds, this ecological group is therefore considered to be ‘**Not Sensitive’** to this pressure. By default, **resistance** and **resilience** are therefore assessed as **‘High’**.

Resistance

Quality of evidence is ‘Medium’ – based on ecological and life history information rather than targeted studies.
Applicability of evidence is ‘Low’ – based on general ecology rather than pressure specific information.
Concordance of evidence is ‘Not assessed’ – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – no impact to recover from.
Applicability of evidence is ‘High’ – no impact to recover from.
Concordance of evidence is ‘High’ – no impact to recover from.

4.13.3 Hydrological changes (inshore/local)

IV. Salinity changes - local

Echinoderms are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl 1987; Russell 2013). This means that they are unable to tolerate wide fluctuations in salinity and are considered sensitive to a decrease in salinity at the pressure benchmark.

However, there are examples where *Ophiura*, *Ophiothrix* and *Amphiura* have been recorded to persist in low salinity habitats. For example:

- dense *Ophiothrix* aggregations in areas where normal salinity is only 16.5ppt (Wolff 1968, cited from Hughes 1998), with the species found to persist down to 10ppt;

- *Amphiura filiformis* was recorded in the Sado estuary in Portugal (Monteiro Marques 1982, cited in Stickle & Diehl 1987; Russell 2013) where the salinity is 25.5‰ or in the Black Sea where it tolerated 8.9‰ (Russell 2013);

- *Ophiura albida* tolerated 20.7‰ in Loch Etive, Scotland (Russell 2103); and

- *Ophiocomina nigra* tolerated 27.6‰ in experiments (Russell 2013).

Evidence from the MNCR database that indicates biotopes where *Ophicomina nigra*, *Ophiura albida* and *Ophiura ophiura* are characterising species occur in full (30-40 units) as well as variable salinity (18-40 units).

Populations can adapt to prevailing environmental conditions so that sensitivity of different populations of the same species may differ. Pagett (1981), for example, examined the tolerance of *Amphiura chiajei* to brackish water (0.5-30psu) in specimens taken from Loch Etive, Scotland. Loch Etive is a sea loch subject to periods of reduced salinities owing to heavy rain and fresh-water runoff. Pagett (1981) found that specimens nearer freshwater influxes were more tolerant of reduced salinities than those nearer the open sea. *Amphiura chiajei* taken from an area of 24psu had an LD_{50} of >21 days for a 70% dilution (17psu) and an LD_{50} of 8.5 days for a 50% dilution (12psu). In comparison, specimens taken from an area with salinity 28.9psu, had an LD_{50} of >12.5 days for a 70% dilution (20psu) and an LD_{50} of 6 days for a 50% dilution (14psu).

As with *Asterias rubens* (section 4.6.3) the ophiuroids are probably capable of localised physiological adaption to reduced or variable salinities. However, the circalittoral habitats under investigation in this report are less likely to experience variable salinities, and resident species are, therefore, less likely to adapt to variation in salinity, as suggested by the results given by Pagett (1981). **Resistance** is therefore assessed as **'Low'** (loss of 25-75% of individuals). **Resilience** (following the removal of this pressure) is assessed as **'Medium'** (2-10 years) as some rapid recolonisation by adults may be expected through passive water transport or migration from adjacent populations but establishing full age-structured populations is predicted to take up to 10 years. **Sensitivity** is assessed as **'Medium'**.

Resistance

Quality of evidence is 'Medium' - based on inferences from peer reviewed literature.
Applicability of evidence is 'Medium' - similar features and pressures in other areas.
Concordance of evidence is 'Medium' - based on agreement in direction but variation in magnitude between studies and habitat.

Resilience (section 4.13.7)

Quality of evidence is 'Medium' – based on expert judgement supported by evidence from the peer reviewed and grey literature pertaining to population dynamics and life-history traits.
Applicability of evidence is 'Low' – based on life history rather than recovery from specified pressures.
Concordance of evidence is 'Medium' – based on agreement on direction but not magnitude.

V. Temperature changes - local

Brittlestars are cosmopolitan species with the entire, global population experiencing a wide range of temperatures (although regional populations are likely to be adapted to the particular temperature range typically experienced). The distribution of *Ophiothrix fragilis* is large, ranging from northern Norway, south to the Cape of Good Hope. Consequently, this species is exposed to temperatures both above and below those found in the British Isles. Total geographic range of *Ophiocomina nigra* is from Norway to the Azores and the Mediterranean.

Brittlestar beds exist across virtually the entire geographic extent of the UK and Ireland. In Galway Bay long term recordings of water temperature at a site of high density aggregations of *Amphiura filiformis* showed the species is subject to annual variations in temperature of about 10 °C (O'Connor *et al* 1983).

Short term acute changes in temperature are noted to cause a reduction in the loading of subcutaneous symbiotic bacteria in echinoderms such as *Ophiothrix fragilis*. Reductions in these bacteria are probably indicative of levels of stress and may lead to mortality (Newton & McKenzie 1995).

Brittlestar populations have experienced mass mortalities when exposed to very low water temperatures in winter. Populations of *Ophiothrix fragilis* inhabiting shallow subtidal habitats (5-7m depth) in the Dutch Oosterschelde Estuary were greatly reduced (to less than 10% spatial coverage) following cold winters in 1978-79, 1984-85 and 1985-86. These populations increased in abundance following mild winters in the following years (1979-80 and 1987-88), showing that populations can recover rapidly; with the animals occupying 60 - 90% of the available hard substratum in layers up to 5cm deep (Leewis *et al* 1994). Similarly, a population of *Amphiura filiformis* at 27m depth off the Danish coast was killed by the winter of 1962-63 (Muus 1981) and a population at 35-50m depth in the inner German Bight was killed in the winter of 1969-1970; a new population was not re-established until 1974 (Gerdes 1977). Ursin (1960, cited in Gerdes 1977) suggests that *Amphiura filiformis* does not occur in areas with winter temperatures below 4°C although in Helgoland waters can reach temperatures as low as 3.5°C. Populations of *Amphiura chiajei* also seem periodically affected by winter cold. Mean densities of *Amphiura chiajei* in Killarney Harbour, west coast of Ireland, decreased following months with the lowest recorded bottom temperatures, 4°C and 6°C, for February 1986 and January 1987 respectively (Munday & Keegan 1992).

Increases in temperature may have beneficial effects on populations through enhanced growth and reproduction rates. Muus (1981) showed that juvenile *Amphiura filiformis* are capable of much higher growth rates in experiments with temperatures between 12 and 17°C. Juvenile disk diameter increased from 0.5 to 3.0mm in 28 weeks under these conditions compared to over 2 years in the North Sea (Duineveld & van Noort 1986).

The evidence indicates that this ecological group occurs within a wide range of temperatures. An increase or decrease in temperature at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore **'High'** and as there is no impact, **resilience** is **'High'.** Therefore, this group is considered **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on geographic distribution supported by peer reviewed observations.
Applicability of evidence is 'Medium' – based on geographic distribution supported by peer reviewed observations.
Concordance of evidence is 'Medium' – based on geographic distribution as a proxy for the pressure, and supported by peer reviewed observations.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

VI. Water flow (tidal current) changes - local

Amphiura filiformis respond rapidly to currents by extending their arms into the water column to feed. Under laboratory conditions they were shown to maintain this vertical position at currents of 0.3m/s (Buchanan 1964). *Amphiura filiformis* feed on suspended material in flowing water, but will change to deposit feeding in stagnant water or areas of very low water flow (Ockelmann & Muus 1978). Unlike *Amphiura filiformis*, *Amphiura chiajei* shows no clear response to directional bottom currents or an increase in water current rate (Buchanan 1964, cited in Budd 2006). In laboratory conditions, *Amphiura chiajei* maintained a position within the sediment with its arms stretched out across the sediment until 0.3m/s, when the arms streamed out in the direction of the water current (Buchanan 1964, cited in Budd 2006).

Dense brittlestar beds are found in a range of water flows from sea lochs with restricted water flows to higher-energy environments on open coastlines. In the Dover Strait, *Ophiothrix* beds experience current speeds of up to 1.5m/s during average spring tides (Davoult & Gounin 1995). Davoult and Gounin (1995) found that current speeds below 0.2m/s were optimal for suspension feeding by *Ophiothrix fragilis*; if velocity exceeded 0.3m/s the animals cease feeding, flatten themselves against the substratum and link arms, so increasing their collective stability in the current. These values agree with those found by Warner (1971).

Similarly strong tidal streams (1.0-1.2m/s) were also recorded over beds in the Isle of Man (Brun 1969). In both locations, *Ophiothrix* densities of up to 2000 individuals/m^2 were recorded. Hughes (1998b) suggests that high density aggregations can probably only be maintained where strong currents can supply enough suspended food. Food requirements probably set a lower limit on the current regime of areas able to support brittlestars. However, above a certain water speed (25cm/s) the feeding arms are withdrawn from the water column (Warner & Woodley 1975; Hiscock 1983). At water speeds above about 28 cm/s individuals or even small groups may be displaced from the substratum and they have been observed being rolled along the seabed by the current (Warner 1971). Living in dense aggregations may reduce displacement by strong currents (Warner & Woodley 1975).

Suspension feeding by *Ophiothrix* is more or less continuous during neap tides, but the flux of particles is small because the slow current speed inhibits resuspension of material from the sea bottom. During spring tides, current speeds increase rapidly, bringing about a large resuspension of particles. Feeding bouts at these times are brief, but more efficient due to the increased concentration of suspended matter (Davoult & Gounin 1995).

The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data (see section 3.2.1 for caveats regarding assumptions). Recorded water flow strength experienced by biotopes characterised by members of this ecological group follow.

- *Amphipholis squamata*: very weak to strong (negligible -<0.5-3m/s).
- *Amphiura brachiata*: moderately strong (<0.5-1.5m/s, based on one biotope record).
- *Amphiura chiajei*: very weak to weak (negligible - <0.5m/s).
- *Amphiura filiformis*: very weak to moderately strong (negligible -1.5m/s).
- *Ophiocomina nigra*: very weak to very strong (negligible ->3m/s).
- *Ophiothrix fragilis* very weak to very strong (negligible ->3m/s).
- *Ophiura albida* very weak to moderately strong (negligible -1.5m/s).
- *Ophiura ophiura*: very weak to moderately strong (negligible -1.5m/s).

The pressure benchmark refers to a change in peak spring tide flow so that exposure is periodic rather than chronic. The evidence available suggests that brittlestars have behavioural adaptations to changes in water flow. An increased flow rate by increasing suspension and transport of organic particles can enhance feeding rates and if the flow is too strong, brittlestars may flatten, link arms, or withdraw arms into sediment. At lower flow rates species may switch to deposit feeding. The range of flow speeds experienced by biotopes in which the species are found suggest that a change in the maximum water flow experienced by mid-range populations for the short periods of peak spring tide flow would not have negative effects on this ecological group. **Resilience** is therefore considered to be **'Very High'** and this group is assessed as **'Not Sensitive'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed evidence and habitat distribution information.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'High' – based on general consistency in the evidence.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

VII. Wave exposure changes - local

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by this ecological group. The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data (see section 3.2.1 for further information and caveats). The records indicate the wave exposure categories for biotopes characterised by members of this ecological group as follows:

- *Amphipholis squamata*: sheltered to very exposed.
- *Amphiura brachiata*: very sheltered to extremely exposed.
- *Amphiura chiajei*: extremely sheltered to moderately exposed.
- *Amphiura filiformis*: extremely sheltered to moderately exposed.
- *Ophiocomina nigra*: extremely sheltered to exposed.
- *Ophiothrix fragilis*: extremely sheltered to extremely exposed.
- *Ophiura albida*: extremely sheltered to very exposed.
- *Ophiura ophiura*: very sheltered to extremely exposed.

The records indicate that the biotopes in which the ecological group is found occur within a range of wave exposure categories. An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this ecological group. **Resistance** is therefore considered to be **'High'** and as there is no impact to recover from, **resilience** is considered to be **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on habitat preferences information.
Applicability of evidence is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on habitat preferences alone.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.13.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

Abrasion at the surface of the sediment has the potential to directly impact this ecological group. Many of the species represented by this group are epifaunal and would be directly exposed to any source of abrasion. *Amphiura* species are shallow burrowers but extend arms above the surface to feed, these would be directly exposed to abrasion. In some structurally complex habitats, individuals beneath stones or in crevices may avoid this pressure. Abrasion could lead to damage through crushing or mortality of exposed individuals. Ophiuroids may also autotomise arms in response to abrasion; this mechanism is part of an escape response. Arms can be regrown or regenerated.

This assessment is largely based on the evidence presented for the penetration and sub-surface disturbance presented below as no evidence was found for surface abrasion only (see section 4.13.4.IX).

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

This ecological group is considered sensitive to direct physical impacts from activities that lead to penetration and disturbance of the seabed. The evidence suggests that different species within this group experience different levels of mortality, dependent on ecology (particularly typical position within sediment). Although some general trends can be identified there are some discrepancies between different studies.

By-catch

Members of this ecological group appear to have high levels of catchability by towed fishing gears as a number of studies report the presence of these species as by-catch in hauled nets. Captured species suffer high levels of damage and survival following removal and exposure to the air appears to be very low. All *Ophiura ophiura* that were caught in otter trawls from the *Nephrops* fishery in the Clyde Sea were found to be damaged with more than 70% suffering medium-severe injury (Bergman *et al* 2001). Broken arms were the most frequent injury (95%) but 13% also sustained damage to discs and 5% lost all arms (Bergman *et al* 2001). Post mortality rates of 100% were observed through the damage sustained and aerial exposure (Bergmann & Moore 2001).

Direct Mortality Estimates

Direct mortality (percentage of initial density) of *Amphiura* species from a single pass of a beam trawl was estimated from experimental studies on sandy and silty grounds as 9% (Bergman & van Santbrink 2000a).

High intensity clam dredging at a previously undisturbed site in the Mediterranean led to a decrease in abundance of *Ophiura ophiura*; abundance remained low over the 35 day sampling period following the disturbance (Constantino *et al* 2009).

Hansson *et al* (2000) repeatedly trawled a Swedish fjord previously closed to fishing activities for six years. They used an otter trawl for 7-12 months (two hauls once a week). Following this experiment, total number of brittlestars, particularly *Amphiura chiajei,* significantly decreased (on average by 31%) at the disturbed sites compared with the undisturbed control. The effect on *A. chiajei* may have been exacerbated by sub-lethal effects of oxygen stress at the enclosed site, which meant that normally more deeply buried individuals approached the surface exposing them to impacts.

Collie *et al* (2000) suggests that chronic dredging would lead to a 93% reduction for ophiuroids in general, whereas a single dredge event is predicted to lead to a 76% reduction.

Comparative studies

Amphiura chiajei were present at a wreck site that prevented fishing disturbance and were absent from fished sites in the Irish Sea (Ball *et al* 2000b). Large specimens of *A. chiajei* were quite common at the undisturbed site by contrast, while juveniles of some of these species were occasionally taken at the offshore trawling station, large specimens were never found.

Examination of historical and recent samples suggest that the spatial presence of *Ophiothrix fragilis* and *Amphiura* spp. in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al* 2007). Conversely, the presence of *Ophiura ophiura* has increased over this period. The presence of *Ophiura albida* was apparently unchanged during this period.

Re-sampling of grounds that were historically studied (from the 1930s) indicates that *Ophiothrix fragilis* has declined in areas subject to scallop fishing (Bradshaw *et al* 2002). Conversely, *Ophiocomina nigra*, *Ophiura albida* and *Amphiura filiformis* all increased in abundance.

Scavenging behaviour

Abrasion and sub-surface damage may indirectly benefit members of this ecological group by increasing scavenging opportunities. Two brittlestars (*Ophiura ophiura* and *O. albida*) were recorded regularly in baited traps, sometimes in relatively high numbers, indicating that these species are mobile and exhibit scavenging behaviour (Groenewold & Fonds 2000). *Ophiura ophiura* has been observed scavenging in trawl tracks after the passage of a scallop dredge although divers noted that many were damaged (Ramsay *et al* 1998).

Pressure Effects

De Groot (1984) found that when beam trawls were fitted with ticklers the number of brittlestars (not identified to species level) caught reduced. There was only an increase in the catch of about 1.3 times when the number of tickler chains was increased to four. However, owing to pressure, about three quarters of the numbers caught were badly damaged. Regenerated brittlestars were not found (as was often observed in starfishes). Therefore, it was assumed that the damaged brittlestars do not survive their stay in the net.

Sensitivity

Based on the estimates of direct mortality (Bergman & van Santbrink 2000a), the rates of by-catch damage (Bergman *et al* 2001; Bergman & Moore 2001), and the observation of decreased abundances following trawling (Hansson *et al* 2001), **resistance** is assessed as **'Low'** for all the selected species. **Resilience** is assessed as **'Medium'** (see section 4.13.7) and **sensitivity** is therefore **'Medium'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on directly applicable peer reviewed studies.
Concordance of evidence is 'Medium' – based on agreement in direction but not always in magnitude of effect.

Resilience (section 4.13.7)

Quality of evidence is 'Medium' – based on expert judgement supported by evidence from the peer reviewed and grey literature pertaining to population dynamics and life-history traits
Applicability of evidence is 'Low' – based on life history rather than recovery from specified pressures.
Concordance of evidence is 'Medium' – based on agreement on direction but not magnitude.

X. Change in suspended solids

No direct evidence was found relating to the sensitivity of this ecological group to this pressure. Although some brittlestar species are able to perceive differences in light and dark visual perception is limited and changes in clarity are therefore not considered to directly impact this ecological group. Local increases in turbidity in waters previously within the photic zone, may alter local abundances of phytoplankton and surface diatoms and the zooplankton and other small invertebrates that feed on them. An increase in suspended solids may therefore indirectly reduce feeding efficiency. However, since phytoplankton may arrive from distant sources and brittlestars may also feed on organic detritus or invertebrate prey any effects are expected to be small and so the intolerance to increased turbidity is likely to be low (Hill 2001). However, where the pressure results from an increase in suspended organic matter this would be beneficial to this ecological group by providing increased food material (and perhaps local stimulation of phytoplankton abundance where nutrients are recycled back to the water column).

No evidence was found to assess the impact of this pressure and sensitivity was 'Not assessed'.

XI. Habitat structure changes - removal of substratum (Extraction)

The process of extraction will remove all members of this ecological group as they do not have rapid escape responses and either live on the surface or are shallowly buried. **Resistance** is therefore assessed as **'None'** based on expert judgment but supported by the literature relating to the position of these species on or within the seabed. As brittlestars do not have specific habitat requirements the exposed sediments are considered to be suitable for recolonisation almost immediately following extraction. Where populations are removed or significantly reduced over large areas then recovery will depend on recruitment of juveniles and rely on the supply of new larvae, establishing full age-structured populations is predicted to take up to 10 years. **Resilience** (following the removal of this pressure) is assessed as **'Medium'** (2-10 years). **Sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on expert judgment and on supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' – based on proxy rather than direct evidence.

Resilience (section 4.13.7)

Quality of evidence is 'Medium' – based on expert judgement supported by evidence from the peer reviewed and grey literature pertaining to population dynamics and life-history traits.
Applicability of evidence is 'Low' – based on life history rather than recovery from specified pressures.
Concordance of evidence is 'Medium' – based on agreement on direction but not magnitude.

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

Direct evidence for the effects of siltation on this ecological group is limited to the experiments undertaken by Last *et al* (2011). Last *et al* (2011) buried *Ophiura ophiura* individuals under three different depths of sediment; shallow (2cm), medium (5cm) and deep (7cm). The results indicated that *Ophiura ophiura* is highly tolerant of short term (32 days) burial events, with less than 10% mortality of all buried specimens. This is largely a reflection of the ability of the species to re-emerge from all depths across all sediment fractions tested. Survival of specimens that remained buried was low, with 100% mortality of individuals that remained buried after 32 days. Percentage mortality increased with both depth and duration of burial. The experiments utilised three different fractions of kiln dried, commercially obtained marine sediment: coarse (1.2-2.0mm diameter), medium fine (0.25-0.95mm diameter) and fine (0.1-0.25mm diameter). It should be noted that the burial depths used in these experiments are much smaller than the pressure benchmark (30cm).

Ophiura ophiura are found in sandier habitats that are subject to high rates of natural disturbance, these species are therefore likely to experience burial through natural sediment movements and be adapted to this, as suggested by the results of experimental smothering (Last *et al* 2011). *Amphiura* species burrow into sediments and are likely to experience some burial where natural disturbances move fine-grained sediments and to be able to regain the surface following light siltation. No evidence for re-emergence thresholds was found.

Hill (2001) states that dense beds of brittlestars do not persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer 1962, cited in Aronson 1992). Aronson (1989, cited from Hill 2001) refers to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively attributes this to increased sedimentation caused by the localised dumping of construction materials (Hill 2001).

No evidence was found for the length of time members of this ecological group could survive being buried under 30cm of sediment. In areas of high water flow dispersion of fine sediments may be rapid and this will mitigate the magnitude of this pressure by reducing the time exposed and the depth of over burden that species must crawl through. **Resistance** is assessed as **'None'** due to the depth of overburden and the low mobility of epifaunal species. **Resilience** was assessed as **'Medium'** (2-10 years) and **sensitivity** was therefore categorised as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on peer reviewed studies for some species, and inferences for others.
Applicability of evidence is 'Low' – based on directly relevant studies in some species, and observations or habitat preferences in others.
Concordance of evidence is 'Low' – based on variation between studies and species.

Resilience (section 4.13.7)

Quality of evidence is 'Medium' – based on expert judgement supported by evidence from the peer reviewed and grey literature pertaining to population dynamics and life-history traits.
Applicability of evidence is 'Low' – based on life history rather than recovery from specified pressures.
Concordance of evidence is 'Medium' – based on agreement on direction but not magnitude.

4.13.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

Hughes (1998b) reports that brittlestar beds have been recorded on a wide variety of substrata, ranging from bedrock through boulders and cobbles to gravel, sand and mud. Beds on cobbles, gravel and mixed coarse sediments are probably the most common. Increased fine sediment may impair suspension feeding where these are disturbed and re-suspended so that fine mud sediments are less suitable.

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The records indicate the substratum types for biotopes characterised by members of this ecological group as follows.

- *Amphiura filiformis*: silty mud; cohesive sandy mud; fine to very fine muddy sand; muddy sand and gravel; clean fine sands; mixed sediment (with stones and shells).

- *Ophiocomina nigra*: muddy sand; sandy muds; stones or shells on muddy sediment; mixed muddy sandy gravel; mixed sediment (with stones and shells); *maerl*; shell gravel; stones and coarse sediment; bedrock, boulders; cobbles, pebbles and *Modiolus* shells.

- *Ophiothrix fragilis*: mud and muddy gravel with shell; mixed sediment; *maerl*; shell gravel; stones and coarse sediment; mixed muddy sandy gravel; bedrock; boulders; cobble; pebble; calcareous tubes.

- *Ophiura ophiura*: silty mud; fine to very fine muddy sand; sandy mud; clean fine sands.

A change in classification of one Folk class (based on the Long 2006 classification) between mixed sediments, muddy sands and sandy muds is not predicted to negatively affect species within this ecological group which are found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no impact to recover from). This ecological group is therefore assessed as **'Not Sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on expert judgment and on supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' – based on proxy rather than direct evidence.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.13.6 Pollution

XIV. Organic enrichment

Organic enrichment may be beneficial to deposit feeders as a direct source of food and may indirectly enhance food supply where enrichment stimulates local growth of phytoplankton and diatoms. In the Skagerrak, an increase in abundance and biomass of *Amphiura filiformis* between 1972 and 1988 was attributed to organic enrichment (Hernroth *et al* 2012).

Rosenberg *et al* (2004) also reported that *Amphiura filiformis* appeared to be more densely packed in the sediment when food occurred superabundantly compared to when food was less common. Sköld and Gunnarsson (1994) reported enhanced growth and gonad development in response to short-term enrichment of sediment cores containing *Amphiura filiformis* maintained in laboratory mesocosms. Raymont (2008) recorded an increase in *Ophiocomina nigra* populations following the addition of fertilisers to the waters of an enclosed basin of Loch Sween, Argyll.

A dense aggregation of *Ophiothrix* and *Ophiocomina* was recorded in 1974 from a site at the mouth of Killary Harbour, western Ireland (Budd 2008a). A salmon farm was established at the site in the late 1980s, within 100m of the main beds. The extent and density of the brittlestar beds appear not to have changed despite presence of the farm (B. Ball, personal communication, cited in Hughes 1998).

Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), assigned *Amphiura filiformis*, *Ophiura albida* and *Ophiura ophiura* to their Ecological Group II (Species indifferent to enrichment, always present in low densities with non-significant variations with time) (from initial state, to slight unbalance) (Gittenberger & van Loon 2011). Borja *et al* (2000) assigned *Ophiothrix fragilis* to Ecological Group I (Species very sensitive to organic enrichment and present under unpolluted conditions (initial state) whereas Gittenberger and van Loon (2011) assigned this species to Ecological Group II. *Ophiocomina nigra* has not been assigned an AMBI category.

An increase in organic matter may increase food availability for these suspension feeders and the height above the seabed reduces sedimentation effects. This group is generally found in areas with some water movement and this will disperse organic matter reducing organic material load. Based on the AMBI assessments and field observations and experiments (Josefson 1990; Raymont 1950; Rosenberg *et al* 1997) **resistance** to organic enrichment is assessed as **'High'** and **resilience** as **'High'** as there is no impact to recover from. This group is therefore assessed as **'Not Sensitive'** to organic enrichment.

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on peer reviewed literature and observations from the UK and the broad.
Concordance of evidence is 'High' – based on agreement on direction and magnitude of impacts.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.13.7 Review of likely rates of recovery based on the species present within the ecological group

Recovery of this ecological group will depend on tolerance and the character of the impact including the spatial footprint. Very small disturbed patches surrounded by abundant populations of the same species may recover rapidly by adult migration. *Ophiura ophiura* and *O. albida* were recorded regularly in baited traps, sometimes in relatively high numbers, indicating that these species are mobile (Groenewold & Fonds 2000). Adult ophiuroids have some mobility but are not highly active. Recovery by adult immigration may therefore be limited although this will be mediated by the spatial footprint of an impact.

Where populations are removed or significantly reduced over large areas then recovery will be through recruitment of juveniles and will depend on the supply of new larvae. Larvae suffer high mortality rates. Muus (1981) showed the mortality of new settling *Amphiura filiformis* to be extremely high with less than 5% contributing to the adult population in any given year. Sköld *et al* (1994) also commented on the high mortality and low rates of recruitment in this species. In Galway Bay populations (O'Connor *et al* 1983), small individuals make up ca. 5% of the population in any given month, which also suggests the actual level of input into the adult population is extremely low.

Muus (1981) estimated the life span of *Amphiura filiformis* to be 25 years based on oral width (which does not change with gonadal growth) with recruitment taking place at the 0.3mm size. In very long term studies of *A. filiformis* populations in Galway Bay, O'Connor *et al* (1983) indicate a life span of some 20 years is possible.

A. filiformis reaches sexual maturity after 2 years breeds annually and in the UK one period of recruitment occurs in the autumn (Pedrotti 1993). The species is thought to have a long pelagic life. Sköld *et al* (1994) estimated the time lag between full gonads and settlement to be 88 days. This duration is comparable to the time period when pelagic larvae have been recorded in the plankton from July to November in one prior study and August to December in another prior study (Fosshagen 1965 and Thorson 1946 respectively, cited in Sköld *et al* 1994). A long planktonic life stage means this species is predicted to disperse over considerable distances.

Amphiura chiajei is a long lived (>10 years), slow growing species. It has an annual reproductive cycle and is likely to be quite fecund owing to its planktonic development, but juvenile recruitment tends to be very sporadic. In the laboratory, Fenaux (1970) observed completion of larval development within eight days at 18°C. It is not clear whether this is representative of field conditions but such a short planktonic existence would limit the species powers of dispersal (Budd 2006).

Ophiocomina nigra grows slowly and lives for up to 14 years (Hughes 1998b). Juvenile *Ophiocomina* appear not to settle among adults. The Clyde populations studied by Gorzula (1977) were each dominated by a single size-class of animals, suggesting that each *Ophiocomina* bed is formed by a single settlement of juveniles which thereafter receives little or no recruitment.

Ophiura spp. are found in sandy, high-energy environments where the sediment is subject to natural disturbance. This species has life history traits associated with opportunistic species with short generation times, rapid reproduction and high dispersal potential.

Tyler (1977) found that populations of *Ophiura albida* in the Bristol Channel had a well-marked annual reproductive cycle, with spawning taking place in May and early June. Spent adults and planktonic larvae were found up to early October. This short annual reproductive period led to the occurrence of distinct size cohorts in the adult population. In contrast, the larger *Ophiura ophiura* had a more protracted breeding season, and adult size classes were less distinct. Gage (1990) suggested a life span of 5-6 years for *O. ophiura* from the west of Scotland.

There is some disagreement concerning the life span of *Ophiothrix fragilis*. Davoult et al (1990) suggested a life span of 9-20 months. Taylor (1958, quoted in Gorzula 1977) recorded that *Ophiothrix* reached a disc diameter of about 14mm in two years, and that most individuals died after spawning in their second summer. However, other researchers have considered the animals to be much longer-lived. Gorzula (1977) quotes evidence that Swedish *Ophiothrix* can live for up to eight years. A life span of over nine years has been suggested based on counts of growth bands in the skeletal arm plates of *Ophiothrix* (Gage 1990). It is possible that growth rates may vary widely in different areas, or that the different varieties of *Ophiothrix fragilis* recognised by French workers may have contrasting population dynamics.

Ophiothrix has a lengthy breeding season, with some spawning taking place throughout the summer and autumn. Settlement is at its peak in September/October, but some recruitment may take place at other times of year. New recruits settle on the arms of adult individuals.

Ophiothrix fragilis has an extended breeding season running roughly from April to October (Smith 1940; Ball *et al* 1995). In the Dover Strait, the main period of larval settlement is in September/October, but some settlement also occurs in February, April and June (Davoult *et al* 1990). Maximum population densities (approximately 2000 individuals m^2) are found during the main recruitment period in September (Davoult *et al* 1990). A similar seasonal pattern was found by Brun (1969) in the Isle of Man, where newly-settled juveniles were found in August and September. Peak juvenile numbers occurred in November in a Bristol Channel population (George & Warwick 1985). In Kinsale Harbour, Ireland, post-settlement juveniles could be found throughout the year, with maximum numbers (up to 1000 juveniles/m^2) in October (Ball *et al* 1995). Mortality was high, leading to low levels of recruitment into the adult population. All studies agree that recruits initially settle on the arms of adults.

The larvae of *Ophiothrix fragilis* can disperse over considerable distances in areas such as the English Channel where there are strong water flow rates (Davoult *et al* 1990). With water that may move several kilometres per day due to residual flow (Pingree & Maddock 1977) and a larval duration of 26 days, the larvae can disperse up to 70-100 km and establish populations elsewhere. This may preclude auto-recruitment of local populations (Davoult *et al* 1990). Adults, although mobile, are not highly active. Some immigration of adults from nearby populations may be possible. Longevity estimates vary from 9 months (Davoult *et al* 1990) to over 10 years (Gage 1990). Reproductive capability may be reached in 6-10 months depending on time of recruitment (Davoult *et al* 1990).

The longest lived species in this ecological group have episodic recruitment and populations may consist of a life stage and be stable over a long period. The adults may consume juvenile life stages preventing recruitment. Heavy and successful settlement of *Amphiura chiajei* can dominate an area for over 10 years. Buchanan (1964) sampled *Amphiura chiajei* off the Northumbrian coast between 1958 and 1965, and found the entire population to consist of large individuals (disc diameter >7.5mm). Between 1958 and 1964, there was no evidence of any new recruitment to the population, but at the end of 1965 a heavy and successful recruitment occurred. Prior to this settlement, it was apparent that the same single ageing population had been measured for over 8 years. Spawning had occurred but without successful recruitment. This pattern of longevity and of episodic recruitment is consistent with that if the population of *Amphiura chiajei* in Killary Harbour, west coast of Ireland (Munday & Keegan 1992). The mortality rate was measured between 1961 and 1963 and shown to be small. Munday and Keegan (1992) only recorded a successful recruitment of juvenile *Amphiura chiajei* following the significant demise of adults after depressed winter temperatures in Killary Harbour, Ireland.

Overall assessment:

Minor damage to individuals is likely to be repaired, missing arms that are shed as part of an escape/disturbance response can be regrown. Recovery from impacts with a small spatial footprint may occur through migration of adults and some species such as *Ophiura spp*. are mobile as shown by bait trapping experiments (Groenewold & Fonds 2000). Where the majority of the population remain, and/or recruitment by adult mobility is possible recovery (resilience) is likely to be ‘High’.

Where impacts remove a significant proportion of the population, recovery will require larval recolonisation. Sexual maturity is reached within 2 years for most species and reproduction is annual and in some cases protracted providing a supply of larvae. However, ophiuroids demonstrate sporadic and unpredictable recruitment (Buchanan 1964), even though they have long-lived pelagic larvae with a high dispersal potential. Therefore, where a significant part of the population is lost, recovery is likely to be ‘Medium’ (2-10 years). Within this time period it is likely that most species could have re-established biomass and age structured populations.

Assessments of recovery are based on expert judgement supported by evidence from the peer reviewed and grey literature pertaining to population dynamics and life-history traits. Confidence in the quality of evidence is therefore assessed as ‘Medium’, confidence in applicability is ‘Low’ and, due to general consistency, concordance is assessed as ‘Medium’.

4.13.8 Knowledge gaps

This group is relatively well studied and evidence for the ecology and the sensitivity of the species that form large aggregations was reviewed by Holt *et al* (1998). This report has been drawn on extensively for this ecological group. Ophiurids are relatively conspicuous members of subtidal assemblages so their presence is recorded and responses to impacts observed. Large brittle star beds are of ecological and scientific interest stimulating research effort.

The evidence base to assess sensitivity to abrasion and sub-surface penetration and disturbance was the most developed. As fishing is the most widespread human activity impacting subtidal sediments, the impetus to understand impacts has been greater for this pressure than any others. Sensitivity assessments for the hydrological pressures were based largely on inferences drawn from distribution records as evidence for tolerance thresholds is limited. Similarly, responses to some pressures were based on life-history traits, e.g. extraction. Little quantitative information was found to assess impacts and where evidence was available this was rarely comparable to the pressure benchmarks so that expert judgement was required to develop assessments. No specific studies have been conducted to assess resilience and these assessments were therefore based on expert judgement (supported by information on population dynamics and life-history). No information was found on sensitivity to electromagnetic fields or changes in suspended sediment.

The species *Amphipholis squamata* is poorly studied and no evidence was found for this species to include within the review.

4.14 Ecological Group 8d Large burrowing holothurians

4.14.1 Definition and characteristics of group including characteristic species

Neopentadactyla mixta is a large deep-burrowing sea cucumber, characteristic of coarse sediment and maerls. It has a distinct lifestyle, and overwinters at depth in coarse sediment. The sensitivity of this species will be assessed as the sole member of this group (**Table 4.14**).

There is little information on the autecology and life history of *N. mixta* and information on impacts is derived by impacts on its habitat or inferred from its reported distribution. It is known to be a suspension feeder (Smith 1983), with a preference for gravel-type substrata, occurring at highest densities in loose mobile deposits. It lives in a ‘U-shaped’ burrow at a depth of 15-25cm, exhibits a diurnal feeding cycle and retracts into the sediment between sunrise and sunset. On the west coast of Ireland, it burrows to a depth of 30-60cm and enters a state of torpor between September and March (Konnecker & Keegan 1973; Smith & Keegan 1985).

Table 4.14. List of biotopes in which ecological group 8d species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.Nmix	*Neopentadactyla mixta*

4.14.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

No information on the direct effects of non-native species on *Neopentadactyla mixta* was found. *N. mixta* is a characteristic species in maerl beds and other coarse, gravelly sediments. *Crepidula fornicata* beds may form on sedimentary habitats. For example, Grall and Hall-Spencer (2003) note that beds of invasive slipper limpet *Crepidula fornicata* grew across maerl beds in Brittany. As a result, the maerl thalli were killed, and the bed clogged with silt and pseudo-faeces, so that the associated community was drastically changed. It may be possible for *Crepidula* beds to adversely affect other coarse sedimentary habitats.

Overall, a **resistance** of **‘None’** is suggested. **Resilience** is probably **‘Very Low’,** as *Crepidula* beds can persist and recovery of the underlying sediment would require the *Crepidula* bed to be removed. Hence, a **sensitivity** of **‘High’** is suggested. The resistance assessment is based on reported effects on a key habitat for this ecological group, so the confidence in quality, applicability and concordance is 'High'. The resilience assessment is related to the nature of the impact, so the overall confidence is also 'High'.

Resistance

Quality of evidence is ‘High’ – based on reported effects on a key habitat for this ecological group.
Applicability of evidence is ‘High’ – based on reported effects of this pressure on a key habitat for this ecological group.
Concordance of evidence is ‘High’ – based on agreement on direction and magnitude of impact.

Resilience

Quality of evidence is ‘Medium’ – based on inference from peer reviewed literature.
Applicability of evidence is ‘Medium’ – based on peer reviewed literature about the effects of

the pressure on similar habitats.
Concordance of evidence is ‘Low’ – based on a single literature source and expert judgment.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. However, *Neopentadactyla mixta* is a characterising species in coarse gravels and maerl beds, and maerl is a biogenic habitat. Maerl extraction for the coralline algae itself can result in complete destruction of maerl beds. For example, in Brittany, the clean maerl gravel of the Glenan maerl bank described in 1969, was degraded to muddy sand dominated by deposit feeders and omnivores within 30 years (Grall & Hall-Spencer 2003). Whereas, Birkett *et al* (1998) noted that although maerl beds subject to extraction in the Fal estuary exhibit a diverse flora and fauna, they were less species-rich than those in Galway Bay, although direct correlation with dredging was unclear (Grall & Hall-Spencer 2003). Grall and Glemarec (1997, cited in Birkett *et al* 1998) reported few differences in biological composition between exploited and control beds in Brittany. The degree of impact therefore depends on the intensity of extraction. In addition, extraction by scallop dredging may break up maerl nodules into smaller pieces resulting in easier displacement by wave action, resulting in a reduced structural heterogeneity and lower diversity of species (Kamenos *et al* 2003).

Overall, extraction of dead and/or live of maerl represents a permanent loss of substratum for *N. mixta*, and a **resistance** of **‘None’** is suggested, and as maerl cannot recover (maerl is effectively a non-renewable resource); **resilience** is likely to be **‘Very low’** and **sensitivity** is therefore assessed as **‘High’**. The assessment of resistance and resilience of maerls beds and the species they support is based on 'High' quality, applicable and concordant evidence. The assessment of resilience is made by inference from the life history of members of the same phylum, so confidence is Low.

Resistance

Quality of evidence is ‘High’ – based on peer reviewed literature.
Applicability of evidence is ‘High’ – based on directly relevant literature.
Concordance of evidence is ‘High’ – based on agreement on direction and magnitude of impacts.

Resilience

Quality of evidence is ‘Low’ – based on expert judgement and the nature of the impact.
Applicability of evidence is ‘Not assessed’ - based on expert judgement.
Concordance of evidence is ‘Not assessed’ - based on expert judgement.

III. Removal of Non-Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.14.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be ‘Not Exposed’ to targeted removal of the ecological group and ‘**Not Sensitive’** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

4.14.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

Echinoderms are restricted to the marine environment and one of the only stenohaline phyla in the animal kingdom (Russell 2013). Although some species can acclimatise to hypo/hypersaline conditions, Russell (2013) did not mention *N. mixta* amongst them. Smith (1983) noted that hypo or hypersaline water caused the animal to withdraw its tentacles. *N. mixta* is not reported from shallow water, and it is only likely to be exposed due to hypo/hypersaline effluents, although in these cases it would probably gain protection by withdrawing into the sediment and the interstitial water would buffer the animals from extreme or sudden changes in salinity. However, prolonged reduction of salinity (e.g. a change of 10 salinity units for a year) might flush through the coarse sediment, even at depth, and would probably be fatal in the affected area. Therefore, a **resistance** of **'None'** is suggested, with a **resilience** of **'Medium'** and **sensitivity** is assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' – based on physiological characteristics of the taxonomic group.
Applicability of evidence is 'Low' – based on a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

Resilience (section 4.14.7)

Quality of evidence is 'Low' – based on inference from the life history of members of the same phylum.
Applicability of evidence is 'Low' – based on a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

V. Temperature changes - local

Little information on temperature tolerances was found for this ecological group and the assessment is based largely on reported global distribution.

The majority of records of *N. mixta* occur in the British Isles although its range extends from northern Norway and the Barents Sea to the Bay of Biscay (OBIS 2014). OBIS (2014) provide a recorded temperature range of 11.5 -11.9°C for the recorded distribution (although it is unclear how the figures are obtained). This range might indicate the thermally stable nature of its habitat or a lack of data. However, based on this evidence it is likely to tolerate chronic change in temperature.

N. mixta is not reported from shallow water, and it is only likely to be exposed to acute temperature changes due to thermal effluents. It is likely to withdraw into the sediment, away from the thermal plume, and be protected by the temperature of the interstitial waters. Only long term acute change (greater than the benchmark) is likely to adversely affect the population. In winter months, it is probably too deep to be affected by significant decreases in temperature. However, if exposed for a month (as per the benchmark) it will probably be unable to feed, resulting in loss of condition. Overall, a **resistance** of **'High'** is suggested, with a **resilience** of **'High'** and therefore **sensitivity** is assessed as **'Not sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on geographical distribution rather than targeted studies.
Applicability of evidence is 'Low' – based on geographical distribution as a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on geographical distribution as a proxy rather than direct evidence.

Resilience

Quality of evidence is 'High' – no impact to recover from.
Applicability of evidence is 'High' – no impact to recover from.
Concordance of evidence is 'High' – no impact to recover from.

VI. Water flow (tidal current) changes - local

Neopentadactyla mixta occurs in maerl beds and coarse gravel sediments, both of which are associated with water flow either due to tidal streams (moderately strong to weak, Connor et al 2004) or wave mediated water movement. Water flow is an important structuring factor in habitats dominated by *N. mixta* (e.g. SS.SCS.CCS.Nmix and SS.SMp.Mrl.Pcal.Nmix), maintaining an open matrix of maerl or coarse sediment, removing fine sediments, allowing oxygenation deep within the sediment and providing adequate food supply to suspension feeders such as *N. mixta* (see Sewell *et al* 2008).

For example, the beds of *N. mixta* examined by Konnecker and Keegan (1973) were found in tidal currents of up to 2.5 knots (ca 1.28m/s). Nevertheless, artificially increased current beyond the calm weather, spring tide, maximum of ca 1.5 m/s caused *N. mixta* to stop feeding and withdraw into its burrow, as did bombardment with dislodged sediment (Smith & Keegan 1985). Similarly, a heavy gale in August caused *N. mixta* to withdraw deep into the sediment for six to ten days (Smith & Keegan 1985). The species regularly undertakes a 6 month long torpor period, during which it loses condition and lipid energy stores. Smith and Keegan (1985) suggested that the overwinter torpor may be a response to poor food availability coupled with increased turbulence experienced in winter at their study site. An increase in water flow of 0.2m/s for a year is likely to prevent feeding, and may result in death of individuals from starvation. Such an increase in water flow may also modify the sediment, causing a loss of the sediment from the surface and mobilisation of the bed, although these sediments routinely bear mega-ripples caused by current flow and storms. Alternatively, a decrease in flow by 0.2m/s for a year will probably result in deposition of fine sediments and detritus, resulting in a change in sediment type, a complete change in the biological community, and probably loss of *N. mixta*. Therefore, a **resistance** of **'None'** is suggested, with a **resilience** of **'Medium'**, giving a sensitivity of **'Medium'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on peer reviewed literature on the effects of this pressure.
Concordance of evidence is 'High' – based on agreement on direction and magnitude of impact.

Resilience (section 4.14.7)

Quality of evidence is 'Low' – based on inference from the life history of members of the same phylum.
Applicability of evidence is 'Low' – based on a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

VII. Wave exposure changes - local

An increase in nearshore wave height (>3% but <5%) is likely to increase wave mediated flow at the sediment surface, and probably likely to prevent feeding, and may result in death of individuals from starvation or their migration to deeper water, if available habitat exists (see section 4.13.3.VI). Such an increase in water flow may also modify the sediment, causing a loss of the sediment from the surface and mobilisation of the bed, although these sediments routinely bear mega-ripples caused by current flow and storms. Therefore, a **resistance** of **'Low'** is suggested, with a **resilience** of **'Medium'**, giving a **sensitivity** of **'Medium'.**

Resistance

Quality of evidence is 'High' – based on peer reviewed literature.
Applicability of evidence is 'High' – based on peer reviewed literature on the effects of this pressure.
Concordance of evidence is 'High' – based on agreement on direction and magnitude of impact.

Resilience (section 4.14.7)

Quality of evidence is 'Low' – based on inference from the life history of members of the same phylum.
Applicability of evidence is 'Low' – based on a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

4.14.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

The burrow of *Neopentadactyla mixta* in spring/autumn is 15-25cm deep, and 30-60cm deep during its winter torpor (Smith & Keegan 1985). Therefore, it is unlikely to be directly impacted by surface abrasion. For example, in long-term studies of scallop dredging and subsequent recovery (Hall-Spencer & Moore 2000a, 2000b) deep burrowing species including *N. mixta* were not impacted and their abundance changed little over the four year period. It should be noted however that no information on juveniles is available. Therefore**,** a **resistance** of **'High'** is suggested, while **resilience** is probably also **'High'** as there is no impact to recover from. The ecological group is therefore considered **'Not Sensitive'**.

Resistance

Quality of evidence is ‘High’ – based on peer reviewed literature.
Applicability of evidence is ‘High’ – based on peer reviewed literature on the effects of this pressure.
Concordance of evidence is ‘High’ – based on agreement on direction and magnitude of impact.

Resilience

Quality of evidence is ‘High’ – no impact to recover from.
Applicability of evidence is ‘High’ – no impact to recover from.
Concordance of evidence is ‘High’ – no impact to recover from.

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

In long-term studies of scallop dredging and subsequent recovery (Hall-Spencer & Moore 2000a, 2000b) deep burrowing species including *N. mixta* were not impacted and their abundance changed little over the four year period. However, experimental hydraulic blade dredging removed and damaged deep-burrowing species, including small numbers of *N. mixta* (Hauton *et al* 2003b), and affected the maerl bed to a depth of 9 cm. Hydraulic dredging in coarse sand and gravel may have similar effects.

Overall, penetrative gear may adversely affect *N. mixta* populations and a **resistance** of **‘Medium’** is suggested, **resilience** is likely to be **‘Medium’** and **sensitivity ‘Medium’**.

Resistance

Quality of evidence is ‘High’ – based on peer reviewed literature.
Applicability of evidence is ‘High’ – based on peer reviewed literature on the effects of this pressure.
Concordance of evidence is ‘High’ – based on agreement on direction and magnitude of impact.

Resilience (section 4.14.7)

Quality of evidence is ‘Low’ – based on inference from the life history of members of the same phylum.
Applicability of evidence is ‘Low’ – based on a proxy for resilience.
Concordance of evidence is ‘Not assessed’ – based on a proxy rather than direct evidence.

X. Change in suspended solids

Neopentadactyla mixta can be abundant in coarse sediments, gravels and maerl beds, which themselves occur in areas of moderate water flow that prevents the deposition or build-up of fine sediments. Suspension feeders may initially benefit from an increase in particulates and hence food. However, oxygenation and water flow is vital to the development of the diverse community of coarse sediments, so increase suspended solids may fill in the sediment preventing deep oxygenation required by deep burrowing species, such as *N. mixta*. So an increase in suspended solids may result in filling of the coarse sediment over a period of a year and adversely affect the *N. mixta* population. Therefore, a **resistance** of **'Low'** is suggested, which together with a **resilience** of **'Medium'** suggests a **sensitivity** of **'Medium'.** No direct evidence of impact from this pressure was found and the assessment is based on expert judgement.

Resistance

Quality of evidence is ‘Low’ – based on expert judgment.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (section 4.14.7)

Quality of evidence is ‘Low’ – based on inference from the life history of members of the same phylum.
Applicability of evidence is ‘Low’ – based on a proxy for resilience.
Concordance of evidence is ‘Not assessed’ – based on a proxy rather than direct evidence.

XI. Habitat structure changes - removal of substratum (Extraction)

Overall, extraction of dead and/or live of maerl represents a permanent loss of substratum for *N. mixta*, and a **resistance** of **‘None’** is suggested. As maerl cannot recover (maerl is effectively a non-renewable resource); **resilience** is likely to be **‘Very low’** and **sensitivity ‘high’**. Extraction of coarse gravel beds may have similar effects, except that the gravel will be replaced over time, so **resilience** is probably **'Low'**, although **sensitivity** remains **'High'.**

Resistance

Quality of evidence is ‘Low’ – based on expert judgment.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (section 4.14.7)

Quality of evidence is ‘Low’ – based on inference from the life history of members of the same phylum.
Applicability of evidence is ‘Low’ – based on a proxy for resilience.
Concordance of evidence is ‘Not assessed’ – based on a proxy rather than direct evidence.

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

The addition of 30cm of fine material over the surface of the sediment will likely prevent *N. mixta* from feeding, forcing it to withdraw into its tube. Fine sediment will also penetrate the surface of the sediment in the affected area, significantly reducing water flow, and increasing the possibility of anoxia within the sediment. If the smothering sediment remained, it would result in a complete shift of the community and loss of the *N. mixta* population. However, in the areas of tidal streams in which these habitats occur it is unlikely that the smothering sediment would persist, depending on the local hydrography. As *N. mixta* can survive ca 6 months without feeding (Konnecker & Keegan 1973; Smith & Keegan 1985) it is likely that **resistance** is **‘High’** and **resilience** is also **‘High’.** The ecological group is therefore considered **‘Not Sensitive’**.

Resistance

Quality of evidence is ‘Low’ – based on expert judgment.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience

Quality of evidence is ‘High’ – no impact to recover from.
Applicability of evidence is ‘High’ – no impact to recover from.
Concordance of evidence is ‘High’ – no impact to recover from.

4.14.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

Neopentadactyla mixta is only characteristic of coarse gravel (SS.SCS.CCS.Nmix) and maerl (SS.SMp.Mrl.Pcal.Nmix) and only found in coarse gravel / maerl sediment. Therefore, a change is one Folk class would result in a significant loss in abundance of this species, as well as major changes in the associated community. Therefore, **resistance** is considered **'Low'**, **resilience** is considered **'Medium'** and therefore **sensitivity** is assessed as **'High'.**

Resistance

Quality of evidence is ‘Low’ – based on expert judgment.
Applicability of evidence is ‘Not assessed’ – based on expert judgment.
Concordance of evidence is ‘Not assessed’ – based on expert judgment.

Resilience (section 4.14.7)

Quality of evidence is ‘Low’ – based on inference from the life history of members of the same phylum.
Applicability of evidence is ‘Low’ – based on a proxy for resilience.
Concordance of evidence is ‘Not assessed’ – based on a proxy rather than direct evidence.

4.14.6 Pollution

XIV. Organic enrichment

Organic enrichment due to sewage and other effluents has been implicated in the loss of maerl beds, and complete shift in their resident communities. For example in Brittany, numerous maerl beds were affected by sewage outfalls and urban effluents, resulting in increases in contaminants, suspended solids, microbes and organic matter with resultant deoxygenation (Grall & Hall-Spencer 2003). This resulted in increased siltation, higher abundance and biomass of opportunistic species, loss of sensitive species and reduction in biodiversity. Grall and Hall-Spencer (2003) note that two maerl beds directly under sewage outfalls were converted from dense deposits of live maerl in 1959 to heterogeneous mud with maerl fragments buried, under several centimetres of fine sediment, with communities dominated by only a few species by 1997. Similarly, changes in sediment community structure from diverse communities to communities dominated by opportunistic deposit feeders is well documented (Pearson & Rosenberg 1978; Diaz & Rosenberg 1995).

Although the evidence available could not be compared directly with the benchmark, the evidence suggests that organic enrichment could lead to a complete change in the community and loss of *N. mixta* populations. However, it is not possible to compare the reported evidence to the benchmark level of impact. **Therefore a resistance** of **‘Low’** is suggested. A **resilience** of **‘Low’** is suggested as the habitat would need to recover before the species could return. **Sensitivity** is therefore assessed as **’High’.**

Resistance

Quality of evidence is 'Medium' – based on inferences from peer reviewed literature rather than targeted studies.
Applicability of evidence is 'Medium' – based on inferences from similar habitats and pressures.
Concordance of evidence is 'Medium' – based on agreement in direction but not magnitude.

Resilience (section 4.14.7)

Quality of evidence is 'Low' – based on inference from the life history of members of the same phylum.
Applicability of evidence is 'Low' – based on a proxy for resilience.
Concordance of evidence is 'Not assessed' – based on a proxy rather than direct evidence.

4.14.7 Review of likely rates of recovery based on the species present within the ecological group

Very little is known about the population dynamics of *Neopentadactyla mixta*, or their life history characteristics. They are recorded as frequent (ca 1-9/100m^2) in coarse gravel (biotope SS.SCS.CCS.Nmix) and maerl (biotope SS.SMp.Mrl.Pcal.Nmix) and can reach high densities, for example >200/m^2 on the west coast of Ireland (Konnecker & Keegan 1973). Their abundance might suggest either good local recruitment and or sporadic but high level recruitment. They are dioecious, with large eggs (ca 300µm in size), so that it has been suggested that larval development is lecithotrophic (Southward & Campbell 2006).

As a group, echinoderms are highly fecund; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability. For example, the heart urchin *Echinocardium cordatum* recruitment was recorded as sporadic, only occurring in 3 years out of a 10 year period (Buchanan 1967). Millport populations of *E. esculentus* showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980 and 1981 (Nichols 1984). Bishop and Earll (1984) suggested that the population of *E. esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years.

Overall, there is no direct evidence of larval development, recruitment and/or population dynamics in *N. mixta*. However, many echinoderms show sporadic and variable recruitment, suggesting that any population could take anywhere from one year to perhaps ten years to recruit and recolonise a habitat from which they were reduced in abundance and or removed. Therefore, **resilience** is given a precautionary rank of **'Medium'** (2-10 years). However, the assessment of resilience is made by inference from the life history of members of the same phylum, so confidence is 'Low'.

4.14.8 Knowledge gaps

There is very little information on the biology, life history and population dynamics of *Neopentadactyla mixta*. All studies of its biology were carried out before 1985 and in west Ireland. Therefore, it is difficult to estimate resistance or resilience with confidence. As with many benthic invertebrate species, information on species specific responses to changes in physio-chemical conditions (temperature, salinity, oxygenation, turbidity, water flow and wave mediated oscillation), contaminants inc. litter, noise and vibration, and biological pressures, remain poorly studied. The resilience and resistance of species (and species populations) have to be inferred from their distribution or biology, rather than direct experimental or comparative studies.

Most of the assessments for physical pressures are inferred from detailed peer reviewed studies of the effects of physical disturbance on maerl beds, rather than their effects on gravel beds.

4.15 Ecological Group 9 Burrowing hard-bodied species

4.15.1 Definition and characteristics of the ecological group

The burrowing crustaceans *Calocaris macandreae* and *Nephrops norvegicus* have some conspicuous life history differences in size and feeding type (**Table 4.15**). However, these species were clustered in ordination plots produced in the phase 1 report (Tillin & Tyler-Walters 2014) based on longevity and life habit and habitat preferences. These species were therefore considered to form an ecological group based on biological traits which also reflect the biotopes in which they are found (stable, deep or sheltered mud habitats that allow species to create and maintain burrows). The sensitivity of both species are reviewed for this group.

Table 4.15. List of biotopes in which ecological group 9 species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SMu.CFiMu.SpnMeg	*Nephrops norvegicus*
SS.SMu.CFiMu.SpnMeg.Fun	*Nephrops norvegicus*
SS.SMu.CFiMu.MegMax	*Nephrops norvegicus* *Calocaris macandreae*

4.15.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

Nephrops is a commercially targeted species that is harvested by static and mobile gears, information on the European fisheries for this species is summarised by Ungfors *et al* (2013). No evidence was found for the proportion of the population that is removed by targeted harvesting. This evidence gap reflects the difficulty of conducting stock assessments on *Nephrops* which can only be selectively harvested by trawls and static gears. Video studies have found that only a low proportion (circa 5%) of *Nephrops* that approached creels entered them (Bjordal 1986; Adey 2007, cited in Ungfors *et al* 2013). Factors that govern emergence will influence catch rates as only individuals that have emerged from burrows will be caught by trawl hauls. The degree of emergence from burrows for feeding or mating appears to be mainly governed by light intensities and therefore depends on factors such as time of day and season and varies between populations at different depths (Katoh et al 2013). Experimental trawling (Ameyaw-Akumfi & Naylor 1987) to evaluate catch rates showed that catchability varied between vessels in the same area and that catch rates were strongly linked to tidal cycles with increased catch rates at spring rather than neap tides. Catch rates differ between genders (Ungfors *et al* 2013 and references therein), berried females tend to stay within burrows and are rarely caught in trawls (Aguzzi & Sarda 2008, cited in Katoh *et al* 2013).

Resistance is assessed as **'Medium'** for targeted harvesting as individual *Nephrops* can exhibit escape responses and only a proportion of the population will be removed (estimated as <25%). **Resilience** is assessed as **'Medium** (within 2-10 years) as populations persist at intensively fished areas. No evidence was found to assess resilience rates and quantitative evidence on growth, longevity and age of sexual maturity are lacking (see section 4.15.7) and this assessment should be applied with caution. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance (*Nephrops*)

Quality of evidence is 'Low'- the resistance assessment is based on expert judgement as no quantitative evidence for catchability and hence the proportion of the population removed was found.
Applicability of evidence is 'Not assessed '- the resistance assessment is based on expert judgement alone.
Concordance of evidence is 'Not assessed '- the resistance assessment is based on expert judgement alone.

Resilience (*Nephrops*)

Quality of evidence is 'Low' - the assessments are based largely on expert judgement.
Applicability of evidence is Not assessed' - the assessments are based on expert judgement.
Concordance of evidence is Not assessed' - the assessments are based on expert judgement.

Calocaris macandreae is considered to be **'**Not exposed' to this pressure as it is not commercially targeted and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species. **Resistance** and **resilience** are therefore assessed as **'High'** by default. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. Remains of *C. macandreae* have been found in the stomachs of cod and haddock as well as *Nephrops*, although Buchanan (1963) concluded that *C. macandreae* are well protected within burrows and predation on populations is probably insignificant.

Resistance (*C. macandreae*)

Quality of evidence is 'Medium' – the assessment is based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – the assessment is based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – no specific evidence is drawn on for this assessment.

Resilience (*C. macandreae*)

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.15.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. No obligate life-history or ecological associations were identified and this ecological group is considered to be '**Not Sensitive'.** By default, **resistance** and **resilience** are therefore assessed as **'High'.** This assessment is based on ecological and life history information rather than targeted studies.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information rather than targeted studies.
Applicability of evidence is 'Low' – based on general ecology rather than pressure specific information.
Concordance of evidence is 'Not assessed' – no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

4.15.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No evidence was found to assess salinity tolerance of *Calocaris macandreae*. It is found in fully marine conditions and no habitat records from estuaries or brackish water were found.

There is little evidence to assess salinity tolerances of *Nephrops norvegicus* at the pressure benchmark. Studies have suggested a lower salinity limit of 29-30 units for its distribution and an upper limit of 35.8-38.7ppt in the Adriatic (Poulsen 1946; Farmer 1975, cited from Paine & Levin 1981). Höglund (1942, cited in Paine & Levin 1981) suggested that the absence of *N. norvegicus* in the Baltic Sea was due to its intolerance to very low salinities.

The effects of low salinity exposure and emersion were tested to simulate the conditions experienced by discarded *Nephrops* in the Kattegat area as these are transported through the halocline (Paine & Levin 1981). *Nephrops* exposed to 15psu suffered mortalities of 25-42% overall. Exposed animals gained mass rapidly as water was absorbed and showed delayed or absent responses to stimulation following return to waters of 33psu. (Paine & Levin 1981). Extrapolating these results to the pressure benchmark is problematic, however, as the exposure is to lower salinities than considered for a short period only.

This ecological group is considered to have limited tolerance to changes in salinity at the pressure benchmark. A decrease in 4psu may be tolerated without adverse effect (based on Farmer 1975) however a reduction up to 10psu is considered likely to significantly reduce habitat quality leading to migration or mortality of exposed animals. **Resistance** is therefore assessed as **'Low'** (for both species) and **resilience** as **'Medium'** for *Nephrops* (within 2-10 years) and **'Low'** (10-25 years) for *C. macandreae*. The differing resilience scores mean that the **sensitivity** of *Nephrops* is assessed as '**Medium'** and the sensitivity of *C. macandreae* is assessed as **'High'**. Resilience rates are discussed in more detail in section 4.15.7.

Resistance

Quality of evidence is 'Medium' – the assessment is based on inferences made from habitat distribution of both species rather than empirical evidence.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a single source (distribution records).

Resilience (N. norvegicus and *C. macandreae) (section 4.15.7)*

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

V. Temperature changes - local

Calocaris macandreae is abundant in muddy sediments around the British east and west coasts, extending from Scandinavia to West Africa and the Mediterranean (Ingle & Christiansen 2004).

Nephrops norvegicus is distributed from Iceland to the eastern Mediterranean at temperatures between 6 and 17°C (Gardner 1996). Hernroth *et al* (2012) exposed individuals from a population found in the Skagerrak to temperature elevations 4°C above normal for the area for four months. No signs of oxidative stress were observed and mortality rates were not affected.

Overall, short term acute changes in temperature and long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely this ecological group as global distribution suggest *N. norvegicus* and *C. macandreae* can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'.** This group is therefore considered to be **'Not Sensitive'.**

Resistance

Quality of evidence is 'Medium' – based on inferences made from distribution rather than direct evidence.
Applicability of evidence is 'Low' – the global distribution data used is a proxy for the pressure.
Concordance of evidence is 'Not assessed' – based on a single source (distribution records).

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

VI. Water flow (tidal current) changes - local

No evidence was found to assess this pressure for this ecological group.

4.15.4 Physical Damage (Reversible Change)

VII. Abrasion/disturbance of the substrate on the surface of the seabed

No direct evidence was found to assess the sensitivity of this ecological group to surface abrasion. The burrowing life habit of this ecological group would confer some protection from surface disturbance although *Nephrops norvegicus* would be exposed when walking on the surface or close to the surface feeding. *Calocaris macandreae* is suggested to rarely venture onto the surface (Nash *et al* 1984). *N. norvegicus* burrows have been studied using resin casting (Rice & Chapman 1971; Nash *et al* 1984), and have been found to penetrate to a depth of 30cm. *C. macandreae* creates sub-surface burrow complexes up to 20cm deep.

During an experimental study it was reported that trawl caught *Nephrops f*emales had fewer eggs on average than creel caught females from the same area and that it was likely that the eggs may be lost due to physical abrasion (Chapman & Ballantyne 1980). The proportion of eggs lost to abrasion ranged from 11-22 % in samples taken from the Clyde and West of Kintyre (Chapman & Ballantyne, 1980). Burrows are also likely to be damaged by abrasion. However, Marrs *et al* (1998) reported that burrows were re-established within 2 days providing that the occupant had remained unharmed (Marrs *et al* 1998).

Assuming that the burrowing habit of this ecological group confers some protection, **resistance** is assessed as **'Medium'** (loss of <25% of individuals) as some individuals may be exposed within the direct footprint when on the surface or in shallow parts of the burrow. **Resilience** is assessed as **'Medium'** (recovery within 2-10 years for both species) as a significant proportion of the population remains to support recovery. This assessment is supported by the presence of both these species at intensively fished grounds but no direct information on actual recovery rates from impacts was found (see recovery section 4.15.4). **Sensitivity** is assessed as **'Medium'**.

Resistance

Quality of evidence is 'Low' - as the lack of empirical evidence means the resistance assessment is based on expert judgement.
Applicability of evidence is 'Not assessed' - based on expert judgement alone.
Concordance of evidence is 'Not assessed' - based on expert judgement alone.

Resilience

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

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

Evidence for the direct effects of sub-surface penetration and disturbance on *Calocaris macandreae* was obtained from the reported impacts of fishing activities. No similar comparative evidence for *Nephrops* was found and the lack of areas undisturbed by trawling has constrained studies on the ecology of *Nephrops* (Johnson & Johnson 2013).

Comparisons between grab samples collected at trawled and untrawled sites in the Oslofjord, a northern branch of the Skagerrak in the North Sea showed that *C. macandreae* were depleted at trawled sites (mean abundance of *C. macandreae* was 41.5 individuals per m^2 (ci. ±9.91) in non-trawled areas and 14.5 individuals per m^2 (ci.±4.99) in trawled areas) (Olsgard *et al* 2008). Trawled areas were visited by otter trawlers targeting *Pandalus montagui* between 50 and 100 times per year, and based on the size of the trawls and the boat speed, each part of these areas are trawled on average 2–3 times per year (Olsgard *et al* 2008). It is not clear whether the impact is cumulative with decreases in the population occurring incrementally or if the first passes remove the most vulnerable individuals and those that remain are either new recruits or individuals that are more resistant due to factors such as burrow depth.

Nephrops maintain deeper burrows than *C. macandreae* (see the abrasion pressure section above) and this may confer greater resistance to activities that result in sub-surface penetration and disturbance. As described in section 4.15.2.II (removal of target species) no information regarding the proportion of a *Nephrops* population by harvesting activities was found. This evidence gap reflects the difficulty of conducting stock assessments of this species which can only be selectively harvested by trawls and static gears. No evidence is therefore available to quantify the impact of this pressure on *Nephrops*.

The **resistance** of *C. macandreae* (based on Olsgard *et al* 2008), to this pressure is assessed as **'Low'** (loss of 25-75% of exposed individuals). **Resilience** is assessed as **'Low'** (recovery within 10-25 years) and **sensitivity** is therefore **'High'**. This assessment **Resistance** of *Nephrops* (based on greater burrow depths) is assessed as **'Medium'** (loss of <25%) and **resilience** is assessed as **'Medium'** (recovery within 2-10 years). **Sensitivity** is therefore considered to be **'Medium'**. These assessments are largely based on expert judgement and should be applied with caution. The limitations regarding the resilience assessments are described in more detail in section 4.15.7.

Resistance (*C. macandreae*)

Quality of evidence is 'Low' - assessment is based on largely on expert judgement as the peer reviewed paper refers to higher trawling intensities than the pressure benchmark.
Applicability – 'Not assessed' - resistance assessment is based on expert judgement alone.
Concordance – 'Not assessed' - resistance assessment is based on expert judgement alone.

Resistance (*Nephrops*)

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

Resilience (C. macandreae and *Nephrops*)

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

IX. Change in suspended solids (water clarity)

No direct evidence was found to assess the sensitivity of this ecological group to changes in suspended solids. The eye of *Nephrops norvegicus* is well adapted to low levels of light at the sea bed and hence changes in clarity are unlikely to interfere with visual perception. *Nephrops norvegicus* emerge from burrows and due to adaptations to ambient light *Nephrops* in shallower waters emerge from burrows at dawn and dusk, whereas those from deeper waters emerge about midday (Ball *et al* 2000b). Alteration in light intensity due to turbidity may therefore alter emergence rhythms. Aréchiga and Atkinson (1975) reported that the burrowing activity of *N. norvegicus* is restricted to an optimum range of light intensity from about 10,000 to 10m-c (meter/candles) (equivalent to approximately, 10% to 0.001% of natural daylight).

Calocaris macandreae are considered to rarely emerge from the burrow system and to mostly feed on organic material within the burrow deposits. This species is therefore not impacted by changes in the water column that do not affect water or sediment chemistry and is considered **'Not sensitive'** to increased turbidity (by default resistance and resilience are considered to be **'High'**). Again, *Nephrops* only emerges for short periods of time, and so is protected from this pressure by the burrowing life habit. **Resistance** is therefore assessed as **'High'** based on its burrowing habit and **Resilience** is **'High'** (based on no impact to recover from) and the species is assessed as **'Not sensitive'**.

Resistance

Quality of evidence is 'Medium' – based on inferences made from biological and ecological species traits rather than direct evidence.
Applicability of evidence is 'Low' – the trait information is used as a proxy for the response.
Concordance of evidence is 'Not assessed' – based on a single source (species traits).

Resilience

Quality of evidence is 'High' - based on no impact to recover from.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

X. Habitat structure changes-removal of substratum (Extraction)

No direct evidence was found to assess the impacts of this pressure. Based on burrow depths (maximum depth 20cm for *Calocaris macandreae* and 30cm for *Nephrops norvegicus*, see abrasion pressure information) extraction is considered to disturb and remove the majority of the population. **Resistance** is assessed as **'None'** (removal of >75% of individuals) and **resilience** is assessed as **'Medium'** (2-10 years) for *Nephrops* and **'Low'** (10-25 years) for *C. macandreae*. **Sensitivity** is therefore assessed as **'Medium'** for *Nephrops* and **'High'** for *C. macandreae***.** The more rapid resilience assessment for *Nephrops* is based on the greater dispersal potential of this species through pelagic larvae to aid recolonisation. *C. macandreae* does not have a pelagic developmental phase restricting recolonisation where large spatial areas are impacted. It should be noted that these resilience assessments are based on expert judgement due to a lack of empirical evidence and targeted studies. The limitations and assumptions of the resilience judgements are described in more detail in 4.15.7.

Resistance

Quality of evidence is 'Medium' – based on expert judgment and on supporting information from peer reviewed and grey literature on habitat position.
Applicability of evidence is 'Low' – based on species traits as proxy for resistance.
Concordance of evidence is 'Not assessed' – based on proxy rather than direct evidence.

Resilience (C. macandreae and *Nephrops*) *(section 4.15.7)*

Quality of evidence is 'Low' – assessments are based on expert judgement
Applicability of evidence is 'Not assessed' - resilience assessments are based on expert judgement alone.
Concordance of evidence is 'Not assessed' - resilience assessments are based on expert judgement alone.

XI. Siltation rate changes, including smothering (depth of vertical sediment overburden

No evidence was found to assess this pressure at the benchmark for this ecological group. Sensitivity to this pressure is therefore 'Not assessed'.

4.15.5 Physical Loss (Permanent Change)

XII. Physical change (to another seabed type)

Species creating permanent burrows will typically have specific sediment requirements, relating to the maintenance of burrow structures. *Nephrops* has been shown to be more frequent in sandy-muds than muds off the southwest and south eastern grounds off Portugal (Daly & Mathieson 1977). In coarse, sandy sediments, population density is low because of the instability of the sediment and the tendency of burrows made in it to collapse. In medium-grained mud sediments, *Nephrops* are able to construct stable burrows, and population density peaks. In very fine-grained, soft muds, *Nephrops* excavate extensive burrow complexes, and competition for space is a limiting factor on population density (Afonso-Dias 1998).

This ecological group occurs in a relatively restricted range of sediment types, related to the burrowing life habit (and feeding for *C. macandreae*). The species are therefore considered to have **'Low' resistance** to a change in sediment type of one Folk class for a year. **Resilience** is assessed as **'Medium'** for *Nephrops* (within 2-10 years) and **'Low'** (10-25 years) for *C. macandreae*. The differing resilience scores mean that the **sensitivity** of *Nephrops* is assessed as '**Medium'** and the sensitivity of *C. macandreae* is assessed as **'High'**. Resilience rates are discussed in more detail in section 4.15.7.

Resistance

Quality of evidence is 'Medium' - based on inferences made from habitat distribution of both species rather than empirical evidence.
Applicability of evidence is 'Low' – based on a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on a single source (distribution records).

Resilience (C. macandreae and *Nephrops*) *(section 4.15.7)*

Quality of evidence is 'Low'- based largely on expert judgement.
Applicability of evidence is 'High' - based on no impact to recover from.
Concordance of evidence is 'High' - based on no impact to recover from.

4.15.6 Pollution and other chemical changes

XIII. Organic enrichment

No evidence was found to support this assessment. Neither species is likely to use organic matter deposited on sediments directly as a food source. *Calocaris macandreae* feeding methods are a somewhat unclear in relation to the presence of surface deposits outside of the burrow; the species seems to feed on matter from excavated or re-excavated areas within the burrow (Winter 1972; Moore 1977 and references therein). Benthic habitats may receive pulsed inputs of organic matter following phytoplankton blooms that provide a food source to the benthos and are re-mineralised. An enhanced food supply may support growth of prey species including crustaceans, polychaetes and molluscs utilised by *Nephrops norvegicus*, leading to a potentially beneficial indirect effect. It is not considered that deposits of organic matter (at the pressure benchmark) would have significant effects on this ecological group which are protected from indirect effects of siltation within burrows and are able to tolerate hypoxia (a potential indirect effect). **Resistance** is therefore assessed as **'High'** and **resilience** is assessed as **'High'** (no impact to recover from). This group is therefore considered to be '**Not Sensitive'**.

Resistance

Quality of evidence is ‘Low’ - assessment is based on expert judgement rather than empirical evidence and species traits do not relate directly to this pressure.
Applicability – ‘Not assessed’ - resistance assessment is based on expert judgement alone.
Concordance – ‘Not assessed’ - resistance assessment is based on expert judgement alone.

Resilience

Quality of evidence is ‘High’ - based on no impact to recover from.
Applicability of evidence is ‘High’ - based on no impact to recover from.
Concordance of evidence is ‘High’ - based on no impact to recover from.

4.15.7 Review of likely rates of recovery based on the species present within the ecological group

Buchanan (1963) examined the population dynamics of *Calocaris macandreae* off the Northumberland coast. The oldest individuals in that population appeared to be 9 years old and it was suggested that an age of almost ten years may be attained by a few (Doherty *et al* 2009). *C. macandreae* are hermaphrodites and eggs are produced at five years old. Around 50 eggs are attached to the pleopods and are carried for nine months until Sept-Oct of the sixth year. Annual moults follow but the next batch of eggs takes two years to mature and the second laying is at the end of the seventh year with occasionally a third at the end of the ninth year. Mortality of a year group is almost wholly confined to the ninth and tenth years (Theisen 1982).

No evidence was found for recovery rates following perturbations and assessing recovery is therefore problematic for *Calocaris macandreae*. As this is a species that may be locally abundant recovery from disturbance with a small spatial footprint is likely to occur through local reproduction and some (probably very limited) horizontal migration by adults. Due to the reported lack of a pelagic phase and the reduced number of eggs, dispersal potential is likely to be low. Recovery of a population requires that there is a local supply of benthic larvae to re-populate areas where populations have been removed or reduced. As this species is relatively long lived, recovery of the abundance and age structure of a significantly reduced population is considered to be prolonged. Resilience is therefore assessed as ‘Medium’ (2-10 years) where resistance is assessed as ‘Medium (loss of <25% of population) and Low’ (10-25 years) where resistance is categorised as ‘Low’ or ‘None’. As the recovery assessments are based on expert judgement, confidence in the quality of evidence is assessed as 'Low' and confidence is not assessed for applicability and concordance as these are not relevant to assessments based on expert judgement.

Nephrops norvegicus has a pelagic larval stage lasting up to 50 days (Johnson *et al* 2013; Powell & Eriksson 2013). While this may support long-range dispersal and recolonisation of depleted populations, water currents may prevent larvae reaching locations away from source populations and may remove larvae from populations preventing self-recruitment in small stocks (Johnson *et al* 2013). Recolonisation of depleted populations may also be limited by the requirement for existing burrows for successful recruitment (Tuck *et al* 1994, cited in Johnson *et al* 2013). Adults are essentially sedentary as tagging studies have revealed movements of no more than 100m from their burrow in adult life (Chapman & Rice 1971). Resilience is assessed as ‘Medium’ (2-10 years) although confidence in the quality of evidence for recovery is low as this assessment is based on expert judgement, taking into consideration the apparent long-term stability of *Nephrops* fishing grounds (Ungfors *et al* 2013).

In summary, recovery rates are likely to be dependent on the spatial scale of impact and the ability of adults to survive exposure and provide a potential supply of colonists (particularly for *C. macandreae* which lack a pelagic stage). The evidence from fishing grounds indicates that *N. norvegicus* can persist in areas where they are subject to targeted removal suggesting that the population can withstand and recover from repeated disturbances. However it is not clear what proportion of the population is removed and hence what the recovery rate to an undisturbed state would be.

4.15.8 Knowledge gaps

Nephrops norvegicus is an important commercial species and the fishery has provided impetus and funding to study this species. Much of the information available therefore relates to parameters that are relevant to fisheries management. Recent papers on the biology and ecology of *Nephrops* have been collected in a review volume (Johnson & Johnson 2013). In comparison to *Nephrops, Calocaris macandreae* is less studied.

In general, little is known regarding some of the key aspects of this ecological group including life history (particularly longevity), response to pressures and likely resilience. Studies of the ecology and sensitivity of this species are also compromised by the lack of undisturbed populations to provide a comparative baseline (Johnson *et al* 2013). Hence all assessments for this ecological group are subject to considerable uncertainty. In many instances the *Nephrops* fishery appears sustainable suggesting that populations can recover from the removal of a proportion of the population (Ungfors *et al* 2013).

Due to the lack of empirical evidence from targeted studies the resilience rates used in the sensitivity assessments were based largely on expert judgement. This is particularly the case where resistance is ‘None’ or ‘Low’. The dispersal potential of *C. macandreae* was considered to be low but there was no direct evidence to suggest how long recovery may take for significantly depleted populations.

No evidence was found to assess the hydrological pressures and the sensitivity assessments were developed based on distribution records. Similarly, there was no direct empirical evidence to assess sensitivity to organic enrichment. The response to abrasion, extraction and changes in sediment type were also inferred based species traits (position within sediment) and distribution records.

In summary, there is little direct evidence to support sensitivity assessment of this ecological group and the assessments should be applied with caution.

4.16 Ecological Group 10 Burrowing soft bodied species

4.16.1 Definition and characteristics of group including characteristic species

The soft-bodied burrowing species *Branchiostoma lanceolatum*, *Maxmuelleria lankesteri* and *Cerianthus lloydii* are taxonomically distinct and have some clear differences in life history and habitat preference (Table 4.16). *B. lanceolatum* for example is more mobile and is found in more unstable coarse sediments than the other, more sessile, species which are characteristic of stable habitats. This group is therefore not characteristic of a biotope type and is taxonomically disparate. However, these species were considered to form an ecological group based on burrowing life style and soft bodies (thus separating this group from ecological group 9 which have hard exo-skeletons. The sensitivity of all species is assessed in order to assess the range of sensitivities. As the distribution of *B. lanceolatum* does not overlap with the other species that are found muddy habitats the appropriate sensitivity assessment can be applied when required.

Table 4.16. List of biotopes in which ecological group 10 species occur as characterising species.

Level 5 biotopes represented	Key or characterising species assessed
SS.SCS.CCS.Blan	*Branchiostoma lanceolatum*
SS.SMu.CSaMu.VirOphPmax	*Cerianthus lloydii*
SS.SMu.CFiMu.SpnMeg	*Cerianthus lloydii*
SS.SMu.CFiMu.SpnMeg.Fun	*Cerianthus lloydii*
SS.SMu.CFiMu.MegMax	*Maxmuelleria lankesteri*
SS.SMx.CMx.ClloMx	*Cerianthus lloydii*
SS.SMx.CMx.ClloMx.Nem	*Cerianthus lloydii*
SS.SMx.CMx.ClloModHo	*Cerianthus lloydii*

4.16.2 Biological Pressures

I. Introduction or spread of non-indigenous species (NIS)

There is no evidence that non-indigenous species are present at, or having an adverse impact on, the habitats where this ecological group are found. This pressure is therefore not assessed, based on **'No evidence'**.

II. Removal of Target Species

This ecological group is not targeted by commercial fisheries and hence is not directly affected by this pressure. Members of this ecological group may be directly removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts are assessed under abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological effects resulting from the removal of target species on this ecological group. No obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial. No direct adverse effects on this ecological group are therefore predicted to arise from this pressure and this group is considered to be **'Not Exposed'** to targeted removal of the ecological group and **'Not Sensitive'** (to the ecological effects only) of targeted removal of other species.

Resistance

Quality of evidence is 'Medium' – based on ecological and life history information.
Applicability of evidence is 'Low' - based on general ecology rather than pressure specific

information.
Concordance of evidence is ‘Not assessed’ - as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

III. Removal of Non-Target Species

Members of this ecological group may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration of the seabed pressures (section 4.16.4). The sensitivity assessment for this pressure considers any biological effects resulting from the removal of non-target species on this ecological group. No obligate life-history or ecological associations were identified and this ecological group is considered to be ‘**Not Sensitive’.** By default, **resistance** and **resilience** are therefore assessed as **‘High’.**

Resistance

Quality of evidence is ‘Medium’ - the assessment is based on ecological and life history information.
Applicability of evidence is ‘Low’ as the assessment for resistance is based on general ecology rather than pressure specific information.
Concordance of evidence is ‘Not assessed’ as no specific evidence is drawn on for this assessment.

Resilience

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

4.16.3 Hydrological Changes (inshore/local)

IV. Salinity changes - local

No evidence could be found for osmoregulation by *Cerianthus lloydii* and *Maxmuelleria lankesteri*. Binyon (1979) suggested that *Branchiostoma lanceolatum* was a stenohaline invertebrate capable of withstanding limited dilution of its environment, but being unable to control the osmotic pressure of its body fluids.

Based on the lack of reports of *Cerianthus lloydii* and *M. lankesteri* in areas of low or varying salinity and the inability of *Branchiostoma lanceolatum* to osmoregulate these species are considered to be restricted to fully marine environments and are judged to have **‘No’ resistance** to a decrease in salinity at the pressure benchmark. **Resilience** (following restoration to full salinity) is assessed as **‘Medium’** (2-10 years) as recruitment may be episodic or slow. The resilience assessment is based on limited information regarding species traits and ecology as no empirical evidence was available in relation to this pressure. Information gaps and assumptions regarding the resilience assessments for this ecological group are described in section 4.16.7. **Sensitivity** is therefore assessed as **‘Medium’.**

Resistance

Quality of evidence is 'Medium' – the assessment is based largely on inferences from habitat distribution of species and a single, peer reviewed paper for *B. lanceolatum*.
Applicability of evidence is 'Low' – the assessment is based largely on a proxy (habitat distribution) for resistance.
Concordance of evidence is 'Not assessed' – based on a single source (distribution records).

Resilience (section 4.16.7)

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

V. Temperature changes - local

No information on temperature tolerances was found for members of this ecological group and the assessment is based on reported global distribution as follows:

- *Branchiostoma lanceolatum:* Widely distributed along Northeast Atlantic coasts, from northern Norway (67°N) to the Mediterranean Sea and Black Sea (may be absent from the Atlantic Spanish coasts). Entered in the Indian Ocean after passage through the Suez Canal; widely distributed in the northern Indian Ocean and tropical South western Indian Ocean along the East African coast (Marine Species Information Portal)

- *Cerianthus lloydii*: Adults are locally abundant in many localities on all coasts of the British Isles and in some areas are common on the shore. This species occurs on all western coasts of Europe from Greenland and Spitzbergen south to Biscay. Larvae, but not adults, have been recorded from the Mediterranean (Marine Species Information Portal)

- *Maxmuelleria lankesteri*: Kattegat, Skagerrak, Irish Sea and west Scotland (Marine Species Information Portal).

The distribution records for *M. lankesteri* indicate that the species reaches its southern limit in west Scotland (although this may relate to factors other than temperature) suggesting this species may be intolerant of an acute or chronic increase in temperature. **Resistance** to either a chronic increase or a short term acute increase in temperature is assessed as **'Low'. Resilience** (following habitat recovery) is assessed as **'Medium'** (2-10 years) based on life-history traits as described in 4.16.7. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance (*M. lankesteri*)

Quality of evidence is 'Medium' – this pressure has not been the focus of targeted studies and the assessment of resistance is based on inferences made from geographic distribution.
Applicability of evidence is 'Low' – the assessment is based largely on a proxy (habitat distribution) for resistance.
Concordance of evidence is 'Not assessed' – based on a single source (distribution records).

Resilience (*M. lankesteri*) *(section 4.16.7)*

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

judgement.
Concordance of evidence is ‘Not assessed’ - the assessments are based on expert judgement.

Overall, short term acute or long term chronic changes in temperature at the pressure benchmark are considered unlikely to adversely affect *B. lanceolatum* and *C. lloydii* as the distribution records suggest these species can potentially adapt to a wide range of temperatures experienced in both northern and southern waters. **Resistance** is therefore assessed as **‘High’** and resilience as **‘High’.** This group is therefore considered to be **‘Not Sensitive’.**

Resistance (*B. lanceolatum and C. lloydii*)

Quality of evidence is ‘Medium’ – this pressure has not been the focus of targeted studies and the assessment of resistance is based on inferences made from geographic distribution.
Applicability of evidence is ‘Low’ – the assessment is based largely on a proxy (habitat distribution) for resistance.
Concordance of evidence is ‘Not assessed’ – based on a single source (distribution records).

Resilience (*B. lanceolatum and C. lloydii*)

Quality of evidence is ‘High’ – based on no impact to recover from.
Applicability of evidence is ‘High’ – based on no impact to recover from.
Concordance of evidence is ‘High’ – based on no impact to recover from.

VI. Water flow (tidal current) changes - local

No evidence was found to assess this pressure for this ecological group.

VII. Wave exposure changes - local

No evidence was found to assess this pressure for this ecological group.

4.16.4 Physical Damage (Reversible Change)

VIII. Abrasion/disturbance of the substratum on the surface of the seabed

No direct evidence was found to assess the sensitivity of this ecological group to surface abrasion. The burrowing life habit of the species specifically assessed would confer some protection from surface disturbance although individuals would be more exposed when close to the surface feeding. *Cerianthus lloydii* inhabits a soft tube, which can be up to 40cm long and is permanently buried. The anemone can move freely within the tube and can retract swiftly if required. The lancelet, *Branchiostoma lanceolatum* is usually partially buried in the sand filtering microscopic food particles from the water (Riisgard & Svane 1999). *Maxmuelleria lankesteri* inhabits a burrow that extends up to 80cm deep in the sediment although the mean depth of cast burrows was 42cm (Nickell *et al* 1995a).

As members of this ecological group inhabit tubes or burrows that provide some protection, **resistance** is assessed as **‘Medium’** (<25% mortality). **Resilience** is assessed as **’Medium’** (recovery 2-10 years) and **sensitivity** is therefore assessed as **‘Medium’.** The information available to assess resilience is limited, as discussed in section 4.16.7. No empirical evidence was found for recovery rates of *M. lankesteri* and *C. lloydii*. It is considered that recruitment may be episodic and that restoration of biomass may require a number of years.

Resistance

Quality of evidence is 'Medium' - the assessment is based on expert judgement but supported by information on movements and burrow depth.
Applicability of evidence is 'Low'- the assessment is based on proxies (species traits) rather than pressure information.
Concordance of evidence is 'Not assessed' as information on traits rather than pressures is used and the assessment is not supported by multiple sources with relevance to pressure impacts.

Resilience (section 4.16.7)

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

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

No direct evidence for the sensitivity of this ecological group to abrasion and penetration of the seabed below the surface was found. The only indirect evidence comes from Strangford Lough, Ireland, where dive surveys suggested that *Cerianthus lloydii* had increased in abundance after a 10 year period of increased trawling, in comparison with surveys prior to increased disturbance (Strain *et al* 2012). No information was found for rates of damage, exposure or by-catch. Hughes *et al* (1996) note that *Maxmuelleria lankesteri* collected using sampling gear or divers were 'rarely collected in an undamaged state' suggesting that these animals are not robust. All members of this ecological group are soft-bodied and would be likely to be damaged by physical impacts.

The burrowing life habit of the species specifically assessed would confer some protection from surface and shallow disturbance. *Cerianthus lloydii* inhabits a soft tube, which can be up to 40cm long and is permanently buried. The anemone can move freely within the tube and can retract swiftly if required. The lancelet, *Branchiostoma lanceolatum* is usually partially buried in the sand filtering microscopic food particles from the water (Riisgard & Svane 1999). *Maxmuelleria lankesteri* inhabits a burrow that extends up to 80cm deep in the sediment although the mean depth of cast burrows was 42cm (Nickell *et al* 1995). Individuals may however be more exposed when close to the surface feeding. Hughes *et al* (1996) noted that individuals of *Maxmuelleria lankesteri* collected in the field appeared unable to rebury in sediment filled aquaria. Displaced animals may therefore be unable to re-establish burrows exposing them to predation.

Based on expert judgement, **resistance** is assessed as **'Low'** (loss of 25-75% of individuals) and **resilience** as **'Medium'** (recovery within 2-10 years). The resilience assessment is based on expert judgement supported by information on species traits as described in section 4.16.7. It is considered likely that recruitment rates may vary and be episodic and that a number of years may be required for biomass to be restored. **Sensitivity** is therefore assessed as **'Medium'**.

Resistance

Quality of evidence is assessed as 'Medium' - this assessment uses expert judgement but is based on supporting information on burrow depth and movement from peer reviewed literature.

Applicability of evidence is 'Low' - the species traits are used a proxy for resistance.
Concordance of evidence is 'Not assessed' - the resistance assessment is based on a proxy rather than direct evidence.

Resilience (section 4.16.7)

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

X. Change in suspended solids

No empirical evidence was found regarding the effects of turbidity on members of this ecological group. The soft-bottom habitats where this group are found may experience periodic high levels of suspended particles and the burrowing habit of these species may mediate exposure. Increased organic matter in suspension or that is subsequently deposited may enhance food supply to this group and the feeding apparatus of this group are considered more robust than the more delicate structures of, for example, filter feeding molluscs, although no evidence was found regarding the likelihood of clogging. **Resistance** is therefore assessed as **'High'** and **resilience** as **'High'** (no effect to recover from). This group is therefore assessed as **'Not Sensitive'.**

Resistance

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

Resilience

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

XI. Habitat structure changes - removal of substratum (Extraction)

No direct evidence was found to assess the impacts of this pressure. *Cerianthus lloydii* inhabits a soft tube, which can be up to 40cm long and is permanently buried. The anemone can move freely within the tube and can retract swiftly if required. The lancelet, *Branchiostoma lanceolatum* is usually partially buried in the sand filtering microscopic food particles from the water (Riisgard & Svane 1999). *Maxmuelleria lankesteri* inhabits a burrow that extends up to 80cm deep in the sediment although the mean depth of cast burrows was 42cm (Nickell *et al* 1995).

Resistance is assessed as **'Low'** (removal of 25-75% of individuals) as some species may escape either through mobility (*B. lanceolatum*) or through burial depth (*C. lloydii* and *M. lankesteri*) and **resilience** is assessed as **'Medium'** (2-10 years). No direct evidence was found to assess recovery. A Mediterranean population of *B. lanceolatum* exposed to dredging recovered rapidly (within one year - see section 4.16.7). However, the relevance of this study to UK populations was not clear. The evidence limitations and assumptions regarding the resilience assessment are discussed further in section 4.16.7; as recruitment may be episodic and species relatively long-lived and slow growing recovery was considered to require 2-10 years. **Sensitivity** is therefore assessed as **'Medium'.**

Resistance

Quality of evidence is 'Medium' - the assessment uses expert judgement but is based on supporting information on burrow depth and movement from peer reviewed literature.
Applicability of evidence is 'Low' - the species traits are used a proxy for resistance.
Concordance of evidence is 'Not assessed' as the resistance assessment is based on a proxy rather than direct evidence.

Resilience

Quality of evidence is 'Low'- as the assessment is based on expert judgement.
Applicability of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.
Concordance of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.

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

B. lanceolatum are not found in silty sediments and as the pressure benchmark refers explicitly to fine sediments this species may be unsuited to burrowing through the deposited overburden which would be different in composition to its usual habitat. *C. lloydii* can move rapidly within its tube but no information was found for the ability of this species to extend the tube through a 30cm deposit of sediment to reach the surface. Hughes *et al* (1996) note that individuals of *M. lankesteri* collected in the field appeared unable to rebury in sediment filled aquaria, this species may therefore have limited abilities to burrow through an overburden of 30cm.

Based on general body form and the points raised above **resistance** was assessed as **'None'** and **resilience** as **'Medium'**. **Sensitivity** is therefore assessed as **'Medium'.** The information available to assess resilience is limited, as discussed in section 4.16.7. No empirical evidence was found for recovery rates of *M. lankesteri* and *C. lloydii*. It is considered that recruitment may be episodic (Hughes *et al* 1996) and that restoration of biomass may require a number of years.

Resistance

Quality of evidence is 'Medium' - the assessment uses expert judgement but is based on supporting information on burrow depth and movement from peer reviewed literature.
Applicability of evidence is 'Low' as the species traits are used a proxy for resistance.
Concordance of evidence is 'Not assessed' - the resistance assessment is based on a proxy rather than direct evidence.

Resilience

Quality of evidence is 'Low' - the assessment is based on expert judgement.
Applicability of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.
Concordance of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.

4.16.5 Physical Loss (Permanent Change)

XIII. Physical change (to another seabed type)

The introduction of artificial hard substratum is not considered at the pressure benchmark level (which refers to changes in sedimentary classification). However, it is noted that this ecological group is not able to colonise artificial hard substratum and the introduction of this would reduce the extent of suitable habitat.

Records from the MNCR database were used as a proxy indicator of the resistance to physical change by this ecological group (see section 3.2.3 for caveats). The recorded substratum types for biotopes characterised by members of this ecological group follow.

- *Branchiostoma lanceolatum*: medium to coarse sand with some gravel or shell gravel (1 record).

- *Cerianthus lloydii*: mud; shelly and gravelly mud; fine to very fine muddy sand; mixed muddy sand with gravel, pebbles and cobbles; fine to very fine sand with a fine silt fraction; sandy mud; sandy muddy gravel; pebble; mixed sediment; clean fine sands; gravel and shells on sandy mud sediments; very coarse sand with a finer sand fraction; stony mixed sediment; gravel and coarse sand with some pebbles; muddy maerl gravel; boulders; cobbles; pebbles.

- *Maxmuelleria lankesteri*: mud and mixed sediment (1 record).

A change in classification of one Folk class (based on the Long 2006 classification) between mixed sediments, muddy sands and sandy muds is not predicted to negatively affect *C. lloydii* which is found in a range of sedimentary types. **Resistance** is therefore assessed as **'High'** and **Resilience** as **'High'** (no impact to recover from). This species is therefore assessed as '**Not Sensitive'**.

Resistance (*C. lloydii*)

Quality of evidence is 'Medium' – based on inferences made from biotope records and habitat preferences.
Applicability of evidence is 'Low' – based on habitat preferences as a proxy for resistance.
Concordance of evidence is 'Not assessed' – based on habitat preferences alone source.

Resilience (*C. lloydii*)

Quality of evidence is 'High' – based on no impact to recover from.
Applicability of evidence is 'High' – based on no impact to recover from.
Concordance of evidence is 'High' – based on no impact to recover from.

M. lankesteri and *B. lanceolatum* each appear to occur in a relatively restricted range of sediment types, related to burrowing, feeding and other characteristics. The species are therefore considered to have **'Low' resistance** (loss of 25-75% of population) to a change in sediment type of 1 Folk class for a year. **Resilience** is assessed as **'Medium'** (**2-10 years** following habitat recovery) based on episodic recruitment (Hughes *et al* 1996) and slow growth rates of *M. lankesteri*. The empirical evidence to assess recovery rates is extremely limited and this estimate of resilience is based on considerations outlined in the recovery section 4.16.7). It is noted that the resilience assessment may be relatively precautionary for *B. lanceolatum* (as described in section 4.16.7). **Sensitivity** is therefore assessed as **'Medium'**.

Resistance (*M. lankesteri* and *B. lanceolatum*)

Quality of evidence is 'Medium' – the assessment is based on inferences made from biotope records for both species rather than empirical evidence.
Applicability of evidence is 'Low' – assessment is based on a proxy for resistance (biotope records).
Concordance of evidence is 'Not assessed' – the assessment is based on a single source (biotope records).

Resilience (*M. lankesteri* and *B. lanceolatum*)

Quality of evidence is 'Low'- as the assessment is based on expert judgement.
Applicability of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.
Concordance of evidence is 'Not assessed' - as this category is not relevant when expert judgement alone is used.

4.16.6 Pollution and other chemical changes

XIV. Organic enrichment

No evidence was found to assess this pressure for *Branchiostoma lanceolatum* and *Maxmuelleria lankesteri*. *M. lankesteri* feeds by skimming detritus off the sediment surface by extending its single proboscis from the burrow opening. The species is found in organic rich muds, particularly among the sea lochs of western Scotland (Hughes *et al* 1993). In muds inhabited by this species in Loch Sween organic content is 3.5-4% (Hughes *et al* 1994; Nickell *et al* 1995b).

Borja *et al* (2000) and Gittenberger and van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI) index to assess disturbance (including organic enrichment) both assigned *Cerianthus lloydii* to their Ecological Group I, (species very sensitive to organic enrichment and present under unpolluted conditions (initial state). The basis for their assessment and relation to the pressure benchmark is not clear.

Maxmuelleria lankesteri is probably '**Not sensitive'** to organic enrichment at the benchmark level, since it occurs in areas of high organic content. However, the evidence of the other members of the group is uncertain. Therefore, no assessment has been made for this ecological group **('No evidence').** When species are suggested by the AMBI categorisation to be sensitive to enrichment, as *C. lloydii* is, it is unclear how this relates to the pressure benchmark which is relatively precautionary and is interpreted as relating to enrichment rather than pollution see section 3.1.3.VII.

4.16.7 Review of likely rates of recovery based on the species present within the ecological group

Little evidence was found to support recovery assessments for this ecological group. Previous trait reviews (MES 2010) have suggested that the genus *Cerianthus* would be likely to have a low recovery rate following physical disturbance based on long-life span and slow growth rate suggesting that recovery of biomass and age-structured populations will be relatively slow (MES 2010). No specific evidence was cited to support this conclusion. The MES (2010) review also highlighted that there were gaps in information for this species and that age at sexual maturity and fecundity is unknown although the larvae are pelagic. As this species is relatively common and occurs in a range of habitat types which suggests that in many areas there is some larval supply, resilience is assessed as 'Medium' (recovery within

2-10 years). There is no information regarding inter-connectivity between populations or other facets of recruitment.

Sarda *et al* (2000) reported that recolonisation of dredged shallow soft bottoms (10 to 30m depth) off the Tordera River (Catalonia) was rapid. Density values rose sharply during the following spring and autumn with exceptionally large numbers of *Branchiostoma lanceolatum* recorded**.** This evidence suggests that recolonisation of disturbed habitats by *B. lanceolatum* can be rapid and recovery potential may be high. However, the applicability of recovery rates from Mediterranean to UK populations is unclear.

Hughes *et al* (1996) suggest that recruitment may be sparse and infrequent for *M. lankesteri* and that direct development is the most likely mechanism rather than a pelagic larval stage. Dispersal potential is therefore low which will support recruitment from local populations where a proportion of the breeding population is unimpacted but inhibit recovery where the population is removed or significantly depleted (threshold is not clear).

No empirical evidence was found for recovery rates following perturbations for *Maxmuelleria lankesteri* and *Cerianthus lloydii*. Unlike *B. lanceolatum* these species have limited horizontal mobility and recolonisation via adults is unlikely.

Branchiostoma is likely to recruit as adults from surrounding habitats due to its mobility (ca 2 years) while *Maxmuelleria* may exhibit local recruitment via direct development but be slow growing (ca 10 years to recover). Recovery of *C. lloydii* from severe perturbations that remove much of the local populations will rely on successful recruitment of pelagic larvae (potential recovery rate unclear). Recovery of the Ecological Group is assessed as 'Medium' (2-10 years) where resistance is assessed as 'Low' or 'Medium' (loss of <25% of population or 25-75%). This assessment may be relatively precautionary for *B. lanceolatum* based on (Sarda *et al* 2000), however recovery rates shown by populations in lower latitudes may be different to populations in UK waters and the observation has therefore been treated with caution. As the recovery assessments are based largely on expert judgement, confidence in the quality of evidence is assessed as 'Low' (unless resistance is 'High') and confidence is not assessed for applicability and concordance as these are not relevant to assessments based on expert judgement.

4.16.8 Knowledge Gaps

Members of this ecological group are not of particular economic or conservation interest and have not been the subject of extensive study. *Branchiostoma lanceolatum* has been better studied than other members of the group as it is of biological interest; however the ecology of this species has received less attention. For *Maxmuelleria lankesteri*, in particular, there was very little information available, this species has been the focus of targeted ecological studies but has a restricted distribution and is difficult to observe and capture.

Little is known of key aspects of this ecological group including longevity, growth rates and recruitment. No empirical evidence was found to assess the impact of any of the assessed pressures. The sensitivity assessments for this ecological group are therefore based on information on species traits or distribution records and are subject to considerable uncertainty.

In summary, there is little direct evidence to support sensitivity assessment of this ecological group and the resilience and resistance assessments should be applied with caution.

5 Application of sensitivity assessments – assumptions and limitations

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

5.1 Key points

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

- The sensitivity assessments are generic and NOT site specific. They are based on the likely effects of a pressure on a 'hypothetical' population in the middle of its 'environmental range'[9].
- Sensitivity assessments are NOT absolute values but are relative to the magnitude, extent, duration and frequency of the pressure effecting the species or community and habitat in question; thus the assessment scores are very dependent on the pressure benchmark levels used.
- The assessments are based on the magnitude and duration of pressures (where specified) but do not take account of spatial or temporal scale.
- The significance of impacts arising from pressures also needs to take account of the scale of the features.
- The sensitivity assessment methodology takes account of both resistance and resilience (recovery). Recovery pre-supposes that the pressure has been alleviated but this will generally only be the case where management measures are implemented.
- There are limitations of the scientific evidence on the biology of features and their responses to environmental pressures on which the sensitivity assessments have been based.

5.2 Generic nature of assessments

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

5.3 Sensitivity of assessment scores to changes in pressure levels

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

[9] 'Environmental range' indicates the range of 'conditions' in which the species or community occurs and includes habitat preferences, physio-chemical preferences and, hence, geographic range.

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

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

5.3.1 Spatial and temporal scale of pressures

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

5.3.2 Scale of features relative to scale of pressures

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

5.4 Assumptions about recovery

The sensitivity assessment methodology takes account of both resistance and resilience (recovery). Recovery is assumed to have occurred if a species population and/or habitat returns to a state that existed prior to the impact of a given pressure, not to some hypothetical pristine condition. Furthermore, we have assumed recovery to a 'recognisable' habitat or similar population of species, rather than presume recovery of all species in the community and/or total recovery to prior biodiversity.

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

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

5.5 Limitations of scientific evidence

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

5.5.1 Biology of species and habitat features

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

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

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

5.5.2 Understanding the Effects of Pressures

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

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

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

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

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

5.6 Use of confidence scores

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

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

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

5.7 Limitations – general

It follows from the above, that the sensitivity assessments presented are general assessments that indicate the likely effects of a given pressure (likely to arise from one or more activities) on species or habitats of conservation concern. They need to be interpreted within each region against the range of activities that occur within that region and the habitats and species present within its waters.

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

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

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

Similarly, all assessments are made based 'on the level of the benchmark'. Therefore, a score of '**not sensitive' does not mean that no impact is possible** from a particular 'pressure vs. feature' combination, only that a limited impact was judged to be likely at the specified level of the benchmark. It is particularly true of the pollution (contaminant) benchmark, which are set to Water Framework Directive compliant levels so that all features are 'not sensitive' by definition. However, this does not mean that feature are 'not sensitive' to accidental spills, localised discharges or other pollution incidents.

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

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

6 Sources of uncertainty – knowledge gaps and expert judgement

Sensitivity assessment, like all 'assessment' methodologies such as Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA) and others, is designed to collate available evidence, and balance uncertainty and gaps in that evidence, in order to provide a basis for decision making. The chosen sensitivity assessment approach provides a systematic approach for the collation of existing evidence to assess resistance, resilience (recovery) and hence sensitivity to a range of pressures that may result from human activities or natural events. Nevertheless, the evidence base itself is incomplete both in relation to the biology of the features and understanding of the effects of human pressures. Hence, a degree of expert judgement is often required to make assessments.

The main sources of uncertainty and gaps in knowledge were:

- lack of understanding on the response of species, communities and habitats to pressures;

- lack of detailed evidence compared to the benchmark level of effect for specific pressures; and

- lack of understanding of the biology, life history and population dynamics of species (or ecological groups of species) and how that influences both the effects of pressures and, especially, the ability of the species population to recovery from any effects.

6.1 Understanding the effects of pressures

There are significant limitations in understanding of the effects associated with some of the pressures. As a result, several were excluded from the assessment at the beginning of the review.

- There is a paucity of research concerning the effects of underwater noise on marine invertebrates. While it is generally believed that invertebrates are relatively insensitive to these pressures, compared to other marine receptors such as marine mammals and fish, the evidence base for this is poor (Tasker *et al* 2010).

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

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

- There is very limited information on the effects of the introduction of light on marine invertebrates. Tasker *et al* (2010) excluded this pressure when developing indicators relating to the introduction of energy for the purposes of the Marine Strategy Framework Directive 'due partly to their relatively localised effects, partly to a lack of knowledge and partly to lack of time to cover these issues'.

- Radionuclide contamination is often detected and bioaccumulation noted in some species (Cole *et al* 1999) but information on specific effects is limited.

- The effects of more recent pollutants such as nano-particulates on marine species continue to be studied, while novel endocrine disruptors have been shown to affect inshore shellfish and depress reproduction (Langston *et al* 2007), but information on population effects is lacking.

In addition, there was limited evidence on the effects of non-indigenous species on subtidal habitats. Although *Crepidula fornicata* was probably the most relevant and some evidence was found, impacts from other non-natives were either not relevant in the subtidal, or were not documented.

Clearly, the evidence base for these pressures will grow and the ability to assess sensitivity will need to be re-evaluated.

6.2 Comparing evidence to the pressure benchmark

A major source of uncertainty and hence 'lack of confidence' in the assessments was caused by the disparity between the evidence about the effects of pressures and the level of effect described by the pressure benchmark.

- The pressure benchmark for 'microbial pathogens' concentrated on shellfish diseases, rather than other disease and pests, and became only relevant to commercial shellfish, and could not be applied to other species.

- Evidence for physical pressures such as abrasion or penetration was obtained primarily from fisheries impact literature, where there has been considerable study and review. However, the benchmark levels of effect are broad and can result from numerous fishing gear types, from bottom trawls to hydraulic dredges, to pots, creels, and any activity that physically sits on or passes across the seabed. As a result, the exact nature of the activity assessed varied between assessment and between ecological groups. In addition, many of the best studies were experimental studies that may or may not be directly applicable to the effects of fisheries in the marine environment.

- The effects of hydrology (water flow, wave exposure), are well studied and well understood for many species and habitats. But there was a disparity between the evidence and benchmarks because of the way in which the wave action and/or water flow are expressed. For example, many studies may address wave exposure and height on the shore or shelter from wave exposure in general terms, they are rarely defined in MNCR terms, as are the habitat preferences of the species expressed in biotopes. In particular, the benchmark for wave exposure was expressed as a change in wave height, which is not directly comparable to standard MNCR terms of wave exposure or shelter. In addition, detailed studies of the effects of water flow on marine species are limited to a few particular species. Hence, assessments on the effects of changes in hydrology were based on general habitat preferences and sediment characteristics.

- Many, studies record species from 'muds' or 'gravel' but few define these terms in strict BGS, Folk (Long 2006) or MNCR terms, so interpretation is required to base an assessment on the habitat preferences of the species within the ecological group under assessment.

- Similarly, there is detailed information on habitat preferences, e.g. siltation rate (turbidity), temperature and salinity for a number of species, but these are limited to those that can be studied in laboratory conditions. While detailed studies are lacking for many other, so that reactions to changes in temperature and salinity must be inferred from species distribution and or habitat characteristics.

- Even where the effects of a given pressure are well studied, e.g. organic enrichment, it was difficult to relate directly to the benchmark (expressed in mgC/l), in all but a few cases.

6.3 Biology, life history and population dynamics of species

There is a lack of basic biological knowledge about many common and ecologically important benthic invertebrates (Tyler *et al* 2011). Commercial, charismatic and experimental model species have been well studied (e.g. oysters, mussels, shrimp, crabs, corals), and yet little is known about otherwise common species (e.g. many polychaetes, cnidarians, sponges, echinoderms) where an understanding of their biology is often inferred from a relatively small number of the species in the group.

Information on population dynamics and life history characteristics - vital for assessing recruitment, recovery and resilience - are lacking. For example, the life history (e.g. larval ecology) of species such as *Eunicella verrucosa*, *Atrina pectinata* and *Leptopsammia pruvoti*, and hence their recruitment and potential recovery rates, are poorly known. Even where life histories are well known and recovery rates might be expected to be good (due to highly dispersive and numerous larvae), other factors influence their recovery. For example, native oyster and horse mussel have not recovered from past losses due to a multitude of factors including poor recruitment, high juvenile mortality, continued impact, or loss of (or competition for) habitat. Yet studies of the effects of aggregate dredging, fishing and artificial substrata (e.g. wrecks, oil rigs, artificial reefs) have proved to be invaluable insights into recruitment and colonisation. In most cases, such studies examine a wide range of species simultaneously and information on the species or ecological groups of interest has to be gleaned from a variety of sources.

Deep sea species and habitats have generally been less well studied than those in coastal areas and information both on their biology and their response to human pressures is limited.

As a result, many of the resilience estimates have to be based on general information on recruitment in entire groups (e.g. echinoderms or bivalves), or members of the same family (e.g. polychaetes). Alternatively, resilience is inferred from larval characteristics, where short-lived benthic larvae are presumed to have poor dispersal and hence poor recruitment potential, while long-lived pelagic larvae are thought to have good recruitment potential. Although, there are always exceptions, such as bivalves, e.g. mussels *Mytilus* and *Modiolus* where populations could recruit annually, but where observed recruitment is unpredictable and often prolonged (see Olafsson *et al* 1994; Tyler-Walters *et al* 2009).

The confidence assessments made throughout the sensitivity assessment process were designed to demonstrate the source of the uncertainty in the evidence and the degree of expert judgement and interpretation required to make an assessment. For example, ‘High’ quality evidence may still not be directly applicable to the assessment, and excellent evidence may disagree.

7 Conclusions

The Tillin *et al* (2010) sensitivity assessment methodology was modified to use the best available scientific evidence. An extensive literature review was compiled to examine current understanding about the effects of pressures from human activities on circalittoral and offshore sedimentary communities in UK continental shelf waters, together with information on factors that contribute to resilience (recovery) of marine species. This review formed the basis of an assessment of the sensitivity of the sixteen ecological groups identified in Phase 1 of the project (Tillin & Tyler-Walters 2014).

As a result:

- the state of knowledge on the effects of each pressure on circalittoral and offshore benthos was reviewed;

- the resistance, resilience and, hence, sensitivity of sixteen ecological groups, representing 96 characteristic species, were assessed for eight separate pressures;

- each assessment was accompanied by a detailed review of the relevant evidence;

- knowledge gaps and sources of uncertainty were identified for each group;

- each assessment was accompanied by an assessment of the quality of the evidence, its applicability to the assessment and the degree of concordance (agreement) between the evidence, to highlight sources of uncertainty as an assessment of the overall confidence in the resilience and resistance scores underpinning each sensitivity assessment, and finally

- limitations in the methodology and the application of sensitivity assessments were outlined.

This demonstrated that the ecological groups identified in Phase 1 (Tillin & Tyler-Walters 2014) were viable groups for sensitivity assessment, and could be used to represent the 33 circalittoral and offshore sedimentary biotopes identified at the beginning of the project.

The results of the sensitivity assessments show:

- the majority of species and hence ecological groups in sedimentary habitats are sensitive to physical change, especially loss of habitat and sediment extraction, and change in sediment type;

- most sedimentary species are sensitive of physical damage, e.g. abrasion and penetration, although deep burrowing species (e.g. the Dublin Bay prawn - *Nephrops norvegicus* and the sea cucumber - *Neopentadactyla mixta)* are able to avoid damaging effects to varying degrees, depending on the depth of penetration and time of year;

- changes in hydrography (wave climate, tidal streams and currents) can significantly affect sedimentary communities, depending on whether they are dominated by deposit, infaunal feeders or suspension feeders, and dependant on the nature of the sediment, which is itself modified by hydrography and depth;

- sedentary species and ecological groups that dominate top-layer of the sediment (shallow burrowing) or are epifauna, remain the most sensitive to physical damage;

- mobile species (e.g. interstitial and burrowing amphipods, and perhaps cumaceans) are the least sensitive to physical change or damage, and hydrological change as they are already adapted to unstable, mobile substrata;

- sensitivity to changes in organic enrichment and hence oxygenation, is variable between species and ecological groups, depending on the exact habitat preferences of the species in question, although most species are at least of medium sensitivity to acute deoxygenation;

- there is considerable evidence on the effects of bottom fisheries and aggregate dredging on sedimentary communities, although not all evidence is directly applicable to every ecological group;

- there is lack of detailed information on the physiological tolerances (e.g. to oxygenation, salinity, and temperature), habitat preferences, life history and population dynamics of many species, so that inferences has been made from related species, families, or even the same phylum;

- there was inadequate evidence to assess the effects of non-indigenous species on most ecological groups, and

- there was inadequate evidence to assess the effects of electromagnetic fields and litter on any ecological group.

The resultant report provides an up-to-date review of current knowledge about the effects of pressures resulting from human activities of circalittoral and offshore sedimentary communities. It provides an evidence base to facilitate and support the provision of management advice for Marine Protected Areas, development of UK marine monitoring and assessment, and conservation advice to offshore marine industries.

However, such a review will require at least annual updates to take advantage of new evidence and new research as it becomes available. Also further work is required to test how ecological group assessments are best combined in practice to advise on the sensitivity of a range of sedimentary biotopes, including the 33 originally examined and others.

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9 Acronyms

AMBI - AZTI Marine Biotic Index

ASFA - Aquatic Sciences and Fisheries Abstracts

AZTI - Tecnalia is an expert technology centre in marine and food research

BENTIX - BENthic IndeX

DEPOMOD - DEPOsitional MODel

FEAST – Feature Activity Sensitivity Tool - http://www.scotland.gov.uk/Topics/marine/marine-environment/FEAST-Intro

GBNNSIP - Great British Non-native Species Information Portal (http://www.nonnativespecies.org/)

ICG-C - Intercessional Correspondence Group on Cumulative Effects

LD_{50} – Lethal Dose at 50% percentile.

MarLIN – Marine Life Information Network (www.marlin.ac.uk)

MCZ – Marine Conservation Zone

NIS - Non-indigenous Species

NMBL - National Marine Biological Library (http://www.mba.ac.uk/NMBL/)

OBIS - Ocean Biogeographic Information System (www.iobis.org)

OSPAR – Oslo and Paris Commission

SPM – suspended particulate matter

Appendix 1 - Sensitivity assessment methodology

Introduction

The UK Review of Marine Nature Conservation (Defra 2004) defined sensitivity as 'dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery'. Sensitivity can therefore be understood as a measure of the likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience). The concepts of resistance and resilience are widely used in this way to assess sensitivity.

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

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

- The Marine Life Information Network (MarLIN) developed an approach to sensitivity assessment based on species tolerance and ability to recover from pressures (Hiscock & Tyler-Walters 2006; Tyler-Walters *et al* 2009). Based on this methodology detailed assessments are available on-line[10] for a number of biotopes and species.

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

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

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

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

To facilitate the assessment of features, pressure definitions and benchmarks were established. Pressure definitions and associated benchmarks were supplied by JNCC for each of the pressures that were to be assessed (Appendix 2). The pressure descriptions used in this report were created by the Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR 2011). The benchmarks were taken from Tillin *et al* (2010) and applied to the relevant ICG-C pressure.

Sensitivity assessment

The sensitivity assessment method used (Tillin *et al* 2010) involves the following stages:

A. Defining the key elements of the feature to be assessed (in terms of life history, and ecology of the key and characterising species).

B. Assessing feature resistance (tolerance) to a defined intensity of pressure (the benchmark).

C. Assessing the resilience (recovery) of the feature to a defined intensity of pressure (the benchmark).

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

E. Assess level of confidence in the sensitivity assessment.

F. Written audit trail.

A) Defining the key elements of the feature

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

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

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

The assessment scales used for resistance (tolerance) and resilience (recovery) are given in Tables 9.1 and 9.2 and 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.

Table 9.1. Assessment scale for resistance (tolerance) to a defined intensity of pressure.

Resistance (Tolerance)	Description
None	Key functional, structural, characterising species severely decline and/or physio-chemical parameters are also affected e.g. removal of habitats causing change in habitats type. A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat element e.g. loss of 75% substratum (where this can be sensibly applied).
Low	Significant mortality of key and characterising species with some effects on physio-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 physio-chemical character of habitat and no effect on population viability of key/characterising species but may affect feeding, respiration and reproduction rates.

Table 9.2. 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

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

The resistance and resilience scores can be combined, as follows, to give an overall sensitivity score as shown in Table 9.3.

Table 9.3. Combining resistance and resilience scores to categorise sensitivity.

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

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

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

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

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

E) Confidence Assessments

Confidence scores are assigned to the individual assessments for resistance (tolerance) and resilience (recovery) in accordance with the criteria in Table 9.4.

The confidence assessment categories for resistance (tolerance) and resilience (recovery) are combined to give an overall confidence score for the confidence category (i.e. quality of information sources, applicability of evidence and degree of concordance) for each individual feature/pressure assessment, using Table 9.5.

Table 9.4. Confidence assessment categories for evidence.

Confidence Level	Quality of Information Sources	Applicability of evidence	Degree of Concordance
High (H)	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies (give number) 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 heavily on grey literature or expert judgement on feature or similar features.	Assessment based on similar pressures on the feature in other areas.	Agree on 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 9.5. Combined confidence assessments (Based on Quality of Information Assessment only).

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

F) Written Audit Trail

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

Appendix 2 - Literature Review

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

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

The literature review examined:

- Concepts of resistance and resilience relevant to species within the ecological groups.

- Effects of the agreed pressures on species within the ecological groups, with an emphasis on UK habitats but with other examples where relevant/required.

- Evidence of the magnitude, extent (spatial) and duration (temporal) of direct and indirect effects of pressures.

- Structural and functional effects of pressures, including effects on the sedimentary habitats and associated species assemblages.

- Likely rates of recovery based on habitat (sediment type) and the species assemblages present within the ecological group.