Marine Institute

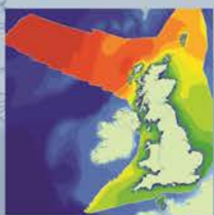
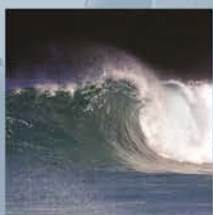
Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 Sites

Report II: Intertidal and Subtidal Sands

Report R.2070

October 2013

Creating sustainable solutions for the marine environment

Marine Institute

Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 Sites

Report II: Intertidal and Subtidal Sands

Date: October 2013

Project Ref: R/3962

Report No: R.2070

Version	Details of Change	Authorised By	Date
1	Draft	H M Tillin	03/05/13
2	Final Draft	H M Tillin	14/05/13
3	Final	H M Tilling	24/10/13

Document Authorisation		Signature	Date
Project Manager:	H M Tillin	H. Tillin	24/10/13
Quality Manager:	N J Frost	[illegible]	24/10/13
Project Director:	S C Hull	Steve Hull	24/10/13

ABP Marine Environmental Research Ltd
Quayside Suite, Medina Chambers
Town Quay
SOUTHAMPTON
Hampshire
SO14 2AQ

Tel: +44(0)23 8071 1840
Fax: +44(0)23 8071 1841
Web: www.abpmer.co.uk
Email: enquiries@abpmer.co.uk

ABPmer is certified by:

Summary

This report and accompanying annexes is part of a series of documents that present a risk assessment tool developed by ABPmer to assess the effects of fishing and aquaculture activities on the Annex I habitats and Annex II species present in Natura 2000 sites. The tool is designed to support the preparation of screening statements and Appropriate Assessments. Specifically this report presents the project deliverables for the assessment of intertidal and subtidal sand habitats and describes the potential use of the risk assessment tool.

A key component of this tool is the Activity x Pressure matrix which indicates the pressures on the environment (or pathways for effects), such as physical disturbance and extraction of species, that arise through major classes of fishing and aquaculture activities. When considering interactions adopting a pressure-based approach rather than an activity based approach has a number of advantages. By identifying the pathways through which an activity affects the environment this approach allows for a global analysis of literature to support the sensitivity assessments. Separating activities into pressures also means that parts of the operation that are particularly detrimental can be recognised and addressed where possible through mitigation strategies. The pressure-based approach also supports cumulative and in-combination assessment of effects across fishing and aquaculture and other types of human activities. Finally, such an approach means that as long as similar pressures can be identified, new activities e.g. new gear types can be assessed using the existing evidence. This is particularly useful for fishing activities where new gear types may be introduced that have not been broadly tested.

The appendices of this report present the Sensitivity Matrix and associated evidence proformas for intertidal and subtidal sand habitats and characterising species. The matrix takes the form of a table in which the sensitivity of these features is scored, based on the degree to which they can resist and recover from benchmark levels of the pressures in the Activity x Pressure matrix.

The accompanying proformas record the evidence used in these sensitivity assessments and assess the confidence (quality) of each assessment. A comprehensive literature search was undertaken to populate these evidence proformas and sensitivity matrices. The resistance, recovery and sensitivity assessments are reported and the evidence and rationale behind the assessment is recorded in the proformas.

The matrices and proformas provide evidence to support the screening stage of Appropriate Assessment and the development of Appropriate Assessments, as described in more detail in this report. It should be noted that the impacts of fishing and aquaculture will be modified by site-specific factors including environmental conditions and the intensity, duration, seasonality and spatial distribution of activities. These sensitivity assessments therefore support, but do not replace, site-specific assessments that take into account the type and intensity of aquaculture and fishing activities, site specific environmental conditions, habitat types and location and the overlap of these.

Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 Sites

Report II: Intertidal and Subtidal Sands

Contents

Page

Appendices

Tables

Figures

1. Introduction

1.1 Report Background

Ireland has many coastal and marine habitats and species that are of national and international conservation importance. The value of these has been recognised by the designation of a number of Special Areas of Conservation and Special Protected Areas through the EU Habitats Directive (92/43/EEC) and EU Birds Directive (2009/147/EC). Together these sites form part of the European network of Natura 2000 sites.

Inshore fishing and aquaculture activities are important economic activities on all coasts of Ireland, supporting thousands of jobs in peripheral coastal communities. Where these activities occur within, or proximal to, Natura 2000 sites an Appropriate Assessment must be made to determine the implications for the conservation status of the designated site (in compliance with the EU Habitats Directive). The Appropriate Assessment statement is considered by the competent authorities who will decide whether the plan or project will adversely affect the integrity of the site concerned. Only when the likelihood of significant effects is discounted can fishing and aquaculture activities be licensed in Natura 2000 sites, unless a series of strict additional tests set out in Article 6(4) of the Directive are met (consideration of alternatives, imperative reasons of over-riding public interest (IROPI) and provision of all necessary compensatory measures).

The Marine Institute has been tasked by its parent department, the Department of Agriculture, Fisheries and Food (DAFF), together with the Department of Arts, Heritage and the Gaeltacht (DAHG), to oversee the preparation of Appropriate Assessments for existing fishery and aquaculture activities that may affect Natura 2000 sites.

This report presents work undertaken by ABPmer in partial fulfilment of the brief to support the Marine Institute in preparing these Appropriate Assessments. Specifically, this report outlines the methodological development and potential use of the 'Sensitivity Matrix', presented in this report, which shows the sensitivity of intertidal and subtidal sand habitats to a range of pressures resulting from fishing and aquaculture activities, accompanied by more detailed evidence tables (proformas). Together these two outputs present our assessment of the likely risk that aquaculture and fishing activities will negatively impact these features where they are present in Natura 2000 sites.

1.2 Project Methodology and Deliverables

In outline the stages involved in this project were:

1) Definition of relevant fishing and aquaculture activities and the resulting pressures that these may give rise to in the marine environment (Appendices A, B and C, this report);
2) Development of feature lists, including characterising species;
3) Evidence gathering and sensitivity assessment; and
4) Production of sensitivity (risk) matrices and associated proformas detailing the evidence collected and used in the assessments.

The Appropriate Assessment tools provided in this report comprise the following matrices and proformas:

- An Activity x Pressure matrix indicating potential exposure and, where appropriate, an indication of magnitude and/or spatial footprint (Appendix C);
- A Sensitivity Matrix and associated matrices for intertidal and subtidal sand habitats and species showing resistance and recovery scores (pressures x features/species) (Appendix E); and
- Evidence proformas (Appendix F).

Separate reports and outputs submitted to the Marine Institute include:

- A more detailed methodology report;
- Activity and pressure proformas; and
- A report, sensitivity matrices and evidence proformas for the following features:

Report I: Muds;
Report II: Sands (this report);
Report III: Muddy sands, sandy muds;
Report IV: Mixed Sediments;
Report V: Coarse sediments;
Report VI: Biogenic reef;
Report VII: Reef; and
Report VIII: Vegetation dominated communities.

A key deliverable presented in this report is the Activity x Pressure matrix (Appendix C) which identifies the pressures with the environment (or pathways for effects) for major classes of fishing metiers and aquaculture activities. The cells within this matrix indicate the likely exposure and, where appropriate, the potential magnitude and/or spatial footprint of the pressure. The accompanying activity/pressure proformas provide additional evidence in support of this matrix (supplied separately to the Marine Institute). This Activity x Pressure matrix addresses the first question of the screening stage and Appropriate Assessment, i.e. 'what are the likely effects that arise from the project or plan on Annex I habitats and Annex II species?' Section 2 (below) provides further detail about the pressure-based approach.

The Sensitivity Matrix for intertidal and subtidal sand habitats (Appendix E) and the associated evidence proformas (Appendix F) together provide a high level, evidence based, tool that identifies the potential compatibility and incompatibility of the environmental pressures that arise from benchmark levels of human activities (fishing and aquaculture) on these habitats. These outputs address the second question of the screening stage and Appropriate Assessment 'what are the likely significant effects arising from the project or plan and how quickly will the feature recover? Further information on the sensitivity assessment approach and deliverables is provided in Section 3 (below).

The intention is that the Sensitivity Matrix and proformas form a database that will support transparent, consistent and coherent decision making across multiple-site assessments. This will, to some extent, make the Appropriate Assessment process more efficient, which is important given the number of designated sites to be assessed and the urgency of producing these assessments.

It should be noted that the impacts of fishing and aquaculture will be modified by site-specific factors including environmental conditions and the intensity, duration, seasonality and spatial distribution of activities. The matrix is therefore not intended to replace site-specific assessments that take into account the type and intensity of aquaculture and fishing activities, site specific environmental conditions, habitat types and location and the overlap of these. Instead the matrices provide information on the reported impacts associated with benchmark levels of human pressure that can be used to inform site specific assessments (see Section 2.2).

1.3 Report Structure

This report consists of Section 1: this introductory section; Section 2: a description of the pressure based approach and selection of features for assessment; Section 3: a description of sensitivity assessment and the development of the sensitivity matrix; Section 4: discussion on the use of the matrix and proformas in support of Appropriate Assessment and Section 5: conclusions.

2. Adopted Approach - Pressure Based Assessments

This section on methodological development details the approach adopted for this project to identify the pressures on the environment arising from fishing and aquaculture activities and to assess the sensitivity of features (habitats and species) to these. Section 2.1 describes the overall approach and provides the rationale for adopting a pressure rather than activity based approach. Section 2.2 describes benchmarks and Section 2.3 describes how feature components are selected for assessment.

2.1 Pressure Based Approach to Assessing Sensitivity

The methodology developed for assessing the sensitivity of Natura 2000 features uses a pressure rather than an activity based approach. This means that the sensitivity of features to generic categories of pressures from fishing and aquaculture activities on the ecosystem are assessed, e.g. the sensitivity to abrasion, organic enrichment, or removal of target species (see Appendix B for full list). This approach contrasts with activity based sensitivity assessments, such as the Beaumaris Approach (Hall et al. 2008) developed by the Countryside Council for Wales (CCW), where feature sensitivity to activities is assessed, e.g. potting or mussel cultivation on ropes.

Rather than activities being assessed 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. The approach is intended to generate a clearer understanding of which activity stages result in pressures on the ecosystem that may result in significant effects. The approach is therefore intended to identify which aspects of an activity are likely to be incompatible with maintaining Favourable Conservation Status (FCS) in Natura sites, and, conversely, which activities, or stages of activities are of least concern. This approach is particularly useful for activities which involve a number of different stages that are carried out in different habitats, and supports the development of mitigation approaches. For example a number of pressures are linked to the cultivation of oysters on trestles including, changes in water flows, increased siltation/organic matter sedimentation, shading and trampling of sediments as trestles are visited. Changes in water flows and shading, for example, may not create a significant impact on the seabed habitat but trampling may. If the pressures had not been separated (as in our approach) then it could be difficult to identify the stage in the operation which gives rise to the impact.

Adopting a pressure based approach also means that a wide range of evidence, including information from different types of activities that produce the same pressures, field observations and experimental studies can be used to prepare the sensitivity assessments and to check these for consistency.

The approach also facilitates the identification of in-combination effects for Appropriate Assessment by identifying which activities have similar pressures with the ecosystem, e.g. surface abrasion may result from dredging for mussels, trawling for flatfish using beam and otter trawls and potting for crustaceans. By identifying all activities causing the pressure the cumulative effect can be more clearly quantified for a site and /or feature type. Furthermore, documentation of all activities can facilitate the application of appropriate management actions in order to mitigate impacts.

Outputs

The fishing metiers and aquaculture types considered for sensitivity assessments are shown in Appendix A. Evidence relating to the pressures arising from these activities on the environment was recorded in activity proformas, where evidence was found during the feature literature searches. These were presented as stand-alone evidence tables to the Marine Institute. A list of generic pressures was identified from primary and secondary sources, expert knowledge and consultation with fishing stakeholders. The full list is shown in Appendix B. To link activities to pressures the Activity x Pressure matrix (Appendix C) was created. This matrix also indicates the spatial extent and magnitude of these activities.

2.2 Developing Benchmarks for Assessing Sensitivity to Pressures

For sensitivity assessments to be meaningful they should refer to a benchmark level that is relevant to the level of impact that will arise from activities. However, there is limited, generically applicable information on pressure intensities to use to set benchmarks or to assess responses and quantitative benchmarks may not be relevant across disparate habitat types. Following the advice of National Parks and Wildlife Services (NPWS) at a consultation meeting ABPmer has not generally set quantitative benchmarks in the sensitivity assessments but have instead collated available information on impacts of pressures in the proformas and then provided a generic sensitivity assessment taking into consideration qualitative benchmarks as outlined in Table 1. The exceptions to this rule are some pressures which change water/sediment chemistry as widely supported Ecological Quality Standards (EQS) are available for these.

Some approaches to assessing sensitivity have incorporated a defined spatial area as a benchmark against which to measure the sensitivity of a feature e.g. Hall et al. (2008). ABPmer suggest that the spatial extent of the activity is not taken into account in benchmarking for this project. Information on the spatial extent of activities in the SAC would be used in combination with the sensitivity assessment to provide a measure of vulnerability (exposure) when making assessments. Vulnerability assessments should be used for the site-specific Appropriate Assessment (AA), as they provide context for a significance effect.

Table 1. Types of benchmark and associated pressures used in the sensitivity assessments

Type of Benchmark	Pressures
Presence Benchmark -Assessment relates to the presence of the pressure, rather than a quantitative benchmark.	Assessments are made on the assumption that the pressure pathway is likely to be present. Pressures in this category include biological pressures e.g. genetic impacts that are assessed whenever the Annex I feature includes wild populations of species that are also cultivated e.g. *Ostrea edulis*; introduction of non-native invasive species and introduction of parasites and pathogen and the removal of target species, non-target species and primary production are also assessed in terms of the presence or likely presence of the pressure rather than a benchmark, although for the removal of species it is assumed that fisheries are managed with regard to sustainability.
'Footprint' Benchmark- Assessment relates to the impact within the footprint of the pressure. Where applicable the assessment refers to a single event, e.g. the passage of one trawl leading to surface and shallow abrasion.	Physical damage pressures: surface abrasion; shallow and deep disturbance, trampling (foot and vehicle), extraction, smothering), Prevention of light reaching seabed surface.
Condition Benchmark refers to change in condition against usual background.	Habitat Quality changes: Changes in water flow, changes in turbidity/suspended sediment, decreased oxygen in water column and sediments, increased sediment coarseness or fine fraction, increased organic enrichment and siltation.
Benchmarks related to existing water and sediment quality guidelines where available.	Eutrophication (stimulation of plant growth through addition of nutrients) and organic enrichment and chemical pressures (introduction of antifoulants).
Pressures not assessed for benthic habitats and plant/invertebrate species (relevant to Annex II species).	Disturbance Pressures: Collision risk, noise, visual disturbance, Litter and Barrier to species movement; ecosystem changes-loss of biomass.

2.3 Selection of Features for Assessment

For Annex I habitat features the Conservation Objectives developed by National Parks and Wildlife Services typically refer to the habitat features and associated characterising species which are identified in the supporting documents (provided alongside the site Conservation Objectives). Some habitats are defined by a single species or a few species that create much of the habitat structure, and the loss of these species would alter the habitat type. For example, the loss of horse mussels (*Modiolus modiolus*) from a habitat defined as horse mussel bed would result in a re-classification of this habitat type. These habitats are described as ‘biogenic’ where animals create the habitat or ‘vegetation dominated’ where plants create the habitat structure. For these habitats the sensitivity of the habitat-forming species is of primary interest and the assessments and proformas are species based.

Habitats that were assessed on the basis of a single species or type of species that are structurally important were:

- Saltmarsh;
- Seagrass (*Zostera*) beds;
- *Ostrea edulis* beds;
- Maerl beds;
- Littoral *Sabellaria* (*alveolata*) reefs (honeycomb worm); and
- Kelp dominated reefs.

For sedimentary and hard substratum habitat sub-features and communities the basis of the assessment was less clear. Seabed habitats can be highly diverse and the identity of many of the species present may vary between habitats that are classified as being of the same type. For these habitats, in general, it was considered desirable that the assessment was guided by the sensitivity of the abiotic habitat and the sensitivity of the characterising species (identified in the supporting documents to the Conservation Objectives) as the loss of these would result in habitat reclassification (according to the NPWS scheme).

There were also concerns that the number of assessments could become unmanageable if a large number of assemblages were defined. To address this the associated biological assemblage identified for each sediment and habitat type (e.g. sublittoral fine sand, littoral muds) in the site-specific Conservation Objectives and supporting documents were classified by sediment type and the associated species according to the EUNIS habitat classification scheme at the biotope type level (level 4 and 5). Individual biotope sensitivity assessments were then developed. This approach grouped habitats from different SACs where the sensitivity based on the sedimentary habitat or substratum and the associated species were similar. All the characterising species identified in the supporting documents to the Conservation Objectives are recorded in the biotope proforma and assessed so this approach does not result in the loss of biological information through the grouping of habitats.

The initial list of characterising species was relatively long. To prioritise effort ABPmer identified species that were specifically referred to in the supporting documents as characterising the biotope, were present in a number of biotopes and/or were ecologically or commercially important and therefore had been the focus of research so that an evidence base to support assessment was available (Appendix D).

ABPmer also developed high level habitat proformas based on sediment or substratum type and location (intertidal or subtidal) for sediment and reef habitats (Reports I-V). These provide an overview of the general sensitivity of the habitat and are biased towards the abiotic habitat. These proformas capture general sensitivity and activity information that is relevant to the habitat and prevent replication of information across the biotope level proformas.

It should be noted that some species that may be important to ecological function, as a key predator or prey item, may not characterise the habitat and are therefore not considered within the sensitivity assessment. For instance, shrimp (*Palaemon*) could be considered a key functional species in some sites, however, as mobile epifauna they do not characterise benthic habitats, they are therefore not considered within any habitat sensitivity assessments. As an aside it should be noted that at some Natura 2000 sites these are commercially extracted and the physical effect of the activity on benthic habitats is considered as part of the AA. Conversely another mobile epifaunal species, the Dublin Bay prawn (*Nephrops norvegicus*), maintains burrows in soft muds, the presence of these animals defines a burrowed mud biotope in the MNCR and EUNIS habitat classifications and hence where these occur they may be subject to sensitivity assessment.

3. Sensitivity Assessment Methodology

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 resist (tolerate) change and its recovery (the ability to recover). A feature is defined as very sensitive when it is easily adversely affected by human activity (low resistance) and/or it has low recovery (recovery is only achieved after a prolonged period, if at all). Figure 1 (below) provides an outline of the methodology used to develop sensitivity assessments. Further details are provided in the following sections on the scales used to categorise resistance and recovery.

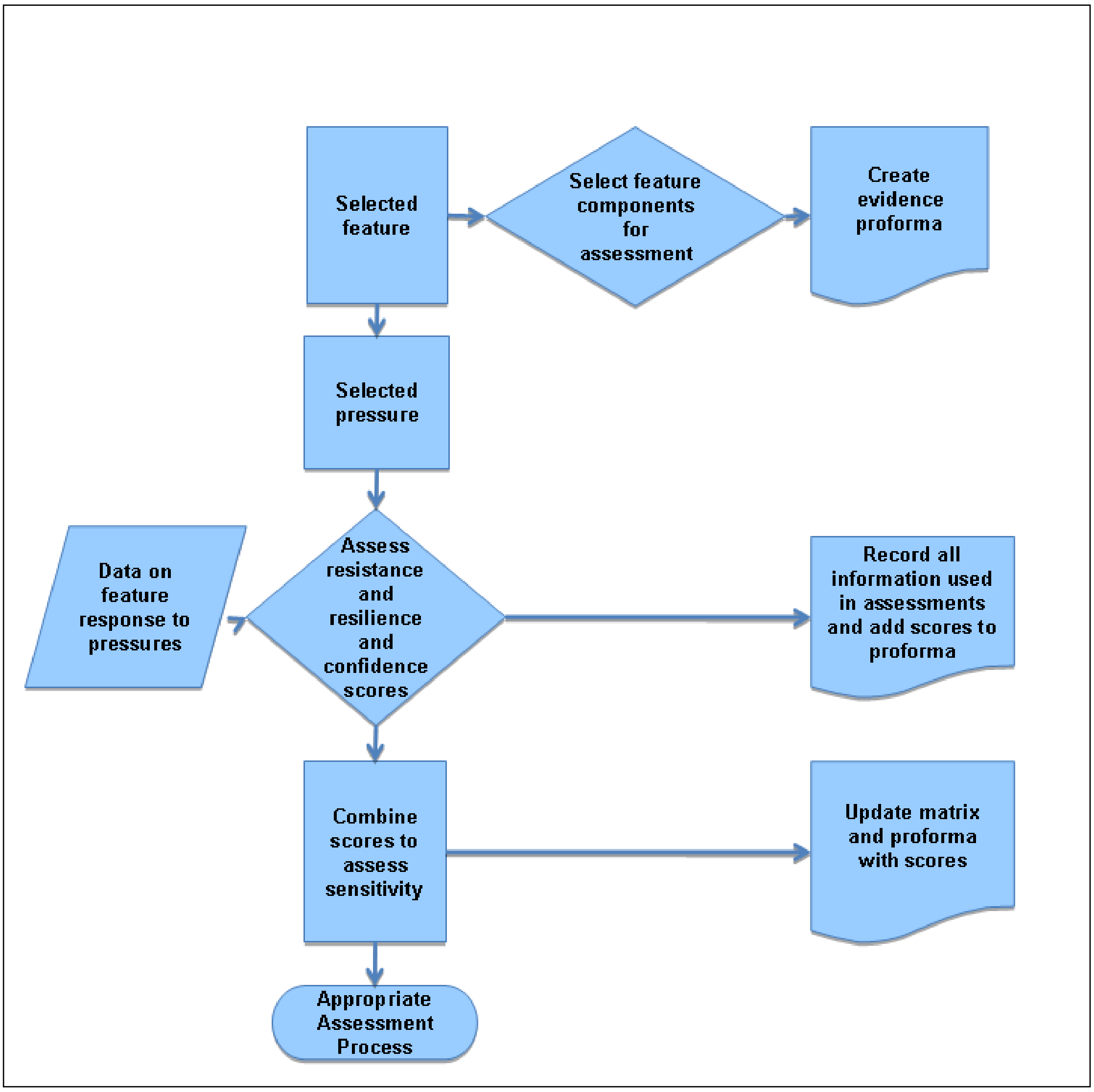


Figure 1. Sensitivity Assessment methodology used to populate the Sensitivity Matrix with assessments

3.1 Assessment of Resistance (Tolerance of Feature)

The resistance scales used (Table 2) are informed by elements from other sensitivity assessment approaches including the Beaumaris Approach (Hall et al. 2008), MarLIN (Tyler-Walters et al. 2001; 2009) and Tillin et al. (2010). The resistance scales relate to the degree to which a feature can tolerate an impact without significantly changing, the score for each feature is recorded in the evidence proformas.

Table 2. Resistance Scale for Sensitivity Assessments

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

3.2 Assessment of the Recovery (Resilience) of the Feature

The recovery scale (Table 3) used for the sensitivity assessments takes into account the use of the Sensitivity Matrix for AA where, with regard to assessment of impacts on Favourable Conservation Status (FCS), short-time scales are of interest. 'Full recovery' is envisaged as a return to the state of the habitat that existed prior to impact. In effect, a return to a recognisable habitat and its associated community. However, this does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognisable as the habitat of conservation concern. The assessment is therefore based on theoretical recovery rates, based on traits and available evidence for a species population or habitat where the activity has ceased. It should be noted that recovery to the pre-impact state may not take place for a number of reasons; including regional changes in environmental conditions or repeated disturbance that maintains the habitat and associated community in an early stage of recovery, or recovery to an alternative stable state that represents an recognisable habitat.

Table 3. Recovery Scale For Sensitivity Assessments

Recovery Category	Description
Low	Full recovery 6+ years
Medium	Full recovery within 3-5 years
High	Full recovery within ≤ 2 years
Very High	Full recovery within 6 months

3.3 Assessment of Sensitivity

To assess sensitivity the resistance and recovery categories are combined as shown in Table 4. The sensitivity assessment takes into account the resistance assessment as the point from which recovery begins: recovery periods are likely to take different lengths of time from slight compared to severe impacts. The sensitivity categories can broadly be described as follows:

Not Sensitive: An assessment of 'not sensitive' is based on the ability of a feature to resist (tolerate) impacts. An assessment of not sensitive indicates that the assessed pressure is not expected to lead to significant effects on structural habitat elements or characterising species. Where resistance is assessed as high, any rate of recovery will result in a not sensitive assessment, as there are no significant impacts for the feature to recover from. Increased pressure intensity, frequency or duration may however lead to greater impacts and a different sensitivity assessment.

Low Sensitivity: 'Low sensitivity' is defined on the basis of resistance and recovery. A feature is assessed as having low sensitivity to a given pressure level where resistance is assessed as medium so that there is no significant impact but recovery may take between 6 months to more than 6 years. Alternatively the resistance threshold may be none, or low, however, recovery is rapid (within 6 months).

Medium Sensitivity: Features assessed as expressing 'medium sensitivity' to a pressure benchmark are those where resistance is categorised as none but where recovery takes place within two years, or those where resistance is low (the pressure leads to a significant effect) where recovery is predicted to occur within >2 -5 years (medium to high recovery).

High Sensitivity: Features assessed as being of 'high sensitivity' experience significant impacts following the pressure (no to low resistance) with full recovery requiring at least three years. The feature may not be recovered after six years.

Very High Sensitivity: Features assessed as having 'very high sensitivity' are those that are predicted to have no resistance to the pressure (75% decline of assessed elements), where full recovery is predicted to take more than 6 years.

Table 4. Combining Resistance and Recovery Scores to Categorise Sensitivity

		Resistance			
		None (severe decline)	Low (25-75% decline)	Medium (≤25% decline)	High (no effects)
Recovery	Low (6+ years)	Very High	High	Low	Not Sensitive
	Medium (3-5 years)	High	Medium	Low	Not Sensitive
	High (≤2 years)	Medium	Medium	Low	Not Sensitive
	Very High (6 months)	Low	Low	Low	Not Sensitive

3.4 Confidence Assessments

Confidence scores are assigned to the individual resistance, recovery and sensitivity assessments based on the quality of evidence that was available to support the assessments. Where possible empirical studies on effects have been used to inform the assessments, however these are not always available for all features, or at the pressure benchmarks. For some assessments, similar habitats and species are used to prepare an assessment, in other cases expert judgement has been relied upon. Some sensitivity assessments will be predictions based on knowledge of the life history of species or based on knowledge of the relationship of habitats and species to the biological, physical and chemical environment.

Confidence scores have been assigned to the individual pressure-feature sensitivity assessments in accordance with the criteria in Table 5. The confidence assessment refers to the availability of information to support the sensitivity assessment and is therefore an indication of the quality of evidence that was available. More information on confidence scores is provided within Appendix F.

Table 5. Confidence Assessment Categories for Evidence

Evidence Confidence	Definition
Low Confidence - Evidence (LE)	There is limited, or no, specific or suitable proxy information on the sensitivity of the feature to the relevant pressure. The assessment is based largely on expert judgement.
Medium Confidence - Evidence (ME)	There is some specific evidence or good proxy information on the sensitivity of the feature to the relevant pressure.
High Confidence - Evidence (HE)	There is good information on the sensitivity of the feature to the relevant pressure. The assessment is well supported by the scientific literature.

3.5 Audit Trail Proformas

The sensitivity assessments and the evidence for these decisions are recorded in the standard evidence proformas presented in Appendix F. The proformas show the resistance and recovery scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The proformas form an accompanying evidence database to the Sensitivity Matrix (Appendix E) , showing the information that was used in each assessment, so that together the proformas provide a collation of the best available scientific evidence of effects of fishing and aquaculture on features. Although the sensitivity assessment process is pressure rather than activity led information related to specific fishing metiers or aquaculture activities on levels or effects has been recorded where available.

This auditing approach allows comparison of results between this and other impact assessments and provides a transparent audit trail so that the underlying rationale for assessments can be communicated to stakeholders.

3.6 Sensitivity Matrix Block Filling

Some features could be identified, a priori, as not requiring sensitivity assessments to complete the matrix and proformas, as the feature was not considered likely to be exposed to the pressure. For example, subtidal mud habitats are not exposed to disturbance by foot traffic. Similarly the pressures collision risk, noise and visual disturbance were not considered to impact benthic habitats and the macroinvertebrates that the assessments are largely based on. In these instances the Sensitivity Matrix, cells and evidence proformas were 'block filled' with the category 'No Exposure'.

For some pressures the evidence base was not considered to be developed enough for sensitivity assessments to be made, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as Not Assessed in the matrix.

For a limited number of features the assessment 'No Evidence' was recorded. This indicates that ABPmer were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on similar features.

3.7 Literature Search

Evidence was first gathered from previous sensitivity assessment work e.g. the Marine Life Information Network (MarLIN), the assessment of fishing and aquaculture by the Countryside Council for Wales (Hall et al. 2008) and sensitivity assessment work undertaken for Marine Conservation Zone planning in the UK (Tillin et al. 2010) and authoritative reviews (including Roberts et al. (2010) and reviews of SAC features for the UK Marine SACs project). Previous sensitivity assessments are clearly referenced in the proformas and the approach indicated, e.g. 'Hall et al. 2008, assessment based on expert judgement at workshop'.

Following the initial information gathering exercise a more thorough review of recent literature was conducted using the referencing service Web of Science and a search of the grey literature on google/google scholar.

4. Use of Matrices and Other Tools to Support Appropriate Assessment

This section provides brief guidance on the potential use of the tools developed by this project to support Appropriate Assessment (AA) of fishing and aquaculture activities.

Any plan or project not directly connected with, or necessary to, the management of a site must be subject to AA of its implications for the Natura 2000 site in view of the site's conservation objectives. If it cannot be concluded, on the basis of objective information, that it will not have a significant effect on that site, either individually or in combination with other plans or projects (EC, 2006). Fundamentally, the AA process addresses two questions; i) whether effects will arise from activities detailed in the project plan and ii) whether these will have significant impacts on the conservation features (Annex I habitats and Annex II species for which the site is designated (NPWS, 2012). The sections below identify key stages for screening for AA and AA and provide a brief outline on the use of project deliverables. The Department of Environment, Health and Local Government has previously issued more detailed guidance on AA (DoEHLG, 2009) and NPWS have recently produced guidance specifically for the marine environment (NPWS, 2012).

Guidance from DoEHLG (2009) on Appropriate Assessment states that 'all likely sources of effects arising from the plan or project under consideration should be considered together with other sources of effects in the existing environment and any other effects likely to arise from proposed or permitted plans or projects. These include *ex situ* as well as *in situ* plans or projects.

4.1 Initial Screening to Determine if Appropriate Assessment is Required

Screening for Appropriate Assessment Guidance

The initial stage of AA is referred to as 'screening' (DoEHLG, 2009). Screening is the process that addresses and records the reasoning and conclusions in relation to the first two tests of Article 6(3):

i) Whether a plan or project is directly connected to or necessary for the management of the site; and
ii) Whether a plan or project, alone or in combination with other plans and projects, is likely to have significant effects on a Natura 2000 site in view of its conservation objectives (DoEHLG, 2009).

Figure 2 outlines the stages involved in the development of a screening statement. Screening Step 1 precedes screening and involves the preparation of i) a site-specific plan detailing activities and ii) the identification of the qualifying interests present through survey and setting of the site-specific Conservation Objectives (this aspect has been undertaken by NPWS). The Conservation Objectives developed by NPWS and the associated supporting documents provide further detail on the Annex I habitats and Annex II species for which the site is designated.

The project or plans for each site will provide detailed information concerning fishing activities and licensed aquaculture activities that are taking place, or are proposed to take place within the site. NPWS have provided draft guidance on the information that should be contained in the project plan to support screening and AA (NPWS, 2012).

The screening statement (Screening Step 3) should indicate whether or not significant effects are considered likely to arise. DoEHLG (2009) have indicated that as well as direct and indirect effects, the potential for in-combination effects should be reported. The screening report should 'clearly state what in combination plans and projects have been considered in making the determination in relation to in combination effects' (DoEHLG, 2009). More information on in-combination/cumulative effects is provided below in Section 4.2: Step 5. A conclusion of no significant effects should be accompanied by a clear and reasoned explanation, supported by scientific/technical evidence. Information contained within activity/pressure proformas and/or the evidence proformas may be drawn on to provide key evidence. Where significant effects are considered likely or certain either a modified plan can be drawn up to avoid obvious detrimental effects and re-submitted or the project may proceed to the second AA stage as described below.

Potential Use of Tools Developed by ABPmer

Appendix A (this report) identifies major fishing metiers and aquaculture activities, and indicates the classes these are grouped into. These classes are then presented in the Activities x Pressure matrix (Appendix C). Each activity class leads to a range of pressures on the receiving environment. The cells of the matrix identify generic pressure intensity and/or the spatial exposure range. The Activity x Pressure matrix (Appendix C) and associated proformas will support initial screening (Screening Step 2) by identifying the potential pathways (pressures) for impacts arising from activities and the potential exposure range (i.e. within footprint of activity, outside of footprint but attenuating at distance etc).

Where features are likely to be exposed to a pressure which will lead to effects (impacts), the Sensitivity Matrix (supported by evidence proformas) will indicate the potential sensitivity of the feature to these at a pre-defined benchmark. NPWS in their guidance document have provided a draft table of pressures (described as effects, see NPWS, 2012), not all of these are considered to arise from aquaculture or fishing activities (e.g. changes in temperature, changes in emergence regime). Others are assessed in this project but there are some differences in nomenclature: the NPWS displacement/exclusion of species, for example, is likely to be covered by the pressure assessments ‘barrier to species movement’ in this project.

The greater the feature sensitivity to the pressure the more likely it is that the associated activity will lead to significant effects. It should be noted that the screening assessment should interpret the sensitivity assessment with regard to the site specific levels of activity indicated within the site plan. The evidence proformas provide information on responses to different intensities where available. In many cases the assessment within the Sensitivity Matrix indicates the likely response to a single event (particularly for the physical disturbance pressures). At higher intensities the sensitivity is likely to be higher and impacts are additive. In these instances consideration of the resistance and recovery scores should be informative about the likely significance of the pressure at the site specific activity frequencies.

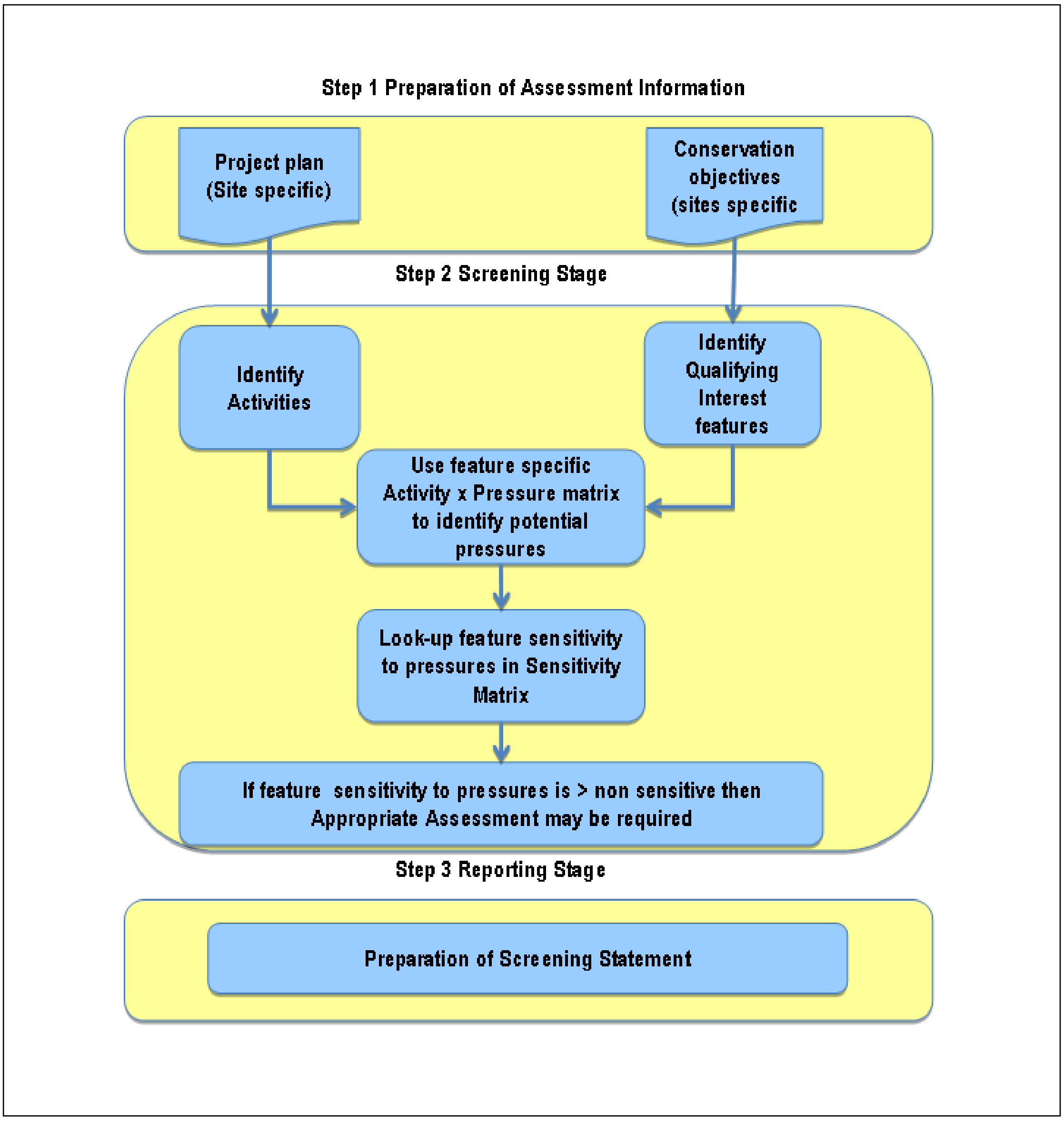


Figure 2. Outline of Screening Stage of Appropriate Assessment

4.2 Guidance on the Preparation of the Appropriate Assessment Statement

A suggested outline for the preparation stages of the AA (where this is required) is shown in Figure 3 which also identifies where the tools developed by ABPmer and presented in this report are used. These stages are described in further detail below. Section 4.3 outlines some further, specific uses of the tools to address concerns regarding Favourable Conservation Status (FCS).

Step 1: Determine Exposure

This step requires that the degree to which the features for which the site is designated are exposed to fishing and aquaculture pressures is determined. Information contained in the site specific project plan and the Activity x Pressures table will be useful to identify potential pressures on features (although this step will largely build on the screening stage assessments).

This stage uses the following tools/information:

- Project plan;
- Conservation Objectives and supporting documents (developed by NPWS);
- Activity x Pressure matrix (see Appendix C); and
- Activity proformas (see separate report).

The site-specific project plan provides the available information on the fishing and aquaculture activities taking place and the intensity, frequency and duration of these activities. Each activity should be reviewed in the Activity x Pressure matrix to identify the likely pressures on features. The cells of this matrix also indicate the potential range of exposure. For example, fishing with towed gears leads to physical disturbance in the footprint of the dredge. Overlaying the activity extent with the known feature distribution (from the Conservation Objectives) identifies the features that are directly exposed to this pressure. Features outside the direct footprint can be assumed to not be exposed. The project plan may contain further information on the levels of activity within the site, e.g. areas subject to frequent disturbance by this activity vs. areas where exposure levels are much lower so that feature exposure can be assessed in greater detail.

The pressures arising from fishing activities will be largely confined to the footprint of the activity e.g. physical disturbance, increased sediment coarseness (although re-suspension of sediments and some nutrient enrichment may occur from bottom disturbance, these effects are weak in most instances, unless intensities and frequencies are particularly high in fine sediment habitats). Aquaculture, however, may lead to pressures that are more extensive. For example, increased siltation of organic matter (uneaten food, faeces) from fish farms may occur at high levels beneath cages, with lower levels of siltation surrounding the cage where particles are moved by tides and currents. Features beneath the farm are therefore directly exposed to a high level of this pressure while surrounding features may be indirectly exposed to a lower level of pressure. The activity proformas collate some information on the footprint of activities and other relevant information that may aid assessment of likely exposure extent and pressure level. Table 7 (below) presents pressures that are solely, or mainly, associated with aquaculture activities and indicates the spatial footprint of these.

Working through the project plan and the conservation objectives in a GIS platform, supported by the Activity x Pressures matrix will identify the spatial extent of pressures to which each feature is exposed. Where further information is available about activity levels, exposure can be characterised in further detail to aid assessment (although such information may not be available).

Some considerations regarding exposure levels are outlined below with regard to the spatial extent of exposure (discrete vs. far-reaching).

Discrete Pressures

Four pressures (smothering, barrier to species movement, shading and extraction) are confined to the installation and decommissioning (extraction) and presence of fixed aquaculture installations or the placement of bivalves on the seabed. These pressures are not considered to require detailed assessment of pressure levels (see Step 2) as the field of impact is discrete, spatially separated from other activities and not linked to different intensity levels, e.g. the presence of a long-line that leads to shading at a location prevents the addition of more longlines so that the pressure benchmark is based on presence/absence. For these pressure types exposure assessments based on the spatial footprint of the activity will indicate the extent of the feature affected. For example one longline or trestle may not impact on a seal haulout site but high numbers of these would be expected to alter its functional value.

It should be noted that some pressures in Table 6, e.g. siltation have a relatively discrete footprint but the magnitude, frequency and duration of the pressure can be highly variable, or is mitigated by site-specific environmental variables and requires characterisation for each site (see Step 2).

Far-reaching Pressures

Conversely a number of pressures that arise from aquaculture activities lead to diffuse effects on the wider environment. These pressures could therefore be considered to require assessment of indirect effects over a wider area based on the level of activity within an area. These potentially far-reaching impacts are also shown below in Table 6, with consideration of the potential footprint (taken from Huntington et al. (2006).

Where features are not exposed they can be considered to not be vulnerable. Where features are exposed there may be a risk that the activity can lead to unacceptable changes leading to the feature falling outside of Favourable Conservation Status.

Table 6. Pressures and associated footprints arising from aquaculture activities only

Pressure	Footprint (Huntington et al. 2006)
Extraction	Zone A- related to infrastructure installation and decommissioning
Siltation	Zone A
Smothering	Zone A
Changes to sediment composition (increased fine fraction)	Zone A
Organic enrichment of water column - Eutrophication	Zone A, B and C*
Organic enrichment of sediments (sedimentation)	Zone A except where due to indirect effects of eutrophication
Decrease in oxygen levels (sediments)	Zone A except where due to indirect effects of eutrophication
Decrease in oxygen levels (water column)	Zone A

Pressure	Footprint (Huntington et al. 2006)
Increased removal of primary production - Phytoplankton	Zone A, B and C**
Genetic impacts on wild populations and translocation of indigenous species	Zone A, B and C
Introduction of parasites/pathogens	Zone A, B and C
Prevention of light reaching seabed features	Zone A
Zone A: Local to discharge-metres (dissolved substances and free buoyant particles remain in this zone for only a few hours, and most sinking particles including food, faeces and dead fish reach the seabed here). Zone B: Water body-kilometres (dissolved nutrients and other dissolved substances produced by farms spread through and remain in this zone for a few days, giving rise to long-term increases in mean concentration, and the residence time allows phytoplankton biomass to increase significantly if light is adequate). Zone C: The regional scale, with water residence times of weeks to months, often spatially heterogeneous (e.g. with mixed, frontal and stratified waters), and only impacted by the aggregate output of large sources of pollutants. * Where the farm contributes nutrients to the total regional (Zone C) budget. ** A problem in enclosed areas with limited water exchange, these are not likely to extend to a regional scale.	

Step 2: Determine pressure level taking site-specific characteristics into consideration

A number of pressures may require more detailed assessment of pressure levels as the level of pressure varies (i.e. magnitude, intensity, and duration) or they are caused by cross-sectoral activities i.e. result from fishing and aquaculture activities, or also arise from different activities within these sectors. For example, surface disturbance results from dredging for bivalve seed for relaying, the use of static gears such as pots and creels, benthic netting and the use of towed gears. The assessment of the pressure level of these will be guided by the site specific plans and the feature exposure layers to each activity and pressure (further informed by the Activity x Pressure matrix). In some cases activities that occur at a site and that result in the same pressure may be spatially separated and affect different feature types simplifying quantification of exposure. These cases are highlighted below (Table 7).

In general the pressure level will be additive where the footprint of the activities or pressure overlap (e.g. increased intensity, duration, and frequency of pressure so that the magnitude of impact may be greater). Alternatively where a feature is impacted throughout its extent the exposure is greater but the pressure level may be variable so that some areas have low levels of pressure and others greater.

Table 7 shows the pressures that are cross-sectoral (fishing and aquaculture), pressure-levels from these activities will be additive in the footprint. As described in Step 2 (and in Section 2 of this report) some pressures are not benchmarked and therefore do not require the pressure level characterising e.g. shading, barriers to species movement, smothering, extraction, genetic impacts, introduction of non-natives and parasites and pathogens. Removal of target species and removal of non-target species are not benchmarked but are considered in the assessments to be managed through sustainable fisheries.

Table 7. Pressures which require more detailed consideration of pressure levels

Pressures	Activities that give rise to Pressures
Surface Disturbance	Fishing, harvesting and aquaculture activities
Shallow Disturbance	Bottom trawling, dredging and harvesting
Deep Disturbance	Bottom trawling and dredging
Trampling (by foot and vehicle)	Harvesting and aquaculture activities
Collision risk	Aquaculture/vessel based activities
Underwater noise	Vessel based activities or predator exclusion alarms from aquaculture
Visual Disturbance	Access/vessel based activities/harvesting
Changes in turbidity/ suspended sediment	Changes in turbidity following fishing activities short-term and could be considered negligible, main impacts for assessment arise through aquaculture activity (see Table 6 above)
Organic enrichment - Water column/sediment	Changes in turbidity following fishing activities short-term and could be considered negligible, main effects for assessment arise through aquaculture activity (see Table 6 above)
Deoxygenation sediments/ water column	Aquaculture (linked to organic enrichment water column (indirectly through algal blooms) and sedimentation of organic matter)
Litter	Relates to Annex II species and likely to be data deficient
Removal of Target Species	Fishing and other harvesting activities and harvesting of seed bivalves for aquaculture
Removal of Non-target species	Fishing and other harvesting activities and harvesting of seed bivalves for aquaculture

Repeated exposure to many of the pressures shown in Table 7 would be considered to be additive as are pressures caused by the same activity. In general additive effects would be assessed by reference to the resistance and resilience assessments and the spatial extent and intensity of activities. It should be recognised that in some instances, beyond a given frequency, intensity or duration, effects of pressures may plateau, e.g. frequent, intense trampling on an intertidal canopy of macroalgae will progressively remove cover until all plants are removed, beyond this point the habitat will not change further. Information on these thresholds is limited but the proformas will contain useful evidence on the sensitivity of habitat structural elements and typical species (biological assemblage) where this is available.

Where the same pressure results from different activities the impact may not be simply additive, for example a number of activities give rise to the surface disturbance pressure; however, the nature of the impacts between these activities may be different in intensity and the magnitude of impacts. Fisheries prosecuted using pots use static gears (with pots, anchors and ropes in contact with the seabed) where the damage from each event is localised, (although the activity may be a chronic pressure as the pots may be used for many months of the year). In comparison, the use of a towed gear also results in surface disturbance but may cause heavy shear stress which may be more abrading and lead to greater sediment disturbance and mortality of species. The resistance of a feature to these impacts will vary due to the nature of the impact while recovery timescales will vary due to the spatial scale of effect. The biological communities associated with sediment habitats will recover from the defaunation of a small area through the migration of adults of mobile species into the area from surrounding habitat. Where disturbances impact wider areas, recovery from surrounding populations will be limited and recovery will take place over longer time scales through the mechanisms of larval supply. The frequency of activity will mediate these distinctions, constant and intensive weekly potting would potentially lead to a habitat being outside FCS for longer than a single pass of a relatively light towed gear, such as an otter trawl, every ten years. Activity type alone is therefore not a wholly reliable indicator of the exposure level that can be assigned to a gear type/activity.

Where activities giving rise to similar pressures are not spatially separated through zonation (e.g. trawlers avoiding potting areas) or the features targeted (rock-hopper trawls vs beam trawls) then quantitative information and expert judgement on activity distribution (exposure), level of activity and feature sensitivity are required to asses pressure levels. Separating the impacts caused by the addition of the same pressure is problematic. This may be compounded by the lack of information on intensity levels. Formulating a rule-based approach for assessing the impact of these cumulative effects with regard to Conservation Objectives is problematic, but it is suggested that an assessment should have regard to the following points:

1) Simplify assessments where possible by identifying any spatial separation of activities through the features targeted or the spatial exclusion of activities, for example seasonal potting will exclude the use of towed gears;
2) Develop an exposure assessment of the extent of feature exposed (to support assessment of impacts on range and condition, see below); and
3) Identify other overlapping pressures associated with the feature that may further inform the assessment, for example dredging results in deep disturbance that will cause greater impacts on a feature than the surface abrasion pressure associated with potting- where these activities are both prosecuted in a feature the vulnerability of the feature (exposure x sensitivity) and the significance of the activity on Conservation Status will be informed by the more impacting element of the activity.

The nature of the receiving environment should also be taken into consideration as this may magnify or ameliorate pressures. The main environmental variables that may influence pressure exposure or modify pressure levels and/or feature sensitivity are as follows:

- Water movements: degree of water exchange between water body and recharge, residual or tidal currents and flushing times. Flushing removes wastes and resupplies oxygen, phytoplankton. Wave and tidal currents influences the degree of natural suspension/turbidity, re-suspension of sediments and associated chemicals and organic matter;
- Water turbidity: reference conditions influenced by depth and the degree of suspended matter;
- Nutrient status: reference condition nutrient status of receiving waters will influence response to additional inputs, more oligotrophic systems may show a stronger response to increased nutrients and organic matter, systems that are more eutrophic may be adapted to process high levels of production;
- Water temperature: influences capacity of water to hold dissolved oxygen;
- Assimilative capacity: ability to absorb wastes;
- Carrying capacity: ability of a given environment to provide food for populations of organisms depends on local production. Where carrying capacity is high, effects of shellfish culture on bivalves may be mitigated.

This stage may require more in-depth characterisation of pressures taking into account the character of the receiving environment through the use of surveys or modelled approaches. These stages lie outside the scope of this project.

Step 3: Determine feature sensitivity to each pressure

The Sensitivity Matrix presents an assessment of the resistance and resilience of the feature with further information contained in the accompanying evidence proformas. It should be recognised that these form the basis of a sensitivity assessment for AA and not the end-point. The information present in the matrix and proformas should be used by experts to support an assessment, taking into consideration the pressure levels and characteristics of the environment as described above. Re-assessment may be required where the pressure levels assessed in Steps 4 and 5 exceed or are below the pressure benchmark.

The extent of exposure and the pressure levels (indentified in Steps 1 and 2) should be taken into consideration. Where the pressure level exceeds the pressure benchmark the resistance score is likely to overestimate the ability of the feature to tolerate the pressure. Where resistance is predicted to be lower, the recovery score will also require revision to allow for greater impacts. It should be noted that resistance and resilience are not linear processes and step changes may occur in natural habitats or populations when thresholds are exceeded. The literature relating to such effects is limited and is not available on a feature by activity basis. Where effects reported in the literature vary widely for features this may suggest the presence of thresholds but equally may be due to site-specific characteristics impeding or facilitating recovery from impacts.

Where the pressure level or strength is less than that assessed, resistance may be higher and recovery times may be reduced. Again the caveats around linearity should be considered.

The resistance and recovery scores provided in the matrices and proformas will also be modified by the frequency and duration of exposure. In nearly all cases the recovery score is assessed based on the recovery time following cessation of the pressure and habitat recovery. (Introduction of non-native species is an exception as in most cases it is not expected that these would be eradicable once established). The frequency of exposure may mean that a habitat or species is in an early stage of recovery when it is re-exposed. Where recovery has not taken place resistance may be lower as repeated perturbations may have greater impacts. Further discussion on repeated exposure is provided below in Step 5 (assessment of cumulative effects).

To overcome these issues the resistance and recovery times should be considered and re-assessed alongside activity information and site-specific characteristics to make the best possible judgement on sensitivity using the available evidence.

Step 4: Assess Vulnerability

Based on the steps above, the vulnerability of the assessed features can be described generically as set out in Table 8 below. Vulnerability is a measure of the degree to which a feature is sensitive to a pressure and exposed to that pressure. Vulnerability can be considered to be an expression of the likely significance of effects, where features have high vulnerability they are more likely to be changed by the activity-related pressures under consideration.

In support of mitigation, vulnerability assessments could be used to identify where activities could be spatially planned to reduce effects.

Table 8. Assessment matrix to determine potential vulnerability

Exposure	Sensitivity			
	High	Medium	Low	Not Sensitive
Feature directly exposed to pressure at benchmark level or above	High Vulnerability	Medium Vulnerability	Low Vulnerability	Not vulnerable
Feature indirectly exposed to pressure, or pressure strength attenuates at distance, below benchmark level requiring case specific assessment.	High vulnerability	Medium Vulnerability	Low Vulnerability	Not vulnerable
Not Exposed	Not Vulnerable	Not Vulnerable	Not Vulnerable	Not vulnerable

Step 5: Cumulative and In-combination Effects Assessment

Aquaculture and fishing activities will take place at the same time as other activities and plans or projects. All activities and plans have the potential to result in additional impacts on the same features within the site resulting in a cumulative and/or in-combination impact.

ABPmer considers that a cumulative/in combination assessment needs to take account of the total effects of all pressures acting upon all relevant receptors in seeking to assess the overall cumulative/in-combination significance. Consideration should be given to in-combination effects resulting from fishing and aquaculture activities (see also Steps 2 and 3 above). Additionally, consideration should be given to any other activities and plans or projects, including any impacts that do not directly overlap spatially but may indirectly result in a cumulative/in-combination impact.

In summary the assessment of in-combination effects should include:

- Approved but as yet uncompleted plans or projects;
- Permitted ongoing activities such as discharge consents or abstraction licences;
- Plans and projects for which an application has been made and which are currently under consideration but not yet approved by competent authorities;
- Completed plans or projects;
- Activities for which no consent was given or required; and
- Natural processes (by natural mechanisms and at a natural rate).

The assessment of effects arising from fishing and aquaculture activities in combination with other projects and plans are site-specific and outside the scope of this report. The pressure based approach we have used will facilitate assessment, where the equivalent pressures arising from other plans, projects, activities or processes are identified and where feature exposure can be assessed (GIS tools using feature datalayers and activity datalayers would be especially useful to identify the overlap). The pressure approach supports assessment of the combined significance of each effect e.g. total siltation levels across the SAC and will also support assessment of the total effect on each feature, e.g. the effect of deep disturbance, siltation and organic enrichment on intertidal mud habitats.

Step 6: Report Preparation

The NPWS (2012) Appropriate Assessment guidance indicates that for Annex I habitats the final reporting should consider the following questions (see this document for other details that are required):

- How do impacts arise in relation to the proposed development?
- How are the existing physical, chemical and/or biological aspects of the qualifying interest likely to be impacted?
- What is the likely duration of the impact?
- Is there likely to be an adverse impact to physical or chemical parameters, or principal biological communities of the Annex I habitat?
- Where applicable, how quickly are the biological communities likely to recover once the operation/activity has ceased?
- In the absence of mitigation, are the physical, chemical or biological impacts of the proposed operation/activity likely to have a significant effect on the favourable conservation condition or relevant conservation targets (where available) of the Annex I habitat at the site (see below)?
- What measures can be implemented to mitigate the significance of the likely adverse impact into insignificance?

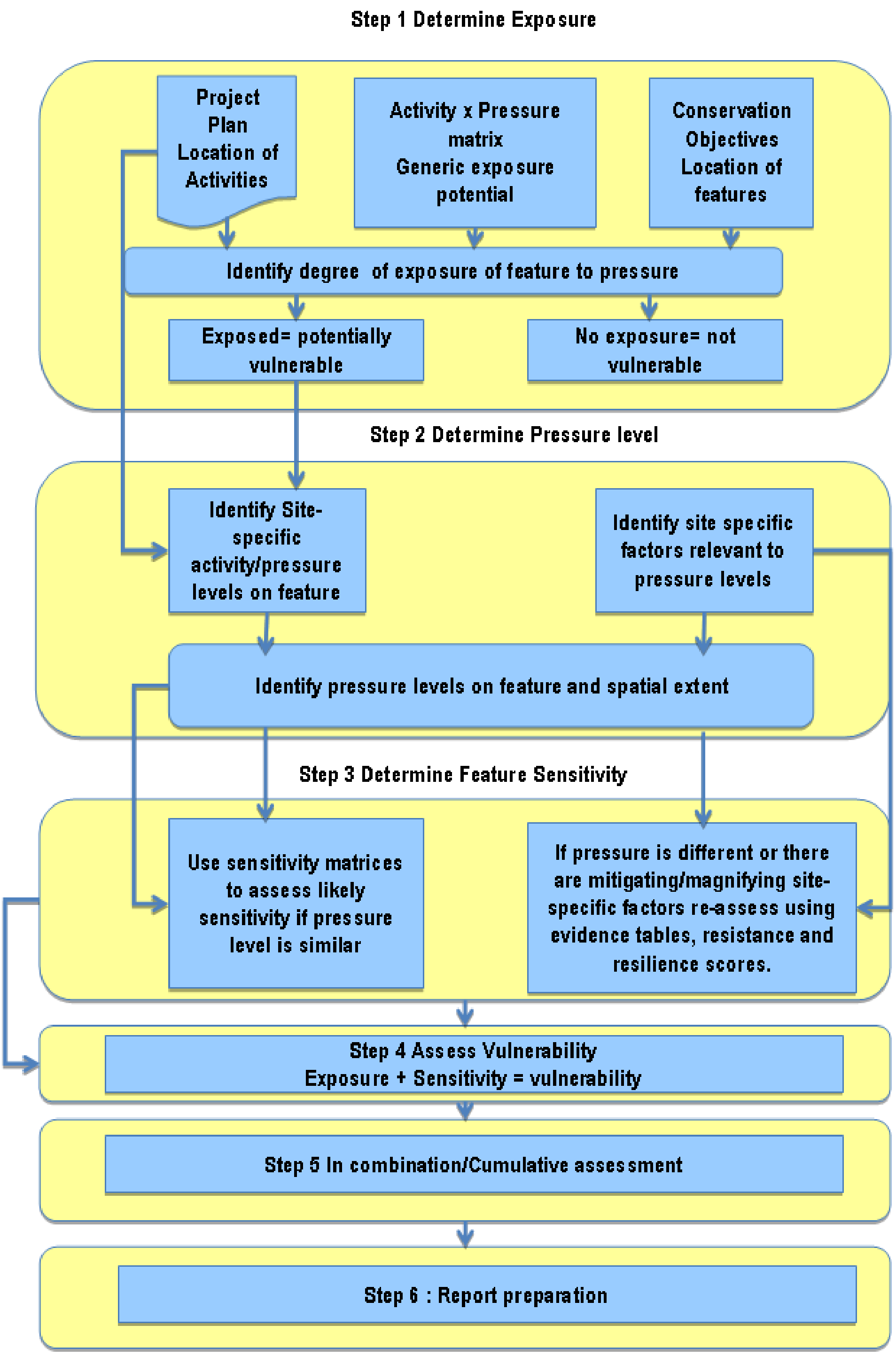


Figure 3. Flow diagram outlining the suggested steps to develop an Appropriate Assessment using project deliverables

4.3 Assessment Against Conservation Objectives - Determining the Likelihood of Significant Effect

The Sections below indicate briefly how the generic AA process may address some specific questions relating to impacts of activities on the site specific Conservation Objectives. These assessments require the tools presented in this report with additional support and information (from project plan and survey and the use of GIS platforms).

Article 1(e) of the Habitats Directive defines the Favourable Conservation Status of a habitat as when:

- Its natural range, and area it covers within that range, is stable or increasing; and
- The ecological factors that are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future; and
- The conservation condition of its typical species is favourable.

FCS for a species is defined as Article 1(i) of the Directive as when:

- Population data on the species concerned indicate that it is maintaining itself; and
- The natural range of the species is neither being reduced or likely to be reduced for the foreseeable future; and
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

The proposed sensitivity assessment methodology addresses these Conservation Objectives in the following ways:

Range of habitat is stable or increasing, or the range of the species is neither being reduced, or likely to be reduced for the foreseeable future

Determining the vulnerability of the habitat or population to range changes can be understood by using information on baseline distribution (from surveys) combined with mapping in GIS package the proportion of range that is identified as sensitive to pressures that are likely to result in range changes and exposed to these pressures. In effect the proposed assessment identifies whether the range is likely to decrease due to human activities.

For example serpulid reefs are highly sensitive to physical damage. Identifying whether any proportion of existing habitat is likely to be exposed to physical damage pressures will indicate whether the range of this species is likely to decrease. We suggest that the following protocol is adopted:

1) Create baseline maps of feature distribution for all SAC features;
2) Identify activities resulting in pressures affecting the feature using activity x pressure matrix and site project/plan to create an exposure layer; and
3) Create a vulnerability layer for each feature.

Ecological factors for maintenance likely to exist for foreseeable future (habitats)

This issue is addressed by ensuring that pressures between assessed activities and the ecological factors that are important for maintaining habitats are included in the assessment, e.g. water flow, sediment composition. Identifying species that are important for maintenance of the habitat e.g. important characterising and functional species also addresses this issue (see below) in the removal of target species and non- target species pressure assessments.

Conservation condition of typical species is favourable (for habitats)

The characteristic or typical species associated with the feature are described in the introductory sections of the proformas and are largely based on the associated species identified by NPWS in the site-specific supporting documents produced to describe the qualifying interests of the Natura sites in further detail. The proformas assess both the structural attributes of the feature and the associated biological assemblage of associated species. Typically the assessment of the sensitivity of the biological assemblage is presented separately from the assessment of the structural habitat features. The sensitivity of the assemblage with regard to the pressures and the site specific levels of activity (assessed using the exposure layers generated in GIS) will indicate the level of risk that the biological assemblage of typical species will be impacted.

Population maintained (species)

This variable is directly measurable; however the sensitivity and vulnerability assessments for a species and associated habitats provide an indication of the likelihood of unfavourable change.

Natural range is neither being reduced or is likely to be reduced in the foreseeable future (species)

The sensitivity and vulnerability assessments will provide information on the likely trajectory of range change. These assessments will depend on the identification of species habitat.

Sufficiently large habitat to maintain population on long-term basis (species)

The assessment of range change above will provide information on whether range changes are likely, this quantitative information will support the assessment of whether habitat will remain to maintain populations. Assigning thresholds for extents of habitats required is likely to be problematic, however where significant contraction in habitat range was predicted this would provide a warning that the population may be at risk.

4.4 Beneficial Effects

It should be noted that directly and indirectly activities may also be considered to have a beneficial effect on habitats and species and the ecosystem, for example;

- Encrusting biota associated with aquaculture structures may provide attachment space for organisms and provide feeding opportunities for fish and other species; Organic

enrichment from fin fish farming provides a food source to benthic communities enhancing productivity;
- Increased biomass of suspension feeders such as mussels will remove plankton from the water column, decreasing turbidity allowing greater light penetration to support macroalgae and eelgrass;
- Sequestration of carbon in bivalve shells; and
- Reduced likelihood of eutrophication or severity of eutrophication through increased bivalve biomass and nutrient/phytoplankton uptake.

However, we have not considered such effects within this project as the purpose is to identify the significance of effect on the integrity and condition of the existing habitat and species at the time of designation, in accordance with the Habitats and Birds Directives.

4.5 Management and Future Matrix Use

Assessing the pressures associated with each stage could allow adaptive management and mitigation of activities using measures such as spatial zonation or temporal zonation to reduce impacts to acceptable levels. Alternatively a fishing gear may have an unacceptable effect on the features present but could be replaced by a less damaging metier.

Although a secondary consideration, given that there is growing interest in marine spatial planning of human activities to support sustainable development, the pressure approach will lead to greater longevity of the outputs as these can be updated as new aquaculture techniques/fishing metiers are added and as further research leads to greater knowledge of the effects of human activities on the marine environment. Alternatively, if associated pressures can be identified, new activities e.g. new gear types can be assessed using the existing evidence. This is particularly useful for fishing activities where new gear types may be introduced that have not been tested experimentally.

5. Conclusions

This report and accompanying annexes is part of a series of documents that present a risk assessment tool developed by ABPmer to assess the effects of fishing and aquaculture activities on the Annex I habitats and Annex II species present in Natura 2000 sites. The tool is designed to support the preparation of screening statements and Appropriate Assessments.

A key component of this tool is the Activity x Pressure matrix which indicates the pressures with the environment (or pathways for effects) such as physical disturbance and extraction of species that arise through major classes of fishing and aquaculture activities.

This report also presents a Sensitivity Matrix and associated evidence proformas for intertidal and subtidal sand habitats and characterising species. The matrix takes the form of a table in which the sensitivity of these features is scored, based on the degree to which they can resist and recover from benchmark levels of the pressures in the Activity x Pressure matrix.

The sensitivity assessment methodology developed has the advantage that it can be consistently applied, is replicable and is transparent as an audit trail of decision making and confidence assessments are provided. Case law has determined that assessments should be undertaken on the basis of the best scientific evidence and methods – (DoEHLG, 2009). The proformas that accompany the Sensitivity Matrix perform the dual function of database and audit trail. They show the resistance and resilience scores underlying the assessment, and provide either, references to literature sources or, indicate where expert judgement was used and the rationale for the judgement made, e.g. based on knowledge of effects on similar species or habitats, or based on likely recoverability, etc. The proformas also record the confidence assessment of these decisions.

Adopting a pressure-based approach rather than an activity based approach has a number of advantages. By identifying the pathways through which an activity affects the environment this approach allows for a global analysis of literature to support the sensitivity assessments. Splitting activities into pressures also means that parts of the operation that are particularly detrimental can be recognised and addressed where possible through mitigation strategies. This approach also supports cumulative and in-combination assessment of effects across fishing and aquaculture and other types of human activities.

The potential use of these tools in relation to the screening and plan assessment stages of Appropriate Assessment have been outlined.

6. References

Department for Environment, Food and Rural Affairs (Defra). 2004. Review of Marine Nature Conservation. Working Group report to Government, Defra, London.

DoEHLG. 2009. Appropriate Assessment of Plans and Projects in Ireland. Guidance for Planning Authorities. Department of Environment, Heritage and Local Government.

EC. 2006. Nature and biodiversity cases: Ruling of the European Court of Justice. Office for Official Publications of the European Communities, Luxembourg.

Hall, K., Paramor, O.A.L., Robinson L.A., Winrow-Giffin, A., Frid C.L.J., Eno, N.C., Dernie, K.M., Sharp, R.A.M., Wyn, G.C. and Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters- development of a protocol. CCW [Policy Research] Report No: 8/12, 85pp.

Hiscock, K. and Tyler-Walters, H. 2006. Assessing the sensitivity of seabed species and biotopes - the Marine Life Information Network (MarLIN). Hydrobiologia, 555, 309-320.

Huntington, T.C., Roberts, H. Cousins, N., Pitta, V., Marchesi, N., Sanmamed, A., Hunter-Rowe, T., Fernandes, T.F., Tett, P., McCue, J., Brockie, N., 2006. 'Some Aspects of the Environmental Impact of Aquaculture in Sensitive Areas'. Report to the DG Fish and Maritime Affairs of the European Commission.

NPWS. 2012. Marine Natura Impact Statements in Irish Special Areas of Conservation. A Working Document, April 2012. Prepared by the National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht.

Roberts, C., Smith, C., Tillin, H. and Tyler-Walters, H. 2010. Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. Report for the Environment Agency. Report: SC080016/R3.

Tyler-Walters, H., Hiscock, K., Lear, D.B. and Jackson, A. 2001. Identifying species and ecosystem sensitivities. Report to the Department for Environment, Food and Rural Affairs from the Marine Life Information Network (MarLIN), Marine Biological Association of the United Kingdom, Plymouth. Contract CW0826. [Final Report.].

Tyler-Walters, H., Rogers, S.I., Marshall, C.E. and Hiscock, K. 2009. A method to assess the sensitivity of sedimentary communities to fishing activities. Aquatic Conservation: Marine and Freshwater Ecosystems 19: 285-300.

Tillin, H.M., Hull, S.C. and Tyler-Walters, H. 2010. Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs (Defra) from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. .Defra Contract No. MB0102 Task 3A, Report No. 22.

Appendices

Appendix A

Fishing Gears And Aquaculture Activities for Assessment

Appendix A. Fishing Gears and Aquaculture Activities for Assessment

Sector	Category	Type	Gears	Sub-Gears	
Fishing	Mobile Gears	Trawls	Demersal (single, twin or triple rigs)	Otter Trawls	
				Benthic Scraper	
				Rock Hopper	
			Pelagic	Midwater Trawl	a) Single
					b) Pair
				Scottish Seine	
				Purse Seine	
		Dredges	Hydraulic	Suction	
				Non-suction	
			Non-hydraulic	Toothed	a) Spring loaded
					b) Fixed
				Blade	a) Oyster
					b) Mussel
				Box	
	Static Gears	Pots	Side Entrance	Hard Eye-Shrimp	
				Soft Eye- D-shaped Creels (lobster and crab)	
			Top Entrance	Hard Eye-Whelk	
				Hard Eye Crab and lobster	
		Nets	Bottom Set	Trammel	
				Tangle	
				Gill	
			Surface Set	Drift	
				Draft	
		Hooks and Lines	Static	Hand Operated	
				Mechanised	
			Trolling		
	Non Vessel Based	Hand Collection			
		Hand Raking			
		Bait Digging			
Aquaculture	Cage Production				
	Suspended Production	Long-lines			
		Trestles			
	Substrate on-growing				

Appendix B

Pressures Arising From Fishing And Aquaculture On Qualifying Interests (Habitats And Species)

Appendix B. Pressures Arising From Fishing and Aquaculture Activities on Qualifying Interests (Habitats and Species)

Pressure Type	Pressure
Physical Damage	Surface Disturbance
	Shallow Disturbance
	Deep Disturbance
	Trampling - Access by foot
	Trampling - Access by vehicle
	Extraction
	Siltation (addition of fine sediments, pseudofaeces, fish food)
	Smothering (addition of materials biological or non-biological to the surface)
Disturbance	Collision Risk
	Underwater Noise
	Visual - Boat/vehicle movements
	Visual - Foot/traffic
Change in Habitat Quality	Changes to sediment composition - Increased coarseness
	Changes to sediment composition - Increased fine sediment proportion
	Changes to water flow
	Changes in turbidity/suspended sediment
	Organic enrichment (eutrophication) - Water column
	Organic enrichment of sediments - Sedimentation
	Increased removal of primary production - Phytoplankton
	Decrease in oxygen levels - Sediment
	Decrease in oxygen levels - Water column
Biological Pressures	Genetic impacts on wild populations and translocation of indigenous populations
	Introduction of non-native species
	Introduction of parasites/pathogens
	Removal of Target Species
	Removal of Non-target species
	Ecosystem Services - Loss of biomass
Chemical Pollution	Introduction of antifoulants
	Introduction of medicines
	Introduction of hydrocarbons
Physical Pressures	Introduction of litter
	Prevention of light reaching seabed/features
	Barrier to species movement

Appendix C

Activity x Pressure Matrix

Appendix C. Activity x Pressure Matrix

Generic Activity x Pressure matrix, the fishing metiers or aquaculture activities within each class are shown above in Appendix A. The cells indicate potential exposure to the pressure as outlined in the key below.

	Mobile gears: Demersal trawls and dredges*	Static gears: Pots/Creels and bottom set nets*	Mobile gears: Pelagic nets and static pelagic nets*	Static gears: Hook and Line Fishing*	Hydraulic Dredges*	Non vessel based: Hand collection/raking and digging	Aquaculture:Substrate ongrowing	Aquaculture: Suspended production Trestles/long-lines/cages
Surface Disturbance								
Shallow Disturbance								
Deep Disturbance								
Trampling - Access by foot[1]								
Trampling - Access by vehicle[1]								
Extraction (Infrastructure)								
Siltation[2]	Wk		Wk		Wk	Wk		OF
Smothering								
Collision Risk								
Underwater Noise								
Visual - Boat/vehicle movements								
Visual - Foot/traffic								
Changes to sediment composition - Increased coarseness[1]	Md				Md	Md		
Changes to sediment composition - Increased fine sediment proportion	Md				Md		OF	OF FF
Changes to water flow								Md Wk
Changes in turbidity/suspended sediment[2]	Wk		Wk		Wk			OF FF
Organic enrichment - Water column[2]	Wk		Wk		Wk			OF FF
Organic enrichment of sediments - Sedimentation[2]							OF	OF FF
Increased removal of primary production - Phytoplankton								
Decrease in oxygen - Sediment[2]								

	Mobile gears: Demersal trawls and dredges*	Static gears: Pots/Creels and bottom set nets*	Mobile gears: Pelagic nets and static pelagic nets*	Static gears: Hook and Line Fishing*	Hydraulic Dredges*	Non vessel based: Hand collection/raking and digging	Aquaculture:Substrate ongrowing	Aquaculture: Suspended production Trestles/long-lines/cages
								OF
Decrease in oxygen - Water column[2]								OF
Genetic impacts on wild populations and translocation of indigenous populations								
Introduction of non-native species								
Introduction of parasites/pathogens								
Removal of target species								
Removal of non-target species								
Ecosystem Services - Loss of biomass								
Introduction of antifoulants								OF
Introduction of medicines								OF
Introduction of hydrocarbons								Md/OF
Introduction of litter								
Prevention of light reaching seabed/features								
Barrier to species movement								

[1] Pressure may arise through access to facilities or fishing grounds.
[2] Pressure pathway identified in Huntington et al. (2006).
* Activity unlikely to directly overlap with this habitat.

Key to cells

Colour	Exposure
	Pressure occurs within direct footprint of the activity and magnitude/intensity/frequency or duration may be high.
	Pressure occurs within direct footprint of the activity but magnitude/intensity/frequency or duration may be moderate (Md). Or pressure may occur outside of footprint and exposure is mitigated by distance (OF).
	Potential widespread effect, occurring at footprint but effects ramifying beyond this.
	Either a weak pressure (Wk), occurs at low intensities/magnitude/duration or frequency or this is potentially a far-field effect that is considered unlikely to exceed background levels due to distance (FF).
	No pressure pathway or negligible effect.

Appendix D

List of Species Proformas

Appendix D. List of Species Proformas

Species Proformas: Initial List of Prioritised Species		
Polychaetes	Oligochaetes	Algae
Lumbrineris latreilli	*Tubificoides benedii*	*Ascophyllum nodosum*
Magelona filiformis	*Tubificoides pseudogaster*	*Chorda filum*
Magelona minuta	*Tubificoides amplivasatus*	*Fucus spiralis*
Protodorvillea kefersteini	Nematoda	*Fucus vesiculosis*
Eteone sp.	*Nematoda*	*Furcellaria lumbricalis*
Pholoe inornata	Crustaceans	*Halydris siliquosa*
Sigalion mathilidae	*Semiballanus balanoides*	*Laminaria digitata*
Glycera alba	*Amphipods*	*Laminaria hyperborean*
Glycera lapidum	*Ampelisca brevicornis*	*Laminaria sacchaarina*
Hediste diversicolor	*Ampelisca typica*	*Pelvetia canaliculata*
Nephtys cirrosa	*Bathyporeia sp*	*Saccorhiza polyschides*
Nephtys hombergii	*Corophium volutator*	Porifera
Arenicola marina	Echinodermata	*Cliona celata*
Capitella capitata	*Echinus esculentus*	*Halichondria panicea*
Capitomastus minimus	Cnidaria	Lichens
Notomastus sp	*Metridium senile*	*Xanthoria parietina*
Scoloplos armiger	*Caryophyllia smithi*	*Verrucaria maura*
Euclymene oerstedii	*Corynactis viridis*	*Caloplaca marina*
Clymenura leiopygous	*Alcyonium digitatum*	*Caloplaca thallincola*
Heteroclymene robusta	Molluscs	
Owenia fusiformis	*Abra alba*	
Pomatoceros lamarkii	*Abra nitida*	
Pomatoceros triquester	*Angulus tenuis*	
Scalibregma inflatum	*Cerastoderma edule*	
Prionospio	*Fabulina fabula*	
Prionospio fallax	*Hydrobia ulvae*	
Pygospio elegans	*Littorina littorea*	
Scolelepis squamata	*Macoma balthica*	
Spio filicornis	*Mysella bidentata*	
Spio martinensis	*Nucula turgida*	
Spiophanes bombyx	*Nucula nitidosa*	
Streblospio shrubsolii	*Patella vulgata*	
Melinna palmata	*Phaxas pellucidus*	
Caulleriella alata	*Scrobicularia plana*	
Caulleriella zetlandica	*Thracia papyracea*	
Lanice conchilega	*Thyasira flexuosa*	
	Timoclea ovata	
	Goodalia triangularis	
	Venerupis senegalensis	

* All species in the table were described as an associated, characterising species in the supporting documents, those that are underlined were highlighted in supporting document text as significant characterising species.

Appendix E

Sensitivity Matrices

Appendix E. Sensitivity Matrices

Table 1(i). Matrix showing the habitat and characterising species resistance scores x pressure categories (surface disturbance – changes in water flow) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F)

	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion	Changes to water flow
Habitat A2.23	H (*)	M (*)	M (*)	H (*)	M-H (*)	N-L (*)	L-M (*)	N-L (*)	NE	NS	NS	NS	N-L (***)	N-L (***)	L-M (*)
Habitat A5.23	H (*)	M (*)	M (***)	NE	NE	N-L (*)	L-M (*)	N-L (*)	NE	NS	NS	NS	N-L (*)	N-L (*)	L-M (*)
Abra alba	M (*)	M (***)	M (***)	M (*)	M (*)	N (*)	H (***)	N (*)	NE	NS	NS	NS	L (*)	H (*)	H (*)
Angulus tenuis	H (*)	M (*)	M (***)	H (*)	M (*)	N (*)	H (*)	N (*)	NE	NS	NS	NS	N-L (*)	H (***)	L-M (*)
Bathyporeia spp.	H (*)	M (**)	M (***)	H (*)	M (*)	N-L (*)	M (***)	L-M (*)	NE	NS	NS	NS	L (*)	L (*)	H (*)
Capitella spp.	L-M (*)	L-M (**)	L-M (**)	L-M (***)	L-M (*)	N (*)	L (*)	N (*)	NE	NS	NS	NS	H (*)	H (***)	H (*)
Cerastoderma edule	M (*)	L (***)	L (***)	L (***)	L (*)	N (*)	M (***)	N (*)	NE	NS	NS	NS	N (*)	H (*)	M (*)
Fabulina fabula	H (*)	M-H (*)	M-H (*)	H (*)	H (*)	N (*)	H (*)	N (*)	NE	NS	NS	NS	N-L (*)	L-M (*)	M (*)
Glycera sp.	H (*)	L-M (***)	L-M (*)	H (*)	L-M (*)	N (*)	H (*)	H (*)	NE	NS	NS	NS	H (*)	H (*)	H (*)
Hediste diversicolor	H (*)	L-M (**)	N-L (***)	H (*)	M (*)	N (*)	H (***)	L (*)	NE	NS	NS	NS	N (*)	H (*)	H (*)
Lanice conchilega	H (*)	M-H (***)	M-H (***)	H (*)	M-H (*)	N-L (*)	H (***)	N-L (*)	NE	NS	NS	NS	H (*)	H (***)	H (*)
Lumbrineris latreilli	H (*)	H (*)	H (*)	H (*)	H (*)	N (*)	H (***)	L (*)	NE	NS	NS	NS	H (*)	H (*)	H (*)

	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion	Changes to water flow
Nephtys cirrosa	H (*)	M (***)	M (***)	H (*)	M (*)	N (*)	H (***)	H (*)	NE	NS	NS	NS	M (*)	H (*)	M (*)
Nephtys hombergii	H (*)	M (***)	M (***)	H (*)	M (*)	N (*)	H (**)	H (*)	NE	NS	NS	NS	N (*)	H (*)	H (***)
Owenia fusiformis	H (*)	M (***)	M (***)	H (*)	M (*)	N (*)	H (***)	N-L (*)	NE	NS	NS	NS	L-M (*)	M (*)	M (*)
Phaxas pellucidus	H (*)	L (***)	L (***)	NE	NE	N (*)	H (***)	L (*)	NE	NS	NS	NS	H (*)	H (*)	H (*)
Pygospio elegans	L-M (*)	L (**)	N (***)	L-M (*)	L-M (*)	N (*)	L (***)	N (***)	NE	NS	NS	NS	N (*)	H (**)	N-L (*)
Scoloplos armiger	H (*)	M (*)	L-M (***)	H (*)	M (*)	N (*)	H (*)	H (*)	NE	NS	NS	NS	H (*)	H (*)	H (*)
Spio spp.	M(*)	M (***)	M (***)	M (*)	M (*)	N (*)	H (*)	N (*)	NE	NS	NS	NS	L-M (*)	L-M (*)	H (*)
Spiophanes bombyx	M (*)	L (***)	N-L (***)	M (*)	L (*)	N (*)	H (*)	N (*)	NE	NS	NS	NS	M (*)	M (*)	H (*)
Thracia papyracea	H (*)	H (*)	H (*)	H (*)	H (*)	N (*)	H (*)	N (*)	NE	NS	NS	NS	L-M (*)	L-M (*)	L-M (*)
Tubificoides spp.	H (*)	H (*)	M (**)	M (*)	M (*)	N (*)	H (*)	M (*)	NE	NS	NS	NS	H (*)	H (*)	H (***)

Table 1(ii). Matrix showing the habitat and characterising species resistance scores x pressure categories (changes to turbidity/suspended sediment - barrier to species movement) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F).

	Decrease in turbidity/ suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments - Sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of non-target species	Ecosystem services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/ features	Barrier to species movement
Habitat A2.23	H (*)	H (*)	H (*)	H (*)	M-H (*)	(M-H (*)	NE	H (***)	NE	H (*)	H (*)	NA	H (*)	H (*)	M (*)	H (*)	NA
Habitat A5.23	H (*)	H (*)	H (*)	H (*)	M-H (***)	M-H (***)	NE	H (***)	NE	H (*)	H (*)	NA	H (*)	H (*)	M (***)	H (*)	NA
Abra alba	M (*)	H (*)	H (*)	H (*)	L-M (***)	L-M (***)	NE	L (*)	NE	H (*)	H (*)	NA	H (***)	NEv	M (**)	H (*)	NA
Angulus tenuis	H (*)	H (*)	Nev	M-H (*)	NEv	NEv	NE	L (*)	NE	H (*)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA
Bathyporeia spp.	H (*)	N (*)	N (*)	H (*)	N (***)	N (***)	NE	L-M (*)	NE	H (*)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA
Capitella spp.	H (*)	H (***)	H (***)	H (*)	M (***)	M (***)	NE	H (*)	NE	H (*)	H (*)	NA	H (***)	L-M (**)	H (***)	H (*)	NA
Cerastoderma edule	H (*)	H (*)	H (**)	M-H (*)	L (***)	L (***)	NE	L (*)	NE	L (*)	H (*)	NA	H (*)	NEv	L (***)	H (*)	NA
Fabulina fabula	H (*)	M (*)	N-L (***)	M-H (*)	M-H (***)	M-H (***)	NE	L (*)	NE	H (*)	H (*)	NA	H (*)	NEv	L-M (***)	H (*)	NA
Glycera spp.	H (*)	H (*)	H (***)	H (*)	H (***)	H (***)	NE	H (*)	NE	H (*)	H (*)	NA	NA	NEv	H (***)	H (*)	NA
Hediste diversicolor	H (*)	H (***)	H (**)	H (*)	H (***)	H (***)	NE	L (*)	NE	L (*)	H (*)	NA	H (***)	N-L (***)	N-L (***)	H (*)	NA
Lanice conchilega	H (*)	H (*)	H (*)	H (*)	L (***)	L (***)	NE	N-L (*)	NE	H (*)	H (*)	NA	H (*)	NEv	L-M (***)	H (*)	NA
Lumbrineris latreilli	H (*)	H (*)	H (***)	H (*)	M (***)	M (***)	NE	H (*)	NE	H (*)	H (*)	NA	L (***)	NEv	L (***)	H (*)	NA
Nephtys cirrosa	H (*)	H (*)	H (*)	H (*)	H (*)	H (*)	NE	L (*)	NE	L (*)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA

	Decrease in turbidity/ suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments - Sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of non-target species	Ecosystem services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/ features	Barrier to species movement
Nephtys hombergii	H (*)	H (***)	H (***)	H (*)	H (***)	H (***)	NE	H (*)	NE	L (**)	H (*)	NA	H (**)	NEv	N (***)	H (*)	NA
Owenia fusiformis	H (*)	H (*)	H (***)	M-H (*)	L (***)	L (***)	NE	N-L (*)	NE	H (*)	H (*)	NA	H (***)	NEv	L-M (*)	H (*)	NA
Phaxas pellucidus	H (*)	H (*)	L-M (*)	M-H (*)	NEv	NEv	NE	L (*)	NE	H (*)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA
Pygospio elegans	H (*)	H (*)	H (***)	H (*)	M (**)	M (**)	NE	L (*)	NE	H (*)	H (*)	NA	H (**)	NEv	NEv	H (*)	NA
Scoloplos armiger	H (*)	H (**)	H (***)	H (*)	L (***)	L (***)	NE	L (*)	NE	L (**)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA
Spio spp.	H (*)	H (*)	H (***)	H (*)	NEv	NEv	NE	H (*)	NE	H (*)	H (*)	NA	H (*)	NEv	H (***)	H (*)	NA
Spiophanes bombyx	H (*)	H (***)	H (***)	H (*)	L (***)	L (***)	NE	L (*)	NE	H (*)	H (*)	NA	H (*)	NEv	M (***)	H (*)	NA
Thracia papyracea	H (*)	H (*)	L-M (***)	M-H (*)	NEv	NEv	NE	N (*)	NE	H (*)	H (*)	NA	H (*)	NEv	NEv	H (*)	NA
Tubificoides spp.	H (*)	H (***)	H (***)	H (*)	H (***)	H (***)	NE	H (*)	NE	H (*)	H (*)	NA	H (**)	NEv	NEv	H (*)	NA

Table 2 (i). Matrix showing the habitat and characterising species resilience scores x pressure categories (surface disturbance – changes to water flow) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F).

Pressure	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion
Habitat A2.23	VH (*)	VH (*)	H-VH (***)	VH (*)	H-VH (*)	H-VH (*)	H-VH (*)	H-VH (*)	NE	NS	NS	NS	H-VH (*)	VH (*)
Habitat A5.23	VH (*)	VH (*)	VH (***)	NE	NE	H-VH (*)	H-VH (*)	H-VH (*)	NE	NS	NS	NS	H-VH (*)	VH (***)
Abra alba	VH (**)	VH (***)	VH (***)	VH (*)	VH (*)	H (***)	VH (***)	H (***)	NE	NS	NS	NS	VH (*)	VH (*)
Angulus tenuis	VH (*)	H-VH (*)	H-VH (***)	VH (*)	H-VH (*)	M (*)	VH (*)	M (*)	NE	NS	NS	NS	M-H (*)	VH (***)
Bathyporeia spp.	VH (***)	VH (***)	VH (***)	VH (*)	VH (*)	H-VH (***)	VH (***)	H-VH (*)	NE	NS	NS	NS	H-VH (*)	H-VH (*)
Capitella spp.	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	NE	NS	NS	NS	VH (***)	VH (***)
Cerastoderma edule	H-VH (*)	VH-M (*)	VH-M (***)	VH-H (***)	VH-M (***)	VH -M (***)	VH (***)	VH-M (***)	NE	NS	NS	NS	VH-M (***)	VH (***)
Fabulina fabula	VH (*)	M-VH (*)	M-VH (*)	VH (*)	VH (*)	M (*)	VH (*)	H (*)	NE	NS	NS	NS	M-H (*)	M-H (*)
Glycera spp.	VH (*)	M-H (***)	M-H (*)	VH (*)	M-H (*)	M-H (*)	VH (*)	VH (*)	NE	NS	NS	NS	VH (*)	VH (*)
Hediste diversicolor	VH (*)	M-VH (**)	M-VH (***)	VH (**)	H (**)	M-VH (**)	VH (***)	M-VH (**)	NE	NS	NS	NS	M-H (**)	VH (*)
Lanice conchilega	VH (*)	H-VH (***)	H-VH (***)	VH (*)	VH (*)	M-H (***)	VH (*)	M-H (*)	NE	NS	NS	NS	VH (*)	VH (**)
Lumbrineris latreilli	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	L (*)	VH (***)	M (*)	NE	NS	NS	NS	VH (*)	VH (*)
Nephtys cirrosa	VH (*)	VH (***)	H-VH (***)	VH (*)	VH (*)	H (*)	VH (***)	VH (*)	NE	NS	NS	NS	H (**)	VH (*)
Nephtys hombergii	VH (**)	VH (*)	VH (***)	VH (**)	VH (**)	H (**)	VH (**)	VH (*)	NE	NS	NS	NS	H (**)	VH (*)
Owenia fusiformis	VH (*)	H-VH (***)	H-VH (***)	VH (*)	H-VH (*)	H (*)	VH (***)	H (*)	NE	NS	NS	NS	H (*)	H-VH (*)

Pressure	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion
Phaxas pellucidus	VH (*)	M (*)	M (*)	NE	NE	M (*)	VH (***)	M (*)	NE	NS	NS	NS	VH (*)	VH (*)
Pygospio elegans	VH (***)	VH (***)	H (***)	VH (**)	VH (**)	H-VH (***)	H-VH (***)	H-VH (***)	NE	NS	NS	NS	H-VH (***)	VH (***)
Scoloplos armiger	VH (*)	H (*)	M-H (*)	VH (*)	H (*)	M (*)	VH (*)	VH (*)	NE	NS	NS	NS	VH (*)	VH (*)
Spio spp.	VH (***)	VH (***)	VH (***)	VH (***)	VH(***)	H-VH (*)	VH (*)	H (***)	NE	NS	NS	NS	H-VH (*)	H-VH (*)
Spiophanes bombyx	VH (***)	VH (***)	VH (*)	VH (***)	VH (*)	VH (*)	VH (*)	VH (*)	NE	NS	NS	NS	VH (*)	VH (*)
Thracia papyracea	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	M (*)	VH (*)	M (*)	NE	NS	NS	NS	M-H (*)	M-H (*)
Tubificoides spp.	VH (*)	VH (*)	H (**)	H (*)	H (*)	H (*)	VH (*)	H (*)	NE	NS	NS	NS	VH (*)	VH (*)

Table 2(ii). Matrix showing the habitat and characterising species resilience scores x pressure categories (changes to turbidity/suspended sediment - barrier to species movement) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F).

	Increase in turbidity /suspended sediment	Decrease in turbidity/suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments- sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of non-target species	Ecosystem services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/features	Barrier to species movement
Habitat A2.23	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	NE	VH (***)	NE	VH (*)	VH (*)	NA	VH (*)	VH (*)	VH (*)	VH (*)	NA
Habitat A5.23	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	VH (***)	VH (***)	NE	VH (***)	NE	VH (*)	VH (*)	NA	VH (*)	VH (*)	VH (*)	VH (*)	NA
Abra alba	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	VH (***)	H (***)	NE	H-VH (*)	NE	VH (*)	VH (*)	NA	VH (***)	NEv	VH (***)	VH (*)	NA
Angulus tenuis	H (*)	VH (*)	VH (*)	NEv	H-VH (*)	NEv	NEv	NE	M-H (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Bathyporeia spp.	VH (*)	VH (*)	H-VH (***)	H-VH (***)	VH (*)	H-VH (***)	H-VH (***)	NE	H-VH (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Capitella spp.	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	NE	VH (*)	NE	VH (*)	VH (*)	NA	VH (**)	VH (***)	VH (***)	VH (*)	NA
Cerastoderma edule	VH (*)	VH (*)	VH (*)	VH (**)	VH-M (*)	H-VH (*)	H-VH (*)	NE	H-VH (*)	NE	H (*)	VH (*)	NA	VH (*)	NEv	H-VH (*)	VH (*)	NA
Fabulina fabula	VH (*)	VH (*)	H (*)	M (*)	VH-M (*)	H-VH (***)	H-VH (***)	NE	M-H (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	M (***)	VH (*)	NA
Glycera spp.	VH (*)	VH (*)	VH (*)	VH (***)	VH (*)	VH (***)	VH (***)	NE	VH (*)	NE	VH (*)	VH (*)	NA	NA	NEv	VH (***)	VH (*)	NA
Hediste diversicolor	VH (**)	VH (**)	VH (**)	VH (**)	VH (**)	VH (**)	VH (**)	NE	M-VH (**)	NE	M-VH (**)	VH (*)	NA	VH (*)	M-H (**)	M-H (**)	VH (*)	NA
Lanice conchilega	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	M-H (*)	M-H (*)	NE	M-H (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	VH (***)	VH (*)	NA
Lumbrineris latreilli	VH	VH (*)	VH (*)	VH	VH (*)	M-H	M-H	NE	VH (*)	NE	VH (*)	VH (*)	NA	L (*)	NEv	L (*)	VH (*)	NA

	Increase in turbidity /suspended sediment	Decrease in turbidity/suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments- sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of non-target species	Ecosystem services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/features	Barrier to species movement
	(***)			(***)		(*)	(*)											
Nephtys cirrosa	VH (**)	VH (**)	VH (*)	VH (*)	VH (*)	VH (*)	VH (*)	NE	H (*)	NE	M-H (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Nephtys hombergii	VH (**)	VH (**)	VH (**)	VH (**)	VH (*)	VH (***)	VH (***)	NE	VH (*)	NE	M-H (*)	VH (*)	NA	VH (**)	NEv	H (***)	VH (**)	NA
Owenia fusiformis	VH (*)	VH (*)	VH (*)	VH (***)	H-VH (*)	H (*)	H (*)	NE	H (*)	NE	VH (*)	VH (*)	NA	VH (***)	NEv	H (*)	VH (*)	NA
Phaxas pellucidus	VH (*)	VH (*)	VH (*)	M (*)	VH-H (*)	NEv	NEv	NE	M-H (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Pygospio elegans	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	NE	VH (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Scoloplos armiger	VH (*)	VH (*)	VH (***)	VH (***)	VH (***)	H (***)	H (***)	NE	H (*)	NE	M-H (***)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Spio spp.	VH (*)	VH (*)	VH (*)	VH (***)	VH (***)	NEv	NEv	NE	VH (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	VH (***)	VH (*)	NA
Spiophanes bombyx	VH (*)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	VH (***)	NE	VH (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	VH (***)	VH (*)	NA
Thracia papyracea	M-H (*)	VH (*)	VH (*)	M (*)	H-VH (*)	NEv	NEv	NE	M-VH (*)	NE	VH (*)	VH (*)	NA	VH (*)	NEv	NEv	VH (*)	NA
Tubificoides spp.	VH (*)	VH (*)	VH (***)	VH (***)	VH (*)	VH (***)	VH (***)	NE	VH (*)	NE	VH (*)	VH (*)	NA	VH (**)	NEv	NEv	VH (*)	NA

Table 3 (i). Matrix showing the habitat and characterising species sensitivity scores x pressure categories (surface disturbance – changes to water flow) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F).

Pressure	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion	Changes to water flow
Habitat A2.23	NS (*)	L (*)	L (*)	NS (*)	L-NS (*)	L-M (*)	L-M (*)	L-M (*)	NE	NS	NS	NS	L-M (*)	M (*)	L-M (*)
Habitat A5.23	NS (*)	L (*)	L (*)	NE	NE	L-M (*)	L-M (*)	L-M (*)	NE	NS	NS	NS	L-M (*)	M (*)	L-M (*)
Abra alba	L (*)	L (***)	L (*)	L (*)	L (*)	M (*)	NS (***)	M (*)	NE	NS	NS	NS	L (*)	NS (*)	NS (*)
Angulus tenuis	NS (*)	L (*)	L (***)	NS (*)	L (*)	M (*)	NS (*)	H (*)	NE	NS	NS	NS	M-H (*)	NS (*)	L-M (*)
Bathyporeia spp.	NS (*)	L (***)	L (***)	NS (*)	L (*)	L-M (*)	L (***)	L-M (*)	NE	NS	NS	NS	L-M (*)	L-M (*)	NS (*)
Capitella spp.	L (*)	L (**)	L (**)	L (***)	L (*)	L (*)	L (*)	NS (*)	NE	NS	NS	NS	NS (*)	NS (***)	NS (*)
Cerastoderma edule	L (*)	L-M (*)	L-M (***)	L-M (***)	L-M (*)	L-H (*)	L (***)	L-M (*)	NE	NS	NS	NS	L-H (*)	NS (*)	L (*)
Fabulina fabula	NS (*)	L-NS (*)	L-NS (*)	NS (*)	NS (*)	M (*)	NS (*)	M (*)	NE	NS	NS	NS	M-H (*)	L (*)	L (*)
Glycera spp.	NS (*)	L-M (***)	L-M (*)	NS (*)	L-M (*)	M (*)	NS (*)	NS (*)	NE	NS	NS	NS	NS (*)	NS (*)	NS (*)
Hediste diversicolor	NS (*)	L-M (**)	L-H (**)	NS (*)	L (*)	L-H (*)	NS (***)	L-M (*)	NE	NS	NS	NS	M-H (*)	NS (*)	NS (*)
Lanice conchilega	NS (*)	NS-L (***)	NS-L (***)	NS (*)	NS-L (*)	M-H (*)	NS (*)	M-H (*)	NE	NS	NS	NS	NS (*)	NS (***)	NS (*)
Lumbrineris latreilli	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	VH (*)	NS (***)	M (*)	NE	NS	NS	NS	NS (*)	NS (*)	NS (*)
Nephtys cirrosa	NS (*)	L (***)	L (***)	NS (*)	L (*)	L (*)	NS (***)	NS (*)	NE	NS	NS	NS	L (*)	NS (*)	L (*)
Nephtys hombergii	NS (*)	L (*)	L (***)	NS (*)	L (*)	L (*)	NS (**)	NS (*)	NE	NS	NS	NS	L (*)	NS (*)	NS (**)
Owenia fusiformis	NS (*)	L (*)	L (*)	NS (*)	L (*)	M (*)	NS (***)	M (*)	NE	NS	NS	NS	L-M (*)	L (*)	L (*)
Phaxas pellucidus	NS (*)	M (*)	M (*)	NE	NE	H (*)	NS (***)	M (*)	NE	NS	NS	NS	NS (*)	NS (*)	NS (*)
Pygospio elegans	L (*)	L (**)	M (***)	L (*)	L (*)	L-M (*)	L (***)	L-M (***)	NE	NS	NS	NS	L-M (*)	NS (**)	L-M (*)

Pressure	Surface Disturbance	Shallow Disturbance	Deep Disturbance	Trampling - Access by foot	Trampling - Access by vehicle	Extraction	Siltation	Smothering	Collision risk	Underwater Noise	Visual - Boat/vehicle movements	Visual - Foot/traffic	Changes to sediment composition - Increased coarseness	Changes to sediment composition - Increased fine sediment proportion	Changes to water flow
Scoloplos armiger	NS (*)	L (*)	L-M (*)	NS (*)	L (*)	H (*)	NS (*)	NS (*)	NE	NS	NS	NS	NS (*)	NS (*)	NS (*)
Spio spp.	L (*)	L (***)	L (***)	L (*)	L (*)	L-M (*)	NS (*)	M (*)	NE	NS	NS	NS	L-M (*)	L-M (*)	NS (*)
Spiophanes bombyx	L (*)	L (***)	L (***)	L (*)	L (*)	L (*)	NS (*)	L (*)	NE	NS	NS	NS	L (*)	L (*)	NS (*)
Thracia papyracea	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	M (*)	NS (*)	M (*)	NE	NS	NS	NS	L-M (*)	L-M (*)	L-M (*)
Tubificoides spp.	NS (*)	NS (*)	L (**)	L (*)	L (*)	M (*)	NS (*)	L (*)	NE	NS	NS	NS	NS (*)	NS (*)	NS (***)

Table 3(ii). Matrix showing the habitat and characterising species sensitivity scores x pressure categories (changes to turbidity/suspended sediment - barrier to species movement) for sand habitats

See Report Sections 2 and 3 for methodological information. The evidence base supporting these assessments is presented in the habitat and species proformas (Appendix F).

	Increase in turbidity/suspended sediment	Decrease in turbidity/suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments - Sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of Non-target species	Ecosystem Services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/ features	Barrier to species movement
Habitat A2.23	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	L-NS (*)	L-NS (*)	NE	NS (***)	NE	NS (*)	NS (*)	NA	NS (*)	NS (*)	L (*)	NS (*)	NA
Habitat A5.23	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	L-NS (***)	L-NS (***)	NE	NS (***)	NE	NS (*)	NS (*)	NA	NS (*)	NS (*)	L (*)	NS (*)	NA
Abra alba	L (*)	L (*)	NS (*)	NS (*)	NS (*)	L (***)	L-M (***)	NE	L-M (*)	NE	NS (*)	NS (*)	NA	NS (***)	NEv	L (***)	NS (*)	NA
Angulus tenuis	L (*)	NS (*)	NS (*)	NEv	L-NS (*)	NEv	NEv	NE	M (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Bathyporeia spp.	NS (*)	NS (*)	L-M (*)	L-M (*)	NS (*)	L-M (***)	L-M (***)	NE	L-M (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Capitella spp.	NS (*)	NS (*)	NS (***)	NS (***)	NS (*)	L (***)	L (***)	NE	NS (*)	NE	NS (*)	NS (*)	NA	NS (***)	L (***)	NS (***)	NS (*)	NA
Cerastoderma edule	NS (*)	NS (*)	NS (*)	NS (**)	L-NS (*)	L-M (*)	L-M (*)	NE	M (*)	NE	M (*)	NS (*)	NA	NS (*)	NEv	L-M (*)	NS (*)	NA
Fabulina fabula	NS (*)	NS (*)	L (*)	M-H (*)	L-NS (*)	NS-L (***)	L-NS (*)	NE	M (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	L-M (*)	NS (*)	NA
Glycera spp.	NS (*)	NS (*)	NS (**)	NS (***)	NS (*)	NS (***)	NS (***)	NE	NS (*)	NE	NS (*)	NS (*)	NA	NA	NEv	NS (***)	NS (*)	NA
Hediste diversicolor	NS (*)	NS (*)	NS (**)	NS (**)	NS (*)	NS (**)	NS (**)	NE	L-M (*)	NE	L-M (*)	NS (*)	NA	NS (*)	M-H (**)	M-H (**)	NS (*)	NA
Lanice conchilega	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	M (*)	M (*)	NE	M-H (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	L (***)	NS (*)	NA

	Increase in turbidity/suspended sediment	Decrease in turbidity/suspended sediment	Organic enrichment - Water column	Organic enrichment of sediments - Sedimentation	Increased removal of primary production - Phytoplankton	Decrease in oxygen levels - Sediment	Decrease in oxygen levels - Water column	Genetic impacts	Introduction of non-native species	Introduction of parasites/pathogens	Removal of Target Species	Removal of Non-target species	Ecosystem Services - Loss of biomass	Introduction of antifoulants	Introduction of medicines	Introduction of hydrocarbons	Prevention of light reaching seabed/ features	Barrier to species movement
Lumbrineris latreilli	NS (***)	NS (*)	NS (*)	NS (***)	NS (*)	L (*)	L (*)	NE	NS (*)	NE	NS (*)	NS (*)	NA	M (*)	NEv	M (*)	NS (*)	NA
Nephtys cirrosa	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	NS (*)	NE	M (*)	NE	M (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Nephtys hombergii	NS (*)	NS (*)	NS (*)	NS (**)	NS (*)	NS (***)	NS (***)	NE	NS (*)	NE	M (*)	NS (*)	NA	NS (**)	NEv	M (***)	NS (*)	NA
Owenia fusiformis	NS (*)	NS (*)	NS (*)	NS (***)	L-NS (*)	M (*)	M (*)	NE	M (*)	NE	NS (*)	NS (*)	NA	NS (***)	NEv	L-M (*)	NS (*)	NA
Phaxas pellucidus	NS (*)	NS (*)	NS (*)	L (*)	L-NS (*)	NEv	NEv	NE	M (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Pygospio elegans	NS (*)	NS (*)	NS (*)	NS (***)	NS (*)	L (**)	L (**)	NE	M (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Scoloplos armiger	NS (*)	NS (*)	NS (***)	NS (***)	NS (*)	M (***)	M (***)	NE	M (*)	NE	M (**)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Spio spp.	NS (*)	NS (*)	NS (*)	NS (***)	NS (*)	NEv	NEv	NE	VH (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NS (***)	NS (*)	NA
Spiophanes bombyx	NS (*)	NS (*)	NS (***)	NS (***)	NS (*)	L (***)	L (***)	NE	L (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	L (***)	NS (*)	NA
Thracia papyracea	L (*)	NS (*)	NS (*)	L-M (*)	NS-L (*)	NEv	NEv	NE	NS-L (*)	NE	NS (*)	NS (*)	NA	NS (*)	NEv	NEv	NS (*)	NA
Tubificoides spp.	NS (*)	NS (*)	NS (***)	NS (***)	NS (*)	NS (***)	NS (***)	NE	NS (*)	NE	NS (*)	NS (*)	NA	NS (**)	NEv	NEv	NS (**)	NA

ABP mer
marine environmental research

Appendix F

Evidence Proformas

Appendix F. Evidence Proformas

Report II Intertidal and Subtidal Mixed Sand Habitats

Sand habitats can be broadly divided into intertidal and subtidal components (see Fig II.1). Within the EUNIS level A2.2 and A5.2 categories there are some sandy mud sub-units. These are assessed within Section III (muddy sands/sandy muds).

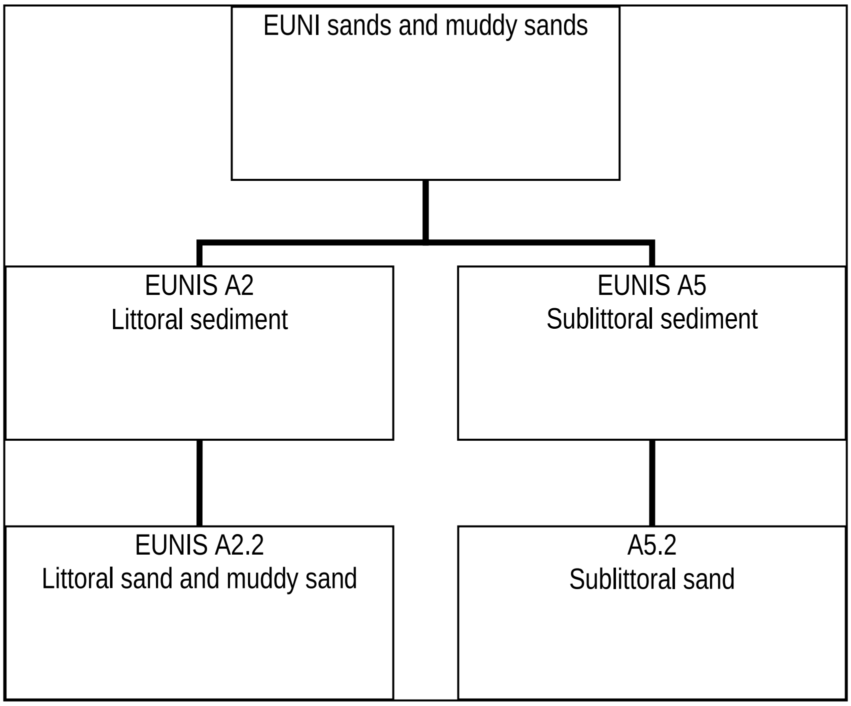


Figure II.1 Hierarchical diagram showing relevant elements of the EUNIS descriptive framework for littoral sand habitats (Levels 2-3 only)

Littoral Sands

Intertidal (littoral) sand shores are submerged at high tide and exposed at low tide. They form a major component of the Annex 1 features; Intertidal mud and sandflats, Estuaries and Large shallow inlets and bays but they also occur along the open coast and in lagoonal inlets.

Sublittoral Sands

Sublittoral sand shores are not exposed during any part of the tidal cycle. They form a major component of the Annex 1 features; Submerged sandbanks, Estuaries and Large shallow inlets and bays but they also occur along the open coast.

Sublittoral sand habitats occur in a wide variety of environments, from sheltered (sea lochs, enclosed bays and estuaries) to highly exposed conditions (open coast). The strength of tidal currents and exposure to wave action are important determinants of the topography and stability of the habitats. The diversity of flora and fauna living within the biotopes varies according to the level of environmental stress to which they are exposed.

Structure of Section II

This Section consists of the following documents:

Introduction (this section)

Littoral Sands Introduction and Assessment (EUNIS A2.2)
EUNIS Biotope A2.23

Sublittoral Sands Introduction and Assessment (EUNIS A5.2)
EUNIS Biotope A5.23

Species Proformas:

1. *Abra alba*
2. *Angulus tenuis*
3. *Bathyporeia* spp.
4. *Capitella* spp.
5. *Cerastoderma edule*
6. *Fabulina fabula*
7. *Glycera* spp.
8. *Hediste diversicolor*
9. *Lanice conchilega*
10. *Lumbrineris latreilli*
11. *Nephtys cirrosa*
12. *Nephtys hombergii*
13. *Owenia fusiformis*
14. *Phaxas pellucidus*
15. *Pygospio elegans*
16. *Scoloplos armiger*
17. *Spio* spp.
18. *Spiophanes bombyx*
19. *Thracia papyracea*
20. *Tubificoides* spp.

Littoral (Intertidal) Sand Sediment: Introduction and Habitat Assessment Information (EUNIS A2.2)

Proforma Information

This habitat proforma has been produced as part of a risk assessment tool to assess the likelihood of impacts of fishing and aquaculture activities on habitats and species, in support of the preparation of Appropriate Assessments (AAs) for Natura 2000 sites.

The key component of the risk assessment tool for the AA preparation is a sensitivity matrix (Appendix E) which shows the sensitivity of SAC and SPA features to pressures arising from fishing and aquaculture activities. The feature being assessed in this proforma has been identified as being present within an SAC or SPA. The purpose of this proforma is to act as an accompanying database to the sensitivity matrix, providing a record of the evidence used in the sensitivity assessment of this feature (Table II.2). The sensitivity information presented in this proforma relates either to the habitat or to general community responses, more specific information is provided in the accompanying biotope level proformas and species proformas.

The following descriptions of the main biological communities associated with this feature are taken from the EUNIS website, the original source for these is Connor et al. (2004). Equivalent habitat designations are shown below in Table II.1

Feature Description (see also Introduction Section)

The littoral sands feature assessment refers to intertidal sand sediments. This assessment has been structured following the EUNIS framework (EUNIS, 2007, see Figure II.2 below). Littoral sand shores are submerged at high tide and exposed at low tide. They form a major component of the Annex 1 features; Intertidal mud and sandflats, Estuaries and Large shallow inlets and bays but they also occur along the open coast and in lagoonal inlets.

The biological community types associated with littoral sand are governed by sediment characteristics including mobility and the proportion of finer mud fractions. These sedimentary conditions reflect the hydrodynamic conditions at the site. The more mobile sand shores are relatively impoverished, with more species-rich communities of amphipods, polychaetes and, on the lower shore, bivalves, developing with increasing stability in finer sand habitats. Muddy sands, the most stable within this habitat complex, contain the highest proportion of bivalves (see Report III).

Three main biological community types have been identified from intertidal sands. Where sands are more stable, then polychaete species as well as amphipods occur. Less exposed shores where the sediments contain greater proportions of mud are associated with more bivalve species. The associated community of more mobile and exposed shores is comparatively impoverished with few, or robust species. There are some similarities in the associated biological community with sublittoral sand sediments (see Assessment A5.2).

It is probable that there are broad transition areas between areas of sandflat, mudflat and mixed sediment biotopes where the sediment consists principally of mud but has significant proportions of gravel and sand mixed in. Hence, it should be noted that there may be some overlap between biological communities or they may form a mosaic or grade into each other at different locations, depending on local conditions. Qualifying interest features and sub features of SACs may overlap and contain some species or characteristics of similar biotopes. In particular, overlap may occur with the following EUNIS biotopes:

- A2.42 Species rich mixed sediment shores (See Report IV);
- A2.24 Polychaete/bivalve-dominated muddy sand shores (Report III); and
- A2.31 Polychaete/bivalve-dominated mid estuarine mud shores (Report I).

These natural variations mean that qualifying interest features and sub features of SACs as identified in field work may not fit neatly into the EUNIS classification system.

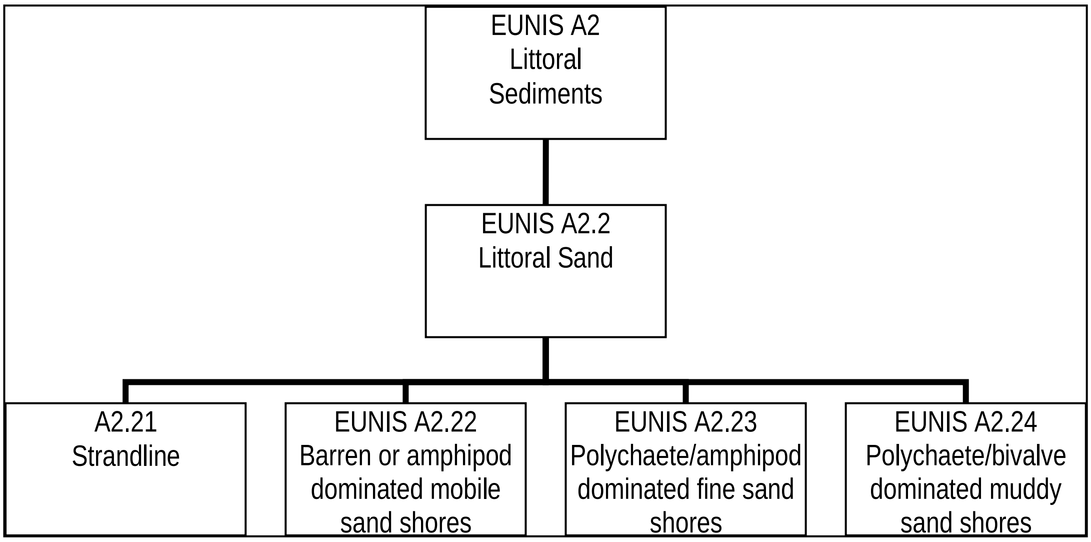


Figure II.2 Hierarchical Diagram showing the EUNIS descriptive framework for Littoral Sands (Levels 2-4 only)

Associated Biological Community (Descriptions from EUNIS)

EUNIS A2.21 Strandline

Not considered relevant.

EUNIS A2.22 Barren or amphipod dominated mobile sand shores

(Source EUNIS: Connor et al. 2004)

Shores consisting of clean mobile sands (coarse, medium and some fine-grained), with little very fine sand, and no mud present. Shells and stones may occasionally be present on the surface. The sand may be duned or rippled as a result of wave action or tidal currents. The sands are non-cohesive, with low water retention, and thus subject to drying out between tides, especially on the upper shore and where the shore profile is steep. Most of these shores support a limited range of species, ranging from barren, highly mobile sands to more stable clean sands supporting communities of isopods, amphipods and a limited range of polychaetes. Species which can characterise mobile sand communities include

Scolelepis squamata, *Pontocrates arenarius*, *Bathyporeia pelagica*, *B. pilosa*, *Haustorius arenarius* and *Eurydice pulchra*.

Situation: Mobile sand shores are typically situated along open stretches of coastline, with a relatively high degree of wave exposure. Bands of gravel and shingle may be present on the upper shore of exposed beaches. Where the wave exposure is less, and the shore profile more shallow, mobile sand communities may also be present on the upper part of the shore, with more stable fine sand communities present lower down. A strandline of talitrid amphipods (A2.211) typically develops at the top of the shore where decaying seaweed accumulates.

Temporal variation: Mobile sand shores may show significant seasonal changes, with sediment accretion during calm summer periods and beach erosion during more stormy winter months. There may be a change in sediment particle size structure, with finer sediment grains washed out during winter months, leaving behind coarser sediments.

Exposed shores are usually made up of coarse mobile sands that are low in diversity, generally have no sedentary species, especially bivalve molluscs, and are dominated by robust mobile swimming species with short-life histories (JNCC, 2007).

EUNIS A2.23 Polychaete/amphipod dominated sand shores

(Source EUNIS: Connor et al. 2004)

Shores of clean, medium to fine and very fine sand, with no coarse sand, gravel or mud present. Shells and stones may occasionally be present on the surface. The sand may be duned or rippled as a result of wave action or tidal currents. The degree of drying between tides is limited, and the sediment usually remains damp throughout the tidal cycle. Typically, no anoxic layer is present. Fine sand shores support a range of species including amphipods and polychaetes. On the lower shore, and where sediments are stable, bivalves such as *Angulus tenuis* may be present in large numbers. An exceptionally rich fine sand community has been recorded from very sheltered reduced salinity shores. Species recorded include *Anaitides maculata*, *Hediste diversicolor*, *Scoloplos armiger*, *Pygospio elegans*, *Tharyx killariensis*, oligochaetes, *Gammarus locusta*, *Hydrobia ulvae*, *Cerastoderma edule* and *Mya truncata*.

Situation: Fine sand communities may be present throughout the intertidal zone on moderately exposed beaches, or they may be present on the lower parts of the shore with mobile sand communities present along the upper shore. A strandline of talitrid amphipods (A2.211) typically develops at the top of the shore where decaying seaweed accumulates.

Temporal variation: Fine sand shores may show seasonal changes, with sediment accretion during calm summer periods and beach erosion during more stormy winter months. There may be a change in sediment particle size structure, with finer sediment grains washed out during winter months, leaving behind coarser sediments.

EUNIS A2.24 Polychaete/bivalve dominated muddy sand shores

(Source EUNIS: Connor et al. 2004)

Muddy sand or fine sand, often occurring as extensive intertidal flats on open coasts and in marine inlets. The sediment generally remains water-saturated during low water. The habitat may be subject to variable salinity conditions in marine inlets. An anoxic layer may be present below 5cm of the sediment surface, sometimes seen in the worm casts on the surface.

Situation: Muddy sand communities are found predominantly on the mid and lower shore, though they may span the entire intertidal. Fine sand or mobile sand communities may be present on the upper shore with muddy sand communities present lower down. In sheltered mid estuarine conditions, muddy sand communities may be present on the upper part of the shore with mid estuarine muddy shore communities (A2.31) lower down.

Muddy sand communities within this level of the EUNIS hierarchy are assessed in Report III.

Key Ecosystem Function Associated with Habitat

Intertidal sand, muddy sand and mixed sediments provide habitat for complex microhabitats supporting abundant populations of microphytobenthos (Underwood and Paterson, 2003; cited in Fletcher et al. 2011). Various fish species often visit sandy sediment including Sole (*Solea solea*) and gadoids. Sea bass and flounder frequent intertidal sandflats as feeding grounds to predate on polychaetes and crustaceans while migratory species like salmon and shad pass through sandflat areas en route to other wetland habitats (Jones et al. 2000; cited in Fletcher et al. 2011). Therefore these intertidal sediments contribute to commercial and recreational fisheries benefits. Intertidal sand, muddy sand and mixed sediments are also important for fish spawning and nursery grounds (Fortes, 2002; cited in Fletcher et al. 2011). Wild harvesting of shellfish also occurs in these intertidal areas, as does bait digging (recreation/sport) and nature watching (bird watching). Shorebirds when migrating from breeding to wintering grounds are important predators on sandflats in north-west Europe (UK sites include the Wash, Morecombe Bay, Poole Harbour and the Solent) (Jones et al. 2000; cited in Fletcher et al. 2011). The erosion control process of this habitat may also contribute to natural hazard protection.

Shorebirds when migrating from breeding to wintering grounds are important predators on sandflats in north-west Europe (Jones et al. 2000; cited in Fletcher et al. 2011).

Conservation interest is primarily in the habitat's ability to support higher trophic levels, especially birds and fish which may use mudflats as nursery areas when these are submerged. Biological productivity is therefore an ecological service, provided by this habitat, which is of key interest.

Features Assessed

The information presented in this document relates to littoral sand sediments and is based primarily on the abiotic habitat. This assessment therefore can be considered to be a higher-level assessment.

The sensitivity of abiotic habitat elements can be considered to be a risk assessment of the degree to which external drivers may change the habitat type and the time taken to recovery. As species occur within a specific range of habitat conditions (the habitat niche), the sensitivity assessment of the habitat indicates, very generally, whether the biological community is likely to change (although this will also depend on the sensitivity of individual species). For example, the type of sediment/substrate present at a location is of primary importance in determining the suitability of a location for many benthic species. Pressures which result in a change in sediment/substrate condition e.g. where the habitat is sensitive to the pressure, would be likely to drive a change in the species assemblage. In the case of SACs this could lead to the habitat being considered to be likely to be outside of Favourable Conservation Status with regard to the Conservation Objectives.

The more detailed biotope assessments that follow in this section include characterising species from the EUNIS habitat classification but are based primarily on distinguishing species that were identified by National Parks and Wildlife Services in the site specific conservation objectives. These assessments should also be considered in relation to the habitat sensitivity outlined below.

Recovery

Sandy habitat types are typically characterised by animals living within the sediment (infauna), rather than attached epifauna and epiflora, although some species may have structures that protrude above the surface, e.g. polychaete and amphipod tubes, adding to the complexity of the habitat. *Sabellaria* reefs are more structurally complex habitats associated with sandy substrates and these are considered in the review of biogenic reefs (Report VI).

The type of biological assemblage that develops at a location is primarily influenced by sediment characteristics, which in turn depend on the prevailing hydrodynamic conditions. Coarse sand sediment occurring in sand-wave formations in shallow water, wave exposed and tide-swept coasts are mobile sediments subjected to high levels of natural disturbance. The infauna in this type of habitat is highly impoverished and is typified by small opportunistic *capitellid* and *spionid* polychaetes and isopods that are adapted to living in an unstable environment.

Loose, coarse sand habitats fully exposed to wave action and swept by strong tidal streams are dominated by small or highly mobile polychaetes, thick shelled and rapidly burrowing bivalves (*Spisula elliptica* and *S. subtruncata*) and mobile amphipods that are adapted to periodic disturbance.

Shallow areas with coarse sand swept by tidal currents but sheltered from wave exposure may develop dense beds of the sand mason polychaete *Lanice conchilega*. The biogenic structures created by these organisms increase habitat complexity and influence physical parameters, for example, reducing near-bed currents and significantly increasing sediment stability. Larsonneur (1994) reported that sand stabilised by sand masons is sufficiently stable to allow subsequent colonization by *Sabellaria alveolata*.

A close variant of this community occurs in fine compacted sands with moderate exposure and weak tidal currents. This habitat is characterised by the thin-shelled bivalve *Fabulina fabula*, and is found in the Irish Sea, north-east coast of England and in numerous Scottish sea lochs (JNCC, 2009).

Fine sands are characterised by robust fauna which could potentially recolonize habitats after disturbance events (Hall et al. 2008). For sand habitats that are dominated by physical processes, habitat restoration (post-fishing activity) is relatively rapid (days to a few months) and recolonization is probably dominated by active and passive migration of adult organisms into the disturbed areas (e.g. McLusky et al. 1983; cited in Kaiser et al. 2006). However, some sandy sediment communities also contain large bodied, slow growing fauna, such as the bivalves *Mya truncata* and *Arctica islandica*, which are sensitive to fishing disturbances and are likely to have long recovery periods (e.g. Witbaard and Bergman, 2003; Beukema, 1995).

In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate following disturbance when compared with muddier sediments.

Habitat Classification

Table II.1 Types of intertidal sand habitats recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (EUNIS, 2007; Connor et al. 2004; OSPAR Commission, 2008). Note A2.24 Muddy sand habitats are assessed in Report III

Annex 1 Habitat	EUNIS	Marine Habitat Classification (0405)	OSPAR Threatened and Declining
Estuaries, Shallow Bays and Inlets, Intertidal Sandflats	A2.22	LS.LSaMoSa*	Intertidal mudflats
	A2.23	LS.LSa.FiSa	
	A2.24**	LS.LSA.MUSA*	
	A2.241	LS.LSa.MuSa.CerPo	
	A2.242	LS.LSa.MuSa.HedMacEte	
	A2.243	LS.LMu.MEst	
	A2.244	LS.LMu.MEst.HedMac	
	A2.245	LS.LMu.MEst.HedMacScr	
	A2.241	LS.LSa.MuSa.MacAre	
* Marlin sensitivity assessments available for this biotope or sub-biotopes. ** A2.24 and sub-biotopes assessed in Report III.			

Table II.2 Information relevant to habitat pressure assessments

Pressure		Benchmark	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	Species associated with sandflats are infaunal and hence have some protection against surface disturbance, although in more stable, sheltered shores, tubes of sedentary polychaetes such as *Lanice conchilega* may project above the sediment surface and damage to these would require repair. Bivalves and other species require contact with the surface for respiration and feeding, fragile animals that are buried close to the surface will be vulnerable to damage, depending on the force of the surface abrasion. Sand shores are less stable than mud and muddy sand shores as the predominant material is unable to form cohesive clumps. This sediment mobility means that pits and ridges left by surface disturbance will be rapidly infilled. Sand shores vary from steeper coarse sand shores to flat, water logged shores of fine sand. Exposed sandy shores are dynamic environments and the associated species are generally present in low abundances and adapted to frequent disturbance suggesting that resistance to surface abrasion would be high. In these habitats bivalves and other sedentary species are typically absent, the predominant species present are agile swimmers such as Haustoriid amphipods and isopods. These species have a short life span and are characterised by their ability to withstand sediment disturbance. Low energy areas such as intertidal sheltered sandflats favour the establishment of a predominantly sessile community of tube dwelling polychaetes and long-lived bivalves (Elliott et al. 1998), which will be more sensitive to surface disturbance. Disturbance events may lead to the development of a transitional community dominated by opportunist species and more mobile infauna such as Haustoriid amphipods and errant polychaetes (Elliott et al. 1998).
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	See also Subtidal sands, Table II.13 for further information). In contrast to rocky shores, few soft sediment fauna are found on the sediment surface at low tide. As a consequence, harvesting of soft sediment fauna requires the physical disturbance of the substratum. Moreover these habitats tend to extend over large areas which, coupled with their low topography and the structure of the substratum, makes them amenable to extensive mechanical harvesting (Kaiser et al. 2001). Towed demersal gears, such as beam trawls, otter trawls, scallop dredges, could be deployed in intertidal sandy and muddy habitats depending on the tidal regime and the morphology of the coastline (Hall et al. 2008), it has been assumed that intertidal raking and dredging (using tractor dredges or hydraulic suction dredges) are the most likely fishing methods to be deployed in intertidal sand shores. Both of these techniques may cause surface, shallow and deep disturbance and these are described below. Fishing can directly alter the physical habitat by influencing sediment particle size (Thrush and Dayton, 2002 and references therein). The use of fishing gears and the collection of infauna through digging and raking etc. can alter the surface topography and expose, remove, reposition or kill and injure benthic organisms. *Activity Specific Information*

Pressure		Benchmark	Evidence
			In a global analysis of the response and recovery of benthic biota to fishing, Kaiser et al. (2006) found that the impact of intertidal dredging in soft-sediment was much more severe than that of intertidal raking, which was probably related to the degree of physical disturbance inflicted upon the substratum. In the case of intertidal raking, the sediment is left in situ even though the upper few centimetres may be disrupted by the passage of the gear. Conversely, intertidal dredging involves the physical removal and resuspension of the substratum into the water column. The furrows that result from these activities may be tens of centimetres deep (Beukema, 1995; Dernie et al. 2003; Hiddink 2003; cited in Kaiser et al. 2006). Thus, for intertidal dredging, there is a significant component of habitat recovery in addition to biological recovery that is required before a site can be considered to approach the condition of nearby undisturbed control plots (Dernie et al. 2003). *Previous Sensitivity Assessments* Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised intertidal sands supporting gaper clams as having high sensitivity to beam trawls and scallop dredges and oyster/mussel dredging and prospecting, at high and medium levels of activity (daily in 2.5 nm x 2.5 nm area and 1-2 times a week in 2.5nm x 2.5 nm areas). Sensitivity to lower levels of activity was considered to be medium (lower levels = 1-2 times a month during a season in 2.5nm x 2.5nm areas and a single pass of the gear). Sensitivity was also considered to be medium to high and moderate levels of intensity of demersal trawls and light demersal trawls and seines (intensity defined as daily in 2.5 nm x 2.5 nm areas and 1-2 times a week in 2.5nm x 2.5 nm, areas respectively). Sensitivity to lower levels of intensity, including a single pass was considered to be low (Hall et al. 2008).
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	*Activity Specific Information* The immediate effects of suction dredging (for the harvesting of intertidal cultivated/harvested shellfish, such as clams and cockles) are quite severe, as the entire upper layers of the substratum and fauna are removed (Kaiser and Beadman, 2002). The greatest visible effect of suction dredging or mechanical raking on the sediment is the creation of depressions or trenches which may take days to months to restore depending on sediment type and location (Dyrynda and Lewis, 1995; Hall and Harding, 1997). These trenches may encourage larval settlement by providing an environment subject to lower current velocities (Snelgrove and Butman, 1994). However, Thrush et al. (1996) report that defaunated sediments become destabilized leading to faunal emigration which greatly delayed recolonization. Recolonisation rate is likely to differ between habitat types depending on a combination of factors including sediment stability and exposure to wave action and currents. In addition, the scale of disturbance will have important implications for recolonisation rate depending whether this occurs through active/passive movement of adults or through larval recruitment (Hall and Harding, 1997).

Pressure		Benchmark	Evidence
			In general, damage to sediment habitats from activities that cause deep disturbance such as bait digging, is most significant in sheltered habitats (e.g. estuaries and inlets), where holes can persist for weeks or months (Fowler, 1999). Studies of the recovery of lugworm beds after bait digging have indicated that complete recolonisation occurs quickly (one month after areas had been experimentally dug out from a sandy beach at Whitley Bay: Blake 1979; cited in Fowler, 1999). Recolonisation of dug beds occurs via recruitment of young worms from separate nursery beds on the upper shore or by migration of adults from unexploited populations in adjacent areas (possibly including subtidal beds), provided these are not also exploited (Olive, 1993; cited in Fowler, 1999). Studies have shown that tractor-towed harvesters leave vehicle tracks as well as dredging furrows which remain visible for varying amounts of time depending on the conditions at the site. In an area of stable sediment (poorly sorted fine sand) dredge tracks may be visible for long periods (more than 6 months have been recorded) whereas in more mobile sediments there may be no alteration in sediment parameters (Gubbay and Knapman, 1999). The effect on infauna also depends on the exposure of the site (Rostron, 1995; Moore, 1991; Rostron, 1993). Research to date suggests that in an area of stable sediments, as well as large reductions in the target species, mechanical dredging can result in a significant decline in numbers of species found at or close to the sediment surface, including the laver spire shell (*Hydrobia ulvae*) and the polychaetes *Pygospio elegans* (Rostron, 1995; Moore, 1991). These effects may still be apparent 6 months later (Rostron, 1995) The sand mason worm (Lanice conchilega), on the other hand, has more robust tubes and can retract below the depth disturbed by the dredge (Moore, 1991; Rees, 1996) and although the distribution of white ragworm (Nephtys hombergii) was affected by dredging, populations have been shown to recover within six months (Rostron, 1995). In general the overall decrease in biomass of target species and non-target species is likely to be more pronounced in areas with stable environmental conditions and diverse communities. In sites with moderately mobile sediments it is possible for natural disturbances to have a greater effect than dredging (Rostron, 1995; Jennings and Kaiser, 1998). Sites with more tube dwelling and sedentary species appear to take longer to recover to pre-fishing levels than areas with more mobile fauna (Gubbay and Knapman, 1999). Comparing the impacts of hand raking with other harvesting methods in comparable environments, Kaiser et al. (2001) ranked the magnitude and intensity of different harvesting techniques as: lugworm harvesting > tractor dredging > bait digging > cockle hand raking. For each of the forms of disturbance the reported recovery rates of the benthic communities were similar (2-6 months) with the exception that the larger fauna (e.g. *Mya arenaria*) take much longer to recover (Kaiser et al. 2001 and references therein). Dernie et al. (2003) compared the recovery rate of benthic assemblages in different sediment types following physical disturbance (the creation of a 'pit' in the sediment surface, the scale of which was chosen to be relevant to bait digging, hand-raking, suction dredging and some forms of trawling) of different intertidal habitats (clean sand, silty sand, sandy mud and mud) in the Menai Strait, North Wales. The results demonstrated a strong relationship between the rate at which the physical structure of soft-

Pressure		Benchmark	Evidence
			sediment habitats are restored and the rate at which the biological components of the system recover. Recovery was most rapid for clean sand habitats, intermediate for mud habitats and the physical and biological recovery rates were longest for muddy-sand habitats. In sand habitats, recolonisation is probably dominated by active and passive migration of adults into the disturbed areas (e.g. McLusky et al. 1983; cited in Kaiser et al. 2006), whereas in the muddy sands recolonisation is likely to require (in part) recruitment of larvae, and is therefore a much longer process (Kaiser et al. 2006).
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	Dune systems at the top of the shore can be very sensitive to trampling but these are not considered within this report. Emerson et al. (1990; cited in Tyler-Walters and Arnold, 2008) examined smothering and burrowing of Mya arenaria (a species found in a variety of soft substratum including clean fine sand) as indirect effects of clam harvesting, in laboratory experiments. Significant mortality (2-60%) in small and large clams occurred at burial depths of 50 cm or more in sandy substrates. However, they suggested that gaper clams buried under 25 cm of sediment would almost certainly die. Trampling is unlikely to disturb enough of the sediment surface to smother individuals but individual burrows may be collapsed along the access path used, potentially resulting in the death of deeply buried individuals as M. arenaria can burrow to depth of 50 cm. Reviewing this evidence, Tyler-Walters and Arnold (2008) suggested that the effects of trampling on Mya arenaria are dependent upon size class. Moffett et al. (1998) experimentally investigated the effects of trampling on sandy beach infauna at an exposed beach on the Easter Cape coast of South Africa. Sensitivity varied between species with the clam Donax serra being slightly affected at all trampling intensities while the congener D. sordidus and isopods were impacted only at high intensities. It was concluded that at low trampling intensities few macrofauna were affected, but substantial damage occurred at high trampling intensities.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	Dune systems at the top of the shore can be very sensitive to damage from vehicle tracks but these are not considered within this report. Vehicle tracks may cause little impact along the wet foreshore of some beaches (Brown and McLachlan, 2002) but some communities are more vulnerable than others. Fragile animals may be crushed including urchins, crabs and other species (Brown and McLachlan, 2002, references therein). Relevant information on the impacts of vehicle access on sandy beaches is limited. Schlacher et al. (2008) compared unimpacted reference areas with areas of high intensity vehicle use (250,000 visits), intensities that are not comparable with impacts from aquaculture and fishing operations. In general the passage of a vehicle is likely to compact sand, cause rutting and crushing infaunal organisms. Tyler-Walters and Arnold (2008) reported that there was limited information on the effect of vehicles on intertidal muds and sands supporting gaper clam populations. Godfrey et al. (1978; cited in Tyler-Walters and Arnold, 2008) reported the impact of off-road vehicles (ORV) on sediments suitable for the clam *Mya arenaria*. Off road vehicles killed clams by compacting sediments, crushing burrows and preventing siphon extension to the surface or by directly crushing individuals. Smaller individuals are less deeply buried due to shorter siphon length and these are most likely to be crushed. Reviewing this evidence Tyler-Walters and Arnold (2008) suggested that the sensitivity of intertidal muds and sands that support gaper clam populations are probably similar to that of intertidal muddy sands but the presence of *M. arenaria* probably increases its sensitivity to vehicular access.

Pressure		Benchmark	Evidence
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment which may be anoxic and/or of a different character or bedrock 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) state that removal of 0.5 m 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. Information from MarLIN LS.LGS.S.BarSnd – EUNIS (Budd, 2008) The biotope is likely to recover from substratum removal. For instance, at Village Bay on St Kilda, an island group far out into the Atlantic west of Britain, an expanse of sandy beach was removed offshore as a result of winter storms to reveal an underlying rocky shore (Scott, 1960). Yet in the following summer, the beach was gradually replaced when wave action was less severe. In view of such observations, that many sandy beaches disappear in winter and reappear in spring, it is likely that recovery would occur in less than a year or six months.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	See also Subtidal Sands (Table II.13) for aquaculture examples. Impacts of towed demersal gears in soft-sediment can include smothering of suspension feeding fauna through the resuspension of sediment by the fishing gears (Jennings and Kaiser, 1998) The quantity of sediment resuspended by trawling depends on the sediment grain size and the degree of compaction, which is higher on mud and fine sand compared to coarse sand (Jennings and Kaiser, 1998). Kaiser et al. (2006) found that otter trawling had the most severe effect on suspension feeders in mud habitats, possibly reflecting the greater depths to which the otter doors penetrate the soft sediment habitat. Re-suspended sand size particles will settle within one tidal cycle (King, 1975; cited in Elliott et al. 1998). Lighter towed gear e.g. light demersal trawls and seines, were reported as having less impact (Drabsch et al. 2001). In the United Kingdom, legislation requires the use of protective netting in Manila clam cultivation to prevent escape of this introduced species (Spencer et al. 1997). Spencer et al. (1996; 1997) found that the application of plastic netting to an estuarine silty sand substratum led to an immediate increase in sedimentation rate over cultivated plots which elevated the organic content of the sediment. Within 6 months the cultivated plots were dominated by opportunistic spionid worms. During the following 24 months, the spionids were replaced by high abundances of larger deposit feeding worm species. The plastic netting also became fouled with *Enteromorpha* spp. which in turn attracted grazing littorinid snails. In relation to intertidal cultivation of bivalves, relaid mussels (i.e. 'on-growing' cultivation) led to the development of 'mussel mud' beneath the mussel bed as the filtration and feeding activities of the mussels increase sedimentation rate. These deposits are composed of dead shells, silt and pseudofaeces, which persist in excess of 18 months after the mussels have been removed

Pressure		Benchmark	Evidence
			(Kaiser and Beadman, 2002). The relaying of cultivated mussels onto the seabed also causes a change in the infaunal community (Beadman et al. in press; unlisted reference; Ragnarsson and Raffaelli, 1999; Dittman, 1990; Committo, 1987; all cited in Kaiser and Beadman, 2002). This is demonstrated by a change in the composition of species of the infaunal community, and also the number of individuals and number of species present. At all but the lowest mussel densities, the infaunal communities of areas cultivated with mussels were found to be less abundant, in terms of both individuals and numbers of species, than the surrounding areas (Beadman et al. in press; Dittman 1990; cited in Kaiser and Beadman, 2002). However, the impact was localised with a reduced effect with increasing distance from the mussel bed. Ragnarsson and Raffaelli (1999) concluded that mussels clearly had marked effects on both the fauna and sediments probably through a combination of biodeposition and filtration by the mussels and the provision of a structurally complex habitat. Studies on the effects of beach nourishment (importing sand to counter the effects of erosion) provide an evidence base to support assessment of this pressure and the smothering and changes in sediment composition pressures. Where the sediment is of a different grade the community structure may change.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	Sediment is often added to shores as a soft defence to mitigate erosion and the ecological effects of this smothering type pressure have been examined. Studies have found that beach 'replenishment' or 'nourishment' can have a number of impacts on the infauna that can subsequently affect higher trophic levels, e.g. shore birds and fish that feed when intertidal sandflats are submerged (Peterson et al. 2000; Peterson et al. 2006). Impacts are more severe when the sediment added differs significantly in grain size or organic content (Nelson et al. 1989; Peterson et al. 2000). A thick layer of sediment has a smothering effect and in most instances buried species will die although some polychaetes can escape up to 90cm of burial In response to nourishment (Speybroek et al. 2007, references therein). Peterson et al. (2000) dominant macrofauna were reduced by 86-99% 5-10 weeks after the addition of sediment that was finer than the original sediments but with a high shell content. In North America, cultivation of clam species including the Manila clam, Tapes philippinarum usually involves some form of habitat modification in the form of adding gravel or gravel and crushed shell over mud and sand beaches, to create a more productive clam habitat (referred to as 'gravelled clam plots'). Such habitat modifications lead to alterations in the local environment and consequently faunal composition. Simenstad and Fresh (1995; cited in Kaiser and Beadman, 2002) reported that the application of gravel to intertidal sediments resulted in a shift from a polychaete to a bivalve and nemertean dominated community, but emphasised that changes are likely to be site-specific. Such shifts in community composition could have repercussions at other trophic levels e.g. changes in the abundance of certain harpacticoid copepod populations which are important prey for juvenile salmon and flatfish species (Simenstad and Fresh, 1995). The addition of gravel and shell material effectively creates a new habitat leading to more persistent changes in local community composition (Kaiser and Beadman, 2002). In relation to intertidal cultivation of bivalves, relaid mussels (i.e. 'on-growing' cultivation) lead to the development of 'mussel mud'

Pressure		Benchmark	Evidence
			beneath the mussel bed as the filtration and feeding activities of the mussels increase sedimentation rate. These deposits are composed of dead shells, silt and pseudofaeces, which persist in excess of 18 months after the mussels have been removed (Kaiser and Beadman, 2002). The relaying of cultivated mussels onto the seabed also causes a change in the infaunal community (Beadman et al. in press; unlisted reference; Ragnarsson and Raffaelli, 1999; Dittman, 1990; Committo, 1987; all cited in Kaiser and Beadman, 2002). This is demonstrated by a change in the composition of species of the infaunal community, and also the number of individuals and number of species present. At all but the lowest mussel densities, the infaunal communities of areas cultivated with mussels were found to be less abundant, in terms of both individuals and numbers of species, than the surrounding areas (Beadman et al. in press; Dittman 1990; cited in Kaiser and Beadman, 2002). However, the impact was localised with a reduced effect with increasing distance from the mussel bed. Ragnarsson and Raffaelli (1999) concluded that siltation from relaid mussels clearly had marked effects on both the fauna and sediments probably through a combination of biodeposition and filtration by the mussels and the provision of a structurally complex habitat. Hence, addition of coarse materials will alter the character of the sediment and reduce suitability for the biotopes associated with this feature. Recovery will depend on removal of the overburden, either naturally or through human activities and recovery will not take place until this has happened.
	Collision risk	Presence of significant collision risk, e.g. access by boat	Not exposed. This feature does not occur in the water column. Collision of benthic features with fishing gear addressed under physical disturbance pathways.
Disturbance	Underwater Noise		Not sensitive.
	Visual- boat/vehicle movements		Not sensitive.
	Visual – foot/traffic		Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	Changes in the coarse fraction of sediments will alter the character of this habitat feature and result in changes to the biological community present as habitat suitability changes. A sand sediment could become coarser if the fine sand sediment fraction is removed through surface disturbance and winnowing, either through physical disturbance or changes in water flow. Any increase or decrease in grain size, silt content etc. will affect species numbers/richness in soft sediment habitats but these should return to normal levels if the disturbance is temporary (Elliott et al. 1998). Fishing can directly alter the physical habitat by influencing sediment particle size (Thrush and 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. 2000). Where changes

Pressure		Benchmark	Evidence
			are long-term a community representative of the new habitat type will develop. A study in the Dutch Wadden Sea showed that suction-dredging for cockles (*Cerastoderma edule*) led to a significant long-term reduction in settlement and stocks of the target bivalve species (Piersma et al. 2001). Analysis of sediment characteristics before and after dredging showed an increase in median grain size and a reduction of silt content, and that these changes were most pronounced in the area dredged for cockles. Sediment characteristics only returned to pre-impact conditions 8-11 years after the suction dredging. The authors concluded that the suction dredging of *C. edule* had long lasting effects on the recruitment of bivalves (particularly the target species *C. edule*, but also *Macoma balthica*) in sandy parts of the Wadden Sea basin. Initial sediment reworking by suction dredging especially during autumn storms) probably caused loss of fine silts and then negative feedback processes appeared to follow that prevented the accumulation of fine-grained sediments conducive to bivalve settlement. Long term increases in grain-size may lead to a permanent change in the faunal composition of the biotope, with colonisation by species adapted to clean sands (such as *Fabulina fabula*, *Donax vittatus*, *Lanice conchilega*) or more mobile sand species such as Haustoriid amphipods becoming more dominant. (See also smothering for activity examples and impact information). However it should be noted that physical processes govern particle size and long-term increases in grain type will only occur if physical conditions are permanently altered. In North America, many native clam species are cultivated including Manila clam, *Tapes philippinarum*, and hard-shelled clam, *Mercenaria mercenaria*. Cultivation usually involves some form of habitat modification in the form of adding gravel or gravel and crushed shell over mud and sand beaches to create a more productive clam habitat (referred to as gravelled clam plots). Such habitat modifications lead to alterations in the local environment and consequently faunal composition. Simenstad and Fresh (1995; cited in Kaiser and Beadman, 2002) reported that the application of gravel to intertidal sediments resulted in a shift from a polychaete to a bivalve and nemertean dominated community, but emphasised that changes are likely to be site-specific. Such shifts in community composition could have repercussions at other trophic levels e.g. changes in the abundance of certain harpacticoid copepod populations which are important prey for juvenile salmon and flatfish species (Simenstad and Fresh, 1995). The addition of gravel and shell material effectively creates a new habitat leading to more persistent changes in local community composition (Kaiser and Beadman, 2002).
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	Changes in the fine fraction of sediments will alter the character of this habitat feature and result in changes to the biological community present as habitat suitability changes. A sand sediment could become a muddy sand sediment where the fine sediment fraction is increased through siltation resulting from changes in deposition rates and particulate supply and/or changes in water flow. Any decrease in grain size, silt content etc. will affect species numbers/richness in soft sediment habitats but these should return to normal levels if the disturbance is temporary (Elliott et al. 1998). Where changes are long-term a community representative of the new habitat type will develop.

Pressure		Benchmark	Evidence
			Intertidal sandflats contain all the grades of sand and to a lesser extent silt and clay (Elliott et al. 1998). Infauna can be affected by changes in sediment as many are adapted to burrow through certain grades of sediment (Trueman and Ansell, 1969), increased fine fractions will support species that maintain permanent burrows. Changes in sedimentary features may also influence the proportions of suspension and deposit feeding animals (Sanders, 1968), with deposit feeders favoured by increases in the proportion of silts and clays. Increased deposition of finer material will lead to increased dominance by species preferring finer and more stable sediments such as *Angulus tenuis*, *Echinocardium cordatum*, *Macoma balthica* and *Cerastoderma edule* (Elliott et al. 1998). Permanent changes in sediment characteristics with the deposition of fine particles would lead to the development of muddy sand biotopes.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	The hydrodynamic regime, including flow rates is an important factor determining the type of sediment present and the stability of the sediment. Increased flow rates e.g. around structures may lead to localised scour, removing finer particles and, if severe, removal of sand particles, increasing the coarse faction or exposing bed rock. Conversely, decreases in flow rate will lead to the deposition of finer particles, increasing the silt and clay content of the sand. Erosion of fine sand of 0.1mm particle diameter occurs at >30 cm s^{-1}, and deposition will occur at <15cm $s^{-1.}$ Particles of 1- 10 µm diameter have a similar relationship, although erosion requires faster current speeds because of consolidation and flocculation (Hedgpeth, 1967). The degree of impact will depend on the area affected and the sediment type. Changes in water flow influence the biological assemblage present through sediment effects and stability. Areas of high flow or wave energy where sediments are less stable are characterised by lower species diversity and the dominance of mobile animals that can re-position themselves following displacement such as Haustoriid amphipods and isopods. These species have a short life span and are characterised by their ability to withstand sediment disturbance. Low energy areas such as intertidal sheltered sandflats favour the establishment of a predominantly sessile community of polychaetes and long-lived bivalves (Elliott et al. 1998). Nugues et al. (1996) examined environmental changes at a relatively small oyster farm in the River Exe, England, and found that that water currents were significantly reduced in close proximity to oyster trestles, which doubled sedimentation rate and increased the organic content of the underlying sediments and led to a reduction in the depth of the oxygenated layer of sediment (Nugues et al. 1996). Nevertheless, the changes observed in the benthic fauna were restricted to the area immediately beneath the trestles. Hence, at low stocking densities, the effects of oyster cultivation are relatively benign and highly localised. Changes in sediment type to coarser or finer types are discussed above, organic enrichment and sedimentation effects are discussed in separate pressure sections in this proforma.
	Changes in turbidity/ suspended	Increase in particulate matter (inorganic and	Intertidal dredging resuspends sediments (Kaiser et al. 2006) as will other sediment disturbing activities. In general, bait digging in sheltered sediments releases fine materials into suspension and can lead to the release of sediment-associated contaminants (Fowler, 1999). The main environmental effects of increased turbidity levels from fishing and aquaculture operations on benthic

Pressure		Benchmark	Evidence
	sediment - Increased suspended sediment/ turbidity	organic)	habitats are a reduction in penetration of light into the water column during periods of emersion and suspended-sediment impacts on the associated biological assemblage, particularly suspension feeding organisms. Effects of 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; summarized in Johnson, 2002). Samples were taken prior to, during, and 10 months after dredging showed that turbidity plumes only lasted for a short time and often did not reach ambient seston (suspended particulate matter) levels. There were few consistent effects on water column chemistry. In areas of intertidal sandflats, deposition of heavier particles occured more quickly so that the plume would have a smaller temporal and spatial scale than that in the experimental study where the habitat was a mudflat. Increased levels of particulate matter will reduce habitat suitability for suspension feeders, due to clogging of feeding apparatus and the energetic costs required to sort more inorganic matter, favouring their replacement by deposit feeders.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	Cultivated (and wild populations) of bivalves remove suspended seston (phytoplankton, bacteria and resuspended sediment and flocculated detrital particles) from the water column when feeding. The removal of particulate matter may be beneficial in preventing eutrophication in estuaries where anthropogenic sources of dissolved nutrients stimulate phytoplankton production (Crawford et al. 2003; Newell, 2004). Bivalves produce faeces and pseudofaeces and local rates of sedimentation may be enhanced supplying deposit feeders with food. Detrimental effects may include organic enrichment of benthic habitats and decreased oxygen due to the enhanced biological oxygen demand accompanying bacterial degradation. 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. In locations with high bivalve biomass and relatively restricted water exchange, the feeding activities of cultured bivalves can remove sufficient organic and inorganic seston particles that the photic zone (depth of light penetration) is increased. This can extend the depths to which seagrass and benthic microalgae can grow. Reductions in the concentration of suspended particles is probably only significant in semi-enclosed situations, examples include the effects of mussel farming on the water clarity of fjord systems (Haamer, 1996; cited in Hartnoll, 1998), and of mussel populations in reclaiming disused docks (Wilkinson et al. 1996; cited in Hartnoll, 1998). In San Francisco Bay the bivalve population has the capacity to filter the volume of the bay daily, and is considered of far greater importance than the zooplankton in grazing down the phytoplankton (Cloern, 1982; cited in Hartnoll, 1998). Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (cited from Hartnoll (1998). Reductions in turbidity are not considered to affect habitat conditions beyond changes in favourability for some elements of the biological assemblage. Increased light may enhance primary production by phytoplankton and benthic microalgae, increasing the available food to higher trophic levels which may compensate

Pressure		Benchmark	Evidence
			for a reduction in organic matter. The biomass of the benthic microalgae often exceeds that of the phytoplankton in the overlying waters (McIntyre et al. 1996) such that benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability as mucilaginous secretions produced by benthic algae may stabilise fine substrata (Tait and Dipper, 1998).
	Organic enrichment - Water column	Eutrophication of water column	Fish cages release dissolved compounds directly into the surrounding water column including ammonia, nitrate and phosphate together with dissolved organic carbon. Nutrient enrichment of the water column can potentially lead to eutrophication and a possible consequence of nutrient enrichment is alteration of the species composition of plankton with possible proliferation of potentially toxic or nuisance species (OSPAR, 2009). However, the current consensus is that enrichment by salmon farm nutrients is generally too little, relative to natural levels, to have such an effect (SAMS and Napier University, 2002; cited in Wilding and Hughes, 2010). A recent modelling study of Loch Creran, Argyll, found that an increased nutrient input from salmon farms between 1975-2003 did not result in a significant increase in nutrient concentrations in the loch (Laurent et al. 2006; cited in Wilding and Hughes, 2010). Little detectable increase in phytoplankton standing crop adjacent to salmon cages in European or American waters has been shown (Weston, 1990; Gowen, 1990; Gubbins et al. 2003; cited in OSPAR, 2009) even though there are increases in ammonia and Smayda (2006; cited in OSPAR, 2009) indicated that increased nutrient loading from fish farm wastes in Scotland had not been accompanied by a detectable increase in harmful algal blooms within Scottish Waters. Bivalve aquaculture and fishing activities do not introduce nutrients into the system (although fishing may release nutrients through sediment disturbance), hence these activities are not considered significant. Eutrophication from caged fish farming are likely to be observed only in enclosed water bodies with low flushing rates. Eutrophication of the water column is not considered likely to directly negatively impact intertidal sandflats or mixed sediments although smothering by ephemeral macroalgae may occur in sheltered conditions and reductions in dissolved oxygen through increased bacterial degradation of dead plant matter may occur (see decreases in oxygen). Such effects are more likely to be due to terrestrial sources of nutrients than aquaculture activities (see evidence above).
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	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. 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. This type of impact is

Pressure		Benchmark	Evidence
			not common other than in localised areas in the estuaries and coastal waters of the UK but has recently been observed in relation to cage fish farm installations (UK Marine SACs project). In grossly polluted environments, the anoxic sediment is defaunated and may be covered by sulphur-reducing bacteria such as *Beggiatoa* spp. Such a change will affect the palatability of the prey and thus impair functioning of marine areas. This sequence has been observed on sandflats and sandbanks (e.g. Majeed, 1987; cited in Elliott et al. 1998) as a result of hydrocarbon pollution (Elliott et al. 1998). Benthic fauna underneath floating salmon farm cages in a Scottish sea loch showed marked changes in species number, diversity, faunal abundance and biomass in the region of the fish farm (Brown et al. 1987). Four 'zones' of effect identified: i) directly beneath and up to the edge of the cages there was an azoic zone, ii) from the edge of the cages out to 8m there was a highly enriched zone dominated by *Capitella capitella* and *Scolelepis fuliginosa*; iii) between 8m and 25m a 'slightly enriched zone' occurred and iv) a 'clean zone' over 25m from the edge of the cages. The authors concluded that salmon farming had similar effects on the benthos as other forms of organic enrichment, but that the effects were limited to a small area in the immediate vicinity of the cages. Hydrographic and physical conditions (water depth, currents, bottom substrate type) determine particulate matter deposition at any given location, organic matter accumulation in or on the bottom and resulting changes in oxygen status due to aquaculture, can be highly variable within a small area. In the United Kingdom, Parliamentary law necessitates the use of protective netting in Manila clam cultivation to prevent escape of this introduced species (Spencer et al. 1997). Spencer et al. (1996; 1997) found that the application of plastic netting to an estuarine silty sand substratum led to an immediate increase in sedimentation rate over cultivated plots which elevated the organic content of the sediment. Within 6 months the cultivated plots were dominated by opportunistic spionid worms. During the following 24 months, the spionids were replaced by high abundances of larger deposit feeding worm species. The plastic netting also became fouled with *Enteromorpha* spp. which in turn attracted grazing littorinid snails. Castel et al. (1989) found that the presence of densely stocked oyster parks (in the lower intertidal zone of Arcachon Bay, France) elevated organic carbon levels in the local sediments which elevated oxygen demand and produced anoxic conditions. As a result meiofauna increased in abundance by a factor of 3-4, while macrofaunal abundance decreased by nearly a half. Nugues et al. (1996) examined environmental changes at a relatively small oyster farm in the River Exe, England, and found that the abundance of macrofauna beneath trestles decreased by a half. They found that water currents were significantly reduced in close proximity to oyster trestles, which doubled sedimentation rate and increased the organic content of the underlying sediments and led to a reduction in the depth of the oxygenated layer of sediment (Nugues et al. 1996). Nevertheless, the changes observed in the benthic fauna were restricted to the area immediately beneath the trestles. Hence, at low stocking densities, the effects of oyster cultivation are relatively benign and highly localised. However, environmental effects are exacerbated as the carrying capacity of

Pressure		Benchmark	Evidence
			enclosed systems is exceeded and the extent of cultivated areas is increased (Castel et al. 1989; cited in Kaiser and Beadman, 2002).
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	Phytoplankton consumption by shellfish has the potential to reduce photoautotrophic biomass, alter primary productivity, and change algal community composition (Prins et al. 1998). Particle depletion, including removal of phytoplankton is of concern when large populations of cultivated bivalves remove food particles faster than tidal exchange and primary production can replace them, resulting in a significant reduction in the particulate food supply for extended periods over relatively large (e.g. bay-wide) scales. Reductions in particulate food supply (including phytoplankton) can reduce the productivity of cultured shellfish (e.g. negative feedback) and reduce the food supply to wild species. 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, 1996). In such areas, water depleted of particles by the cultured shellfish cannot be completely renewed by tidal exchange. Studies in Canada suggest that food supplies are affected by shellfish grazing, but that the magnitude of the effect varies spatially depending on local tidal transport processes. Cultivation methods and densities will influence depletion rates. Studies of food depletion associated with longline culture have provided variable results, with no food depletion reported inside some farms (Frechette et al. 1991; Pilditch et al. 2001), and significant depletions observed inside others (Rosenberg and Loo, 1983; Ogilvie et al. 2000; Ibarra, 2003; Strohmeier et al. 2005). Variability can be explained by site differences in the density of cultivated bivalves and the degree of water exchange, circulation patterns, current speed and mixing processes. Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM (http://www.farmscale.org/), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	The effects of changes in dissolved oxygen concentration on the marine environment can be sub-divided into direct effects (those organisms directly affected by changes in dissolved oxygen concentration) and secondary effects (those arising in the ecosystem as a result of the changes in the organisms directly affected). The direct effects of changes in dissolved oxygen (DO) concentrations are primarily related to reduced DO levels and include: lethal and sub-lethal responses in marine organisms, release of nutrients, and the development of hypoxic and anoxic conditions. The lethal and sub-lethal effects of reduced levels of dissolved oxygen are related to the concentration of dissolved oxygen and period of exposure of the reduced oxygen levels. A number of animals have behavioural strategies to survive periodic events of reduced dissolved oxygen. These include avoidance by mobile animals, such as fish and macro-crustaceans, shell closure and reduced metabolic rate in bivalve molluscs and either decreased burrowing depth or emergence from burrows for sediment dwelling crustaceans, molluscs and annelids.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	

Pressure		Benchmark	Evidence
			Reduced levels of dissolved oxygen in the water column can result in the release of phosphate from suspended particles and the sediment. Sustained reduction in dissolved oxygen concentrations can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. In anoxic environments, anaerobic bacteria proliferate, with nitrogenous oxide reducers absorbing oxygen by reducing nitrate to nitrite and forming ammonia or nitrogen gas. In addition, sulphate-reducing bacteria reduce sulphate to hydrogen sulphide which, when liberated, increases mortality of marine organisms and increases the BOD as it permeates through the water column (Kennish, 1986). Such conditions can occur under a cage fish farm installation where release of hydrogen sulphide has caused fish kills and sediment can become covered in filamentous fungi, such as *Beggiatoa* spp. The lethal and sub-lethal effects of reduced dissolved oxygen concentrations were reviewed by Stiff et al. (1992) for the purposes of EQS derivation. This review was updated by Nixon et al. (1995) in order to derive a General Quality Assessment (GQA) scheme for dissolved oxygen and ammonia in estuaries for the Environment Agency in England and Wales. Stiff et al. (1992) and Nixon et al. (1995) identified crustacea and fish as the most sensitive organisms to reduced DO levels with the early life stages of fish and migratory salmonids as particularly sensitive. For estuarine fish, Stiff et al. (1992) suggested a minimum DO requirement of 3 to 5 mg l^{-1}. On exposed shores the sand sediments are coarser and more porous and therefore have a higher oxygen content. Oxygen depletion becomes a severe problem at all states of the tide on only the very finest grained beaches, and as a general rule, if the percentage of particles of less than 0.25 mm median diameter exceeds 10% of a sediment, then the oxygen concentration of its interstitial water will be less than 20% of the air saturation level, and will drop rapidly during low tide periods (Brafield, 1964). Fine sands tend to have lower oxygen levels because their lower permeability leads to the trapping of detritus which, together with the large surface area for microbial colonisation, leads to higher oxygen uptake (Eagle, 1983).Organic detritus therefore undergoes anaerobic degradation, with hydrogen sulphide, methane or ammonia produced, as well as dissolved organic carbon compounds which can be utilised by aerobic micro-organisms living on the surface (McLusky, 1989; Libes, 1992). These features produce a reducing layer (indicted by the redox potential discontinuity layer, RPD) very close (often <1cm) to the surface. In such habitats, species may be more tolerant of episodes of hypoxia and anoxia. In general, induced anoxic conditions in sand and mudflats may alter community structure and reduce diversity and abundance and interfere with bird feeding (Simpson, 1997; cited in Elliott et al. 1998). In grossly polluted environments, the anoxic sediment is defaunated and may be covered by sulphur-reducing bacteria such as *Beggiatoa* spp. Such a change will affect the palatability of the prey and thus impair functioning of marine areas. This sequence has been observed on sandflats and sandbanks (e.g. Majeed, 1987; cited in Elliott et al. 1998) as the result of hydrocarbon pollution (Elliott et al. 1998).

Pressure		Benchmark	Evidence
			The effects of sediment deoxygenation arising from intertidal oyster parks are described in 'Organic enrichment – sediment' above.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	There are 8 known invasive species in Irish Seas (Invasive Species Ireland project http://invasivespeciesireland.com/toolkit/), slipper limpet (*Crepidula fornicata*) and Pacific Oyster (*Crassostrea gigas*) are of key relevance to this feature (species either occurs in this feature and/or can be spread by aquaculture activities and boat movements). Cord grass (*Spartina anglica*) may occur on the upper shore and the seaweed *Sargassum muticum* may colonise seagrass (*Zostera*) beds within intertidal mudflats or attach to stones and bivalve shells. The ascidian Didemnum vexillum may colonise artificial hard substrates such as aquaculture trestles or mussel and oyster beds. Aquaculture may act as vector through the introduction of broodstock contaminated with potential alien species or through the relaying of stock between water bodies for ongrowing. Management should prevent the spread of non-native species through responsible sourcing of broodstock, licensing requirements and the implementation of the EC Regulation on the use of alien and locally absent species in aquaculture and the Aquatic Animal Health Regulations. Boat movements may transport non-native species between marinas and harbours, management of fouling will help prevent accidental transport. The slipper limpet was first recorded in Northern Ireland at Belfast Lough in 2009 (McNeil et al. 2010). Other records exist from around Ireland over the last century including: Ballinakill Bay, Carlingford Lough, Dungarven Bay, Kenmare Bay and Clew Bay. However, none of these sites are currently thought to be supporting *C. fornicata*. This species most likely arrived in Ireland with consignments of mussels. Other possible pathways include; with consignments of oysters, on drifting materials or due to dispersal of larvae. They may settle near the low water mark on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per ^{m2}. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them.

Pressure		Benchmark	Evidence
			Pacific oysters were first brought to Northern Ireland as part of aquaculture development. They have now been grown in Northern Ireland since the early 1970s when initial growth and survival trials were carried out in Strangford Lough. Feral populations of Pacific oysters are now breeding successfully which may bring about a fundamental change to the ecosystem of the area. Pacific oysters are also known to have spawned in Lough Foyle where populations have formed solid reefs in soft sediment habitats such as the mudflats of the Wadden Sea (Ruesink et al. 2005; Kochmann et al. 2008; cited in OSPAR, 2009) The brown alga *Sargassum muticum* (wire weed) has been recorded at many locations around the coast of Ireland and is now widespread with definite records in Counties Down, Louth, Wexford, Cork, Kerry, Galway and Sligo. It is likely that the species has a much wider distribution and will spread to new areas to colonise all coastal areas. The species is known to occur from the intertidal to the subtidal in a range of substrates including hard rock and *Zostera marina* (eel grass) beds. The species can occupy hard substrates on sheltered shores where it can from dense monospecific stands excluding other species. It is believed that this species arrived with oyster spat introduced for commercial purposes so that aquaculture can be considered a potential vector for spread of this species. This species has very high growth rates and can grow up to 16m in length, forming floating mats on the sea surface. It can grow up to 10cm per day, and it also has a long life span of 3-4 years. Dense mats of *S. muticum* can form very quickly. Fronds, if detached, can continue to shed germlings as they drift. Dense S. muticum stands can reduce the available light for understory species, dampen water flow, increase sedimentation rates and reduce ambient nutrient concentrations available for native species. *Didemnum vexillum* (leathery sea squirt) was first recorded in Cork Harbour in 1971 (Guiry and Guiry, 1973) and may be spread via contaminated aquaculture produce and equipment including trestles and ship movements. This species colonises hard surfaces including aquaculture structures and can smother habitats including hard substrata and biogenic habitats including oysters, scallops and mussels (from www.invaisvespeciesireland.com). *Potential threats* Aquaculture spat from contaminated areas may potentially introduce bivalve predators, not yet established in Ireland that can have serious implications for natural and cultivated populations, these include the Asian rapa whelk (*Rapana venosa*) and oyster drills *Ceratostoma inornatum* and *Urosalpinx cinerea*. Wakame (*Undaria pinnitifada*) is not present in Ireland but aquaculture is a potential vector for introductions. This species can form dense stands creating a thick canopy over the biota in a wide range of shores and exposure. Cord grass (*Spartina anglica*) is a fertile hybrid developed in the south coast of England after the introduction of the non-native species *S. alterniflora* crossed with *S. maritima*. *Spartina anglica* is widespread on sheltered muds at tide level around the coast of

Pressure		Benchmark	Evidence
			Ireland. This species was initially deliberately planted in Ireland to stabilise dunes and is not considered to be introduced or spread by fishing or aquaculture activities. Common cord-grass colonises sheltered coastal mudflats at a tidal level below the normal coastal salt marsh vegetation, producing dense swards. These swards can slow the movement of water and increase the rate of sediment deposition. On intertidal mudflats it reduces the food available for wildfowl and wading birds, notably eel grass beds and invertebrates. (Above information from Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit/). Few invasive invertebrate species have been reported from sandy beaches (Defeo et al. 2009). Sand sediments were considered to have greater resistance to invasive species than the muddy sediments typical of more sheltered shores, due to greater sediment instability and consequent habitat unsuitability. However where the placement of aquaculture infrastructure has the potential to reduce current speeds or provide suitable habitat for colonisation, there may be potential for the establishment of non-native species. Although not directly colonising invasive macroalgae species including Undaria piinitifada and *Sargassum muticum* have been reported to change the biomass and composition of the strandline with potential trophic effects on consumers (Defeo et al. 2009 and references therein).
	Introduction of parasites/ pathogens		Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		*Cerastoderma edule* may occur in littoral sand habitats (coarse clean sand, fine clean sand, sandy mud and muddy sand) and may be targeted for extraction using mechanical methods (e.g. tractor dredges or hydraulic suction dredging) or by large numbers of fishers using hand rakes. *Arenicola marina* may be collected commercially and by individuals for bait, usually by hand digging or bait pumping. Professional and local bait diggers may work over 200m^2 of sediment per tide and have been estimated to remove 50-70% of bait (Tyler-Walters, 2008). Other species associated with this feature which may potentially be harvested for bait or consumption include the polychaete Nephtys hombergii, the common razor shell *Ensis ensis* and the sand gaper clam *Mya arenaria* (Fowler, 1999). Where species are depleted by over-harvesting, common fecund species (e.g. *Arenicola marina*) recover quickly. Less common, slow-reproducing species are of greater concern (e.g. long-lived bivalves, *Nephtys* species) (Fowler, 1999). The effects of removal of these species on the sedimentary habitat are likely to be constrained to physical damage interactions and are considered above in the physical disturbance theme. The feature is not considered to be functionally dependent on commercially targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal. However, the removal of-target species may result in changes to the classification of the assemblage type as assessed in the biotope

Pressure		Benchmark	Evidence
			proformas where these are characterising species.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	The sensitivity of intertidal sandflats to the pressures that arise through the removal of target and non-target species is considered in the above pressure themes. The feature is not considered to be functionally dependent on targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal. However, the removal of non-target species may result in changes to the biological community and hence the classification of the assemblage type as assessed in the biotope proformas where these are characterising species.
	Ecosystem Services - Loss of biomass		Not relevant to SAC habitat features.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	The use of medicinal products in shellfish cultivation is minimal and hence not considered any further. Various medicinal compounds are used within finfish aquaculture, however, it was considered relatively unlikely that these would impact intertidal features as finfish cages are located over subtidal habitats. Sediment re-suspension and currents may transport these but no information was found regarding the potential spatial footprint or the potential for effects on intertidal habitat features.
	Introduction of hydrocarbons	Introduction of hydrocarbons	In general, oil-spills (resulting from tanker accidents) can cause large-scale deterioration of communities in intertidal and shallow subtidal sedimentary systems. Tidal-pulsing has the potential to push oil into intertidal sands (Elliott et al. 1998). Crude oil has a number of effects on species, it can be directly toxic and can also have physical effects, through the smothering of gills and filter-feeding appendages. Oil also has physical effects on the habitat reducing water flow through the beach and leading to anoxia in sediments (Brown and McLachlan, 2002) The meiofauna may recover from an oil spill within a year (McLachlan and Harty, 1981). In grossly polluted environments, the anoxic sediment is defaunated and may be covered by sulphur-reducing bacteria such as *Beggiatoa* spp. This sequence has been observed on sandflats and sandbanks (e.g. Majeed, 1987; cited in Elliott et al. 1998) as the result of hydrocarbon pollution (Elliott et al. 1998). Macrofaunal species take longer to re-establish themselves, early successional stages are led by opportunistic polychaete worms of the families Capitellidae and Cirratulidae which may increase in numbers or invade the beach if not previously present, and temporarily dominate the system (Southward, 1982). The macrofauna of fine sediments takes longer to recover than that of coarser beaches and oil trapped in the sand may influence the system for six years or more (Thomas, 1978).
	Introduction of antifoulants	Introduction of antifoulants	(See subtidal sand for discussion on antifoulant inputs from fish farms and other infrastructure). Where antifoulants are used to prevent fouling of cages in aquaculture they are usually copper based although zinc may also be an active ingredient in some products. Antifoulants are not always used and mechanical cleaning of nets/equipment is often preferred. The use of TBT has not been permitted on aquaculture installations for over 20 years (Marine Institute, 2007). Heavy metals,

Pressure		Benchmark	Evidence
			particularly copper and zinc, can be present at elevated concentrations in sediments beneath fish farm cages (Mendiguchia et al. 2006; Dean et al. 2007) with the principal sources being fish feed and antifoulant paints. Copper and other biocides may be sequestered in sediments beneath aquaculture installations particularly where organic matter content and sulphide levels are high. However some water transport of leached biocides may occur in the water column and further transport, may follow re-suspension after sediment disturbance or during sediment recovery following fallowing (Brooks et al. 2003) increasing the impact footprint of these activities. The impact will depend on the degree to which the substances are bioavailable and the concentration of bioavailable forms. The persistence of chemical residues is highly dependent on the matrix and ambient environmental conditions. In general, residues in water are less likely to be of long-term concern because of photodegradation and dilution to below biologically significant concentrations. Residues incorporated into sediments tend to persist for longer periods, particularly if the sediments are anaerobic (Huntington et al. 2006). No evidence was found relating to the dispersal of copper and zinc from subtidal aquaculture installations to intertidal sediments. The toxicity of copper in water and in sediments is influenced by a number of factors so that it is difficult to predict the subsequent toxicity to aquatic organisms and hence the effects from potential inputs. The chemical form (or speciation) of the copper and site-specific environmental conditions including water pH, organic content, temperature and salinity influence bioavailability and hence toxicity (Kiaune et al. 2011; Burridge et al. 2008). It is uncertain which forms are bioavailable, and no reliable measuring methods for assessment of the size of the bioavailable fraction are available. The actual bioavailability will typically be considerably less than the potential bioavailability. Furthermore, bioavailability is species specific and may also depend on physiology, nutrition, life-stage, age and size of the organisms (Madsen et al. 2000).
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	No evidence. As this feature is not characterised by the presence of primary producers it is not considered that shading would alter the character of the habitat. Changes in microphytobenthos abundance may occur beneath structures. Intertidal sandflats support microphytobenthos in the interstices of the sandgrains. The microphytobenthos consists of unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments, typically appearing only as a subtle brownish or greenish shading. Mucilaginous secretions produced by these algae may stabilise fine substrata (Tait and Dipper, 1998). The biomass of the benthic microalgae often exceeds that of the phytoplankton in the overlying waters (McIntyre et al. 1996) such that benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability. Shading will prevent photosynthesis leading to death or migration of sediment microalgae altering sediment cohesion and food supply to higher trophic levels.
	Barrier to species movement		Not relevant to SAC habitat features.

References

Ball, B., Munday, B. and Tuck, I. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. In: Kaiser, M.J. and Groot, S.J. (Eds.) Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Oxford: Blackwell Science Limited. pp. 69-82.

Beukema, J.J. 1995. Long-term effects of mechanical harvesting of lugworms Arenicola marina on the zoobenthic community of a tidal flat in the Wadden Sea. Netherlands Journal of Sea Research 33: 219-227.

Blake, R.W. 1979. Exploitation of a natural population of *Arenicola marina* (L.) from the north-east coast of England. Journal of Applied Ecology 16: 663-670.

Brown, A. C. and McLachlan, A. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Environmental Conservation 29(1): 62-77.

Brafield, A.E. 1964. The oxygen content of interstitial water in sandy shores. Journal of Animal Ecology 33: 97-116.

Brook, K.M., Stierns, A.R., Mahnken, C.V.W. and Blackburn, D.B. 2003. Chemical and biological remediation of the benthos near Atlantic salmon farms. Aquaculture 219: 355-377.

Brown, J.R., Gowen, R.J. and McLusky, D.S. 1987. The effect of salmon farming on the benthos of a Scottish sea loch. Journal of Experimental Marine Biology 109: 39-51.

Brown, A.C. and McLachlan, A. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Environmental Conservation 29: 62-77.

Buchanan, J.B. and Moore, J.J. 1986. A broad review of variability and persistence in the Northumberland benthic fauna: 1971–85. Journal of the Marine Biological Association of the United Kingdom 66: 641-657.

Budd, G.C. 2008. Barren coarse sand shores. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 23/08/2012]. Available from:
http://www.marlin.ac.uk/habitatbenchmarks. php?habitatid=16&code=2004.

Burridge, L, Weis, J., Cabello, F. and Pizarro, J. 2008. Chemical Use in Salmon Aquaculture: A Review of Current Practices and Possible Environmental Effects. World Wildlife Federation, Salmon Aquaculture Dialogue.

Castel, J., Labourg, P-J., Escaravage, V., Auby, I. and Garcia, M. 1989. Influence of seagrass beds and oyster parks on the abundance and biomass patterns of meio- and macrobenthos in tidal flats. Estuarine, Coastal and Shelf Science 28: 71-85.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Cranford, P.J., Anderson, R., Archambault, P., Balch, T. et al. 2006. Indicators and thresholds for use in assessing shellfish aquaculture impacts on fish habitat. CSAS-DFO Res Doc 2006/034. Fisheries and Oceans Canada, Ottawa. Available at:
www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/ RES2006_034_e.pdf.

Crawford, C.M., Macleod, C.K.A. and Mitchell, I.M. 2003. Effects of shellfish farming on the benthic environment. Aquaculture 224: 117-140.

Dame, R.F. 1996. Ecology of marine bivalves: an ecosystem approach. CRC Press, Boca Raton, FL.

Dean, R.J., Shimmield, T.M. and Black, K.D. 2007. Copper, zinc, and cadmium in marine cage fish farm sediments: An extensive survey. Environmental Pollution 145: 84-95.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. and Scapini, F. 2009. Threats to sandy beach ecosystems: a review. Estuarine, Coastal and Shelf Science, 81: 1-12.

Dernie, K.M., Kaiser, M.J. and Warwick, R.M. 2003 Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology 72: 1043-1056.

Drabsch, S.L., Tanner, J.E. and Connell, S.D. 2001. Limited infaunal response to experimental trawling in previously untrawled areas. ICES Journal of Marine Science 58: 1261-1271.

Dyrynda, P. and Lewis, K. 1995. Ecological studies within the Crymlyn Burrows SSSI (Swansea bay, Wales): impacts of mechanised cockle harvesting. Marine Environment Research Group, University of Wales. 15 pp.

Eagle, G.A. 1983. The chemistry of sandy beach ecosystems - a review. In: McLachan, A. and Erasmus, T. (Eds.) Sandy beaches as ecosystems. The Hague, The Netherlands: Junk. 203-224.

Elliott M., Nedwell S., Jones N.V., Read S.J., Cutts N.D. and Hemingway K.L. 1998. Intertidal Sand and Mudflats and Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs.151 pp.

Emerson, C.W., Grant, J. and Rowell, T.W. 1990. Indirect effects of clam digging on the viability ofsoft-shell clams, *Mya arenaria* L. Netherlands Journal of Sea Research 27(1): 109-118.

EUNIS. 2007. European Environment Agency 2007. European Habitat Type Hierarchical View. Available online at: http://eunis.eea.europa.eu/habitats-code-browser.jsp.

Fletcher, S., Saunders, J. Herbert, R. and Roberts, C. 2011. Description of the ecosystem services provided by broad-scale habitats and features of conservation importance that are likely to be protected by Marine Protected Areas in the Marine Conservation Zone Project area. Natural England.

Fortes, M.D. 2002. Natural biological processes and controls. Proceedings in Marine Science 4: 229-244.

Fowler, S.L. 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. English Nature (UK Marine SACs Project). 132 pages.

Fréchette, M. and Grant, J. 1991. An in situ estimation of the effect of wind-driven resuspension on the growth of the mussel *Mytilus edulis* L. Journal of Experimental Marine Biology and Ecology 148(2): 201-213.

Godfrey, P.J., Leatherman, S.P. and Buckley, P.A. 1978. Impact of off-road vehicles on coastal ecosystems. In: Proceedings of a Symposium on Coastal Zones 1978, 581-600p.

Gubbay, S. and Knapman, P.A. 1999. A review of the effects of fishing within UK European marine sites. English Nature (UK Marine SACs Project). 134pp.

Guiry, G.M. and Guiry, M.D. 1973 Spread of an introduced ascidian to Ireland. Marine Pollution Bulletin 4: 127.

Hall S.J., MJC Harding 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. Journal of Applied Ecology 34: 497-517.

Hall, K., Paramor, O.A.L., Robinson L.A., Winrow-Giffin, A., Frid C.L.J., Eno, N.C., Dernie, K.M., Sharp, R.A.M., Wyn, G.C.and Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters- development of a protocol. CCW [Policy Research] Report No: [8/12], 85pp.

Hartnoll, R.G. 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland [UK Marine SAC Project. Natura 2000 reports].

Hedgpeth, J.W. 1967. The sense of the meeting. In: Lauff (Ed) Estuaries, AAAS, 83, 707- 712.

Hiddink, J.G. 2003. Effects of suction-dredging for cockles on non-target fauna in the Wadden Sea. Journal of Sea Research 50: 315-323.

Huntington, T.C., Roberts, H. Cousins, N., Pitta, V., Marchesi, N., Sanmamed, A., Hunter-Rowe, T., Fernandes, T.F., Tett, P., McCue, J. and Brockie, N. 2006. 'Some Aspects of the Environmental Impact of Aquaculture in Sensitive Areas'. Report to the DG Fish and Maritime Affairs of the European Commission.

Ibarra, D.A. 2003. Estimation of seston depletion by cultured mussels (*Mytilus* spp.) using measurements of diffuse attenuation of solar irradiance from optical moorings. M.Sc. thesis, Dalhousie Univ.

Jennings, S. and Kaiser, M.J. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology, 34, 203-352

JNCC. 2007. Second report by the UK under Article 17 on the implementation of the Habitats Directive from January 2001 to December 2006. Peterborough: JNCC. Available from: www.jncc.gov.uk/article17.

JNCC. 2009. UK Biodiversity Action Plan Priority Habitat Descriptions Subtidal Sands and Gravels. From: UK Biodiversity Action Plan; Priority Habitat Descriptions. BRIG (ed. Ant Maddock) 2008.

Johnson, K.A. 2002. A review of national and international literature on the effects of fishing on benthic habitats (p. 72). US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Jones, L.A., Hiscock, K. and Connor, D.W. 2000. Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. Joint Nature Conservation Committee, Peterborough.

Kaiser, M.J., Broad, G. and Hall, S.J. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. Journal of Sea Research 45(2): 119-130.

Kaiser, M.J. and Beadman, H.A. 2002. Scoping study of the carrying capacity for bivalve cultivation in the coastal waters of Great Britain. The Crown Estate. Interim Report: 39 pp.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. and Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1-14.

Kennish, M. 1986. The ecology of estuaries. Volume 1 Physical and Chemical aspects. CRC Press.

Kiaune, L. and Singhasemanon, N. 2011. Pesticidal copper (I) oxide: Environmental fate and aquatic toxicity. Reviews of Environmental Contamination and Toxicology 213: 1-26.

Larsonneur, C. 1994. The Bay of Mont-Saint-Michel: A sedimentation model in a temperate macrotidal environment. Senckenbergiana Maritima 24: 3-63.

Libes, S.M. 1992. An Introduction to Marine Geochemistry. Wiley, New York, 734pp.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

Majeed, S.A. 1987. Organic-matter and biotic indexes on the beaches of North Brittany. Marine Pollution Bulletin 18(9): 490-495.

Marine Institute. 2007. Veterinary treatments and other substances used in finfish aquaculture in Ireland. Report prepared by the Marine Institute for SWRBD. March 2007.

McIntyre, H.L., Geider, R.J. and Miller, D.C. 1996. Microphytobenthos: the ecological role of the "secret garden" of un-investigated shallow water marine habitats. I. Distribution, abundance and primary production. Estuaries 19: 186-201.

McLachlan, A. and Harty, B. 1981. Effects of crude oil pollution on the supralittoral meiofauna of a sandy beach. Marine Environmental Research 7: 71-80.

McLusky, D.S., Anderson, F.E. and Wolfe-Murphy, S. 1983. Distribution and population recovery of Arenicola marina and other benthic fauna after bait digging. Marine Ecology Progress Series 11: 173-179.

McLusky, D.S. 1989 The Estuarine Ecosystem. Chapman and Hall, Glasgow, 215 pp.

McNeill, G., Nunn, J. and Minchin, D. 2010. The slipper limpet *Crepidula fornicata* Linnaeus, 1758 becomes established in Ireland Aquatic Invasions 5, Supplement 1: S21-S25.

Mendiguchia, C., Moreno, C., Manuel-Vez, M.P. and Garcia-Vargas, M. 2006 Preliminary investigation on the enrichment of heavy metals in marine sediments originated from intensive aquaculture. Aquaculture 254: 317-325.

Moffett, M.D., McLachlan, A., Winter, P.E.D. and De Ruyck, A.M.C. 1998. Impact of trampling on sandy beach macrofauna. Journal of Coastal Conservation and Ecology 4: 87-90.

Moore, J. 1991. Studies on the Impact of Hydraulic Cockle Dredging on Intertidal Sediment Flat Communities: Final Report.

Newell, R.C., Seiderer, L.J. and Hitchcock, D.R. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology: an Annual Review 36: 127-78.

Newell, R.I.E. 2004. Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve mollusks: A review. Shellfish Research 23: 51-61.

Nixon, S.C., Gunby, A., Ashley, S.J., Lewis, S. and Naismith, I. 1995. Development and testing of General Quality Assessment schemes: dissolved oxygen and ammonia in estuaries. NRA Project Record 469/15/HO.

Nugues M., Kaiser, M., Spencer, B. and Edwards, D. 1996 Benthic community changes associated with intertidal oyster cultivation. Aquaculture Research 27: 913-924.

Ogilvie, S.C., Ross, A.H. and Schiel, D.R. 2000. Phytoplankton biomass associated with mussel farms in Beatrix Bay, New Zealand. Aquaculture 181(1): 71-80.

Olive, P.J.W. 1993. Management of the exploitation of the lugworm *Arenicola m*arina and the ragworm *Nereis virens* (Polychaeta) in conservation areas. Aquatic Conservation: Marine and Freshwater Ecosystems 3(1): 1-24.

OSPAR Commission. OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6).

OSPAR. 2009. Background document for Intertidal mudflats. OSPAR Commission, Biodiversity Series. ISBN 978-1-906840-67-9.

Pearson, T. and Rosenberg, R. 1978 Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology. An Annual Review 16: 229-311.

Peterson, C.H., Hickerson, D.H.M. and Johnson, G.G. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research 16: 368-378.

Peterson, C.H., Bishop, M.J., Johnson, G.A., D'Anna, L.M. and Manning, L.M. 2006. Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shore birds. Journal of Experimental Marine Biology and Ecology 338: 205-221.

Piersma, T., Koolhaas, A., Dekinga, A., Beukema, J.J., Dekker, R. and Essink, K. 2001. Long-term, indirect effects of mechanical cockle-dredging on intertidal bivalve stocks in the Wadden Sea. Journal of Applied Ecology 38: 976-990.

Pilditch, C.A., Grant, J. and Bryan, K.R. 2001. Seston supply to sea scallops (*Placopecten magellanicus*) in suspended culture. Canadian Journal of Fisheries and Aquatic Sciences 58(2): 241-253.

Prins, T.C., Smaal, A.C. and Dame, R.F. 1998. A review of the feedbacks between bivalve grazing and ecosystem processes. Aquaculture Ecology 31: 349-359.

Ragnarsson, S.A. and Rafaelli, D. 1999. Effects of the mussel *Mytilis edulis* L. on the invertebrate fauna of sediments. Journal of Experimental Marine Biology and Ecology 241: 31-43.

Rees, E.I.S. 1996. Environmental Effects of Mechanised Cockle Fisheries: a review of research data. Report to MAFF.

Rosenberg, R. and Loo, L-O. 1983. Energy-flow in a *Mytilis edulis* culture in western Sweden. Aquaculture 35: 151-161.

Rostron, D.M. 1995. The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. P111- 117. In Burry Inlet and Loughor Estuary Symposium, March 1995. Part 2. Burry Inlet and Loughor Estuary Liaison Group.

Rostron, D. 1993. The effects of Tractor towed cockle dredging on the invertebrate fauna of Llandhidrian Sands, Burry Inlet. Subsea Survey. Report to Countryside Council for Wales.

Ruesink, J.L., Lenihan, H.S., Trimble, A.C., Heiman, K.W., Micheli, F., Byers, J.E. and Kay, M.C. 2005. Introduction of non-native oysters: ecosystem effects and restoration implications. Annual review of ecology, evolution, and systematics: 643-689.

SAMS and Napier University. 2002. Review and synthesis of the environmental impacts of aquaculture, Report published by the Scottish Executive.

Sanders, H.L. 1968. Marine benthic diversity: A comparative study. American Naturalist 102: 243-28.

Schlacher, T.A., Richardson, D. and McLean, I. 2008. Impacts of off-road vehicles (ORVs) on macrobenthis assemblages on sandy beaches. Environment Management 41: 878-892.

Simenstad, C. and Fresh, K. 1995. Influence of intertidal aquaculture on benthic communities in Pacific northwest estuaries: scales of disturbance. Estuaries 18(1A): 43-70.

Simpson, M.A. 1997. An investigation into the causes, effects and implications of the growth of the green macroalga *Enteromorpha* spp. On Seal Sands, Teesmouth. Unpublished M.Sc. dissertation, University of Hull.

Snelgrove, P., Butman, C. 1994. Animal-sediment relationships revistied: cause versus effect. Oceanography and Marine Biology: An Annual Review 32: 111-177.

Southward, A.J. 1982. An ecologist’s view of the implications of the observed physiological and biochemical effects of petroleum compounds on marine organisms and ecosystems. Philosophical Transactions of the Royal Society of London, Series B 297: 241–255.

Spencer, B., Kaiser, M. and Edwards, D. 1996. The effect of Manila clam cultivation on an intertidal benthic community: The early cultivation phase. Aquaculture Research 27: 261-276.

Spencer, B.E., Kaiser, M.J., Edwards, D.B. 1997. Ecological effects of intertidal Manila clam culitvation: observations at the end of the cultivation phase. Journal of Applied Ecology 34: 444-452.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J.-P., Mathys, M., Provoost, S., Sabbe, K., Stienen, W.M., Van Lancker, V., Vincx, M. and Degraer, S. 2006. Beach nourishment: an ecologically sound coastal defence alternative? A review. Aquatic Conservation: Marine and Freshwater Ecosystems 16: 419-435.

Stiff, R.I. 1992. Environmental quality standards for dissolved oxygen. NRA R&D Note 130. M.J., Cartwright, N.G., Crane.

Tait, R.V. and Dipper, F.A. 1998. Elements of Marine Ecology. Fourth edition. Reed Elsevier plc group.

Thomas, M.L.H. 1978. A comparison of oiled and unoiled intertidal communities in Chedabucto Bay, Nova Scotia. Journal of the Fisheries Research Board of Canada 35: 707–716.

Thrush, S.F., Whitlatch, R.B., Pridmore, R.D., Hewitt, J.E., Cummings, V.J. and Wilkinson, M.R. 1996 Scaledependent recolonization: the role of sediment stability in a dynamic sandflat habitat. Ecology 77: 2472-2487.

Thrush, S.F. and Dayton, P.K. 2002. Disturbance to marine benthic habitats by trawling and dredging: Implications for Marine Biodiversity. Annual Review of Ecology and Systematics 33(1): 449-473.

Trueman, E.R. and Ansell, A.D. 1969. The mechanisms of burrowing into soft substrata by marine animals. Oceanography and Marine Biology: an Annual Review 7: 315-366.

Tyler-Walters, H. 2008. *Arenicola marina*. Blow lug. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 11/07/2011]. Available from:
http://www.marlin.ac.uk/speciesimportance.php?speciesID=2592.

Tyler-Walters, H. and Arnold, C. 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN) [Contract no. FC 73-03-327]. Plymouth, Marine Biological Association of the UK.

Witbaard, R. and Bergman, M. 2003. The distribution of *Arctica islandica* in the North Sea. What possible factors are involved? Journal of Sea Research 50: 11-25.

Wilding, T. and Hughes, D. 2010. A review and assessment of the effects of marine fish farm discharges on Biodiversity Action Plan habitats. ISBN: 978-1-907266-27-0.

Websites

FARM: (http://www.farmscale.org.

Invasive Species Ireland project: http://invasivespeciesireland.com/toolkit.

SMILE project for Northern Ireland Loughs: http://www.longline.co.uk/site/smile.pdf.

Biotope A2.23 Polychaete/amphipod dominated sand shores

(Part of Littoral (Intertidal) Sand Habitats)

Pro-forma Information

This proforma has been produced as part of a risk assessment tool to assess the likelihood of impacts of fishing and aquaculture activities on habitats and species, to support the preparation of Appropriate Assessments (AAs) for Natura 2000 sites.

The key component of the risk assessment tool for the AA preparation is a sensitivity matrix which shows the sensitivity of SAC and SPA features to pressures arising from fishing and aquaculture activities. The feature being assessed in this proforma has been identified as being present within an SAC or SPA. The purpose of this proforma is to act as an accompanying database to the sensitivity matrix, providing a record of the evidence used in the sensitivity assessment of this feature (Table II.6) and a record of the confidence in the assessment made (Table II.6 and Table II.7).

The following description of the main biological community associated with this feature is taken from the EUNIS website, the original source for these is Connor et al. (2004). Equivalent habitat designations are shown below in Table II.3.

Feature Description

This feature refers to intertidal fine sand shores, which are a sub-feature of littoral sand shores. The assessment has been structured following the EUNIS framework shown in Figure II.3 below. It should be noted that there will be some overlap between these communities and those assessed in sublittoral sand (see below) and Report III as similar species may be found in sublittoral and littoral muddy sand and sandy mud and sublittoral mud.

EUNIS A2.23 Polychaete/amphipod dominated fine sand shores.

Shores of clean, medium to fine and very fine sand, with no coarse sand, gravel or mud present. Shells and stones may occasionally be present on the surface. The sand may be duned or rippled as a result of wave action or tidal currents. The degree of drying between tides is limited, and the sediment usually remains damp throughout the tidal cycle. Typically, no anoxic layer is present. Fine sand shores support a range of species including amphipods and polychaetes. On the lower shore, and where sediments are stable, bivalves such as *Angulus tenuis* may be present in large numbers. Fine sand communities may be present throughout the intertidal zone on moderately exposed beaches, or they may be present on the lower parts of the shore with mobile sand communities present along the upper shore. A strandline of talitrid amphipods (A2.211) typically develops at the top of the shore where decaying seaweed accumulates. Temporal variation: Fine sand shores may show seasonal changes, with sediment accretion during calm summer periods and beach erosion during more stormy winter months. There may be a change in sediment particle size structure, with finer sediment grains washed out during winter months, leaving behind coarser sediments.

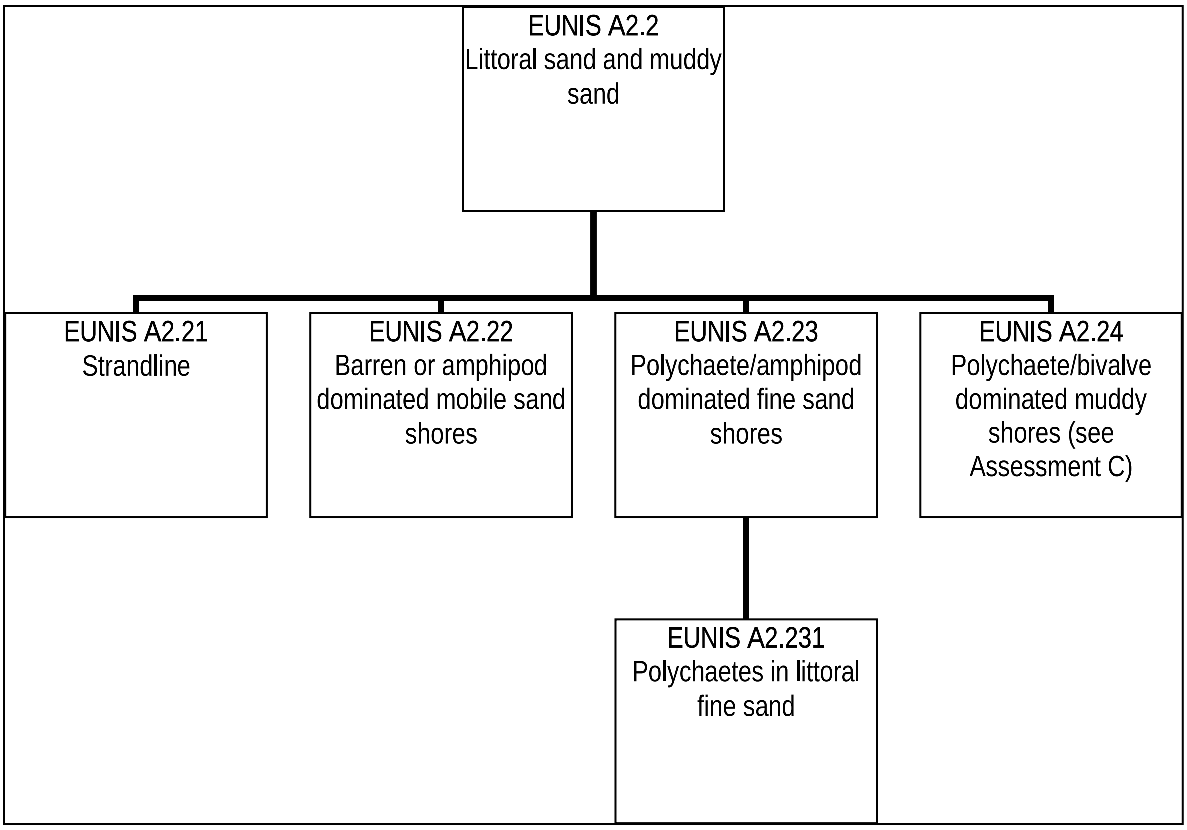


Figure II.3 Hierarchical Diagram showing the EUNIS descriptive framework for Littoral Fine Sand Community Complex (Levels 3-5 only)

Features Assessed

The sensitivity assessment presented in this document relates to the EUNIS biotype type A2.23 and is based primarily on the habitat and characterising species identified as distinguishing species within the Conservation Objectives and listed below (Table II.3). Where indicated, assessments for these species are presented in stand alone proformas. Assessments also refer to other mud shore species that are not referenced in the table below as these could be relevant to further Conservation Objectives that may be developed by National Parks and Wildlife Service and incorporated at a later date or are generally informative about the sensitivity of the habitat.

Table II.3 Distinguishing species that have been identified from SACs representing the biotope A2.23

SAC	Distinguishing Species
River Barrow and River Nore SAC (NPWS, Version 1 2011a)- *Sand to muddy fine sand community complex*	Assessed in Report III Muddy Sands and Sandy Muds
Donegal Bay (NPWS Version 1, 2011b) *Intertidal muddy sand to sand dominated by polychaetes, bivalves and crustaceans community complex.*	Assessed in Report III Muddy Sands and Sandy Muds
Dundalk Bay (NPWS Version 1, 2011c)* *'Fine sand community complex'*	*Angulus tenuis*, Nephtys hombergii*, Nephtys cirrosa* Cerastoderma edule*, Pygospio elegans* Crangon crangon**, Spiophanes bombyx**
Lough Swilly (NPWS Version 1, 2011d)* Fine sand community complex – two intertidal variants	*Spiophanes bombyx* Tubificoides benedii*, Angulus tenuis*, Bathyporeia pilosa*, Donax vittatus, Bathyporeia elegans*, Pygospio elegans**, Nemertea sp., *Scoloplos armiger**
Clew Bay Complex (NPWS Version 1, 2011e) '*Intertidal fine sand dominated by Nephtys cirrosa'*	*Nephtys cirrosa* Moerella donacina, Bathyporeia guilliamsoniana**
Donegal Bay (NPWS Version 1, 2011b) '*Estuarine fine sands dominated by polychaetes and oligochaetes community complex*'	*Hediste diversicolor*, Heterochaeta costata,* Enchytraeidae spp., *Mya truncata, Pygospio elegans*, Tubificoides benedii**, Nematoda spp., *Cerastoderma edule*, Tubificoides pseudogaster**
NOTE: All relevant species listed in the distinguishing tables in the SAC Conservation Objectives Supporting Documents have been added. Those underlined are referred to in the text and are considered to be priority species for assessment. * Species assessed in separate proformas. ** Mobile epifauna - Not assessed.	

Recovery

Some sandy habitats (e.g. stable predominantly subtidal fine sands) are characterised by relatively robust fauna which could potentially recolonize habitats after disturbance events (Hall et al. 2008). For sand habitats that are dominated by physical processes, habitat restoration (post-fishing activity) is relatively rapid (days to a few months) and recolonisation is probably dominated by active and passive migration of adult organisms into the disturbed areas (e.g. McLusky et al. 1983; cited in Kaiser et al. 2006). In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate following disturbance.

Habitat Classification

Table II.4 Types of littoral fine sand habitats recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (EUNIS, 2007; Connor et al. 2004; OSPAR Commission, 2008)

Annex I Habitat containing feature	EUNIS Classification of feature	Britain and Ireland Classification of feature	OSPAR Threatened and declining species or habitat
Intertidal mud and sandflats, Estuaries and Large shallow inlets and bays	A2.23	LS.LSa.FiSa	No
	A2.231	Ls.LSa.FiSa.Po	
	A2.2312	LS.LSa.FiSa.Po.Aten	

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table II.6 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table II. 5a and are combined, as in Table II.5b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score (for the habitat assessment) is assessed in further detail in Table II.6 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table II.5a).

Table II.5a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table II.5b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table II.6 Supporting information for the fine sand biotope (A2.23) assessments shown in the Sensitivity Matrix (Appendix E)

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	Habitat = H (*) Species = L-H	= VH (*) = H-VH	= NS (*) = L-NS	See Introduction Section (Table II.2) for more information. Sand habitats are generally characterised by the presence of an infaunal benthic community, which, due to the position of animals in the sediment are relatively protected from temporary surface disturbance. Fine sands will retain water better than coarse sands and will be relatively cohesive and therefore resistant to erosion following surface disturbance. Although surface abrasion has the potential to damage species or parts of species that are found at the surface, many organisms may be adapted to predation damage e.g. siphon removal by fish during immersion periods, which will allow regeneration of damaged parts. Bivalves and other species require contact with the surface for respiration and feeding, fragile animals that are buried close to the surface will be vulnerable to damage, depending on the force of the surface abrasion. Surface compaction can collapse burrows and reduce the pore space between particles, decreasing penetrability and reducing stability and oxygen content. The tops of burrows may be damaged and repaired subsequently at energetic cost to their inhabitants. Experiments with trampling, a pathway for compaction effects, have shown that areas subject to compaction tend to have reduced species abundance and diversity (see trampling pathway below). Sheehan et al. (2007) proposed that following compaction, organisms avoid or emigrate from affected areas. The abiotic habitat is considered to have 'High' resistance to this pressure as surface abrasion is unlikely to alter the habitat type although there may be some surficial sediment disturbance. Recovery is considered to be 'Very High' due to sediment mobility, the habitat feature is therefore considered to be 'Not Sensitive' to a single event that leads to surface abrasion. The characterising species (see Appendix E and species proformas) are generally considered to have 'High' resistance to surface abrasion (based on infaunal life history), although the bivalves *Cerastoderma edule* and the tubicolous polychaetes *Spiophanes bombyx* and *Pygospio elegans* were considered to have 'Medium' resistance or 'Low to Medium' resistance (see species proformas and sensitivity matrix, Appendix E). The high recovery rates of these species (all species 'High- Very High') mean that overall sensitivity was considered to be 'Not Sensitive to Low'. Higher rates of disturbance would be expected to lead to

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						greater impacts and the spatial scale of disturbance will also determine recovery rates. At small scales recovery is likely to be rapid via active migration or water transport of adults.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	Habitat = M (*) Species = L-H	= VH (*) = M-VH	= L (*) = NS-M	See Introduction Section (Table II.2) for further information and activity specific examples. Comparing the impacts of hand raking with other harvesting methods in comparable environments, Kaiser et al. (2001) ranked the magnitude and intensity of different harvesting techniques as: lugworm harvesting > tractor dredging > bait digging > cockle hand raking. For each of the forms of disturbance the reported recovery rates of the benthic communities were similar (2-6 months) with the exception that the larger fauna (e.g. *Mya arenaria*) took much longer to recover (Kaiser et al. 2001 and references therein). Surface disturbance may alter the surface topography of this habitat, re-suspend sediment and alter sediment characteristics. However, resistance to this pressure is assessed as 'Medium' as the habitat still remains and alterations are confined to surficial layers. In general any tracks or pits resulting from surface damage would be infilled within 6 months or sooner by natural hydrodynamic processes, recovery is therefore judged to be 'Very High'. The sensitivity of the abiotic habitat is therefore categorised as 'Low'. Shallow disturbance may lead to injury and mortality of characterising species. Biological recovery is linked to the recovery of the abiotic habitat, which is likely to be rapid in areas where sediments are relatively mobile and will be aided by water transport or active migration of adults. Sand habitats are relatively dynamic and undergo natural disturbance through wind and water action (winter storms may lead to severe disturbance) and the animals found in this habitat are adapted to this regime. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E), indicate that sensitivity ranges between 'Not Sensitive-Medium' as resistance ranges from 'Low-High' and recovery from 'Medium-Very High'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	Habitat = M (*) Species = N-M	= H-VH (***) = M-VH	= L (*) = L-M	In general, damage to sediment habitats from bait digging is most significant in sheltered habitats (e.g. estuaries and inlets), where holes can persist for weeks or months (Fowler, 1999). Studies of the recovery of lugworm beds after bait digging have indicated that complete recolonisation occurs quickly (one month after areas had been experimentally dug out from a sandy beach at Whitley Bay: Blake 1979; cited in Fowler, 1999). Recolonisation of dug beds occurs via recruitment of young worms from separate nursery beds on the upper shore or migration of adults from unexploited populations in adjacent areas (possibly including subtidal beds), provided these are not also exploited (Olive, 1993;

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						cited in Fowler, 1999). Recovery of the biota indicates that the habitat had also recovered. Kaiser et al. (2006) found that in sand habitats (grain size not defined by many of the studies included in the analysis), intertidal dredging produced the most severe initial impact out of all of the fishing activities analysed, and no recovery had occurred by the final observation time period (time category > 50 days). Dernie et al. (2003) compared the recovery rate of benthic assemblages in different sediment types following physical disturbance (the creation of a 'pit' in the sediment surface, the scale of which was chosen to be relevant to bait digging, hand-raking, suction dredging and some forms of trawling) of different intertidal habitats (clean sand (< 3% silt and clay), silty sand (5-20% silt and clay), sandy mud (35-45% silt and clay) and mud (>55% silt and clay)) in the Menai Strait, North Wales. Ferns et al. (2000) studied the effect of experimental tractor dredging for cockles on non-target invertebrates in areas of both intertidal clean sand and intertidal muddy sand at Burry Inlet, South Wales. The study showed that mechanical cockle harvesting resulted in the loss of a significant proportion of the most common invertebrates from both the clean sand and muddy sand areas. Annelids, molluscs and crustacean declined by 32%, 45% and 81% respectively in the clean sand area respectively post harvesting. Invertebrate populations in the clean sand area with relatively few cockles recovered more quickly than those in the muddy sand area. The time to recovery for the most abundant invertebrate species in the clean sand area were: *Tetrastemma* sp., reduced by 55% post harvesting, 8 days to recovery; *Bathyporeia pilosa*, reduced by 82% post harvesting, 39 days to recovery; and *Hydrobia ulvae*, 56% reduction post harvesting, 8 days to recovery. Deep disturbance from cockle dredging has been shown to lead to decreased density of *M. balthica* but no detectable change in *E. longa* on intertidal flats (sand and muddy sand sediment, median grain size 140-200µm) in the Dutch Wadden Sea (Kraan et al. 2007). Rostron (1995; cited in Gubbay and Knapman, 1999) undertook experimental dredging of sandflats with a mechanical cockle dredger, including a site comprising stable, poorly sorted fine sands with

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						small pools and *Arenicola marina* casts with some algal growths. At this site, post-dredging, there was a decreased number of *Pygospio elegans* with no recovery to pre-dredging numbers after six months and disappearance of *Scoloplos armiger* from some dredged plots. The distribution of *Nephtys hombergii* was disturbed by dredging, with recovery after six months. There was a large decline in numbers of *Hydrobia ulvae*, with statistical differences between the dredged sites and control sites up to six months post-dredging. *Cerastoderma edule* numbers were reduced by dredging, with significant reductions in numbers compared with the control still apparent up to six months post-dredging. The dredge tracks were still visible after 6 months (summarised in Gubbay, 1999) Impacts from deep disturbance are more severe than shallow and surface abrasion damage and may result in changes to habitat such as the formation of pits and trenches. In very sheltered environments the changes to sediment topography may persist for some time but in more dynamic environments sediment infilling will be more rapid and natural agents (such as wave action, tidal currents and storms) will mobilise sediments aiding recovery of the abiotic habitat. Habitat resistance is assessed as 'Medium'. Although some changes in sediment topography and conditions are predicted the habitat will remain and be recognisable following deep disturbance. Recovery is assessed as ''Very High' within sand shore environments (although recovery may be prolonged in very sheltered areas). Sensitivity is therefore considered to be 'Low'. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E) indicate that sensitivity ranges from 'Low-Medium'. Resistance to deep disturbance varies between taxa from 'None' to 'Medium', resilience ranges from 'Medium' to Very High'. As with other pressures the degree of impact will be mediated by the causal activity and intensity and recovery rates will be influenced by spatial extent, site-specific conditions, seasonality and habitat recovery.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	Habitat = H (*) Species = L-H	 = VH (*) = H-VH	 = NS (*) = NS-M	See Introduction Section (Table II.2) for more information. There is limited evidence for the effects of trampling in soft sediment environments (Tyler-Walters and Arnold, 2008). More information is available for muddy habitats (see Report I and III in this series). Moffett et al. (1998) studied the effects of high trampling intensities on sandflats and found that impacts were species specific. Populations of the bivalve *Donax serra* were affected by trampling (6% mortality following 50 passes along a transect, 18% following intense trampling associated with a volleyball game), this level of mortality suggests that the infaunal location of sand species provides a

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						considerable amount of protection to trampling. The habitat assessment is based on surface abrasion. Species sensitivities to trampling vary from 'Low-High'. Resistance was considered to be lowest for *Cerastoderma edule* (based on Rossi et al. 2007, see species proforma) and *Pygospio elegans* which inhabits fragile tubes at the surface. Other worms were considered to have 'Medium-High' resistance to trampling at low intensities. Species that occur within sand biotopes are adapted to sediment disturbance and recovery from this pressure was considered to be 'High- Very High' based on lack of impacts and rapid recovery through opportunistic life history traits, migration of mobile species and passive transport of adults and juveniles.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	Habitat = M-H (*) Species = L-M	= H-VH (*) = M-VH	= L-NS (*) = L-M	See Introduction section (Table II.2) for more information. Relevant information on the impacts of vehicle access on sandy beaches is limited. Schlacher et al. (2008) compared unimpacted intertidal sandflat reference areas with areas of high intensity vehicle use (250,000 visits). These intensities are not comparable with impacts from aquaculture and fishing operations. In general the passage of a vehicle is likely to compact sand, cause rutting and crush infaunal organisms. McLaqchlan and Brown (2002) suggest that vehicles driven along a wet foreshore would have little impact. At low intensities habitat resistance to this pressure is assessed as 'Medium-High' and recovery is considered to be 'Very High', so that sensitivity is considered to be 'Not Sensitive to Low'. Assessment of the characterising species, (see species proformas and sensitivity matrix, Appendix E) show that resistance was considered to be lowest for *Cerastoderma edule* (based on Rossi et al. 2007, see species proforma), *Pygospio elegans* and *Spiophanes bombyx* which inhabit fragile tubes which protrude above the surface Species resistance to this pressure was assessed as 'Low-Medium'. Recovery was assessed as 'High-Very High' based on low levels of impact, life history traits and potential for active and passive migration. Species sensitivity therefore was considered to range from 'Low-Medium' for *Cerastoderma edule* (the most sensitive species) and to be 'Low for the other characterising species.
	Extraction	Removal of Structural components of	Habitat = N-L (*)	= H-VH (*)	= L-M (*)	See Introduction section (Table II.2) for more information. The resistance of the habitat to extraction is assessed as 'None-Low' as sediment is removed, the depth of remaining sediments and their character will be site-specific. Recovery will depend on local

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	Species = N-L	= M-VH	= L-H	factors including hydrodynamics, sediment supply and sediment mobility and the spatial scale affected. Recovery is assessed as 'High- Very High', as effects arising from aquaculture or fishing (e.g. bait digging may be considered within this pressure) are likely to be relatively small-scale. Sensitivity is therefore considered to be 'Low-Medium'. Assessments of the characterising species (see species proformas and the sensitivity matrix) indicate that species are considered to have 'No to Low' resistance to this pressure (due to low mobility and infaunal position), recovery is assessed as 'Medium- Very High', sensitivity is considered to range from 'Low-High' depending on the recovery rate of the species population.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	Habitat = L-M (*) Species = L-H	= H-VH (*) = H-VH	= L-M (*) = L-NS	See Introduction Section (Table II.2) for further information. Addition of fine material will alter the character of this habitat by covering it with a layer of dissimilar sediment and will reduce suitability for the species associated with this feature. Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities. Recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Long-term or permanent addition of fine particles would lead to re-classification of this biotope type from a sand to muddy sand and the biological community present would also change in response with an anticipated increase in species that are better adapted to the new conditions such as deposit feeding polychaetes. The change in sediment pressure assessment (below) considers the long-term impact of an increase in the fine sediment fraction on the habitat and associated community. Siltation may alter the character and classification of this biotope through the addition of fine sediments. Resistance was therefore assessed as 'Low-Medium' based on an assumption that local water flows and other factors are unaffected, as these will remove overburden, aiding habitat restoration. Recovery is assessed as 'High' to Very High'. Sensitivity was therefore considered to be 'Low-Medium'. Species sensitivity varied from 'Low-High' (see species proformas and sensitivity matrix, Appendix E). Most of the species present are adapted to frequent sediment disturbance, have high mobility and are able to reposition within the sediment e.g. *Nephtys hombergii* and *Hediste diversicolor* and *Angulus*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						tenuis. Due to the lack of impact, species were assessed as having 'Very High' recovery and were therefore considered to be 'Not sensitive'. *Bathyporeia* spp., *Pygospio elegans* and *Cerastoderma edule* were assessed as more sensitive, having 'Low-Medium' resistance. As recovery potential of these species is assessed as 'High-Very High' sensitivity was considered to be 'Low'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	Habitat = N-L (*) Species = N-H	= H-VH (*) = M-VH	= L-M (*) = NS-H	See Introduction Section (Table II.2) for further information. Simenstad and Fresh (1995; cited in Kaiser and Beadman, 2002) reported that the application of gravel to intertidal sediments resulted in a shift from a polychaete to a bivalve and nemertean dominated community, but emphasised that changes are likely to be site-specific. Such shifts in community composition could have repercussions at other trophic levels e.g. changes in the abundance of certain harpacticoid copepod populations which are important prey for juvenile salmon and flatfish species (Simenstad and Fresh 1995). The addition of gravel and shell material effectively creates a new habitat leading to more persistent changes in local community composition (Kaiser and Beadman, 2002). The addition of mussels to intertidal fine sand sediments altered sediment characteristics and fauna, mobile epibenthic crustaceans (e.g. *Gammarus* spp. and *Jaera albifrons*) colonised mussel transplant plots, but were absent at all times from the adjacent sandflat sediments. The polychaetes *Eteone longa* and *Pygospio elegans* were both significantly reduced in mussel transplant plots, whilst *Capitella* spp. increased in numbers. Mussels clearly had marked effects on both the fauna and sediments probably through a combination of biodeposition and filtration by the mussels and the provision of a structurally complex habitat. (Ragnarrsson and Rafaelli, 1999). The addition of coarse materials will alter the character of the sediment and reduce suitability for the associated community of this feature. Recovery will depend on removal of the overburden, either naturally or through human activities and recovery will not take place until this has happened. Resistance was assessed as 'None-Low' to reflect the change in habitat type (which may be more severe than siltation as coarse materials are less readily removed by water action). Recovery may be prolonged depending on site specific conditions but in some cases storm disturbance may be great enough to remove over-burden, or recovery may occur through burial of overburden by fine sands. In the case of re-laid bivalves these may be harvested. Recovery was therefore assessed as 'High-Very High' (as sediments are generally mobile and some beaches are eroded and deposited seasonally).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Smothering will kill individuals and reduce habitat suitability. Resistance to smothering by characterising species was assessed as 'None to High' (see species proformas and sensitivity matrix, Appendix E. Sedentary species that live or feed at the surface (e.g. *Pygospio elegans*, *Spiophanes bombyx*, *Cerastoderma edule* and *Angulus tenuis*) were considered to have 'No' resistance. Mobile burrowing species such as *Nephtys hombergii* and *Scoloplos armiger* were considered to be able to escape smothered sediments and were considered to have 'High' resistance. Recovery potential was considered to range from 'Medium-Very High' and sensitivity from 'Not sensitive' to 'Low to Medium'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed. This feature does not occur in the water column. Collision of benthic features with fishing gear is addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual - Boat/ vehicle movements				NS	Not sensitive.
	Visual - Foot/ traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	Habitat = N-L (***) Species = N-H	= H-VH (*) = M-VH	= L-M (*) = NS-H	A study in the Dutch Wadden Sea showed that suction-dredging for cockles (*Cerastoderma edule*) led to a significant long-term reduction in settlement and stocks of the target bivalve species (Piersma et al. 2001). Analysis of sediment characteristics before and after dredging showed an increase in median grain size and a reduction of silt content, and that these changes were most pronounced in the area dredged for cockles. Sediment characteristics only returned to pre-impact conditions 8-11 years after the suction dredging. The authors concluded that the suction dredging of *C. edule* had long lasting effects on the recruitment of bivalves (particularly the target species *C. edule*, but also *Macoma balthica*) in sandy parts of the Wadden Sea basin. Initial sediment reworking by suction dredging especially during autumn storms) probably caused loss of fine silts and then negative feedback processes appeared to follow that prevented the accumulation of fine-grained sediments conducive to

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						bivalve settlement. However, particle size is governed by physical processes and changes are likely to be permanent only if the hydrographic regime is altered. Simenstad and Fresh (1995; cited in Kaiser and Beadman, 2002) reported that the application of gravel to intertidal sediments resulted in a shift from a polychaete to a bivalve and nemertean dominated community, but emphasised that changes are likely to be site-specific. Such shifts in community composition could have repercussions at other trophic levels e.g. changes in the abundance of certain harpacticoid copepod populations which are important prey for juvenile salmon and flatfish species (Simenstad and Fresh, 1995). The addition of gravel and shell material effectively creates a new habitat leading to more persistent changes in local community composition (Kaiser and Beadman, 2002). The character of the habitat is largely determined by the sediment type. Changes to this would lead to habitat re-classification e.g. the addition of coarse sand particles (or removal of fine sand particles) in sufficient quantities would lead to the development of a different habitat, hence resistance to sediment change is assessed as 'None-Low'. Recovery will depend on the degree of effect and site specific habitat forming processes including sediment supply and hydrodynamics. It was considered likely that natural rehabilitation would occur. On many shores, areas of different sediment type are found and the extent and location of these may be fairly dynamic. For some beaches, grain size changes are also seasonal with coarser grains present during winter storms followed by a trend for decreased particle size as finer particles are deposited in the summer months. Recovery was therefore assessed as 'Very-High' although in some instances, as observed by Piersma et al. (2001), recovery may be more prolonged. Changes in sediment characteristics can lead to changes in community structure. An increase in coarse sediments would lead to the development of a community typical of coarse sands and/or gravels and the relative stability may favour the establishment of bivalves and amphipods. This change would alter the character of the biotope present leading to re-classification. Long term increase in grain-size may lead to a permanent change in the faunal composition of the biotope, with colonisation by species adapted to clean sands (such as *Fabulina fabula*, *Donax vittatus*, *Lanice conchilega*).
	Changes in	Fine sediment	Habitat			See Introduction Section (Table II.2) for further information.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment composition – increased fine sediment proportion	fraction increases	= N-L (*) Species = L-H	= VH (*) = H-VH	= M (*) = NS-M	The character of the habitat is largely determined by the sediment type. Changes to this would lead to habitat re-classification. Recovery will depend on the degree of effect and site specific habitat forming processes including sediment supply and hydrodynamics. It was considered likely that natural rehabilitation would occur. On many shores, areas of different sediment type are found and the extent and location of these may be fairly dynamic. For some beaches grain size changes are also seasonal with coarser grains present during winter storms followed by a trend for decreased particle size as finer particles are deposited in the summer months. Recovery was therefore assessed as 'Very-High' although in some instances as observed by Piersma et al. (2001) recovery may be more prolonged. Sensitivity was therefore considered to be 'Medium'. Changes in sediment characteristics can lead to changes in community structure. The addition of fine sediments would lead to the development of a community typical of muddy sands. Suspension feeders, particularly bivalves and species that graze microalgae on sand grains .g. *Bathyporeia* spp., characteristic of the fine sand biotope, would probably be replaced. This change would favour deposit feeders, particularly deposit feeding polychaetes which are adapted to burrow and feed in fine grained sediments. Such changes would alter the character of the biotope present leading to re-classification. Some characterising species are also found in muddy sands and muds (e.g. *Nephtys hombergii* and *Pygospio elegans)* and these species were considered to be 'Not Sensitive' to this pressure. Resistance of the characterising species therefore ranged from 'Low to High' and recovery from 'High to Very High'. Species sensitivities were considered to range from 'Not sensitive to Medium'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	Habitat = L-M (*) Species = N-H	 = H-VH (*) = M-VH	 = L-M (*) = NS-M	See Introduction Section (Table II.2) for further information. Increased water flows may erode fine sediments leading to re-classification of this biotope. Aquaculture cages and lines reduce water flow which can lead to increases in siltation as finer particles are deposited. Resistance to decreases in waterflow is considered to be 'Low-Medium' and recovery as 'High-Very High' as fine sediments are relatively dynamic and restoration is likely to be driven by seasonal processes. Habitat sensitivity is therefore considered to be 'Low-Medium'. Changes below a threshold that led to siltation and changes in sediment composition may however lead to re-classification of this biotope type through sedimentary changes (see above pressures). With the exception of *Cerastoderma edule* and *Pygospio elegans* the characterising species were

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						considered to be 'Not Sensitive' to this pressure, as burrowing life habits coupled with deposit or predatory feeding types were considered to be protective (also change in sediment composition, increase in fine sediment),
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	Habitat = H (*) Species = M-H	= VH (*) = H-VH	= NS (*) = L-NS	See Introduction Section (Table II.2) for further information. An increase in turbidity/suspended sediment would not alter the character of the seabed habitat and hence habitat resistance is considered to be 'High' and recovery is therefore assessed as 'Very High', so that the habitat is considered to be 'Not Sensitive'. Animals associated with this biotope are primarily infaunal and were considered to have 'High' resistance to this pressure (see species proformas and the sensitivity matrix, Appendix E) and subsequently 'Very High' recovery. The characterising species, with the exception of *Angulus tenuis*- see species proformas), were therefore considered to be 'Not Sensitive'. Potential effects from the associated pressures, siltation and shading, are considered elsewhere in this table.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	No evidence was found for habitat effects of decreased turbidity by aquaculture activities on intertidal mixed sediments. Seston is filtered and returned to the environment as faeces and pseudofaeces so that permanent reductions in the supply of sediments are not occurring. Resistance was assessed as 'High' and recovery as 'Very High' so that the abiotic habitat was considered to be 'Not Sensitive'. Increased sedimentation may lead to localised organic enrichment and decreased oxygen but these pressures are assessed separately. As the infauna within this biotope are judged to be insensitive to increased photic depth, resistance is assessed as 'High' with recovery categorised as 'Very High'. Overall sensitivity of species is considered to be 'Not Sensitive'. Decreases in seston outside the activity footprint are likely only in enclosed waterbodies with high stocking densities (see Introduction Section Table IV.2). No evidence was found to assess this impact on suspension feeders.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Organic enrichment - Water column	Eutrophication of water column	Habitat = H (*) Species = N-H	= VH (*) = H-VH	= NS (*) = NS-M	See Introduction Section (Table II.2) for further information. In general, eutrophication may result in increased coverage of intertidal sand and mudflats by opportunistic green algae such as *Enteromorpha*, which will create anoxic conditions in the sediment below the mats, reduce the diversity and abundance of infauna and interfere with bird feeding (Simpson, 1997; cited in Elliott et al. 1998). Eutrophication is not considered to directly affect the abiotic habitat although the development of mats of ephemeral algae will indirectly alter sediment chemistry (see deoxygenation pressures) based on the lack of direct effects, the abiotic habitat is considered to be 'Not Sensitive', resistance is therefore assessed as 'High' and recovery as 'Very High'. The characterising species, with the exception of *Scrobicularia plana*, were considered 'Not Sensitive to this pressure, resistance was assessed as 'High' for these species and recovery as 'Very High'. At the low levels of nutrient enrichment generally associated with aquaculture the characterising species are unlikely to be Sensitive.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	Habitat = H (*) Species = N-H	= VH (*) = H-VH	= NS (*) = NS-M	See Introduction Section (Table II.2) for further information. The abiotic habitat is considered to have 'High' resistance to increased organic matter and Very High' recovery so that intertidal fine sands are considered to be 'Not Sensitive' (at rates elevated above normal background level: gross changes would cause impacts on sediment chemistry and community, see deoxygenation pressures, these changes on intertidal sediments are not considered likely to arise through fishing or aquaculture activities). With the exception of *Bathyporeia* spp., the characterising species (see species proformas and sensitivity matrix, Appendix E) are considered 'Not Sensitive' to this pressure based on 'High' resistance and 'Very High' recovery. (Decreases in oxygen levels may be associated with high levels of organic enrichment, these effects are considered below). *Bathyporeia* spp. are highly sensitive to organic enrichment, (see species proformas), resistance was therefore assessed as 'None', however this species is likely to recover rapidly, resilience was therefore assessed as 'Very High' and sensitivity was assessed as 'Low-Medium'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	Habitat = H (*) Species = M-H	= VH (*) = M-VH	= NS (*) = L-NS	See Introduction Section (Table II.2) for further information. Many of the characterising species associated with this biotope are predators or scavengers or feed on autochthonous production through the microphytobenthos (*Bathyporeia* spp.) For these species removal of primary production e.g. through increased mussel production, is unlikely to negatively impact this community and may enhance it through increased production of faeces/pseudofaeces.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						However, suspension feeders found within this biotope may be negatively affected by increased competition with farmed bivalves. Increased removal of phytoplankton is not considered to negatively affect the abiotic habitat, hence resistance is assessed as 'High', recovery as 'Very High' and the habitat is considered to be 'Not Sensitive'. Assessment of the characterising species (see Table 1 and the sensitivity matrix) indicate that these are considered to be 'Not Sensitive. Resistance is assessed as 'High' and recovery as 'Very High'. The suspension feeders (*Cerastoderma edule* and *Angulus tenuis*) found in this biotope, may be affected by competition from farmed bivalves. Resistance was assessed as 'Medium-High' and recovery as 'Medium-Very High'. The sensitivity of these species was therefore considered to be 'Not Sensitive-Low'. In areas that are well flushed, water exchange should recharge waters.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	Habitat = M-H (*) Species = N-H	= VH (*) = H-VH	= L-NS (*) = NS-M	On exposed shores the sand sediments are coarser and more porous and therefore have a higher oxygen content. Oxygen depletion becomes a severe problem at all states of the tide on only the very finest grained beaches, and as a general rule, if the percentage of particles of less than 0.25 mm median diameter exceeds 10% of a sand, then the oxygen concentration of its interstitial water will be less than 20% of the air saturation level, and will drop rapidly during low tide periods (Brafield, 1964). In general, anoxic conditions in sand and mudflats may alter community structure and reduce diversity and abundance and interfere with bird feeding (Simpson, 1997; cited in Elliott et al. 1998). Intertidal sand sediments are likely to be well flushed and oxygenated although excessive organic enrichment may lead to smothering by algal blooms and subsequent anoxia or bacteria degradation of organic matter may lead to sediment de-oxygention. Resistance to this pressure is therefore assessed as 'Medium-High' to reflect high oxygen content of substratum and the oxygenating effect of sediment disturbance by wave action during tidal immersion. Habitat recovery is assessed as 'Very High'. Sensitivity is therefore considered to be 'Low-Not Sensitive'. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E) indicate that sensitivity is considered to be 'Not Sensitive-Medium'. Some characterising species,
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	Habitat = M-H (*) Species = N-H	= VH (*) = H-VH	= L-NS (*) = NS-M	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						e.g. *Tubificoides* spp. and *Nephtys hombergii* are adapted to muddy conditions where sediments are anoxic below the surface layer and most species are resistant to periodic hypoxia/anoxia. However, other species, including *Bathyporeia* spp. are sensitive to low oxygen levels Overall resistance was assessed as 'None-High') and resistance as 'High-Very High' species sensitivity was therefore considered to be 'Not Sensitive-Low' (with the exception of *Scoloplos armiger* which was considered to have 'Medium' sensitivity.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	Habitat = H (***) Species = L-H	= VH (***) = M-VH	= NS (***) = NS-M	See Introduction Section (Table II.2) for more information. There are few published observations of the establishment of non-native species on sandy beaches (Defeo, 2009) and the dynamic nature of sediments may mean these habitats are relatively resistant to establishment. In some cases invasive macroalgae including *Undaria pinnitifada* and *Sargassum muticum* have changed the nature of the strandline as these are washed up. Given the lower levels of reported invasive species, habitat resistance to the introduction of non-natives is assessed as 'High'. Recovery is therefore considered to be 'Very High' and the habitat is considered to be 'Not Sensitive'. Due to this high natural habitat resistance the characterising species may be less sensitive than the individual assessments suggest (see Sensitivity Matrix, Appendix E and species proformas). These assessments were largely based on expert judgement and do not necessarily take habitat characteristics into account. Species resistance was assessed as 'Low to High' and recovery as 'Medium-Very High' so that sensitivity was considered to range from 'Not Sensitive to Medium' sensitivity. In general bivalves and other surface deposit feeders were considered more sensitive to the introduction of non-native species (largely based on the slipper limpet *Crepidula fornicata*) due to low mobility and increased competition for food and space.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		Habitat = H (*) Species = L-H	= VH (*) = M-VH	= NS (*) = NS-M	See Introduction Section (Table II.2) for further information. Shellfish harvesting (e.g. the cockle Cerastoderma edule) and bait digging for Arenicola marina, *Nephtys hombergii* and *Hediste diversicolor* are two activities which may occur in this habitat. Cockles are harvested either mechanically (e.g. using suction or tractor dredges) or by large numbers of fishers using hand rakes. The effects of removal of these species are likely to be constrained to physical damage interactions and is considered in the physical disturbance theme. Professional and local bait diggers may work over 200m^2 of sediment per tide and have been estimated to remove 50-70% of bait (Tyler-Walters, 2008). The habitat feature is not considered to be functionally dependent on the commercially targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal (Resistance is 'High' and recovery is 'Very High'). The polychaete *Scoloplos armiger* is considered sensitive to the removal of *Arenicola marina* which may be targeted by bait harvesters and *Cerastoderma edule* and *Nephtys* spp. may be commercially exploited. These characterising species are considered to have medium sensitivity to removal (based on 'Low' resistance and 'Medium to High' recovery). All other characterising species were considered to be 'Not sensitive' as these were not targeted and were not considered dependent on targeted organisms.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	The sensitivity of the feature to the pressures that arise through the removal of target and non-target species are considered in the above pressure themes. The feature and characterising species are not considered to be functionally dependent on targeted organisms and therefore are not considered to be sensitive to the biological effect of their removal. However, as outlined above (in the physical disturbance pressures), the removal of target and non-target species may result in changes to the biological community and hence the classification of the assemblage type.
	Ecosystem				NA	Not relevant to SAC habitat features.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Services - Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	Habitat = H (*) Species = NEv	= VH (*) = NEv	= NS (*) = NEv	The use of medicinal products in shellfish cultivation is minimal and hence not considered any further. Various medicinal compounds are used within finfish aquaculture, however, it was considered relatively unlikely that these would impact intertidal features as finfish cages are located over subtidal habitats However, as some compounds are discharged into the water column, general impacts have been described below. Evidence of dispersal into intertidal habitats was not found. There is evidence that antibiotic use in finfish aquaculture can promote the growth of resistant strains of bacteria in mainly mud dominated seabed sediments (Chelossi et al. 2003) although Wildling and Hughes (2010) stated that it is highly unlikely that this form of discharge (antibiotics reaching the seabed both directly and via egestion) would have any effect on benthic animal or plant life. A field trail in Scotland showed that although sea lice treatment emamectin benzoate was detectable in sediments within 10m from salmon cages up to 12 months after treatment, declining concentrations showed that the chemical was degrading (Telfer et al. 2006). Macrobenthic analysis provided no evidence that emamectin benzoate, or its desmethylamino metabolite, in sediments around fish farm cages after treatment had any toxic impacts on organisms in either the water column or sediments. The anti-parasite compound Ivermectin is highly toxic to benthic polychaetes and crustaceans (Black, 1998; Collier and Pinn, 1998; Grant and Briggs, 1998; cited in Wildling and Hughes, 2010). OSPAR (2000) stated that, at that time, Ivermectin was not licensed for use in mariculture but was incorporated into the feed as a treatment against sea lice at some farms. Ivermectin has the potential to persist in sediments, particularly fine-grained sediments at sheltered sites. Data from a farm in Galway indicated that Invermectin was detectable in sediments adjacent to the farm at concentrations up to 6.8µm/kg and to a depth of 9cm (reported in OSPAR, 2000). Infaunal polychaetes have been affected by deposition rates of 78-780mg ivermectin/m^2. The abiotic habitat was considered to be unchanged by the addition of medicines, resistance was

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						therefore assessed as 'High' and recovery as 'Very High', so that the sedimentary habitat is considered to be 'Not Sensitive'. Evidence on sensitivity was not found for the majority of the characterising species so the sensitivity of these is not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	Habitat = M (*) Species = N-M	= VH (*) = M-VH	= L (*) = L-H	See Introduction Section (Table II.2) for further information. Oil covering mudlflats leads to sediment anoxia, leading to an alteration in sediment chemistry, including the production of hydrogen sulphides that would alter habitat conditions. Intertidal fine sand sediments would be expected to show a similar response During normal operations the discharge of hydrocarbons from fishing and aquaculture activities is not permitted, although accidental discharges of small volumes may be possible during operations. Resistance is therefore assessed as 'Medium' and recovery as 'Very High' following the removal of this pressure. Sensitivity is therefore considered to be 'Low'. For a number of species no evidence for tolerance of hydrocarbons could be found. The cockle, *Cerastoderma edule* may be the most sensitive of the characterising species ('Low' resistance, 'Medium-Very High' recovery, depending on scale of effect and habitat recovery).
	Introduction of antifoulants	Introduction of antifoulants	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	In general the habitat and sediment characteristics (higher levels of sediment disturbance and lower levels of finer particles and organic matter) suggest that copper and zinc are less likely to accumulate than in muddier shores. Antifoulants may affect species but they are not considered to alter the chararacter of the abiotic habitat, Habitat resistance is therefore assessed as 'High' and recovery as 'Very High', so that the habitat is considered to be 'Not Sensitive'. Tests of copper toxicity have been carried out on a number of marine organisms although comparison of results requires caution due to the different protocols used and there are inherent problems in extrapolating these to the marine environment, as laboratory tests in clean water (without organic matter) do not reflect lowered toxicity in the marine environment due to the buffering effects of carbon and sulphide which render copper non-labile (not bioavailable) and the influence of water pH, hardness, temperature and salinity etc. Concentrations up to and below the sediment quality guideline of 100 mg kg^{-1} are presumed to protect species. At this pressure benchmark resistance is assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	No evidence. As this feature is not characterised by the presence of primary producers it is not considered that shading would alter the character of the habitat. Beneath structures there may be changes in microphytobenthos abundance. Intertidal sandflats support microphytobenthos (where light penetration is sufficient) on the sediment surface and in the sand grains. The microphytobenthos consists of unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments, typically appearing only as a subtle brownish or greenish shading. Mucilaginous secretions produced by these algae may stabilise fine substrata (Tait and Dipper, 1998). The biomass of the benthic microalgae often exceeds that of the phytoplankton in the overlying waters (McIntyre et al. 1996) such that benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability. Shading will prevent photosynthesis leading to death or migration of sediment microalgae altering sediment cohesion and food supply to higher trophic levels. The characterising species do not photosynthesise and are considered to be 'Not Sensitive' to shading, resistance is assessed as 'High' for all species and recovery as 'Very High'. Reduction in microphytobenthos may lead to localised decreases in sediment stability although waterlogged fine sand sediments should remain relatively cohesive. Habitat resistance is therefore assessed as 'High' and recovery as 'Very High' so that the habitat is considered to be 'Not Sensitive'.
	Barrier to species movement				NA	Not relevant to SAC habitat features.

Table II.7 Habitat Resistance Assessment Confidence Levels

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*** (3)	***	***
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*	N/A	N/A
Decrease in oxygen levels - Water column	*	N/A	N/A
Genetic impacts	Not Exposed		
Introduction of non-native species	*** (1)	***	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	*	N/A	N/A
Introduction of hydrocarbons	*	N/A	N/A
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Black K.D. 1998. The environmental interactions associated with fish culture. In: Black, K.D. and Pickering, A.D. (Eds) Biology of Farmed Fish. Sheffield Academic Press, pp 284-326.

Blake, R.W. 1979. Exploitation of a natural population of *Arenicola marina* (L.) from the north-east coast of England. Journal of Applied Ecology 16: 663-670.

Brafield, A.E. 1964. The oxygen content of interstitial water in sandy shores. Journal of Animal Ecology 33: 97-116.

Brown, A.C. and McLachlan, A. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Environmental Conservation 29(1): 62-77.

Chelossi E., Vezzulli L., Milano A., Branzoni M., Fabiano M., Riccardi G. and Banat I.M. 2003. Antibiotic resistance of benthic bacteria in fish-farm and control sediments of the Western Mediterranean. Aquaculture 219(1-4): 83-97.

Collier, L.M. and Pinn, E.H. 1998. An assessment of the acute impact of the sea lice treatment ivermectin on a benthic community. Journal of Experimental Marine Biology and Ecology 230(1): 131-147.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M. and Scapini, F. 2009. Threats to sandy beach ecosystems: a review. Estuarine, Coastal and Shelf Science, 81: 1-12.

Dernie, K.M., Kaiser, M.J. and Warwick, R.M. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology 72: 1043-1056.

Elliott, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. and Hemingway, K.L. 1998. Intertidal Sand and Mudflats and Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs.151 pp.

EUNIS. 2007. European Environment Agency 2007. European Habitat Type Hierarchical View. Available online at: http://eunis.eea.europa.eu/habitats-code-browser.jsp.

Ferns, P.N., Rostron, D.M. and Siman, H.Y. 2000. Effects of mechanical cockle harvesting on intertidal communities. Journal of Applied Ecology 37: 464-474.

Fowler, S.L. 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. English Nature (UK Marine SACs Project). 132 pages.

Grant, A. and Briggs, A.D. 1998. Toxicity of ivermectin to estuarine and marine invertebrates. Marine Pollution Bulletin 36(7): 540-541.

Gubbay, S. and Knapman, P.A. 1999. A review of the effects of fishing within UK European marine sites. English Nature (UK Marine SACs Project). 134p.

Hall, K., Paramour, O.A.L., Robinson, L.A., Winrow-Giffin, A., Frid, C.L.J., Eno, N.C., Dernie. K.M., Sharp, R.A.M., Wyn, G.C. and Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters – development of a protocol. CCW [Policy Research] Report No: 8/12, 85pp.

Hewitt, J.E. 2001. Effects of suspended sediment levels on suspension-feeding shellfish in the Whitford embayment. Auckland Regional Council.

Kaiser, M.J. and Beadman, H.A. 2002. Scoping study of the carrying capacity for bivalve cultivation in the coastal waters of Great Britain. The Crown Estate. Interim Report: 39 pp.

Kaiser, M.J., Broad, G. and Hall, S.J. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. Journal of Sea Research 45(2): 119-130.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. and Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1-14.

Kraan, C., Piersma, T., Dekinga, A., Koolhaas, A. and van der Meer, J. 007. Dredging for edible cockles (*Cerastoderma edule*) on intertidal flats: short-term consequences of fisher patch-choice decisions for target and non-target benthic fauna. ICES Journal of Marine Science 64: 1735-1742.

McIntyre, H.L., Geider, R.J. and Miller, D.C. 1996. Microphytobenthos: the ecological role of the "secret garden" of un-investigated shallow water marine habitats. I. Distribution, abundance and primary production. Estuaries 19: 186-201.

McLusky, D.S., Anderson, F.E. and Wolfe-Murphy, S. 1983. Distribution and population recovery of *Arenicola marina* and other benthic fauna after bait digging. Marine Ecology Progress Series 11: 173-179.

Moffett, M.D., McLachlan, A., Winter, P.E.D. and De Ruyck, A.M.C. 1998. Impact of trampling on sandy beach macrofauna. Journal of Coastal Conservation and Ecology 4: 87-90.

Nicholls, P., Hewitt, J. and Halliday, J. 2003. Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. Auckland Regional Council Technical Publication No. 211, August 2003.

NPWS. 2011a. River Barrow and River Nore Bay SAC (site code: 2162): Conservation objectives supporting document – marine habitats. Version 1, April 2011.

NPWS. 2011b. Donegal Bay SAC (site code: 0133): Conservation objectives supporting document – marine habitats. Version 1, November 2011.

NPWS. 2011c. Dundalk Bay SAC (site code: 455): Conservation objectives supporting document – marine habitats. Version 1, March 2011.

NPWS. 2011d. Lough Swilly SAC (site code: 2287): Conservation objectives supporting document – marine habitats. Version 1, March 2011.

NPWS. 2011e. Clew Bay SAC (site code: 1482): Conservation objectives supporting document – marine habitats. Version 1, June 2011.

Olive, P.J.W. 1993. Management of the exploitation of the lugworm *Arenicola marina* and the ragworm *Nereis virens* (Polychaeta) in conservation areas. Aquatic Conservation 3 1-24.

OSPAR Commission 2000. Quality Status Report 2000, Region III – Celtic Seas. OSPAR Commission, London. 116 + xiii pp.

OSPAR Commission, OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6).

Piersma, T., Koolhaas, A., Dekinga, A., Beukema, J.J., Dekker, R. and Essink, K. 2001. Longterm indirect effects of mechanical cockle-dredging on intertidal bivalve stocks in the Wadden Sea. Journal of Applied Ecology 38: 976-990.

Ragnarsson, S.A. and Raffaelli, D. 1999. Effect of the mussel *Mytilus edulis* on the invertebrate fauna of sediments. Journal of Experimental Marine Biology and Ecology 241: 31-43.

Rossi, F., Forster, R.M., Montserrat, F., Ponti, M., Terlizzi, A., Ysebaert, T. and Middelburg, J.J. 2007. Human trampling as short-term disturbance on intertidal mudflats: effects on macrofauna biodiversity and population dynamics of bivalves. Marine Biology 151: 2077-2090.

Rostron, D.M. 1995. The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. In: Burry Inlet and Loughor Estuary Symposium, March 1995. Part 2. Burry Inlet and Loughor Estuary Liaison Group, P111- 117.

Schlacher, T.A., Richardson, D. and McLean, I. 2008. Impacts of off-road vehicles (ORVs) on macrobenthis assemblages on sandy beaches. Environment Management 41: 878-892.

Sheehan, E.V. 2007. Ecological impact of the *Carcinus maenas* (L.) fishery 'crab-tiling' on estuarine fauna. Ph.D. Thesis. University of Plymouth, Plymouth.

Simenstad, C. and Fresh, K. 1995. Influence of intertidal aquaculture on benthic communities in Pacific northwest estuaries: scales of disturbance. Estuaries 18(1A): 43-70.

Simpson, M.A. 1997. An investigation into the causes, effects and implications of the growth of the green macroalga *Enteromorpha* spp. On Seal Sands, Teesmouth. Unpublished M.Sc. dissertation, University of Hull.

Tait, R.V. and Dipper, F.A. 1998. Elements of Marine Ecology. Fourth edition. Reed Elsevier plc group.

Telfer, T.C., Baird, D.J., McHenery, J.G., Stone, J., Sutherland, I. and Wislocki, P. 2006. Environmental effects of the anti-sea lice (Copepoda: Caligidae) therapeutant emamectin benzoate under commercial use conditions in the marine environment. Aquaculture 260(1-4): 163-180.

Tyler-Walters, H. 2008. *Arenicola marina*. Blow lug. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 11/07/2011]. Available from http://www.marlin.ac.uk/speciesimportance.php?speciesID=2592.

Tyler-Walters, H. and Arnold, C., 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN) [Contract no. FC 73-03-327]. Plymouth, Marine Biological Association of the UK.

Wilding, T. and Hughes, D. 2010. A review and assessment of the effects of marine fish farm discharges on Biodiversity Action Plan habitats. ISBN: 978-1-907266-27-0.

Sublittoral (Subtidal) Sand Sediment: Introduction and Habitat Assessment Information (EUNIS A5.2)

Proforma Information

This habitat proforma has been produced as part of a risk assessment tool to assess the likelihood of impacts of fishing and aquaculture activities on habitats and species, in support of the preparation of Appropriate Assessments (AAs) for Natura 2000 sites.

The key component of the risk assessment tool for the AA preparation is a sensitivity matrix (Appendix E) which shows the sensitivity of SAC and SPA features to pressures arising from fishing and aquaculture activities. The feature being assessed in this proforma has been identified as being present within an SAC or SPA. The purpose of this proforma is to act as an accompanying database to the sensitivity matrix, providing a record of the evidence used in the sensitivity assessment of this feature (Table II.9). The sensitivity information presented in this proforma relates either to the habitat or to general community responses, more specific information is provided in the accompanying biotope level proformas and species proformas.

The following descriptions of the main biological communities associated with this feature are taken from the EUNIS website, the original source for these is Connor et al. (2004). Equivalent habitat designations are shown below in Table II.8

Feature Description (see also Introduction Section)

The sublittoral sands feature assessment refers to subtidal sand sediments. This assessment has been structured following the EUNIS framework (EUNIS, 2007, see Figure II.4 below). A detailed biotope assessment is available for biotope A5.23).

The biological community types associated with littoral sand are governed by sediment characteristics including mobility and the proportion of finer mud fractions. These sedimentary conditions reflect the hydrodynamic conditions at the site. More mobile sand sediments are relatively impoverished, with more species-rich communities of amphipods, polychaetes and bivalves developing with increasing stability in finer sand habitats. Muddy sands, the most stable within this habitat complex, contain the highest proportion of bivalves (see Report III). It should be noted that there may be some overlap between these communities or, that, in the same area, these may form a mosaic or grade into each other at different locations, depending on local conditions.

A number of biological community types have been identified for subtidal sands. The development of these is governed by salinity, and sediment characteristics including mobility and the proportion of finer mud fractions. These sedimentary conditions reflect the hydrodynamic conditions at the site which are in turn influenced by depth. Where subtidal sands are more stable, then polychaete species as well as amphipods occur. Less dynamic areas where the sediments may contain greater proportions of mud can be characterized by higher densities of bivalve species. The associated community of more mobile and exposed sand sediments is impoverished with few, or robust amphipod species. There are some similarities in the associated biological community with littoral sand sediments (see Assessment A2.23). It should be noted that there may be some overlap between communities which may form a mosaic or grade into each other depending on local conditions. Although the classification system has been based on the EUNIS framework (see Figure II.4, qualifying interest features and sub features of SACs may overlap and contain some species or characteristics of similar biotopes including muddy sands (Report III), mixed sediments (Report IV) and Muds (Report I).

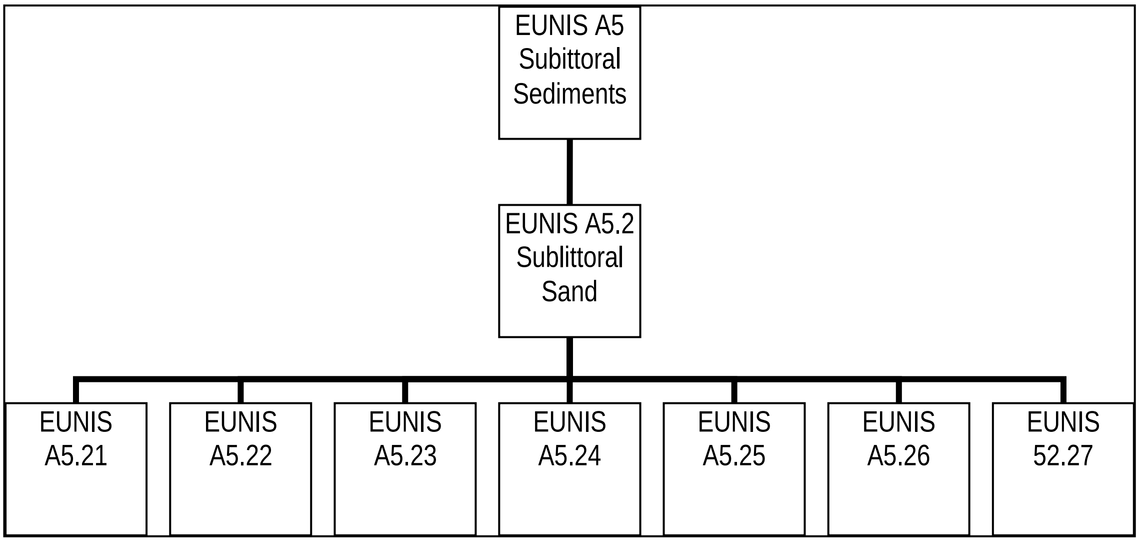


Figure II.4 Hierarchical Diagram showing the EUNIS descriptive framework for Littoral Sands (Levels 2-4, due to space limitations biotope names cannot be displayed, see the text under Associated Biological Community for biotope descriptions)

Associated Biological Community

EUNIS A5.21 Sublittoral sand in low or reduced salinity

(Source EUNIS: Connor et al. 2004)

Shallow sand and muddy sand in areas of low or reduced, although relatively stable salinity (may vary annually), with largely ephemeral faunal communities. The species are often similar to that found in A5.31 and are characterised by *Arenicola marina* with other species, including mysids, tubificoid and enchytraeid oligochaetes, *Corophium volutator*, *Hediste diversicolor*, *Pygospio elegans*, *Hydrobia ulvae* and *Cerastoderma glaucum*, which commonly occur in lagoons. Filamentous green algae such as *Chaetomorpha lin*um may also be present. In some examples of this biotope the polychaete *Fabricia sabella* may be super-abundant and the isopod *Sphaeroma hookeri* common.

A5.22 Sublittoral sand in variable salinity (estuaries)

(Source EUNIS: Connor et al. 2004)

Clean sands that occur in the upper reaches of marine inlets, especially estuaries, where water movement is moderately strong, allowing the sedimentation of sand but not the finer silt fraction. The habitat typically lacks a significant seaweed component and is characterised by brackish-water tolerant fauna, particularly amphipods, polychaetes and mysid shrimps.

A5.23 Infralittoral fine sand

(Source EUNIS: Connor et al. 2004)

Clean sands which occur in shallow water, either on the open coast or in tide-swept channels of marine inlets. The habitat typically lacks a significant seaweed component and is characterised by robust fauna, particularly amphipods (*Bathyporeia)* and robust polychaetes including *Nephtys cirrosa* and *Lanice conchilega.*

A5.24 Infralittoral Muddy Sand

(Source EUNIS: Connor et al. 2004)

Non-cohesive muddy sand (with 5% to 20% silt/clay) in the infralittoral zone, extending from the extreme lower shore down to more stable circalittoral zone at about 15-20 m. The habitat supports a variety of animal-dominated communities, particularly polychaetes (*Magelona mirabilis*, *Spiophanes bombyx* and *Chaetozone setosa),* bivalves (*Fabulina fabula* and *Chamelea gallina*) and the urchin Echinocardium cordatum.

Muddy sand communities within this level of the EUNIS hierarchy are assessed in Report III.

A5.25 Circalittoral fine sand

(Source EUNIS: Connor et al. 2004)

Clean fine sands with less than 5% silt/clay in deeper water, either on the open coast or in tide-swept channels of marine inlets in depths of over 15-20 m. The habitat may also extend offshore and is characterised by a wide range of echinoderms (in some areas including the pea urchin *Echinocyamus pusillus*), polychaetes and bivalves. This habitat is generally more stable than shallower, infralittoral sands and consequently supports a more diverse community.

A5.26 Circalittoral muddy sand

(Source EUNIS: Connor et al. 2004)

Circalittoral non-cohesive muddy sands with the silt content of the substratum typically ranging from 5% to 20%. This habitat is generally found in water depths of over 15-20 m and supports animal-dominated communities characterised by a wide variety of polychaetes, bivalves such as *Abra alba* and *Nucula nitidosa*, and echinoderms such as *Amphiura* spp. and *Ophiura* spp., and *Astropecten irregularis*. These circalittoral habitats tend to be more stable than their infralittoral counterparts and as such support a richer infaunal community.

Muddy sand communities within this level of the EUNIS hierarchy are assessed in Report III.

A5.27 Deep circalittoral sand

(Source EUNIS: Connor et al. 2004)

Offshore (deep) circalittoral habitats with fine sands or non-cohesive muddy sands. Very little data is available on these habitats however they are likely to be more stable than their shallower counterparts and characterised by a diverse range of polychaetes, amphipods, bivalves and echinoderms.

Key Ecosystem Function Associated with Habitat

Subtidal sediments are often important as nursery areas for juvenile commercial fish species such as flatfishes and bass. Offshore, sand and gravel habitats also support internationally important fish and shellfish fisheries (UK Biodiversity Partnership 2010; cited in Fletcher et al. 2011).

Features Assessed

The information presented in Table II.9 r elates to sublittoral sand sediments and is based primarily on the abiotic habitat. The sensitivity of abiotic habitat elements can be considered to be a risk assessment of the degree to which external drivers may change the habitat type and the time taken to recovery. As species occur within a specific range of habitat conditions (the habitat niche), the sensitivity assessment of the habitat indicates, very generally, whether the biological community is likely to change (although this will also depend on the sensitivity of individual species). For example, the type of sediment/substrate present at a location is of primary importance in determining the suitability of a location for many benthic species. Pressures which result in a change in sediment/substrate condition e.g. where the habitat is sensitive to the pressure, would be likely to drive a change in the species assemblage. In the case of SACs this could lead to the habitat being considered to be likely to be outside of Favourable Conservation Status with regard to the Conservation Objectives.

The more detailed biotope assessment that follows in this section includes characterising species from the EUNIS habitat classification but is based primarily on distinguishing species that were identified by National Parks and Wildlife Services in the site specific conservation objectives. These assessments should also be considered in relation to the habitat sensitivity outlined below.

Recovery

Subtidal sand habitats may be more resilient to some types of human pressure than other habitats as they are often subject to significant natural hydrodynamic forces which structure the habitat and associated assemblages. Recovery of the habitat following a disturbance is dependent on physical, chemical and biological processes and can be a more rapid process than in other areas (Bishop et al. 2006; cited in Fletcher et al. 2011). However, recovery times after physical disturbance have been found to vary for different sediment types (Roberts et al. 2010). Dernie et al. (2003) found that muddy sand habitats had the longest recovery times, whilst mud habitats had an ‘intermediate’ recovery time and clean sand communities the most rapid recovery rate.

Population recovery rates will be species specific; species such as long-lived bivalves are likely to have long recovery periods from disturbance whilst other populations are likely to recover more rapidly. Megafaunal species (e.g. molluscs and especially emergent and sessile species, are generally more vulnerable to fishing effects than macrofaunal species as they are slow growing and take a long time to recuperate from disturbance/harvesting.

The rate of natural disturbance experienced by the habitat will influence recovery rates. In locations subject to high levels of natural disturbance, the biological assemblage will be characterised by species able to withstand and recover from perturbations. Habitats within more stable environments, characterised by high diversity and epifauna, are likely to take longer to recover.

Table II.8 Types of subtidal sand habitats recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (EUNIS, 2007; Connor et al. 2004). Note A2.24 Muddy sand habitats are assessed in Report III

Annex 1 Habitat	EUNIS	Marine Habitat Classification (0405)
Sandbanks which are slightly covered by sea water all the time	A5.2	SS.SSa
	A5.21	SS.SSa.SSaLS
	A5.22	SS.SSa.SSaVS
	A5.23	SS.SSa.IFiSa
	A5.24**	SS.SSa.IMuSa
	A5.25	SS.SSa.CFiSa
	A5.26**	SS.SSa.CMuSa
	A2.27	SS.SSa.OSa
* Marlin sensitivity assessments available for this biotope or sub-biotopes. ** A5.24, A5.26 assessed in Report III.		

Table II.9 Information relevant to habitat pressure assessments

Pressure		Benchmark	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	Species associated with sand sediments are predominantly infaunal and hence have some protection against surface disturbance, although in more stable, sheltered shores, tubes of sedentary polychaetes may project above the sediment surface and damage to these would require repair. Bivalves and other species require contact with the surface for respiration and feeding, fragile animals that are buried close to the surface will be vulnerable to damage, depending on the force of the surface abrasion. Surface compaction can collapse burrows and reduce the pore space between particles, decreasing penetrability and reducing stability and oxygen content. The tops of burrows may be damaged and repaired subsequently at energetic cost to their inhabitants According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser et al. 1996; Zajac and Whitlatch, 2003). Nevertheless, in a moderately disturbed environment, Morello et al. (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The frequency and intensity of environmental disturbances such as storms may be among the key factors determining the resilience of the benthic community to fishing (Morello et al. 2006). Conversely, with depth increase the frequency and intensity of natural disturbance events tend to decrease. This will result in more stable environments with communities that are usually less resilient to environmental changes. Animals adapted to highly dynamic seabed environments are more resistant to disturbance (Boesch and Rosenberg, 1981) and may not be significantly affected by fishing gears (DeAlteris et al. 1999). *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide wept coarse sands as having low sensitivity to surface abrasion (damage to seabed surface features). Resistance was considered to be 'medium' (loss of <25% of element) and recovery 'high' (full recovery within 2 years). The assessment was informed by work on Bassurelle sandbank by JNCC (JNCC 2008). The assessment was based on characterising species (burrowing bivalves) and a high energy, gravelly sand habitat (Tillin et al. 2010). The same workshop assessed the sensitivity of subtidal sands and gravels to this pressure as low to medium. Resistance was considered to be 'low to high' (no significant effect-loss of 25-75% of assessed elements) and recovery as 'low-high' (full recovery within 2-25 years). Elements used in the assessment include substrate (characteristic particle size distributions), colonial sessile epifauna and infaunal polychaetes. Expert review indicated that the sensitivity for this feature was best represented as a range as this is such a broad habitat sensitivity to pressures can vary from Low (for highly mobile sediments) to High (for stable sands and long-lived bivalve communities). A range was therefore used in the matrix.

Pressure		Benchmark	Evidence
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	Fishing can directly alter the physical habitat by influencing sediment particle size (Thrush and 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. 2000). Changes in benthic community structure have been observed following beam trawling and other activities that lead to deep penetration of the seabed. The effects of shallow and deep disturbance on benthic habitats will vary between different biotope types due to different sensitivities of the characterising species. Disturbance effects may be more apparent in more sheltered, stable habitats than in disturbed mobile sediments where frequent disturbance typically leads to the development of species poor, biological assemblages (Kaiser and Spencer, 1996). Mixed sediment habitats subject to strong disturbance gradients such as changes in salinity in estuaries or enriched areas, where communities are dominated by opportunistic species assemblages, may be more tolerant of disturbance, typically through the ability of species to recover quickly from disturbance events rather than the ability to resist (tolerate) disturbances. Burrowing and tube dwelling infauna may be less affected than epifauna (Bullimore, 1985). Large, long-lived and fragile species are more sensitive to damage and their populations take longer to recover. Frequent disturbance therefore, selects for smaller, less fragile organisms that have higher resistance to disturbance, through traits such as environmental position (infauna vs epifauna), fragility (robust vs fragile), size (smaller organisms can pass through meshes or are pushed out of the way, although some smaller organisms are more vulnerable as they are more exposed as they live closer to the surface (Bergman and Hup, 1992)). Species that can also recover more quickly (e.g. shorter-lived organisms with rapid life cycles can withstand greater disturbance. Repeated disturbances may lead to the development of assemblages dominated by opportunistic species, typically deposit feeding polychaetes (Rijnsdorp et al. 1996; Jennings and Kaiser, 1998) Predators and scavengers may also benefit from disturbance and congregate in areas where disturbance has left macrofauna, dead, injured or exposed (Caddy, 1973; Kaiser and Spender, 1994; 1996; Lindeboom and Groot, 1998). Overall the effect may be to change the composition of benthic assemblages in an area (Tillin et al. 2006). Surface disturbance, can create tracks on the seabed, re-suspend sediments and reduce habitat complexity by smoothing out structures and displacing and overturning any larger cobbles or boulders present as well as flattening biogenic structures. Fishing gear may penetrate deeper in mud sediments than in other coarser habitat types, beam trawls have been reported to penetrate to 10mm in sandy ground and 30mm in muds (Groot, 1995). Scallop dredging can disturb the top 100 mm of sediment being disturbed by scallop dredging flattening the surface as pits and depressions are filled in and mounds are removed (Currie and Parry, 1996). These physical changes as well as the track marks may still be present months later depending on the conditions at the site. Where there is little current movement the tracks may be visible for a long time and even a relatively minor fishery may have a significant cumulative effect on bottom microtopography (Caddy, 1973). *Previous Sensitivity Assessments*

Pressure		Benchmark	Evidence
			An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having low sensitivity to damage to seabed surface and penetration ≤25mm). Resistance was considered to be 'low' (loss of 25-75% of assessed elements) and recovery as 'high' (full recovery within 2 years). The assessment was informed by work on Bassurelle sandbank by JNCC (JNCC 2008). The assessment was based on characterising species (burrowing bivalves) and a high energy, gravelly sand habitat (Tillin et al. 2010). The same workshop assessed the sensitivity of subtidal sands and gravels to this pressure as low to medium. Resistance was considered to be 'low to high' (loss of 25-75% to no significant effect on the assessed element) and recovery as 'medium' (full recovery within 2-10 years). The assessment was based on the character of the substratum (characteristic particle size distributions) and characterising species including colonial sessile epifauna and infaunal polychaetes.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	*Activity Specific Information* Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that at a shallow site (6 metres depth and characterised by fine sand (40-70%) with some medium and very fine sand fractions (coarse sand <15%), there was a sudden decrease in grain size immediate after dredging followed by a slow increase, the sediments were 'quite similar' to control areas 17 days after dredging (Constantino, et al. 2008). Sediments were mobilised by storm events during the post-dredging monitoring period and this may have aided sediment recovery. At a deeper site (18m) and characterised (>80% of sample coarse sand and gravel fractions) a slight increase in grain size was found 1 day after dredging, after 13 days, mean sediment grain size in the disturbed area was similar to the undisturbed sediments in deeper waters. (Constantino et al. 2008). Sediments were mobilised by storm events during the post-dredging monitoring period and this may have aided sediment recovery. The passage of the dredge on the bottom produced a slightly depressed track, about 10cm deep, where the sedimentary structures were disrupted. The tracks were no longer visible 24 hours after dredging at a shallow site (6m) whereas at 18m depth, tracks were still visible 13 days after dredging (Constantino et al. 2008). The dredging impacts on benthic communities varied according to depth. In general, no clear impacts were observed for shallower areas (6m depth predominantly fine sand) although a general decrease in abundance of the most abundant taxa was observed after dredging. At 18m depth, where habitats were more sheltered from natural disturbance clam dredging caused an immediate effect on the meio- and macrobenthic communities (coarse sand and gravel sediments) . For macrofauna, all biological variables showed a significant decrease immediately after dredging, probably due to the removal of target and non-target species by the gear and/or spatial redistribution of macrobenthic fauna in the dredged area (Constantino, et al. 2008). *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having low sensitivity to penetration and/or disturbance of the substrate below the surface of the seabed (>25mm

Pressure		Benchmark	Evidence
			depth to 30 cm depth). Resistance was considered to be 'low' (loss of 25-75% of assessed elements) and recovery as 'high' (full recovery within 2 years). The assessment was informed by work on Bassurelle sandbank by JNCC (JNCC 2008). The assessment was based on characterising species (burrowing bivalves) and a high energy, gravelly sand habitat (Tillin et al. 2010). The same workshop assessed the sensitivity of subtidal sands and gravels to this pressure as low to medium. Resistance was considered to be 'low to medium' (loss of <25% to loss of 25-75% of assessed elements) and recovery as 'medium- high' (full recovery within 2 years or between 2-10 years). Elements considered in the assessment include substrate (characteristic particle size distributions) and characterising species (colonial sessile epifauna and infaunal polychaetes) (Tillin et al. 2010).
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	Not exposed. Subtidal feature not accessible.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	Not exposed. Subtidal feature not accessible.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment which may be anoxic and/or of a different character or bedrock 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) state that removal of 0.5 m depth of sediment is likely to eliminate benthos from the affected area. Some epifaunal and swimming species may be able to avoid this pressure. The process of extraction is considered in the deep disturbance theme. Extraction of habitat is not considered to be an effect arising from aquaculture. 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. *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having medium sensitivity to extraction of the seabed (to a depth of 30cm). Sensitivity to physical damage pressures was informed by work on Bassurelle sandbank by JNCC (JNCC 2008). Recruitment was judged to be relatively rapid in high-energy environments. The assessment was based on characterising species (burrowing bivalves) and a high energy, gravelly sand habitat (Tillin et al. 2010). The same workshop assessed subtidal sand and gravels as having medium-low sensitivity to extraction, based on no resistance and medium-high recovery. Experts cited Cefas studies, ALSF, ICES reports in support. Elements used in assessment were the substrate (characteristic particle size distributions), colonial sessile epifauna and infauna. Expert review indicated that the sensitivity

Pressure		Benchmark	Evidence
			for this feature was best represented as a range as this is such a broad habitat sensitivity to pressures can vary from Low (for highly mobile sediments) to High (for stable sands and long-lived bivalve communities).
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	Impacts of towed demersal gears in soft-sediment can include smothering of suspension feeding fauna through the resuspension of sediment by the fishing gears (Jennings and Kaiser, 1998) The quantity of sediment resuspended by trawling depends on the sediment grain size and the degree of compaction, which is higher on mud and fine sand compared to coarse sand (Jennings and Kaiser, 1998). Kaiser et al. (2006) found that otter trawling had the most severe effect on suspension feeders in mud habitats, possibly reflecting the greater depths to which the otter doors penetrate the soft sediment habitat. Studies on the influence of suspended bivalve culture on the benthic environment do not show consistent effects. Some studies have not detected biodeposit related responses at bivalve culture sites. For example, a study of the impacts of subtidal longline oyster and mussel farms over fine sands and silts and clay sediments in Tasmania showed that benthic infauna did not differ between sites within and outside each farm site (although they did differ between the three farm sites studies) and that the benthic infauna did not show clear signs of organic enrichment (Crawford et al. 2003). These authors concluded that shellfish farming had little impact on the benthic environment. Similarly, a study by Danovaro et al. (2004), who investigated the impacts of large long-line mussel farm on biochemical, microbial and meiofaunal parameters in the Adriatic Sea (Mediterranean), found no difference in the meiofaunal abundance, community structure and taxa richness between the farm sediments and the control sites. The authors also reported that there was no evidence of eutrophication process, except a slight increase in the bacterial density in the sediments beneath the long line farm during the highest period of mussel stocks. In contrast, some studies have shown that the accumulation of biodeposits may lead to changes in sediment biogeochemistry (e.g. enhanced sulphate reduction, enhanced ammonium release) and structural changes in the resident microbial, meiofaunal and/or macrofaunal communities (Callier et al. 2006 and references therein). For example, Mirto et al. (2000; impact of a mussel farm in the western Mediterranean; sediment type not stated), showed that the accumulation of faeces and pseudofaeces beneath mussel cultures led to reducing conditions resulting in changes in sedimentary conditions (accumulation of chloroplastic pigments, proteins and lipids). Microbial assemblages increased in density compared to the control site (about 1km away) and farm sediments displayed significant changes in meiofaunal density (turbellarian, ostracod and kinorhynch densities decreased significantly while copepods remained constant or increased). Kasper et al. (1985; impact of long-line mussel farming (Perna canaliculus) in New Zealand), showed that sediments at the mussel farm were slightly finer compared to a reference site and that there was decreased diversity of the infaunal assemblage beneath the mussel lines, probably caused by the increased sedimentation rate (the benthic fauna of the mussel-farm sediment consisted only of polychaete worms while the reference site also contained bivalve molluscs, brittle stars and crustaceans). However, the effect on epifauna was different, with the build-up of live mussels and shell material beneath the mussel lines providing sites of attachment for a large epibiota including tunicates, sponges and calcareous polychaetes, forming a reef like aggregation. Hartstein and Rowden (2004; effect of mussel culture in New Zealand; sediment type not stated)

Pressure		Benchmark	Evidence
			found significant differences in macroinvertebrate composition between samples taken inside and outside of the mussel farm in a low energy hydrographic regime, with polychaetes more abundant inside the farm and ophiuroids more abundant outside. The authors concluded that the study indicated that there was a relationship between the hydrodynamic regime of a farm site, organic enrichment of seabed sediments by mussel biodeposition and subsequent modification of the macroinvertebrate assemblages. Callier et al. (2007) stated that such differing effects reported in the literature may be explained in part by site (hydrodynamics, topography, background enrichment, sediment type) and culture (bivalve density, culture depth, mussel size) differences. Together, these factors may influence biodeposit production and dispersion and therefore their potential impact on the benthic environment. In general this aquaculture method is thought to be less damaging than fish farming (Crawford et al. 2003; cited in Hall et al. 2008).The direct physical contact of fishing gear with the substratum can lead to the re-suspension of sediments. The quantity of sediment re-suspended by trawling depends on sediment grain size and the degree of compaction, and is higher on mud and fine sand than on coarse sand (Kaiser et al. 2001). Most bivalve species are capable of burrowing through sediment to feed, e.g. *Abra alba* are capable of upwardly migrating if lightly buried by additional sediment (Schafer, 1972; cited in Budd, 2008). There may be an energetic cost expended by species to either re-establish burrow openings, to self-clean feeding apparatus or to move up through the sediment, though this is not likely to be significant. Most animals will be able to reburrow or move up through the sediment within hours or days. *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having no sensitivity to changes in siltation (low), based on a benchmark of 5cm of fine material added to the seabed in a single event. Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant and Thorpe, 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang and Levings, 1978). Elements used in assessment: burrowing bivalves, substrate gravelly sand, high energy. An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having low sensitivity to changes in siltation (high), based on a benchmark of 30cm of fine material added to the seabed in a single event. Resistance was assessed as ‘Medium’ (loss of <25% of assessed elements) and recovery as ‘High’ (full recovery within 2 years). As the environment was judged to be energetic, deposited sediment would be removed by water action ameliorating effects. The assessment was informed by work on Bassurelle sandbank by JNCC (JNCC, 2008) and was based on

Pressure		Benchmark	Evidence
			characterising species (burrowing bivalves) and a high energy, gravelly sand habitat (Tillin et al. 2010). The same workshops assessed the sensitivity of subtidal sands and gravels to low and high siltation as ranging from not sensitive to medium. Resistance was assessed as none to high (ranging from no significant effect to loss of >75% of assessed elements) and recovery as 'medium-high'. Elements used in assessment include substrate (characteristic particle size distributions), colonial sessile epifauna, infaunal polychaetes. Expert review indicated that the sensitivity for this feature was best represented as a range as this is such a broad habitat sensitivity to pressures can vary from Low (for highly mobile sediments) to High (for stable sands and long-lived bivalve communities).
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	See also Littoral sand sediments (Table II.2) *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having high sensitivity to changes in sediment type, based on a benchmark of a change in 1 folk class for 2 years. Resistance was assessed as 'none' (loss of >75% of assessed elements) and recovery was assessed as medium (considered to require 2-10 years) (Tillin et al. 2010). The same workshops assessed subtidal sand and gravels as having medium-low sensitivity to this pressure based on medium resistance (loss of >25% of assessed elements) and medium-high recovery (full recovery within 2 years or between 2-10 years).
	Collision risk	Presence of significant collision risk, e.g. access by boat	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise		Not sensitive.
	Visual - Boat/ vehicle movements		Not sensitive.
	Visual - Foot/ traffic		Not sensitive.
Change in Habitat	Changes to sediment composition -	Coarse sediment fraction increases	Changes in the coarse fraction of sediments may alter the character of this habitat feature and result in changes to the biological community present as habitat suitability changes. A sand sediment could become a coarser sediment where the fine sediment fraction is removed through surface disturbance and winnowing, either through physical disturbance or changes in water flow. Any

Pressure		Benchmark	Evidence
	Increased coarseness		increase or decrease in grain size, silt content etc. will affect species numbers/richness in soft sediment habitats but these should return to normal levels if the disturbance is temporary (Elliott et al. 1998). Fishing can directly alter the physical habitat by influencing sediment particle size (Thrush and Dayton, 2002 and references therein). Towed demersal gears have been shown to alter the sedimentary characteristics of subtidal sand habitats by penetration of the sediment (Ball et al. 2000). Where changes are long-term, a community representative of the new habitat type will develop. *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having no resistance (loss of >75% of assessed elements) to changes in sediment composition at a benchmark of 'a change in 1 folk class for 2 years' (Tillin et al. 2010). Recovery was assessed as medium (2-10 years). The feature was therefore judged to behave medium sensitivity at the pressures benchmark. The same workshop also assessed subtidal sands and gravels as not sensitive to this pressure. A separate workshop assessed subtidal sands and gravels as having medium resistance and medium to high recovery, sensitivity was therefore considered to be low to medium.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	Changes in the proportion of the fine fraction of sediments may alter the character of this habitat feature and result in changes to the biological community present as habitat suitability changes. A sand sediment could become a muddy sand sediment where the fine sediment fraction is increased through siltation resulting from changes in deposition rates and particulate supply and/or changes in water flow. Any decrease in grain size, silt content etc. will affect species numbers/richness in soft sediment habitats but these should return to normal levels if the disturbance is temporary (Elliott et al. 1998). Where changes are long-term a community representative of the new habitat type will develop. *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having no resistance (loss of >75% of assessed element), to changes in sediment composition at a benchmark of 'a change in 1 folk class for 2 years' (Tillin et al. 2010). Recovery was assessed as medium (2-10 years). The feature was therefore judged to have medium sensitivity at the pressures benchmark. The same workshop also assessed subtidal sands and gravels as not sensitive to this pressure. A separate workshop assessed subtidal sands and gravels as having medium resistance (loss of <25% of assessed elements) and medium to high recovery, sensitivity was therefore considered to be low to medium.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent	The hydrodynamic regime, including flow rates, is an important factor determining the type of sediment present. Increased flow rates e.g. around structures may lead to localised scour, removing finer particles and, if severe, removal of coarser particles, increasing the coarse fraction or exposing bed rock. Conversely, decreases in flow rate will lead to the deposition of finer particles, increasing the silt and clay content of the substratum. Changes in sediment type to coarser or finer types are discussed above. Decreases in

Pressure		Benchmark	Evidence
		structures placed in the water column	water flow with increased siltation of fine particles are considered unlikely to alter the physical character of this habitat type as it is already found in sheltered areas where siltation occurs and where particles are predominantly fine. Increased water flows could lead to localised erosion, removing the upper layers of fine silty sediment and change the sediment type with subsequent changes in the biological assemblage. Erosion of fine sand of 0.1mm particle diameter occurs at >30 cm s-1, and deposition will occur at <15cm s^{-1}. Particles of 1- 10 µm diameter have a similar relationship, although erosion requires faster current speeds because of consolidation and flocculation (Hedgpeth, 1967). *Previous Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having no sensitivity to changes in water flow at a benchmark of 'a change in peak mean spring tide flow speed of between 0.1m/s to 0.2m/s over an area >1km² or 50% of width of water body for more than 1 years' (Tillin et al. 2010). The assessment was based on feature occurrence in areas where tidal streams vary from moderately strong to weak (JNCC on-line biotope descriptions). The feature was therefore judged to be 'not sensitive' at the pressures benchmark. The same workshop also assessed subtidal sands and gravels as not sensitive to this pressure.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	See also Littoral Sand Sediments (Table II.2) Trawling disturbance generates a sediment plume which contributes to fish capture. 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 rock substrates may disturb small pockets of collected sediments but plume formation will be limited. Trawling can create suspended sediment plumes up to 10m above the bottom (Churchill, 1989; cited in Clarke and Wilber 2001). Shrimp trawlers in Texas have increased suspended sediment concentrations to between 100 and 550 mg/l at 2 m above the bottom and 100m astern of trawls (Schubel et al. 1978; cited in Clarke and Wilbur 2001). Information from MarLIN, SS.SMu.CSaMu.VirOphPmax Burrowing infauna in these habitats would not be affected by an increase in suspended sediment. There may be possible clogging of feeding organs in suspension feeders (e.g. venerid bivalves) and there may be some energetic cost to clear their feeding and respiration organs at high particles concentrations. If the suspended sediment has a high organic content, some suspension feeding organisms may benefit. On return to normal suspended sediment levels recovery would be immediate as affected species will be able to self-clean within a few days (Hill and Wilson, 2008). In general, an increase in turbidity may reduce primary production in the water column and therefore reduce the availability of diatom

Pressure		Benchmark	Evidence
			food, both for suspension feeders and deposit feeders. In addition, primary production by the microphytobenthos on the sediment surface may be reduced, further decreasing food availability for deposit feeders. *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands and subtidal sands and gravels as having no sensitivity to changes in water clarity at a benchmark of 'a change in one rank, e.g. from clear to turbid for one year (Tillin et al. 2010).
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	(See also Littoral Sand habitats Table II.2) Decreased seston availability may reduce the food supply suspension feeders and indirectly result in decreased deposition of organic particles on the substratum surface reducing food availability for deposit feeders. This could impair growth and reproduction. A change of 100mg/l for period of a month is unlikely to cause mortality or a decline in species richness. On return to normal suspended sediment levels, feeding activity would return to normal (Durkin, 2008).These changes may be offset by an increase in the light available for photosynthesis by phytoplankton in the water column and microphytobenthos on the sediment surface. This would increase primary production and may mean enhance food availability for deposit feeders and suspension feeders (Durkin, 2008). *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands and subtidal sands and gravels as having no sensitivity to changes in water clarity at a benchmark of 'a change in one rank, e.g. from clear to turbid for one year (Tillin et al. 2010).
	Organic enrichment - Water column	Eutrophication of water column	Fish cages release dissolved compounds directly into the surrounding water column including ammonia, nitrate and phosphate together with dissolved organic carbon. Nutrient enrichment of the water column can potentially lead to eutrophication and a possible consequence of nutrient enrichment is alteration of the species composition of plankton with possible proliferation of potentially toxic or nuisance species (OSPAR, 2009). However, the current consensus is that enrichment by salmon farm nutrients is generally too little, relative to natural levels, to have such an effect (SAMS and Napier University, 2002; cited in Wilding and Hughes, 2010). A recent modelling study of Loch Creran, Argyll, found that an increased nutrient input from salmon farms between 1975-2003 did not result in a significant increase in nutrient concentrations in the loch (Laurent et al. 2006; cited in Wilding and Hughes, 2010). Little detectable increase in phytoplankton standing crop adjacent to salmon cages in European or American waters has been shown (Weston, 1990; Gowen, 1990; Gubbins et al. 2003; cited in OSPAR, 2009) even though there are increases in ammonia and Smayda (2006; cited in OSPAR, 2009) indicated that increased nutrient loading from fish farm wastes in Scotland had not been accompanied by a detectable increase in harmful algal blooms within Scottish Waters. Bivalve aquaculture and fishing activities do

Pressure		Benchmark	Evidence
			not introduce nutrients into the system (although fishing may release nutrients through sediment disturbance), hence these activities are not considered significant. Eutrophication from caged fish farming is likely to be observed only in enclosed water bodies with low flushing rates. Eutrophication of the water column is not considered likely to directly negatively impact subtidal sand sediments although smothering by ephemeral macroalgae may occur in sheltered areas and reductions in dissolved oxygen through increased bacterial degradation of dead plant matter may occur (see decreases in oxygen). Such effects are more likely to be due to terrestrial sources of nutrients than aquaculture activities (see evidence above).
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	Studies on the influence of suspended bivalve culture on the benthic environment do not show consistent effects. Some studies have not detected biodeposit related responses at bivalve culture sites. For example, a study of the impacts of subtidal longline oyster and mussel farms over fine sands and silts and clay sediments in Tasmania showed that benthic infauna did not differ between sites within and outside each farm site (although they did differ between the three farm sites studies) and that the benthic infauna did not show clear signs of organic enrichment (Crawford et al. 2003). These authors concluded that shellfish farming had little impact on the benthic environment. Similarly, a study by Danovaro et al. (2004), who investigated the impacts of a large long-line mussel farm on biochemical, microbial and meiofaunal parameters in the Adriatic Sea (Mediterranean), found no difference in the meiofaunal abundance, community structure and taxa richness between the farm sediments and the control sites. The authors also reported that there was no evidence of eutrophication process, except a slight increase in the bacterial density in the sediments beneath the long line farm during the highest period of mussel stocks. In contrast, some studies have shown that the accumulation of biodeposits may lead to changes in sediment biogeochemistry (e.g. enhanced sulphate reduction, enhanced ammonium release) and structural changes in the resident microbial, meiofaunal and/or macrofaunal communities (Callier et al. 2006 and references therein). For example, Mirto et al. (2000; impact of a mussel farm in the western Mediterranean; sediment type not stated), showed that the accumulation of faeces and pseudofaeces beneath mussel cultures led to reducing conditions resulting in changes in sedimentary conditions (accumulation of chloroplastic pigments, proteins and lipids). Microbial assemblages increased in density compared to the control site (about 1km away) and farm sediments displayed significant changes in meiofaunal density (turbellarian, ostracod and kinorhynch densities decreased significantly while copepods remained constant or increased). Kasper et al. (1985; impact of long-line mussel farming (Perna canaliculus) in New Zealand), showed that sediments at the mussel farm were slightly finer compared to a reference site and that there was decreased diversity of the infaunal assemblage beneath the mussel lines, probably caused by the increased sedimentation rate (the benthic fauna of the mussel-farm sediment consisted only of polychaete worms while the reference site contained also bivalve molluscs, brittle stars and crustaceans). However, the effect on epifauna was different, with the build-up of live mussels and shell material beneath the mussel lines providing sites of attachment for a large epibiota including tunicates, sponges and calcareous polychaetes, forming a reef like aggregation. Hartstein and Rowden (2004; effect of mussel culture in New Zealand; sediment type not stated)

Pressure		Benchmark	Evidence
			found significant differences in macroinvertebrate composition between samples taken inside and outside of the mussel farm in a low energy hydrographic regime, with polychaetes more abundant inside the farm and ophiuroids more abundant outside. The authors concluded that the study indicated that there was a relationship between the hydrodynamic regime of a farm site, organic enrichment of seabed sediments by mussel biodeposition and subsequent modification of the macroinvertebrate assemblages. Callier et al. (2007) stated that such differing effects reported in the literature may be explained in part by site (hydrodynamics, topography, background enrichment, sediment type) and culture (bivalve density, culture depth, mussel size) differences. Together, these factors may influence biodeposit production and dispersion and therefore their potential impact on the benthic environment. In general this aquaculture method is thought to be less damaging than fish farming (Crawford et al. 2003; cited in Hall et al. 2008). *Previous Sensitivity Assessments* An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands and subtidal sands and gravels as having no sensitivity to organic enrichment, based on a benchmark of 100gC/m²/yr. Elements considered in the assessment were: burrowing bivalves, substrate gravelly sand and high energy of the environment and substrate (characteristic particle size distributions), colonial sessile epifauna, infaunal polychaetes, respectively (Tillin et al. 2010).
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	High level habitats are not considered to be sensitive to the removal of phytoplankton.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	The direct effects of changes in dissolved oxygen (DO) concentration on the marine environment are primarily related to reduced DO levels and include: lethal and sub-lethal responses in marine organisms, release of nutrients, and the development of hypoxic and anoxic conditions. The lethal and sub-lethal effects of reduced levels of dissolved oxygen are related to the concentration of dissolved oxygen and period of exposure of the reduced oxygen levels. A number of animals have behavioural strategies to survive periodic events of reduced dissolved oxygen. These include avoidance by mobile animals, such as fish and macrocrustaceans, shell closure and reduced metabolic rate in bivalve molluscs and either decreased burrowing depth or emergence from burrows for sediment dwelling crustaceans, molluscs and annelids. The lethal and sub-lethal effects of reduced levels of dissolved oxygen were reviewed by Stiff et al. (1992) for the purposes of EQS derivation. This review was updated by Nixon et al. (1995) in order to derive a General Quality Assessment (GQA) scheme for dissolved oxygen and ammonia in estuaries for the Environment Agency in England and Wales. Stiff et al. (1992) and Nixon et al. (1995) identified crustacea and fish as the most sensitive organisms to reduced DO levels with the early life stages of fish and

Pressure		Benchmark	Evidence
			migratory salmonids as particularly sensitive. For estuarine fish, Stiff et al. (1992) suggested a minimum DO requirement of 3 to 5 mg l^{-1}.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	Reduced levels of dissolved oxygen in the water column can also result in the release of phosphate from suspended particles and the sediment and contribute to local eutrophication. Sustained reduction of dissolved oxygen can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. In anoxic environments, anaerobic bacteria proliferate, with nitrogenous oxide reducers absorbing oxygen by reducing nitrate to nitrite and forming ammonia or nitrogen gas. In addition, sulphate-reducing bacteria reduce sulphate to hydrogen sulphide which, when liberated, increases mortality of marine organisms and increases the BOD as it permeates through the water column (Kennish 1986). Such conditions can occur under a cage fish farm installation where release of hydrogen sulphide has caused fish kills and sediment can become covered in filamentous fungi, such as *Beggiatoa* spp.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts	Not exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	There are 8 known invasive species in Irish Seas (Invasive Species Ireland project http://invasivespeciesireland.com/toolkit/), slipper limpet (*Crepidula fornicata*) and Pacific Oyster (*Crassostrea gigas*) are of key relevance to this feature (species either occurs in this feature and/or can be spread by aquaculture activities and boat movements). The seaweed *Sargassum muticum* may colonise *Zostera* beds within subtidal mudflats or attach to stones and bivalve shells. The ascidian *Didemnum vexillum* may colonise artificial hard substrates such as aquaculture trestles or mussel and oyster beds. Aquaculture may act as vector through the introduction of broodstock contaminated with potential alien species or through the relaying of stock between water bodies for ongrowing. Management should prevent the spread of non-native species through responsible sourcing of broodstock, licensing requirements and the implementation of the EC Regulation on the use of alien and locally absent species in aquaculture and the Aquatic Animal Health Regulations. Boat movements may transport non-native species between marinas and harbours, management of fouling will help prevent accidental transport. The slipper limpet was first recorded in Northern Ireland at Belfast Lough in 2009 (McNeil et al. 2010). Other records exist from around Ireland over the last century including: Ballinakill Bay, Carlingford Lough, Dungarven Bay, Kenmare Bay and Clew Bay. However, none of these sites are currently thought to be supporting C. fornicata. This species most likely arrived in Ireland with consignments of mussels. Other possible pathways include; with consignments of oysters, on drifting materials or due to dispersal of

Pressure		Benchmark	Evidence
			larvae. They may settle near the low water mark on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment, creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. Pacific oysters were first brought to Northern Ireland as part of aquaculture development. They have now been grown in Northern Ireland since the early 1970s when initial growth and survival trials were carried out in Strangford Lough. Feral populations of Pacific oysters are now breeding successfully which may bring about a fundamental change to the ecosystem of the area. Pacific oysters are also known to have spawned in Lough Foyle. Populations of *C. gigas* have formed solid reefs in soft sediment habitats such as the mudflats of the Wadden Sea (Ruesink et al. 2005; Kochmann et al. 2008; cited in OSPAR, 2009) The brown alga *Sargassum muticum* (wire weed) has been recorded at several locations around the coast of Ireland. This species is now widespread around the coast of Ireland with definite records in Counties Down, Louth, Wexford, Cork, Kerry, Galway and Sligo. It is likely that the species has a much wider distribution and will spread to new areas to colonise all coastal areas. The species is known to occur from the intertidal to the subtidal in a range of substrates including hard rock face and *Zostera marina* (eel grass) beds. The species can occupy hard substrates on sheltered shores where it can from dense monospecific stands excluding other species. It is believed that this species arrived with oyster spat introduced for commercial purposes so that aquaculture can be considered a potential vector for spread of this species. This species has very high growth rates and can grow up to 16 m in length, forming floating mats on the sea surface. It can grow up to 10 cm per day, and it also has a long life span of 3-4 years. Dense mats of *Sargassum* can form very quickly. Fronds, if detached, can continue to shed germlings as they drift. Dense *S. muticum* stands can reduce the available light for understory species, dampen water flow, increase sedimentation rates and reduce ambient nutrient concentrations available for native species. (Above information from Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sand sediments were considered to have greater resistance to invasive species than the muddy sediments typical of more sheltered areas, due to greater sediment instability and consequent habitat unsuitability. However where the placement of aquaculture infrastructure has the potential to reduce current speeds or provide suitable habitat for colonisation, there may be potential for the establishment of non-native species. *Previous Sensitivity Assessments*

Pressure		Benchmark	Evidence
			An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed subtidal sands and gravels as having low to high resistance (ranging from loss of 25-75% of assessed elements to no significant effects) and medium-high recovery (full recovery within 2 years or between 2-10 years) to the introduction of non-native species. Sensitivity was therefore considered to range between 'none to medium. Experts noted that more stable substrates may be susceptible to invasive non-indigenous species but less stable habitats may be resistant (Tillin et al. 2010).
	Introduction of parasites/ pathogens		Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		This feature is not considered to be functionally dependent on commercially targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	The sensitivity of the feature to the pressures that arise through the removal of target and non-target species is considered in the above pressure themes. The feature is not considered to be functionally dependent on targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal. However, as outlined above, the removal of target and non-target species may result in changes to the biological community and hence the classification of the assemblage type as assessed in the associated biotope pro-formas.
	Ecosystem Services - Loss of biomass		Not assessed.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	The use of medicinal products in shellfish cultivation is minimal and hence not considered any further. Various medicinal compounds are used within finfish aquaculture. There is evidence that antibiotic use in finfish aquaculture can promote the growth of resistant strains of bacteria in mainly mud dominated seabed sediments (Chelossi et al. 2003) although Wildling and Hughes (2010) stated that it is highly unlikely that this form of discharge (antibiotics reaching the seabed both directly and via egestion) would have any effect on benthic animal or plant life. A field trail in Scotland showed that although sea lice treatment emamectin benzoate was detectable in sediments within 10m from salmon cages up to 12 months after treatment, declining concentrations showed that the chemical was degrading (Telfer et al. 2006). Macrobenthic faunal analysis provided no evidence that emamectin benzoate, or its desmethylamino metabolite, in sediments around fish farm cages after treatment had any toxic impacts on organisms in either the water column or sediments.

Pressure		Benchmark	Evidence
			The anti-parasite compound Ivermectin is highly toxic to benthic polychaetes and crustaceans (Black, 1998; Collier and Pinn, 1998; Grant and Briggs, 1998; cited in Wildling and Hughes, 2010). OSPAR (2000) stated that, at that time, Ivermectin was not licensed for use in mariculture but was incorporated into the feed as a treatment against sea lice at some farms. Ivermectin has the potential to persist in sediments, particularly fine-grained sediments at sheltered sites. Data from a farm in Galway indicated that Ivermectin was detectable in sediments adjacent to the farm at concentrations up to 6.8µm/kg and to a depth of 9cm (reported in OSPAR, 2000). Infaunal polychaetes have been affected by deposition rates of 78-780mg ivermectin/m^2.
	Introduction of hydrocarbons	Introduction of hydrocarbons	Subtidal sediments may be at less risk from oil spills than intertidal sediments, unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil in to the sediment (Elliott et al. 1998; cited in Budd, 2008). However, large numbers of dead polychaetes and other fauna were washed up at Rulosquet marsh near Isle de Grand following the Amoco Cadiz oil spill in 1978 (Cross et al. 1978; cited in Riley and Ballerstedt, 2005). In general, contact with oil causes an increase in energy expenditure and a decrease in feeding rate in bivalves, resulting in less energy available for growth and reproduction (Suchanek, 1993; cited in Rayment, 2008). Sub-lethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates.
	Introduction of antifoulants	Introduction of antifoulants	The toxicity of copper in water and in sediments is influenced by a number of factors so that it is difficult to predict the subsequent toxicity to aquatic organisms and hence the effects from potential inputs. The chemical form (or speciation) of the copper and site-specific environmental conditions including water pH, organic content, temperature and salinity influence bioavailability and hence toxicity (Kiaune et al. 2011, Burridge et al. 2008). It is uncertain which forms are bioavailable, and no reliable measuring methods for assessment of the size of the bioavailable fraction are available. The actual bioavailability will typically be considerably less than the potential bioavailability. Furthermore, bioavailability is species specific and may also depend on physiology, nutrition, life-stage, age and size of the organisms (Madsen et al. 2000). Copper binds to sulphides and organic matter, including dissolved organic carbon (DOC) to form organic complexes, rendering the copper non-bioavailable. The higher the levels of fine particles (silt and clay) and the higher the amount of sulphide in the sediments, the less bioavailable the copper (and other metals) will be. The combination of acid volatile sulphide (AVS) and total organic carbon (TOC) can explain much of the toxicity of Cu in sediments (Correia and Costa, 2000). This means that values obtained from laboratory bioassays (toxicity tests) may overestimate toxicity when applied to field results. As sediments under fish farms tend to be reducing, have high oxygen demand, and high sulphide from the animal wastes and uneaten feed, these sediments should bind metals to a high degree (Kiaune et al. 2011; Burridge et al. 2010). Zinc, like copper, binds to fine particles and to sulphides in sediments, and even when it is bioavailable, it is much less toxic than copper (Burridge et al. 2010). Zinc pyrithione was reviewed by Madsen et al. (2000) and Guardiola et al. (2012) who note that there is a lack of data on toxicity. Burridge et al. (2010) state that the majority of studies have found that these two metals do not interact synergistically with each other. Most studies have found either additive effects or more often, antagonistic interactions, wherein the presence of zinc reduces the toxic effects of the copper (Burridge et al. 2010). Due to the lower toxicity of zinc, assessments have

Pressure		Benchmark	Evidence
			generally focused on sensitivity to copper. Much of the available literature relates to antifoulant use on boats and sediment accumulation in marinas, ports and harbours, although Guardiola et al. (2012) have recently reviewed the risks of antifouling biocides in aquaculture (effects on species). In general exposure to biotoxins would be predicted to alter species numbers, species richness and hence species diversity. Due to differential effects on taxonomic groups, exposure may alter the structure of the biological assemblage and change the biotope classification of an area by removing characterising species. Research in Norwegian fjords, for example, has found that species diversity significantly decreased with increasing copper concentrations (species number roughly halved with each 10-fold increase in copper concentration) (Rygg, 1985). A number of water quality standards for copper have been set. Hall and Anderson (1999) derived a PNEC (Predicted No Effect Concentration) of 5.6 µg/l based on 65 marine species. Of 101 stations surveyed only 3 failed this level. The Dangerous Substances Directive 2006/11/EC set an EQS of 5 ug/l .The UK Technical Advisory group (Maycock et al. 2011) have proposed a new EQS (based on 29 species) for the Water Framework Directive of 2.64 ug/l (adjusted to local ambient concentrations of dissolved organic carbon) to protect marine life. As copper (and other contaminants) also accumulate in sediments, benthic organisms are exposed to concentrations that are much higher than those in the water column. Benthic organisms are exposed to particulate and dissolved copper in interstitial and overlying waters, as well as to sediment-bound copper through surface contact and sediment ingestion. Although a threshold of effect could not be established with certainty, studies indicate that copper in sediment may cause effects on sediment-living animals at concentrations exceeding 100 mg/kg (Masden et al. 2000). The Sediment Quality Criterion for copper in Scotland is 270 mg kg^{-1}. (SEPA, 2005) Canadian interim sediment quality guidelines (ISQGs) of 18.7 mg kg^{-1} dry weight and probable effect levels (PELs) for Cu (108 mg kg-1 dry weight) refer to total concentrations in surficial sediments (top 5cm) are used to evaluate the degree to which adverse biological effects are likely to occur as a result of exposure to Cu in sediments (Canadian Council of Ministers of the Environment. 1999). These are based mainly on field studies of effects. Organically enriched fish farm sediments generally have a high biological oxygen demand and negative redox potential; conditions that lead to sulphate reduction. Under these conditions, metals such as copper and zinc are unlikely to be biologically available. However, disturbance of the sediments by bioturbation, or re-suspension of particles by filter feeders, currents or trawling could cause the sediments to be redistributed into the water column, and could remobilize the metals. During any fallow periods in which the reduction of organic material and sulphide concentration may release copper and zinc, increasing metal bioavailability. The probable reason for the decline in metals in sediments during remediation is that the metals are released into the water column, and therefore could be more available and toxic to other pelagic organisms in the vicinity (Burridge et al. 2010). Information on habitat recovery is limited. A 2-year microcosm experiment was undertaken to investigate the impact of copper on the

Pressure		Benchmark	Evidence
			benthic fauna of the lower Tyne Estuary (UK) by Hall and Frid (1995). During a 1-year simulated contamination period, 1 mg l^{-1} copper was supplied at 2-weekly 30% water changes, at the end of which the sediment concentrations of copper in contaminated microcosms reached 411 µg g^{-1}. Toxicity effects reduced populations of the four dominant taxa (*Malacoceros fuliginosus*, *Capitella capitata*, nematodes and *Tubificoides* spp.). When copper dosage was ceased and clean water supplied, sediment copper concentrations fell by 50% in less than 4 days, but faunal recovery took up to 1 year, with the pattern varying between taxa. Since the copper leach rate was so rapid it is concluded that after remediation, contaminated sediments show rapid improvements in chemical concentrations, but faunal recovery may be delayed with experiments in microcosms showing faunal recovery taking up to a year. Sediment and sea surface microlayer samples near an open-net salmon farm in Nova Scotia placed in fallow after 15 years of production, were analysed for copper over a period of 27 months. Elevated copper concentrations in the sediments indicated the farm site as a source for elevated levels in the sea surface microlayer which led to an enlarged farm footprint. Over the 27 months period, copper levels persisted in the sediments and decreased gradually in the sea surface microlayer (Loucks et al. 2012).
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	No evidence. As this feature is not characterised by the presence of primary producers it is not considered that shading would alter the character of the habitat. Beneath structures there may be changes in microphytobenthos abundance. Sublittoral sandflats support microphytobenthos (where light penetration is sufficient) on the sediment surface and within the sand grains. The microphytobenthos consists of unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments, typically appearing only as a subtle brownish or greenish shading. Mucilaginous secretions produced by these algae may stabilise fine substrata (Tait and Dipper, 1998). The biomass of the benthic microalgae often exceeds that of the phytoplankton in the overlying waters (McIntyre et al, 1996) such that benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability. Shading will prevent photosynthesis leading to death or migration of sediment microalgae altering sediment cohesion and food supply to higher trophic levels.
	Barrier to species movement		Not assessed.

References

Ball, B., Munday, B. and Tuck, I. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. In: Kaiser, M.J. and Groot, S.J. (Eds.) Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Oxford: Blackwell Science Limited. pp. 69-82.

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beam trawling on macro-fauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science 49:5-11.

Boesch, D.F. and Rosenberg R., 1981. Response to stress in marine benthic communities. In: Barret, G.W. and Rosenberg, R. (Eds.) Stress effects on natural ecosystems. J. Wiley and Sons, New York, pp. 179-200.

Budd, G.C. 2008. *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 30/06/2011]. Available from: http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=154&code=2004.

Bullimore, B. 1985. An investigation into the effects of scallop dredging within the Skomer Marine Reserve. Skomer Marine reserve Subtidal Monitoring Project. Report to the Nature Conservancy Council.

Burridge, L, Weis, J., Cabello, F. and Pizarro, J. 2008. Chemical Use in Salmon Aquaculture: A Review of Current Practices and Possible Environmental Effects. World Wildlife Federation, Salmon Aquaculture Dialogue.

Burridge, L., Weis, J., Cabello, F. and Pizarro, J. 2010. Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. Aquaculture 306: 7-23.

Caddy, J.F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada 30: 173-180.

Callier, M.D., McKindsey, C.W. and Desrosiers, G. 2007. Multi-scale spatial variations in benthic sediment geochemistry and macrofaunal communities under a suspended mussel culture. Marine Ecology Progress Series 348: 103-115.

Canadian Council of Ministers of the Environment. 1999. Canadian sediment quality guidelines for the protection of aquatic life: Copper. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Chang, B.D. and Levings, C.D. 1978. Effects of burial on the heart cockle Clinocardium nuttallii and the Dungeness crab Cancer magister Estuarine and Coastal Marine Science 7: 409-412.

Chelossi, E., Vezzulli, L., Milano, A., Branzoni, M., Fabiano, M., Riccardi, G. and Banat, I.M. 2003. Antibiotic resistance of benthic bacteria in fish-farm and control sediments of the Western Mediterranean. Aquaculture 219(1-4): 83-97.

Clarke, D.G. and Wilber, D.H. 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. DOER Tech. Notes Collection (ERDC TN-DOER-E9). U.S. Army Corps Engineer Research and Development Center, Vicksburg, MS. May 2000. 14 pages.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Constantino, R., Gaspar, M.B., Tata-Regala, J., Carvalho, S., Cúrdia, J., Drago, T., Taborda, R., and Monteiro, C.C. 2008. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. Marine Environmental Research.

Correia, A.D. and Costa, M.H. 2000. Effects of sediment geochemical properties on the toxicity of copper-spiked sediments to the marine amphipod Gammarus locusta. Science of the Total Environment 247: 99-106.

Crawford, C.M, Macleod, C.K.A. and Mitchell, I.M. 2003. Effects of shellfish farming on the benthic environment. Aquaculture 224: 117-140.

Currie, D.R. and Parry, G.D. 1996. Effects of scallop dredging on a soft sediment community: a large experimental study. Marine Ecology Progress Series 134: 131-150.

DeAlteris, J., Skrobe, L. and Lipsky, C. 1999. The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island. In: Benaka, L.R. (Ed.) Fish Habitat: Essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Danovaro, R., Gambi, C., Luna, G.M. and Mirto, S. 2004. Sustainable impact of mussel farming in the Adriatic Sea (Mediterranean Sea): evidence from biochemical, microbial and meiofaunal indicators. Marine Pollution Bulletin 49: 325-333.

Dernie, K.M., Kaiser, M.J. and Warwick, R.M. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology 72: 1043-1056.

Durkin, O.C. 2008. *Moerella* spp. with venerid bivalves in infralittoral gravelly sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

Elliott M., Nedwell S., Jones N.V., Read S.J., Cutts N.D. and Hemingway K.L. 1998. Intertidal Sand and Mudflats and Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 151 pp.

EUNIS. 2007. European Environment Agency 2007. European Habitat Type Hierarchical View. Available online at: http://eunis.eea.europa.eu/habitats-code-browser.jsp.

Fletcher, S., Saunders, J., Herbert, R.J.H. and Roberts, C. 2011. Description of the ecosystem services provided by broad-scale habitats and features of conservation importance that are likely to be protected by Marine Protected Areas in the Marine Conservation Zone Project area. Project Report. Peterborough: Natural England.

Fowler, S.L. 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. English Nature (UK Marine SAC'S Project). 132 pp.

Grant, J. and Thorpe, B. 1991. Effects of suspended sediment on growth, respiration, and excretion of the soft-shell clam (*Mya arenaria*). Canadian Journal of Fisheries and Aquatic Sciences 48(7): 1285-1292.

De Groot, S.J. 1995. On the penetration of the beam trawl into the sea bed. ICES C.M. 1995/B:36.

Guardiola, F.A., Cuesta, A., Meseguer, J. and Esteban, M.A. 2012. Risks of using antifouling biocides in aquaculture. International Journal of Molecular Sciences 13: 1541-1560.

Hall, L.W. and Anderson, R.D. 1999. A Deterministic Ecological Risk Assessment for Copper in European Saltwater Environments. Marine Pollution Bulletin 38: 207-218.

Hall. J.A. and Frid, C.L.J. 1995 Responses of estuarine benthic macrofauna in copper-contaminated sediments to remediation of habitat quality. Marine Pollution Bulletin 30: 694-700.

Hall, K., Paramour, O.A.L., Robinson, L.A., Winrow-Giffin, A., Frid, C.L.J., Eno, N.C., Dernie. K.M., Sharp, R.A.M., Wyn, G.C. and Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters – development of a protocol. CCW [Policy Research] Report No: 8/12, 85pp.

Hartstein, N.D. and Rowden, A.A. 2004. Effect of biodeposits from mussel culture on macroinvertebrate assemblages at sites of different hydrodynamic regime. Marine Environmental Research 57: 339-357.

Hedgpeth, J.W. 1967. The sense of the meeting. In: Lauff (Ed.) Estuaries, AAAS, 83: 707-712.

Hill, J.M. and Wilson, E. 2008. *Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 14/05/2013]. Available from: http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=66&code=2004.

Jennings, S. and Kaiser, M.J. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology 34: 203-352.

Kaiser, M.J. and Spencer, B.E. 1996. The effects of beam-trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology 65: 348-358.

Kaiser, M.J. and Spencer, B.E.1994. Fish scavenging behaviour in recently trawled areas. Marine Ecology Progress Series 112: 41.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. and Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1-14.

Kaiser M.J. and Spencer B.E. 1996. The effects of beam trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology 65: 348-358.

Kaiser, M.J., Broad, G. and Hall, S.J. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. Journal of Sea Research 45(2): 119-130.

Kaspar, H.F., Gillespie, P., Boyer, L.F. and MacKenzie, A.L. 1985. Effects of mussel aquaculture on the nitrogen cycle of benthic communities in Kenepuru Sound, Marlborough Sound, New Zealand. Marine Biology 85: 127-136.

Kennish, M. 1986. The ecology of estuaries. Volume 1 Physical and Chemical aspects. CRC Press.

Kiaune, L. and Singhasemanon, N. 2011 Pesticidal copper (I) oxide: Environmental fate and aquatic toxicity. Rev. Environ. Contam. 213: 1-26.

Lindeboom, H.J. and De Groot, S.J. 1998. The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems. RIVO-DLO Report C003/98.

Loucks, R.H., Smith, R.E., Fisher, C.V. and Fisher, E.B. 2012.Copper in the sediment and the sea surface microlayer near a fallowed open-net fish farm. Marine Pollution Bulletin 64: 1970-197.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen
.
Maycock, D., Merrington, G. and Peters, A. 2011. Proposed EQS for Water Framework Directive Annex VIII substances: copper (saltwater) for consultation. WFD -UK TAG.

McIntyre, H. L., Geider, R.J. and Miller, D.C. 1996. Microphytobenthos: the ecological role of the “secret garden” of un-investigated shallow water marine habitats. I. Distribution, abundance and primary production. Estuaries 19: 186-201.

McNeill, G.,Nunn, J. and Minchin, D. 2010. The slipper limpet Crepidula fornicata Linnaeus, 1758 becomes established in Ireland Aquatic Invasions 5 (Supplement 1): S21-S25.

Mirto, S., La Rosa, T., Danovaro, R. and Mazzola, A. 2000. Microbial and meiofaunal response to intensive mussel-farm biodeposition in coastal sediments of the western Mediterranean. Marine Pollution Bulletin 40: 244-252.

Morello, E.B., Froglia, C., Atkinson, R.J.A. and Moore, P.G. 2006. Medium-term impacts of hydraulic clam dredgers on a macrobenthic community of the Adriatic Sea (Italy). Marine Biology 149: 401-413.

Newell, R.C., Seiderer, L.J. and Hitchcock, D.R. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology: an Annual Review 36: 127-78.

Nixon, S.C., Gunby, A., Ashley, S.J., Lewis, S. and Naismith, I. 1995. Development and testing of General Quality Assessment schemes: dissolved oxygen and ammonia in estuaries. NRA Project Record 469/15/HO.

OSPAR Commission, OSPAR List of Threatened and/or Declining Species and Habitats (Reference Number: 2008-6).

OSPAR. 2009. Background document for Intertidal mudflats. OSPAR Commission, Biodiversity Series. ISBN 978-1-906840-67-9.

Rayment, W.J. 2008. Venerid bivalves in circalittoral coarse sand or gravel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 21/06/2011]. Available from: http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=63&code=2004.

Rijnsdorp, A.D., Buys, A.M., Storbeck, F. and Visser, E.G. 1998. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms. ICES Journal of Marine Science: Journal du Conseil, 55(3): 403-419.

Riley, K. and Ballerstedt, S. 2005. *Pomatoceros triqueter*. A tubeworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 14/07/2011]. Available from: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=4179.

Roberts, C., Smith, C., Tillin, H. and Tyler-Walters, H. 2010. Review of existing approaches to evaluate marine habitat vulnerability to commercial fishing activities. Environment Agency Report: SC080016/R3.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

SAMS and Napier University. 2002. Review and synthesis of the environmental impacts of aquaculture, Report published by the Scottish Executive.

SEPA. 2005. Regulation and Monitoring of Marine Cage Fish Farming in Scotland – A Manual of Procedures. Available from: www.sepa.org.uk/guidance/fish farmmanual/manual.asp.

Stiff, M.J., Cartwright, N.G. and Crane, R.I. 1992. Environmental quality standards for dissolved oxygen. NRA R&D Note 130.

Tait, R.V. and Dipper, F.A. 1998. Elements of Marine Ecology. Fourth edition. Reed Elsevier plc group.

Telfer T.C., Baird D.J., McHenery J.G., Stone J., Sutherland I. and Wislocki P. 2006. Environmental effects of the anti-sea lice (Copepoda : Caligidae) therapeutant emamectin benzoate under commercial use conditions in the marine environment. Aquaculture 260(1-4): 163-180.

Thrush, S.F. and Dayton, P.K. 2002. Disturbance to marine benthic habitats by trawling and dredging: implication for marine biodiversity. The Annual Review of Ecology, Evolution, and Systematics 33: 449-473.

Tillin, H., Hiddink, J.G., Jennings, S. and Kaiser, M.J. 2006. Chronic bottom trawling alters the functional composition of benthic invertebrate communities on a sea-basin scale. Marine Ecology Progress Series 318: 21-45.

Tillin, H.M., Hull, S.C. and Tyler-Walters, H. 2010. Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. .Defra Contract No. MB0102 Task 3A, Report No. 22.

Weston, D.P. 1990. Quantative examination of macrobenthic community changes along an organic enrichment gradient. Marine Ecology Progress Series 61: 233-244.

Wilding, T. and Hughes, D. 2010. A review and assessment of the effects of marine fish farm discharges on Biodiversity Action Plan habitats. ISBN: 978-1-907266-27-0.

Zajac, R.N. and Whitlatch, R.B. 2003. Community and population-level responses to disturbance in a sandflat community. Journal of Experimental Marine Biology and Ecology 294: 101-125.

Biotope A5.23 Infralittoral Fine Sand

(Part of Subittoral (subtidal) Sand Habitats)

Pro-forma Information

This proforma has been produced as part of a risk assessment tool to assess the likelihood of impacts of fishing and aquaculture activities on habitats and species, to support the preparation of Appropriate Assessments (AAs) for Natura 2000 sites.

The key component of the risk assessment tool for the AA preparation is a sensitivity matrix which indicates the sensitivity of SAC and SPA features to pressures arising from fishing and aquaculture activities. The feature being assessed in this proforma has been identified as being present within an SAC or SPA. The purpose of this proforma is to act as an accompanying database to the sensitivity matrix, providing a record of the evidence used in the sensitivity assessment of this feature (Table II.13) and a record of the confidence in the assessment made (Table II.13 and Table II.14).

The following description of the main biological community associated with this feature is taken from the EUNIS website, the original source for these is Connor et al. (2004). Equivalent habitat designations are shown below in Table II.11.

Feature Description

This feature refers to sublittoral fine sand. This assessment has been structured following the EUNIS framework shown in Figure II.5. It should be noted that there will be some overlap between these communities and those assessed in intertidal sand (see biotope A2.23) and biotopes assessed in Report III as similar species may be found in sublittoral and littoral muddy sand and sandy mud.

EUNIS A5.233 *Nephyts cirrosa* and *Bathyporeia* spp. in infralittoral sand

Well-sorted medium and fine sands characterised by *Nephtys cirrosa* and *Bathyporeia* spp. (and sometimes *Pontocrate*s spp.) which occur in the shallow sublittoral to at least 30 m depth. This biotope occurs in sediments subject to physical disturbance, as a result of wave action (and occasionally strong tidal streams). The magelonid polychaete *Magelona mirabilis* may be frequent in this biotope in more sheltered, less tide-swept areas whilst in coarser sediments the opportunistic polychaete *Chaetozone setosa* may be commonly found. The faunal diversity of this biotope is considerably reduced compared to less disturbed biotopes and for the most part consists of the more actively-swimming amphipods. Sand eels *Ammodytes* sp. may occasionally be observed in association with this biotope (and others) and spionid polychaetes such as *Spio filicornis* and *S. martinensis* may also be present. Occasional *Lanice conchilega* may be visible at the sediment surface. Stochastic recruitment events in the *Nephtys cirrosa* populations may be very important to the population size of other polychaetes present and may therefore create a degree of variation in community composition.

EUNIS A5.234 Semi-permanent tube-building amphipods and polychaetes in sublittoral sand

Sublittoral marine sand in moderately exposed or sheltered inlets and voes in shallow water may support large populations of semi-permanent tube-building amphipods and polychaetes. Typically dominated by *Corophium crassicorne* with other tube building amphipods such as *Ampelisca* spp. also common. Other taxa include typical shallow sand fauna such as *Spiophanes bombyx*, *Urothoe elegans*, *Bathyporeia* spp. along with various polychaetes including *Exogone hebes* and *Lanice conchilega*. *Polydora ciliata* may also be abundant in some areas. At the sediment surface, *Arenicola marina* worm casts may be visible and occasional seaweeds such as *Laminaria saccharina* may be present. As many of the sites featuring this biotope are situated near to fish farms it is possible that it may have developed as the result of moderate nutrient enrichment. The distribution of this biotope is poorly known and appears to have a patchy distribution. It is possible that this biotope is a temporal or spatial variant of other more stable biotopes resulting from localised changes to sediment stability and organic status.

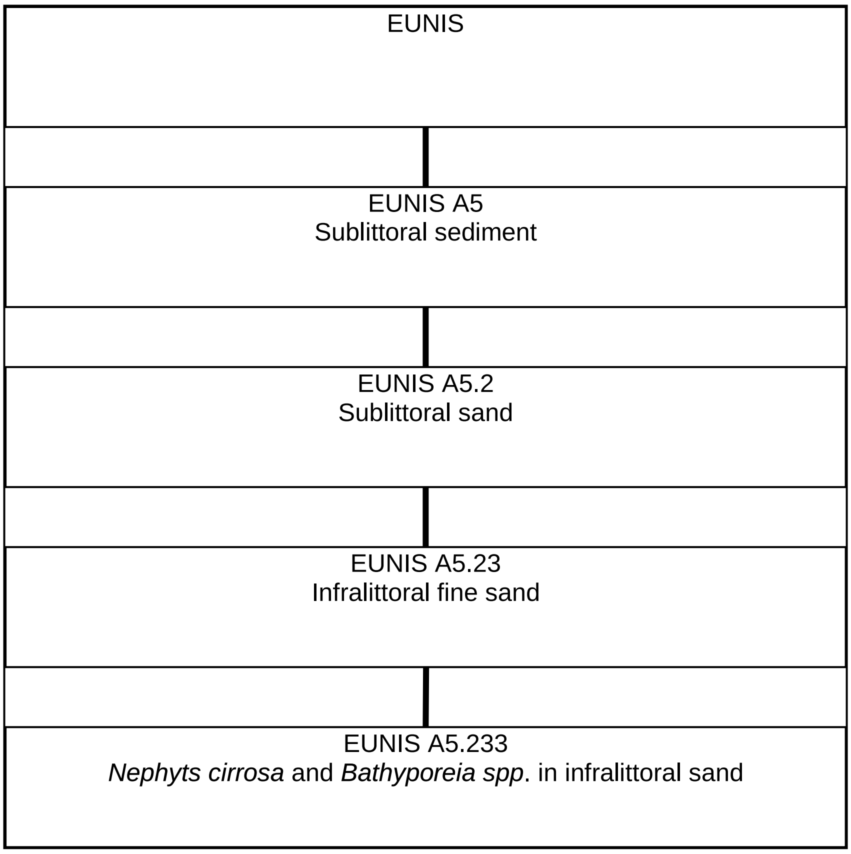


Figure II.5 Hierarchical Diagram showing the EUNIS descriptive framework for Sublittoral Fine Sand Community Complex

Features Assessed

This assessment relates to sublittoral fine sand sediments. The sensitivity assessments are based primarily on species that are dependent upon the habitat (sublittoral fine sand) and therefore the sensitivity assessments have particular regard as to whether the pressures affect the sedimentary environment.

Table II.10 Distinguishing species that have been identified from SACs representing the biotope A5.23

SAC	Distinguishing Species
Roaringwater Bay and Islands SAC (NPWS Version 1, 2011a) *' Shallow sand/mud community complex'*	Assessed in Report III Muddy Sands and Sandy Muds
River Barrow and River Nore SAC (NPWS Version 1 April 2011b) - Sand to muddy fine sand community complex	Assessed in Report III Muddy Sands and Sandy Muds
River Barrow and River Nore SAC (Version1, 2011b) *'Fine sand with Fabulina fabula community'*	*Fabulina fabula**, *Nephtys hombergii**, *Owenia fusiformis**, *Magelona johnstoni*, *Mactra stultorum*, *Magelona filiformis*, *Perioculodes longimanus*, *Sigalion mathildae*, *Glycera tridactyla**, *Abra alba*,* *Ampelisca brevicornis**
Clew Bay Complex SAC (A5.23) (NPWS Version 1, 2011c)	*Nephtys cirrosa**, *Moerella donacina*, *Bathyporeia guilliamsoniana**
Lough Swilly SAC (NPWS Version 1, 2011d) *Fine Sand Community Complex-subtidal variant*	*Spiophanes bombyx**, *Thracia papyracea**, *Phaxas pellucidus**, *Nephtys hombergii**, *Lumbrineris latreilli**, *Tubificoides benedii**, *Angulus tenuis**, *Bathyporeia pilosa**, *Donax vittatus*, *Bathyporeia elegans**, *Pygospio elegans**, *Nemertea* spp., *Scoloplos armiger**
Dundalk-Fine Sand Community Complex (NPWS Version 1, 2011e) (A5.23)	*Angulus tenuis*, *Capitella capitella*, *Spio martinensis*, *Fabulina fabula*, *Sigalion mathildae*, *Lanice conchilega*, *Nephtys hombergii*, , *Cerastoderma edule*, *Pygospio elegans*, *Scoloplos armiger*, *Crangon crangon**, *Spiophanes bombyx*, *Owenia fusiformis*
Donegal Bay (NPWS Version 1, 2011f) '*Estuarine fine sands dominated by polychaetes and oligochaetes community complex*'	*Hediste diversicolor**, *Heterochaeta costata*, Enchytraeidae spp., *Mya truncata*, *Pygospio elegans**, *Tubificoides benedii**, Nematoda spp. *Cerastoderma edule**, *Tubificoides pseudogaster**
Donegal Bay (NPWS Version 1, 2011f) *Subtidal fine sand with polychaetes and bivalves community complex*	*Donax vittatus* ,*Magelona filiformis*, *Nemertea* spp., *Chaetozone christei*, *Nephtys cirrosa*, *Tellina fibula*
Donegal Bay (NPWS Version 1, 2011f)	Assessed in Report III
* Mobile epifauna - Not considered within characterisation. NOTE: All species listed in the distinguishing tables in the SAC Conservation Objectives Supporting Documents have been added. Those underlined are referred to in the text and are considered to be priority species for assessment.	

Recovery

Fine sands are characterised by robust fauna which could potentially recolonize habitats after disturbance events (Hall et al. 2008). For sand habitats that are dominated by physical processes, habitat restoration (post-fishing activity) is relatively rapid (days to a few months) and recolonization is probably dominated by active and passive migration of adult organisms into the disturbed areas (e.g. McLusky et al. 1983; cited in Kaiser et al. 2006). However, some sandy sediment communities also contain large bodied, slow growing fauna, such as the bivalves *Mya truncata* and *Arctica islandica*, which are sensitive to fishing disturbances and are likely to have long recovery periods. In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate following disturbance.

In areas of strong water movement, the recovery of soft sediment and sediment features is dependent on the prevailing hydrodynamic conditions but may be expected to be rapid where sediments are mobile. Schwinghamer et al. (1996) examined the effect of otter trawls on habitat with sand substrate (fine and medium grained sand) in the Grand Banks one and two years after trawling had stopped. The tracks left by the trawl doors were visible for at least ten weeks but not visible or only faintly visible after one year.

Habitat Classification

Table II.11 Types of Sublittoral fine sand habitats recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (EUNIS, 2007; Connor et al. 2004; OSPAR Commission, 2008)

Annex I Habitat containing feature	EUNIS Classification of feature	Britain and Ireland Classification of feature	OSPAR Threatened and declining species or habitat
Submerged sandbanks, Estuaries and Large shallow inlets and bays	A5.23	SS.SSa.IFiSa	No
	A5.233	SS.SSa.IFiSa.NcirBat*	
	A5.234	SS.SSa.IFiSa.TbAmPo*	

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table II.13 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used, (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table II.12a and are combined, as in Table II.12b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score (for the habitat assessment) is assessed in further detail in Table II.14 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table II.12a).

Table II.12a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table II.12b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table II.13 Supporting information for the fine sand biotope (A5.23) assessments shown in the Sensitivity Matrix (Appendix E)

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	Habitat = H (*) Species = L-H	= VH (*) = H-VH	= NS (*) = NS-L	(See Introduction Section, Table II.9 for activity specific information and general discussion). Sand habitats are generally characterised by the presence of an infaunal benthic community, which, due to the position of animals in the sediment are relatively protected from temporary surface disturbance. Fine sands are relatively cohesive and therefore resistant to erosion following surface disturbance. Although surface abrasion has the potential to damage species or parts of species that are found at the surface, many organisms may be adapted to predation damage e.g. siphon removal by fish during immersion periods, which will allow regeneration of damaged parts. Bivalves and other species require contact with the surface for respiration and feeding, fragile animals that are buried close to the surface will be vulnerable to damage, depending on the force of the surface abrasion. Surface compaction can collapse burrows and reduce the pore space between particles, decreasing penetrability and reducing stability and oxygen content. The tops of burrows may be damaged and repaired subsequently at energetic cost to their inhabitants. The abiotic habitat is considered to have 'High' resistance to this pressure as surface abrasion is unlikely to alter the habitat type although there may be some surficial sediment disturbance. Recovery is considered to be 'Very High' due to sediment mobility, the habitat feature is therefore considered to be 'Not Sensitive' to a single event that leads to surface abrasion. The characterising species (see Appendix E and species proformas) are generally considered to have 'High' resistance to surface abrasion (based on infaunal life history), the bivalves *Cerastoderma edule* and *Abra alba* and the tubicolous polychaetes *Spiophanes bombyx*, *Spio* spp., *Capitella capitata* and *Pygospio elegans* are considered to have 'Medium' resistance or 'Low to Medium' resistance (see species proformas and sensitivity matrix, Appendix E). The high recovery rates of these species (all species 'High- Very High') mean that overall sensitivity is considered to be 'Not Sensitive to Low'. Higher rates of disturbance would be expected to lead to greater impacts and the spatial scale of disturbance will also determine recovery rates. At small scales recovery is likely to be rapid via active migration or water transport of adults.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	Habitat = M (*) Species = L-H	= VH (*) = M-VH	= L (*) = NS-M	(See Introduction Section, Table II.9 for activity specific information and general discussion, see also deep disturbance below for relevant evidence). Shallow disturbance will result in the surface disturbance effects outlined above. In general, fishing activities that penetrate the substratum to a greater extent (i.e. beam trawls, scallop dredges and demersal trawls) will potentially damage these habitats to a greater degree than fishing activities using lighter gear (i.e. light demersal trawls and seines) (Hall et al. 2008). Surface disturbance may alter the surface topography of this habitat, re-suspend sediment and alter sediment characteristics. However, resistance to this pressure is assessed as 'Medium' as the habitat still remains and alterations are confined to surficial layers. In general any tracks or pits resulting from surface damage would be infilled by 6 months or sooner by natural hydrodynamic processes, recovery is therefore judged to be 'Very High'. The sensitivity of the abiotic habitat is therefore categorised as 'Low'. Shallow disturbance may lead to injury and mortality of characterising species. Biological recovery is linked to the recovery of the abiotic habitat, which is likely to be rapid in areas where sediments are relatively mobile and will be aided by water transport or active migration of adults. Sand habitats are relatively dynamic and undergo natural disturbance through wind and water action (winter storms may lead to severe disturbance) and the animals found in this habitat are adapted to this regime. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E), indicate that sensitivity ranges between 'Not Sensitive-Medium' as resistance ranges from 'Low-High' and recovery from 'Medium-Very High'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	Habitat = M (***) Species = N-H	= VH (***) = M-VH	= L (*) = NS-M	(See Introduction Section, Table II.9 for activity specific information and general discussion). Deep disturbance will result in the shallow disturbance effects outlined above. In general, fishing activities that penetrate the substratum to a greater extent (i.e. beam trawls, scallop dredges and demersal trawls) will potentially damage these habitats to a greater degree than fishing activities using lighter gear (i.e. light demersal trawls and seines) (Hall et al. 2008). Studies investigating the biological impacts of various towed gears on sand habitats were reviewed by Thrush and Dayton (2002). Gear type and habitat type influenced the severity of the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						effect on benthic communities with several of the studies indicating that certain fishing activities had no detectable impacts on specific habitat types, including Kaiser and Spencer (1996; beam trawling in unstable sand habitats), Kenchington et al. (2001; otter trawling on sand) and Van Dolah et al. (1991; shrimp trawling on sand). Similarly, Kaiser et al. (2006), who undertook a meta-analysis to examine the response of benthic biota in different habitats to different fishing gears, showed that the direct impacts of different types of fishing gear are strongly habitat-specific as some habitats are pre-adapted to natural disturbance and are characterised by species that are relatively resistant or can recover rapidly. The epifauna and infaunal assemblages of both stable and dynamic fine sands are susceptible to direct physical disturbance from towed demersal gears and dredges which penetrate and disturb the sediment e.g. Eleftheriou and Robertson 1992; Kaiser et al. 1998; Robinson and Richardson 1998; Schwinghamer et al. 1996; Freese et al. 1999; Prena et al. 1999; Bergman and Van Santbrick 2000a; 2000b; Tuck et al. 2000; Kenchington et al. 2001; Gilkinson et al. 2005, all cited in Hall et al. 2008. In general, fishing using towed gears results in the mortality of non-target organisms either through physical damage inflicted by the passage of the trawl or indirectly by disturbance, damage, exposure and subsequent predation. Beam trawling, for example, decreases the density of common echinoderms, polychaetes and molluscs (Bergman and Hup, 1992) and decreases the density and diversity of epifauna in stable sand habitats (Kaiser and Spencer, 1996). Towed demersal gear alters the sedimentary habitats of fine sands by penetrating the sediment, smoothing the habitat (Schwinghamer et al. 1996; 1998; cited in Hall et al. 2008) and smothering habitat features by re-suspending sediments in the water column (Jennings and Kaiser 1998). Lighter towed gear e.g. light demersal trawls and seines, have less impact (Drabsch et al. 2001). For sand habitats that are dominated by physical processes, habitat restoration (post-fishing activity) is relatively rapid (days to a few months) and recolonization is probably dominated by active and passive migration of adult organisms into the disturbed areas (e.g. McLusky et al. 1983; cited in Kaiser et al. 2006).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie et al. (2003) found that clean sand communities had the most rapid recovery rate following disturbance. In areas of strong water movement, the recovery of soft sediment and sediment features is dependent on the prevailing hydrodynamic conditions but may be expected to be rapid where sediments are mobile. Schwinghamer et al. (1996) examined the effect of otter trawls on habitat with sand substrate (fine and medium grained sand) in the Grand Banks one and two years after trawling had stopped. The tracks left by the trawl doors were visible for at least ten weeks but not visible or only faintly visible after one year. Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that at a shallow site (6 metres depth and characterised by fine sand (40-70%) with some medium and very fine sand fractions (coarse sand <15%), there was a sudden decrease in grain size immediate after dredging followed by a slow increase, the sediments were 'quite similar' to control areas 17 days after dredging (Constantino, et al. 2008). Sediments were mobilised by storm events during the post-dredging monitoring period and this may have aided sediment recovery. The passage of the dredge on the bottom produced a slightly depressed track, about 10cm deep, where the sedimentary structures were disrupted. The tracks were no longer visible 24 hours after dredging at this site (depth 6m). Impacts from deep disturbance on sublittoral mixed habitats are more severe than shallow disturbance and abrasion damage and may result in changes to the topography of the habitat, such as the formation of pits and trenches. In very sheltered environments the changes to sediment topography may persist for some time but in more dynamic environments sediment infilling will be more rapid and natural agents (such as wave action, tidal currents and storms) will mobilise sediments aiding recovery of the abiotic habitat. Habitat resistance is assessed as 'Medium' as although some changes in sediment topography and conditions are predicted, the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						habitat will remain and be recognisable following deep disturbance in most mixed sediment environments. Some structural changes may be greater in some areas, for example, where the habitat exists as a veneer over a different substrate type that is then exposed. Recovery is assessed as 'Very High' within most mixed sediment environments. Sensitivity is therefore considered to be 'Low'. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E) indicate that sensitivity ranges from 'Low to High'. Resistance to deep disturbance varies between taxa from 'None to High', resilience ranges from 'Medium to Very High'. For most species sensitivity was considered to be "Low', although some species were considered to have 'Medium' sensitivity due to lower resistance e.g. *Cerastoderma edule* and *Pygospio elegans* or lower recovery rates (e.g. *Phaxas pellucidus* and *Glycera* sp. which are relatively long lived and *Scoloplos armiger* which has limited dispersal). Rather than a change in biotope type, deep disturbance was considered likely to change the identities of some species present and abundances rather than the character of the biotope. The degree of impact will depend on the activity and intensity and recovery rates will be influenced by spatial extent, seasonality and habitat recovery.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing			NE	Not exposed. Subtidal feature not accessible
	Trampling - Access by vehicle	Direct damage, caused by vehicle access			NE	Not exposed. Subtidal feature not accessible
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic	Habitat = N-L (*) Species = N-L	= H-VH (*) = M-VH	= L-M (*) = L-H	(See Introduction Section, Table II.9 for activity specific information and general discussion). The resistance of the habitat to extraction is assessed as 'None-Low' as sediment is removed, the depth of remaining sediments and their character will be site-specific. Recovery will depend on local factors including hydrodynamics, sediment supply and sediment mobility and the spatial scale affected. Recovery is assessed as 'High- Very High', as effects arising from aquaculture or

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		reef/ macroalgae				fishing (e.g. bait digging may be considered within this pressure) are likely to be relatively small-scale. Sensitivity is therefore considered to be 'Low-Medium'. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E) indicate that species are considered to have 'No to Low' resistance to this pressure (due to low mobility and infaunal position), recovery is assessed as 'Medium- Very High', sensitivity is considered to range from 'Low-High' depending on the recovery rate of the species population.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	Habitat =L-M (*) Species =L-H	=H-VH (*) =H-VH	=L-M (*) =NS-L	(See Introduction Section, Table II.9 for activity specific information and general discussion). Addition of fine material will alter the character of this habitat by covering it with a layer of dissimilar sediment and will reduce suitability for the species associated with this feature. Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities. Recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Long-term or permanent addition of fine particles would lead to re-classification of this biotope type from a sand to muddy sand and the biological community present would also change in response with an anticipated increase in species that are better adapted to the new conditions such as deposit feeding polychaetes. The change in sediment pressure assessment (below) considers the long-term impact of an increase in the fine sediment fraction on the habitat and associated community. Siltation may alter the character and classification of this biotope through the addition of fine sediments. Resistance was therefore assessed as 'Low-Medium' based on an assumption that local water flows and other factors are unaffected, as these will remove overburden, aiding habitat restoration. Recovery is assessed as 'High' to Very High'. Sensitivity was therefore considered to be 'Low-Medium'. Assessments of the characterising species (see species proformas and the sensitivity matrix, Appendix E) indicate that sensitivity is generally considered to be 'Not Sensitive-Low'. This reflects the more energetic conditions in which this habitat is found, where sediment deposition

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						of fine silt particles is limited, but animals are able to reposition themselves following sediment disturbance to allow survival in a higher energy environment (compared with subtidal muds and muddy sands). Most bivalve species are capable of burrowing through sediment to feed, e.g. *Abra alba* are capable of upwardly migrating if lightly buried by additional sediment (Schafer, 1972; cited in Budd, 2008). Mobile burrowing polychaetes such as *Glycera* sp. and *Scoloplos armiger*) are generally considered to be able to reposition following periodic siltation events or low levels of chronic siltation. For the characterising species, resistance was assessed as 'Low-High', recovery was considered to be 'Very High' and species were considered to either have 'Low' sensitivity or to be 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	Habitat =N-L (*) Species =N-H	 =H-VH (*) =M-VH	 =L-M (*) =NS-H	(See Littoral sands Introduction Section, Table II.2 for activity specific information and general discussion). The addition of coarse materials will alter the character of the sediment and reduce suitability for the associated community of this feature. Recovery will depend on removal of the overburden, either naturally or through human activities and recovery will not take place until this has happened. Resistance was assessed as 'None-Low' to reflect the change in habitat type (which may be more severe than siltation as coarse materials are less readily removed by water action). Recovery may be prolonged depending on site specific conditions but in some cases storm disturbance may be great enough to remove over-burden, or recovery may occur through burial of overburden by fine sands. In the case of re-laid bivalves these may be harvested. Recovery was therefore assessed as 'High-Very High' (as sediments are generally mobile and some beaches are eroded and deposited seasonally). Overall sensitivity is assessed as "Low-Medium'. Smothering will kill individuals and reduce habitat suitability. Resistance to smothering by characterising species was assessed as 'None to High' (see species proformas and sensitivity matrix, Appendix E). Sedentary species that live or feed at the surface (e.g. *Pygospio elegans*, *Spiophanes bombyx*, *Cerastoderma edule* and *Angulus tenuis*) were considered to have 'No' resistance. Mobile burrowing species such as *Nephtys hombergii* and *Scoloplos armiger* were considered to be able to escape smothered sediments and were considered to have 'High' resistance. Recovery potential was considered to range from 'Medium-Very High' and sensitivity

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						from 'Not Sensitive' to 'High'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed. This feature does not occur in the water column. Collision of benthic features with fishing gear is addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	Habitat =N-L (*) Species =N-H	=H-VH (*) =M-VH	=L-M (*) =NS-H	The addition of a thick, permanent layer of coarse sediments would lead to the re-classification of this biotope type. See Introduction Section (Table II.9) for more information. The character of the habitat is largely determined by the sediment type, changes to this would lead to habitat re-classification e.g. the addition of coarse sand particles (or removal of fine sand particles) in sufficient quantities would lead to the development of a different habitat, hence resistance to sediment change is assessed as 'None-Low'. Recovery will depend on the degree of effect and site specific habitat forming processes including sediment supply and hydrodynamics. It was considered likely that natural rehabilitation would occur. Recovery was therefore assessed as 'High-Very High'. Sensitivity is therefore considered to be 'Low-Medium'. Changes in sediment characteristics can lead to changes in community structure. An increase in coarse sediments would lead to the development of a community typical of coarse sands and/or gravels and the relative stability may favour the establishment of bivalves and amphipods. This change would alter the character of the biotope present leading to re-classification. Long term increase in grain-size may lead to a permanent change in the faunal composition of the biotope, with colonisation by species adapted to clean sands (such as venerid bivalves, robust infaunal

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						polychaetes such as *Chaetozone setosa*, *Glycera* spp. and small interstitial polychaetes such as *Hesionura elongata* and *Protodorvillea kefersteini*, and cumacean crustacea such as *Diastylis bradyi)*. This community is likely to include some elements of the fine sand community such as *Fabulina fabula*. Based largely on habitat preferences or life history information, species resistance to changes in sediment composition were considered to range from 'None-High' (see Appendix E and species proformas). Recovery ranges from 'Medium-High' and sensitivity from 'Not Sensitive-High'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	Habitat =N-L (*) Species =L-H	=VH (***) =H-VH	=M (*) =NS-M	See Introduction Section (Table II.9) for further information. The character of the habitat is largely determined by the sediment type, changes to this would lead to habitat re-classification, resistance is therefore classified as 'None-Low'. Recovery will depend on the degree of effect and site specific habitat forming processes including sediment supply and hydrodynamics. It was considered likely that natural rehabilitation would occur and may be rapid in shallow, dynamic areas where this habitat type is found (Constantino et al. 2009). Habitat recovery (following removal of the pressure) is therefore considered to be 'Very High' and sensitivity is assessed as 'Medium'. Changes in sediment characteristics can lead to changes in community structure. The addition of fine sediments would lead to the development of a community typical of muddy sands. Suspension feeders, particularly bivalves and epistrate feeders e.g. *Bathyporeia* spp., characteristic of the fine sand biotope, would probably be replaced. This change would favour deposit feeders, particularly deposit feeding polychaetes which are adapted to burrow and feed in fine grained sediments. Such changes would alter the character of the biotope present leading to re-classification. Some characterising species are also found in muddy sands and muds (e.g. *Nephtys hombergii* and *Pygospio elegans)* and these species were considered to be 'Not Sensitive' to this pressure. Resistance of the characterising species therefore ranged from 'Low to High' and recovery from 'High to Very High'. Species sensitivities were considered to range from 'Not sensitive to Medium'.
	Changes to water flow	Changes to water flow resulting from permanent/	Habitat =L-M (*)	=H-VH (*)	=L-M (*)	(See Introduction Section, Table II.9 for further information). The hydrodynamic regime, including flow rates, is an important factor determining the type of sediment present. Increased flow rates e.g. around structures may lead to localised scour,

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		semi permanent structures placed in the water column	Species =N-H	=M-VH	=NS-M	removing finer particles and if severe, removal of coarser particles, increasing the coarse faction or exposing bed rock. Conversely, decreases in flow rate will lead to the deposition of finer particles, increasing the silt and clay content of the substratum. The degree of impact will depend on the area affected and the sediment type. Changes in sediment type to coarser or finer types are discussed above. Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein). *Increased water flow* In this biotope, water flow may fluctuate between weak to strong and well sorted medium and fine grained sands are typical of the biotope. However, if water flow changed from weak to very strong for a period of a year, it is considered that this would bring about concomitant changes in the grade of the sediment owing to the winnowing away of the finer sediment with consequences for the infauna. For example, *Bathyporeia pilosa* avoided burrowing into substrata with particles >500µm median diameter (Khayrallah and Jones, 1980; cited in Budd, 2008). Thus it is likely that some important characterizing species would become exposed to conditions outside of their habitat preference and would probably no longer be found at such a location. Polychaetes characteristic of the biotope are less likely to be affected by increased water flow rate as they burrow deeper and hunt infaunally. Over a year the biotope may become impoverished as species intolerant of a coarser substratum move elsewhere and the biotope begins to change to another. On return to prior conditions recoverability has been assessed to be very high (Budd, 2008). *Decreased water flow* A reduction in the water flow rate for a period of one year would probably reduce the degree of sorting of grain size, as current velocity in the proximity of the sea bed drops below the critical erosion velocity, causing bedload transport of medium and coarse grained sands to cease. During periods of low wave action, deposition of finer sediments from suspension may occur so that the composition of the substratum begins to change. Finer sediments and increased stability may enhance the survival of more sedentary forms of polychaete and bivalves and the biotope

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						may begin to change. Species richness is likely to rise. Considerable changes in community composition may occur and the biotope no longer be recognized. On return to prior conditions recoverability has been assessed to be very high (Budd, 2008). Increased water flows may erode fine sediments leading to re-classification of this biotope. Aquaculture cages and lines reduce water flow which can lead to increases in siltation as finer particles are deposited. Habitat resistance to decreases in waterflow is considered to be 'Low-Medium'' and recovery as 'High-Very High' as fine sediments are relatively dynamic and restoration is likely to be driven by seasonal processes. Habitat sensitivity is therefore considered to be 'Low-Medium'. Changes below a threshold that led to siltation and changes in sediment composition may however lead to re-classification of this biotope type through sedimentary changes (see above pressures). Many of the characterising species were considered to have 'High' resistance to this pressure and therefore 'Very High' resilience and were assessed as 'Not Sensitive'. For these species burrowing life habits coupled with deposit or predatory feeding were considered to protect from impacts (although species may be sensitive to associated changes in sediment composition, see increases in fine sediment. However suspension feeders including *Cerastoderma edule* and *Angulus tenuis* were considered to have 'Medium' sensitivity due to reduced food supply and increased sediment deposition which may alter feeding feeding efficiency (See sensitivity matrix, Appendix E and species proformas).
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	Habitat =H (*) Species =M-H	=VH (*) =M-VH	=NS (*) =L-NS	(See Introduction Section, Table II.9 for further information). Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein). Owing to the high energy environment, elevated concentrations of suspended sediment are a normal feature of the biotope, especially during and following storm events. Species within the biotope are infaunal and so are offered protection from scour, and characterising species (e.g. the amphipod *Bathyporeia pelagica* and catworm *Nephtys cirrosa*) do not suspension feed. Budd (2008) assessed the biotope as not sensitive to increased suspended sediment.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Increased turbidity would limit primary production within the biotope and, over the period of a year, a loss of condition might be detectable amongst the infauna, but more severe effects are unlikely as long as an adequate amount of organic matter continues to be supplied to the biotope from more productive biotopes and environments elsewhere. On return to prior conditions optimal feeding would be expected to recommence (Budd, 2008). An increase in turbidity/suspended sediment would not alter the character of the seabed habitat and hence habitat resistance is considered to be 'High' and recovery is therefore assessed as 'Very High', so that the habitat is considered to be 'Not Sensitive'. Animals associated with this biotope are primarily infaunal and were considered to have 'High' resistance to this pressure (see species proformas and the sensitivity matrix, Appendix E) and subsequently 'Very High' recovery. The characterising species, with the exception of *Angulus tenuis*- and *Thracia papyracea* see species proformas) were therefore considered to be 'Not Sensitive'. Potential effects from the associated pressures, siltation and shading, are considered elsewhere in this table.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	Habitat =H (*) Species =M-H	=VH (*) =VH	=NS (*) =NS-L	See Introduction Section (Table II.9) for more information. A decrease in turbidity/suspended sediment would not alter the character of the seabed habitat and hence habitat resistance is considered to be 'High' and recovery is therefore assessed as 'Very High', so that the habitat is considered to be 'Not Sensitive'. Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein). Fluctuations of suspended sediment are experienced within this biotope and are a characteristic feature owing to the high energy hydrographic regime. It is unlikely that the community would be adversely affected by a reduction in the amount of suspended sediment for a period of one month. Budd (2008) assessed the biotope as not sensitive to decreased suspended sediment. An increase in primary productivity of the microphytobenthos might be expected with a reduction

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						in turbidity which, although beneficial to the community may be difficult to detect unless organic matter produced from external sources became limiting. An intolerance assessment of not sensitive to decreased turbidity (one category of the water clarity scale for one year) was suggested by Budd (2008) for this biotope. No evidence was found for habitat effects of decreased turbidity by aquaculture activities on intertidal mixed sediments. Seston is filtered and returned to the environment as faeces and pseudofaeces so that permanent reductions in the supply of sediments are not occurring. Resistance was assessed as 'High' and recovery as 'Very High' so that the abiotic habitat was considered to be 'Not Sensitive'. Increased sedimentation may lead to localised organic enrichment and decreased oxygen but these pressures are assessed separately. As the infauna within this biotope are judged to be insensitive to increased photic depth (although some detrimental impacts on food availability may occur for suspension feeders), resistance is assessed as 'Medium-High' with recovery categorised as 'Very High'. Overall sensitivity of species is considered to be 'Not Sensitive-Low'. Decreases in seston outside the activity footprint for aquaculture are likely only in enclosed waterbodies with high stocking densities (see Introduction Section Table II.9). No evidence was found to assess this impact on suspension feeders.
	Organic enrichment - Water column	Eutrophication of water column	Habitat =H (*) Species =N-H	 =VH (*) =H-VH	 =NS (*) =NS-M	(See Introduction Section, Table II.9 for further activity specific information). Eutrophication is not considered to directly affect the abiotic habitat although the development of mats of ephemeral algae will indirectly alter sediment chemistry (see deoxygenation pressures) based on the lack of direct effects, the abiotic habitat is considered to be 'Not Sensitive', resistance is therefore assessed as 'High' and recovery as 'Very High'. The characterising species, with the exception of *Scrobicularia plana*, were assessed as 'Not Sensitive to this pressure, resistance was assessed as 'High' for these species and recovery as 'Very High'. At eutrophication levels associated with aquaculture the characterising species are unlikely to be Sensitive.
	Organic enrichment of	Increased organic matter	Habitat =H (*)	 =VH (*)	 =NS (*)	(See Introduction Section, Table II.9 for further activity specific information).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediments - Sedimentation	input to sediments	Species =N-H	=H-VH	=NS-H	Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein). The substratum has a characteristically low level of organic matter (i.e. nutrients within the biotope are often limiting). Moderately enhanced levels of organic matter would be used as a food resource by meiofauna and macrofauna, secondary production would increase and a mixing of organisms with different responses would increase diversity (although they would need to be tolerant of the prevailing hydrodynamic regime). In extreme instances of enrichment, diversity would be expected to decline and the fauna become dominated by fewer pollution tolerant species, such as the polychaete *Capitella capitata*. Excessive nutrient enrichment leading to anoxia in the sediment is likely to result in defaunation. Such a sequence has been observed in sand biotopes as the result of hydrocarbon pollution (Majeed, 1987; cited in Budd, 2008). The abiotic habitat is considered to have 'High' resistance to increased organic matter and Very High' recovery so that subtidal fine sands are considered to be 'Not Sensitive' (at rates elevated above normal background level: gross changes would cause impacts on sediment chemistry and community (see deoxygenation pressures), With the exception of *Bathyporeia* spp., and the bivalves *Fabulina fabula* and *Phaxas pellucidus* the characterising species (see species proformas and sensitivity matrix, Appendix E) are considered 'Not Sensitive' to this pressure based on 'High' resistance and 'Very High' recovery. (Decreases in oxygen levels may be associated with high levels of organic enrichment, these effects are considered below). *Bathyporeia* spp. are highly sensitive to organic enrichment, (see species proformas), resistance was therefore assessed as 'None', however this species is likely to recover rapidly, resilience was therefore assessed as 'Very High' and sensitivity was assessed as 'Low-Medium'. The longer recovery time of *Fabulina fabula* means that sensitivity is assessed as 'Medium-High' (resistance 'None-Low', recovery 'Medium'). *Phaxas pellucidus* was considered to have higher resistance (Low-Medium) and 'Medium' recovery so that sensitivity was assessed as 'Low-Medium'.
	Increased removal of	Removal of primary	Habitat =H (*)	=VH (*)	=NS (*)	See Introduction Section (Table II.9) for further information. Many of the characterising species associated with this biotope are predators or scavengers or

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	primary production - Phytoplankton	production above background rates by filter feeding bivalves	Species =M-H	=M-VH	=L-NS	feed on autochthonous production through the microphytobenthos (*Bathyporeia* spp.) For these species removal of primary production e.g. through increased mussel production, is unlikely to negatively impact this community and may enhance it through increased production of faeces/pseudofaeces. However, suspension feeders found within this biotope may be negatively affected by increased competition with farmed bivalves. Increased removal of phytoplankton is not considered to negatively affect the abiotic habitat, hence resistance is assessed as 'High', recovery as 'Very High' and the habitat is considered to be 'Not Sensitive'. Assessment of the characterising species (see Table 1 and the sensitivity matrix) indicate that these are considered to be 'Not Sensitive. Resistance is assessed as 'High' and recovery as 'Very High'. The suspension feeders (*Cerastoderma edule* and *Angulus tenuis*) found in this biotope, may be affected by competition from farmed bivalves. Resistance was assessed as 'Medium-High' and recovery as 'Medium-Very High'. The sensitivity of these species was therefore considered to be 'Not Sensitive-Low'. In areas that are well flushed, water exchange should recharge waters.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	Habitat = M-H (***) Species = N-H	= VH (***) = M-VH	= L-NS (***) = NS-M	(See Introduction Section, Table II.9 for further information). Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein). Subtidal sands in wave exposed locations are well-oxygenated owing to the mobile nature of the substratum and tidal pumping of overlying water which ensures a deep anaerobic layer (>15 cm). Any organic matter incorporated in to the substratum is rapidly degraded (Elliott et al. 1998; cited in Budd, 2008). Oxygen within the substratum is unlikely to become limiting under normal conditions, but may do so in the event of an influx of excessive organic matter. Laboratory studies by Khayrallah (1977; cited by Budd, 2008) on *Bathyporeia pilosa* revealed it to have a relatively poor resistance to conditions of hypoxia in comparison to other interstitial animals. It was also susceptible to hydrogen sulphide, supporting the conclusion that aerated deposits are a fundamental requirement of *Bathyporeia pilosa* and also probably other *Bathyporeia* species. It is therefore likely that some crustacean species would be unable to endure hypoxic conditions
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	Habitat = M-H (***) Species = N-H	= VH (***) = M-VH	= L-NS (***) = NS-M	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						for a week and would move away. Evidence (Alheit, 1978; Arndt and Schiedek, 1997; Fallesen and Jørgensen, 1991; all cited in Budd, 2008) indicated *Nephtys hombergii*, to be very tolerant of episodic oxygen deficiency over the duration of one week. Exposure to oxygen concentrations of 2mg/l for 1 week may result in some important characterizing species moving away from the biotope for the duration of the factor but populations are likely to recover rapidly on return to prior conditions (Budd, 2008). Subtidal sands are likely to be well oxygenated and therefore resistance to hypoxia/anoxia is assessed as 'Medium-High' as the sediment type and local hydrodynamics reduce the likelihood of low oxygen conditions developing. Recovery is assessed as 'Very High' due to high resistance and as habitat restoration is likely to be rapid. Habitat sensitivity is therefore considered to be 'Low to Not Sensitive'. Some characterising species are found in mud habitats and are adapted to conditions where sediments are anoxic below the surface layer and most species are resistant to periodic hypoxia/anoxia, e.g. *Nephtys hombergii* and *Tubificoides* spp. *Bathyporeia* spp. were considered to be among the most sensitive species with 'No' resistance to this pressure, although these have a high recovery potential. Overall resistance was assessed as 'None-High' and resistance as 'Medium-Very High', sensitivity was therefore considered to be 'Medium to Not Sensitive'.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of	Cultivation of a	Habitat			(See Introduction Section, Table II.9 for further information).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	non-native species	non-native species and/or potential for introduction of non-natives in translocated stock'	= H (***) Species = L-H	= VH (***) = M-VH	= NS (***) = NS-M	In a sensitivity assessment of subtidal sand sediments based on expert judgement gathered at workshops, Tillin et al. (2010) reported that more mobile biotopes are considered unlikely to experience significant NNS impacts compared to more stable muddy sands which are at risk from species such as *Crepidula*. In reviewing the sensitivity of the EUNIS biotope A5.233, Budd (2008) no evidence was found to suggest that the important characterizing species of the biotope were threatened by NNS. Given the lower levels of reported invasive species, habitat resistance to the introduction of non-natives is assessed as 'High'. Recovery is therefore considered to be 'Very High' and the habitat is considered to be 'Not Sensitive'. Due to this high natural habitat resistance the characterising species may be less sensitive than the individual assessments suggest (see Sensitivity Matrix, Appendix E and species proformas). These assessments were largely based on expert judgement and do not necessarily take habitat characteristics into account. Species resistance was assessed as 'Low to High' and recovery as 'Medium-Very High' so that sensitivity was considered to range from 'Not Sensitive to Medium' sensitivity. In general bivalves and other surface deposit feeders were considered more sensitive to the introduction of non-native species (largely based on the slipper limpet *Crepidula fornicata*) due to low mobility and increased competition for food and space.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		Habitat = H (*) Species = L-H	= VH (*) = M-VH	= NS (*) = NS-M	Target species within shallow subtidal sand habitats may include razor clams (*Ensis* spp.), Common cockle (*Cerastoderma edule*) or sand eels (*Ammodytes* sp., which may occur in the EUNIS biotope A5.233; SS.SSa.IFiSa.NcirBat). The effects of removal of these species are likely to be constrained to physical damage interactions and is considered in the physical disturbance theme. The feature is not considered to be functionally dependent on commercially targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal. The habitat feature is not considered to be functionally dependent on the commercially targeted

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						organisms and therefore is not considered to be sensitive to the biological effect of their removal (Resistance is 'High' and recovery is 'Very High'). The polychaete *Scoloplos armiger* is considered sensitive to the removal of *Arenicola marina* which may be targeted by bait harvesters and *Cerastoderma edule* and *Nephtys* spp. may be commercially exploited. These characterising species are considered to have 'Medium' sensitivity to removal (based on 'Low' resistance and 'Medium to High' recovery). It should be noted that these species may not be exposed to this pressure in subtidal sediments. All other characterising species were considered to be 'Not Sensitive' as these were not targeted and were not considered dependent on targeted organisms.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	The sensitivity of the feature to the pressures that arise through the removal of target and non-target species is considered in the above pressure themes. The feature and characterising species are not considered to be functionally dependent on targeted organisms and therefore are not considered to be sensitive to the biological effect of their removal. However, as outlined above (in the physical disturbance pressures), the removal of target and non-target species may result in changes to the biological community and hence the classification of the assemblage type.
	Ecosystem Services - Loss of biomass				NA	Not relevant to Annex I species and habitat features
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	Habitat = H (*) Species = NEv	= VH (*) = NEv	= NS (*) =N Ev	(See Introduction Section, Table II.9 for further information). The abiotic habitat was considered to be unchanged by the addition of medicines, resistance was therefore assessed as 'High' and recovery as 'Very High', so that the sedimentary habitat is considered to be 'Not Sensitive'. Evidence on sensitivity was not found for the majority of the characterising species so the sensitivity of these is not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	Habitat = M (***)	= VH (*)	= L (*)	Evidence specific to EUNIS biotope A5.233 Information from MarLIN for biotope SS.SSa.IFiSa.NcirBat (Budd, 2008, references therein).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
			Species = L-H	= M-VH	= NS-M	Oil spills resulting from tanker accidents have caused deterioration of sandy communities in the intertidal and shallow sublittoral. Subtidal sediments, however, may be at less risk from oil spills unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil in to the sediment (Elliott et al. 1998; cited in Budd, 2008). Species within the biotope have been reported to be intolerant of oil pollution, e.g. amphipods (Suchanek, 1993; cited in Budd, 2008). After the Amoco Cadiz oil spill there was a reduction in both the number of amphipod species and the number of individuals (Cabioch et al. 1978; cited in Budd, 2008). Initially, significant mortality would be expected, attributable to toxicity. Amphipod populations have been reported not to return to pre-spill abundances for five or more years, which is most likely related to the persistence of oil within sediments (Southward, 1982; cited in Budd, 2008). *Nephtys* species were amongst the fauna that was eradicated from sediments following the 1969 West Falmouth spill of Grade 2 diesel fuel documented by Sanders (1978; cited in Budd, 2008). During normal operations the discharge of hydrocarbons from fishing and aquaculture activities is not permitted, although accidental discharges of small volumes may be possible during operations. Resistance is therefore assessed as 'Medium' and recovery as 'Very High' following the removal of this pressure. Sensitivity is therefore considered to be 'Low'. For a number of species no evidence for tolerance of hydrocarbons could be found. Some characterising species have been identified as pollution tolerant, including some *Glycera* spp., *Spio* spp. and *Capitella capitata*) These species were considered to be 'Not Sensitive ('High' resistance and 'Very High' recovery).
	Introduction of antifoulants	Introduction of antifoulants	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	(See Introduction Section, Table II.9 for further information). In general the habitat and sediment characteristics (higher levels of sediment disturbance and lower levels of finer particles and organic matter) suggest that copper and zinc are less likely to accumulate than in muddier sediments. Antifoulants may affect species but they are not considered to alter the chararacter of the abiotic habitat, Habitat resistance is therefore assessed as 'High' and recovery as 'Very High', so that the habitat is considered to be 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Tests of copper toxicity have been carried out on a number of marine organisms although comparison of results requires caution due to the different protocols used and there are inherent problems in extrapolating these to the marine environment, as laboratory tests in clean water (without organic matter) do not reflect lowered toxicity in the marine environment due to the buffering effects of carbon and sulphide which render copper non-labile (not bioavailable) and the influence of water pH, hardness, temperature and salinity etc. Concentrations up to and below the sediment quality guideline of 100 mg kg^{-1} are presumed to protect species. At this pressure benchmark resistance is assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	Habitat = H (*) Species = H	= VH (*) = VH	= NS (*) = NS	No evidence. As this feature is not characterised by the presence of primary producers it is not considered that shading would alter the character of the habitat. Beneath structures there may be changes in microphytobenthos abundance. Sublittoral sandflats support microphytobenthos (where light penetration is sufficient) on the sediment surface and within the sand grains. The microphytobenthos consists of unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments, typically appearing only as a subtle brownish or greenish shading. Mucilaginous secretions produced by these algae may stabilise fine substrata (Tait and Dipper, 1998). The biomass of the benthic microalgae often exceeds that of the phytoplankton in the overlying waters (McIntyre et al. 1996) such that benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability. Shading will prevent photosynthesis leading to death or migration of sediment microalgae altering sediment cohesion and food supply to higher trophic levels. The characterising species do not photosynthesise and are considered to be 'Not Sensitive' to shading, resistance is assessed as 'High' for all species and recovery as 'Very High'. Reduction in microphytobenthos may lead to localised decreases in sediment stability although waterlogged fine sand sediments should remain relatively cohesive. Habitat resistance is therefore assessed as 'High' and recovery as 'Very High' so that the habitat is considered to be

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						'Not Sensitive'.
	Barrier to species movement				NA	Not relevant to Annex I species and habitat features

Table II.14 Resistance Assessment Confidence Levels

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	***	***	***
Trampling - Access by foot			
Trampling - Access by vehicle			
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (1)	***	N/A
Decrease in oxygen levels - Water column	*** (1)	***	N/A
Genetic impacts			
Introduction of non-native species			
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	*	N/A	N/A
Introduction of hydrocarbons	*** (*)	*	N/A
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Alheit, J. 1978. Distribution of the polychaete genus *Nephtys*: a stratified random sampling survey. Kieler Meeresforschungen 4: 61-67.

Arndt, C. and Schiedek, D. 1997. *Nephtys hombergii*, a free living predator in marine sediments: energy production under environmental stress. Marine Biology 129: 643-540.

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beam trawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of MarineScience 49(1): 5-11.

Bergman, M.J.N. and van Santbrink, J.W. 2000. Mortality in megafaunalbenthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science 57(5): 1321-1331.

Budd, G.C. 2008. *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 30/06/2011]. Available from:
http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=154&code=2004.

Cabioch, L., Dauvin, J.C. and Gentil, F. 1978. Preliminary observations on pollution of the sea bed and disturbance of sub-littoral communities in northern Brittany by oil from the Amoco Cadiz. Marine Pollution Bulletin 9: 303-307.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Constantino, R., Gaspar, M.B., Tata-Regala, J., Carvalho, S., Cúrdia, J., Drago, T., Taborda, R. and Monteiro, C.C. 2008. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. Marine Environmental Research doi: 10.1016/j.marenvres.2008.12.001.

Dernie, K.M., Kaiser, M.J. and Warwick, R.M. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology 72(6): 1043-1056.

Drabsch, S.L., Tanner, J.E. and Connell, S.D. 2001. Limited infaunal response to experimental trawling in previously untrawled areas. ICES Journal of Marine Science 58: 1261-1271.

Eleftheriou, A. and Robertson, M.R. 1992. The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. Netherlands Journal of Sea Research 30: 289-299.

Elliott, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. and Hemingway, K.L. 1998. Intertidal sand and mudflats and subtidal mobile sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. 151 pp.

EUNIS, 2007. European Environment Agency 2007. European Habitat Type Hierarchical View. Available online at: http://eunis.eea.europa.eu/habitats-code-browser.jsp.

Fallesen, G. and Jørgensen, H.M. 1991. Distribution of *Nephtys hombergii* and *Nephtys ciliata* (Polychaeta: Nephtyidae) in Århus Bay, Denmark, with emphasis on the severe oxygen deficiency. Ophelia (Supplement 5): 443-450.

Hall, K., Paramour, O.A.L., Robinson, L.A., Winrow-Giffin, A., Frid, C.L.J., Eno, N.C., Dernie. K.M., Sharp, R.A.M., Wyn, G.C. and Ramsay, K. 2008. Mapping the sensitivity of benthic habitats to fishing in Welsh waters – development of a protocol. CCW [Policy Research] Report No: 8/12, 85pp.

Jennings, S. and Kaiser, M.J. 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology 34: 203-352.

Kaiser, M.J. and Spencer, B.E. 1996. Behavioural responses of scavengers to beam trawl disturbance. Aquatic Pre-dators and Their Prey In: Greenstreet, S.P.R. and Tasker, M.L. (Eds.), pp. 116±123. Fishing News Books, Oxford.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. and Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1-14.

Kenchington, E.L.R., Prena, J., Gilkinson, K.D., Gordon Jr, D.C., Macisaac, K., Bourbonnais, C., Schwinghamer, P.J., Rowell, T.W., Mckeown, D.L. and Vass, W.P. 2001. Effects of experimental otter trawling on the macrofauna of a sandy bottom ecosystem on the Grand Banks of Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences 58(6): 1043-1057.

Khayrallah, N.H. and Jones, A.M. 1980. The ecology of *Bathyporeia pilosa* (Amphipoda: Haustoriidae) in the Tay Estuary. 1. Factors influencing the distribution on Tayport and Tentsmuir beaches. Proceedings of the Royal Society of Edinburgh B 78: 109-119.

Khayrallah, N.H. 1977. Studies on the ecology of Bathyporeia pilosa in the Tay Estuary. PhD thesis, University of Dundee.

McIntyre, H.L., Geider, R.J. and Miller, D.C. 1996. Microphytobenthos: the ecological role of the “secret garden” of un-investigated shallow water marine habitats. I. Distribution, abundance and primary production. Estuaries 19: 186-201.

McLusky, D.S., Anderson, F.E. and Wolfe-Murphy, S. 1983 Distribution and population recovery of Arenicola marina and other benthic fauna after bait digging. Marine Ecology Progress Series 11: 173-179.

Newell, R.C., Seiderer, L.J. and Hitchcock, D.R. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology: an Annual Review 36: 127-78.

NPWS. 2011a. Roaringwater Bay and Islands SAC (site code: 101): Conservation objectives supporting document – marine habitats. Version 1, April 2011.

NPWS. 2011b River Barrow and River Nore SAC (site code: 2162): Conservation objectives supporting document – marine habitats. Version 1, April 2011.

NPWS. 2011c. Clew Bay SAC (site code: 1482): Conservation objectives supporting document – marine habitats. Version 1, June 2011.

NPWS. 2011d. Lough Swilly SAC (site code: 2287): Conservation objectives supporting document – marine habitats. Version 1, March 2011.

NPWS. 2011e. Dundalk Bay SAC (site code: 455): Conservation objectives supporting document – marine habitats. Version 1, March 2011.

NPWS. 2011f. Donegal Bay SAC (site code: 0133): Conservation objectives supporting document – marine habitats. Version 1, November 2011.

Robinson, R.F. and Richardson, C.A. 1998. The direct and indirect effects of suction dredging on a razor clam (*Ensis arcuatus*) population. ICES Journal of Marine Science 55(5): 970-977.

Sanders, H.L. 1978. Florida oil spill impact on the Buzzards Bay benthic fauna: West Falmouth. Journal of the Fisheries Board of Canada 35: 717-730.

Schwinghamer, P., Gordon, Jn D.C., Rowell, T.W., Prena, J., McKeown, D.L., Sonnichsen, G. and Guigne, J.Y. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy-bottom ecosystem on the Grand Banks of Newfoundland. Conservation Biology 12: 1215-1222.

Schwinghamer, P., Guigne, J.Y. and Siu, W.C. 1996. Quantifying the impact of trawling on benthic habitat structure using high resolution acoustic and chaos theory. Canadian Journal of Fisheries and Aquatic Science 53: 288-296.

Southward, A.J. 1982. An ecologist's view of the implications of the observed physiological and biochemical effects of petroleum compounds on marine organisms and ecosystems. Philosophical Transactions of the Royal Society of London B 297: 241-255.

Suchanek, T.H. 1993. Oil impacts on marine invertebrate populations and communities. American Zoologist 33: 510-523.

Tait, R.V. and Dipper, F.A. 1998. Elements of Marine Ecology. Fourth edition. Reed Elsevier plc group.

Telfer, T.C., Baird, D.J., McHenery, J.G., Stone, J., Sutherland, I. and Wislocki, P. 2006. Environmental effects of the anti-sea lice (Copepoda: Caligidae) therapeutant emamectin benzoate undercommercial use conditions in the marine environment. Aquaculture 260 (1-4): 163-180.

Thrush, S.F. and Dayton, P.K. 2002. Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity. Annual Review of Ecology and Systematics 33: 449-473.

Tillin, H.M., Hull, S.C. and Tyler-Walters, H. 2010. Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. Defra Contract No. MB0102 Task 3A, Report No. 22.

Van Dolah, R.F., Wendt, P.H. and Levisen, M.V. 1991. A study of the effects of shrimp trawling on benthic communities in two South Carolina sounds. Fisheries Research 12(2): 139-156.

1. Species: *Abra* spp.

Note: This review is based primarily on *Abra alba* as information could be readily sourced for this species. The sensitivity assessments are considered likely to apply to other species within this genus.

Species Description

- Venerid Bivalve mollusc;
- Infaunal: Thin-shelled surface deposit feeders, typically found in the top 1-2 cm of sediments;
- Abundances typically vary between years due to episodic recruitment/adult mortality;
- Maximum length: 2-2.5 cm;
- Reproduction: Reach sexual maturity in 6 months, prolonged annual spawning events;
- Longevity 1-2.5 years; and
- Annual mortality rate- approaching 100%.
- (Information from Rees and Dare 1993)

Recovery

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 and Dare 1993).

Information from MarLIN (Budd, 2007, references therein).

The life history characteristics of *Abra alba* and its widespread distribution contribute to its powers of recoverability. *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. Such egg production ensures successful replacement of the population, despite high larval mortality which is characteristic of planktonic development. Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month (Dauvin and Gentil, 1989), in which time the larvae may be transported over a considerable distance. Whilst some larvae may settle back into the parent population, the planktonic presettlement period is important for dispersal of the species and spatial separation from the adults also reduces the chances of adult induced mortality on the larvae through adult filter feeding (Dame, 1996). In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting (Sigurdsson et al. 1976, see adult distribution) and probably bedload transport (Emerson and Grant, 1991).

Diaz-Castaneda et al. (1989) investigated experimentally recolonization 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 the plankton. The abundance, total biomass and diversity of the community all increased until a maximum was reached after 20 to 24 weeks, according to the season. The community within the experimental containers matched that of the surrounding areas qualitatively but quantitatively within 4 to 8 months depending on the seasonal availability of recruits, food supply and faunal interactions. The experimental data suggest that *A. alba* would colonize 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 recoverability has been assessed to be high. However, recoverability may be very high in instances where a proportion of the adult population survives (Budd, 2007).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 1.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 1.2a and are combined, as in Table 1.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking, or to incorporate a range of evidence which indicated different responses.

For some pressures, the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as ‘Not Assessed’ (NA) in the matrix.

For a limited number of pressures the assessment ‘No Evidence’ (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 1.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 1.2a).

Table 1.1 *Abra* spp. Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	M (*)	VH (**)	L (*)	Information from MarLIN (Budd, 2007, references therein) Despite their robust body form, bivalves are vulnerable to physical abrasion. *Abra alba* is a shallow burrower and has a fragile shell (Tebble, 1976) which is vulnerable to physical damage (e.g. by otter boards; Rumohr and Krost, 1991). 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), recovery may be 'Very High' 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, so that recovery was assessed as 'Very High'. The sensitivity of this species was therefore considered to be 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	VH (***)	L (***)	The species was assessed as vulnerable to wave induced bottom disturbance but those not damaged or predated are capable of re-establishing within substrate if conditions are favourable (Rees et al. 1997; cited in Rees and Dare, 1993). Information from MarLIN (Budd, 2007, references therein) Despite their robust body form, bivalves are vulnerable to physical abrasion. *Abra alba* is a shallow burrower and has a fragile shell (Tebble, 1976) which is vulnerable to physical damage (e.g. by otter boards; Rumohr and Krost, 1991), but the small size of *A. alba* relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through (Rees and Dare, 1993). Bergmann and Santbrink (2000) reported between <0.5% and 18% mortality of *A. alba* due to trawling in the southern North Sea, depending on the type of trawl (12 m or 6 m beam trawl or otter trawl). They included *A. alba* amongst their list of bivalve species most vulnerable to trawling. However, they noted that many bivalve species were able to maintain a population in the face of fishing effort, depending on their life history characteristics. Based on the above information Resistance was therefore assessed as 'Medium' (<25% mortality), recovery may be 'Very High' 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 probably be

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						complete within six months based on life-history characteristics, so that recovery was assessed as 'Very High'. The sensitivity of this species was therefore considered to be 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (***)	VH (***)	L (*)	Direct mortality of *Donax vittatus*, a similar small and shallowly buried bivalve, from a single pass of a 4 m beam trawl in a sandy area (where penetration is shallower) was 10% (Bergman and Santbrink, 2000). The delicate shells of this species are vulnerable to physical damage (e.g. by otterboards), but small size relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through (Rees and Dare, 1993). This species was characterised as AMBI Fisheries Review Group I-Species very sensitive to fisheries in which the bottom is disturbed. Their populations do not easily recover (Gittenberger and van Loon, 2011). Based on the evidence above from Bergman and Santbrink (2000), resistance to surface disturbance was assessed as 'Medium' (<25% mortality) resistance was assessed as 'High' and recovery as 'Very High' (likely to be complete within 6 months) so that sensitivity was categorised as 'Low'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	M (*)	VH (*)	L (*)	Assessment based on surface abrasion.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	VH (*)	L (*)	Assessment based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	H (***)	M (*)	Information from MarLIN (Budd, 2007) *Abra alba* lives infaunally in muddy sediments. Removal of the substratum would also remove the entire population of the species. Recovery is predicted to be high, where suitable habitat remains or recovers. *Abra* spp. are predicted to have 'No' resistance to extraction, recovery was assessed as 'High' so that this species is considered to have 'Medium' sensitivity to sediment extraction.
	Siltation	Physical effects	H (***)	VH (***)	NS (***)	Information from MarLIN (Budd, 2007)

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	(addition of fine sediments, pseudofaeces, fish food)	resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)				*Abra alba* is a shallow burrower in muddy sediments. It requires its inhalant siphon to be above the sediment surface for feeding and respiration. Sudden smothering with 5 cm of sediment would temporarily halt feeding and respiration and require the species to relocate to its preferred depth and this species is capable of upwardly migrating if lightly buried by additional sediment (Schafer, 1972; cited in Budd, 2008). As an active burrower *A. alba* would be expected to relocate with no mortality. However, growth and reproduction may be compromised owing to energetic expenditure and so intolerance has been assessed to be low. Growth and reproduction would return to normal following relocation (Budd, 2007). This species was characterised as AMBI Sedimentation Group IV - Second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). Based on the above information *Abra* spp. are characterised as having 'High' resistance to siltation and, therefore, 'Very High' recovery, so that this genus is considered to be 'Not Sensitive.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	H (***)	M (*)	No evidence found. As adults are sedentary and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on the return of previous habitat conditions. Resistance is judged as 'None' with recovery as 'High' if original habitat conditions are re-instated, so that the sensitivity of this genus is assessed as 'Medium'. If there was no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	L (*)	VH (*)	L (*)	No evidence found. This genus is found in habitats where the sediment has a high proportion of fine fractions (see changes to water flow below), so the addition of sand to a muddy habitat would not exclude this species, however increasing coarseness is considered likely to reduce habitat suitability. This genus is considered to have some resistance to increased sediment coarseness and may persist in muddy patches, e.g. within mixed sediments. Resistance is therefore assessed as 'Low' and recovery (following habitat rehabilitation) as 'Very High'. Sensitivity is therefore considered to be 'Low'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	Species within this genus occur in muddy sediments or in sediments with a high proportion of fine fraction. The genus is therefore considered to have 'High' resistance to an increase in fine sediments and 'Very High' recovery following habitat rehabilitation. The genus is therefore considered to be 'Not Sensitive'. Sensitivity to the addition of fine sediments is assessed in the Siltation pressure section.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd, 2007, references therein) *Abra alba* lives in low energy environments (Tebble, 1976) where the substratum has a high proportion of fine sediment. Increased water flow rate will change the sediment characteristics in which the species lives, primarily by winnowing away the surface layers and preventing deposition of finer particles (Hiscock, 1983). Furthermore, increased water flow rate may prevent settlement of larvae and therefore reduce recruitment. Mature adults buried at depth are likely to be unaffected as muddy sediments tend to be cohesive. An intolerance assessment of low has been made owing to reduced viability that may result from poor larval recruitment. Recoverability has been assessed to be very high as the adult population is likely to have survived. A decrease in water flow rate will expose the species to conditions of almost negligible flow. Decreased water flow may reduce the availability of food that may be obtained from suspension feeding and the species would have to switch to deposit feeding. A decreased water flow rate may favour the deposition

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						of material upon which *A. alba* could feed. However, a decreased water flow rate may mean that dispersion of planktonic larvae is minimal, and that recruitment to the benthos occurs in the vicinity of the parent population which may result in parent induced mortality (via feeding). Intolerance has therefore been assessed to be low and recoverability assessed to be very high (Budd, 2007). Based on the above information decreases in flow rate (which are more likely to occur through aquaculture infrastructure) may lead to increased deposition of fine sediments and organic matter that may enhance food supply. *Abra* spp. are assessed as 'Not Sensitive' to changes in water flow rate as the species is typical of sheltered, depositional environments with lower water flows. Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	M (**)	VH (*)	L (*)	Information from MarLIN (Budd, 2007, references therein) Levels of suspended sediment are likely to be most relevant to feeding. *Abra alba* practices two alternative modes of feeding. It either holds its feeding organ, the inhalant siphon, at a fixed position just above the sediment surface to filter out food particles suspended in the overlying water or else extends and moves its siphon around on the sediment above it to vacuum up deposited food particles. The alternative feeding methods are likely to make the species insensitive to relatively small changes in suspended sediment. If the level of suspended sediment becomes so high as to risk clogging the feeding structures, *A. alba* could presumably switch to deposit feeding. Furthermore, an increase in suspended sediment is likely to increase the rate of siltation and therefore the food available to deposit feeders. *Abra alba* has been assessed to be tolerant at a benchmark level increase of 100 mg/l for one month, with the potential for growth and reproduction to be enhanced by the increased food supply. However, a more substantial 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 1 km 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). *Abra alba* does not require light and therefore the effects of increased turbidity on light attenuation are not directly relevant. An increase in turbidity may affect primary production in the water column and

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						therefore reduce the availability of phytoplankton food. However, phytoplankton will also be transported from distant areas and so the effect of increased turbidity may be mitigated to some extent. Growth and fecundity would be affected by an increase in turbidity of one category of water clarity for a year. As soon as light levels return to normal, primary production will increase, the species would resume optimal feeding (Budd, 2007). Based on the evidence cited above, resistance to increases in turbidity is assessed as 'High' and recovery as 'Very High', so that this species is considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	M (*)	VH (*)	L (*)	Information from MarLIN (Budd, 2007) A decrease in suspended sediment is likely to decrease the availability of food for both suspension and deposit feeding. The reduction in food availability may result in less energy available for growth and reproduction by *A. alba*. However, a change of 100 mg/l for one month is not expected to result in significant mortality. When suspended sediment returns to original levels, growth and reproduction should quickly return to normal. *Abra alba* does not require light and therefore the effects of decreased turbidity on light attenuation are not directly relevant. It is possible that decreased turbidity would increase primary production in the water column by phytoplankton and by microphytobenthos. The resultant increase in food availability may enhance growth and reproduction in *A. alba*, but only if food was previously limiting (Budd, 2007) Resistance is assessed as 'Medium' with recovery categorised as 'Very High'. Overall sensitivity is considered to be 'Low'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As *Abra* spp. are not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton and algal detritus may be utilised as food by this genus. This species is therefore considered to be 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments -	Increased organic matter input to sediments	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd, 2007, references therein) 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 of the ecological adaptations of the species enabled it to exploit the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Sedimentation					greatly increased supply of nutrients (Caspers, 1981). For example, the Amoco Cadiz oil spill in March 1978 caused vast disturbance to the fine-sand communities of the Bay of Morlaix, France (Dauvin, 1982). Drastic qualitative and quantitative changes in species abundance, diversity and biomass were recorded after the spill. However, the *A. alba* population persisted in the disturbed environment under eutrophic conditions and as an 'opportunistic species' (Hily and Le Bris, 1984), it rapidly adapted its reproductive strategy by increasing its reproductive output to three spawnings per year. Increased growth and abundance was attributable to increased food availability and vacant ecological niches (Dauvin and Gentil, 1989) cited from Budd (2007). This species is found in high abundances in moderately enriched environments (Caspers, 1987). In response to nutrient inputs following the Amoco Cadiz oil spill there were three recruitment events a year (Dauvin and Gentil, 1989). This species was characterised as 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). They are surface deposit-feeding species, as tubicolous spionids (Borja et al. 2000; Gittenberger and van Loon, 2011). This species dominated harbour sediments in Ceuta, North Africa where 'very high' levels of organic matter (5-13% of sediment) and heavy metals were found (Guerra-Garcia and Garcia-Gomez, 2004). Based on the information above, this species was considered to be tolerant to increased organic matter although no evidence for tolerance thresholds was found. Resistance was therefore assessed as 'High' and recovery as 'Very High' so that the genus is considered to be 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	No information found. Increased removal of primary production is not predicted to directly affect this species which is primarily a deposit feeder. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. This genus is therefore considered to have 'High' resistance and 'Very High' recovery to reduced phytoplankton abundance so that the species is considered to be 'Not Sensitive'.
	Decrease in oxygen levels	Hypoxia/anoxia of sediment	L -M (***)	VH (***)	L (***)	Information from MarLIN (Budd, 2007, references therein) *Abra alba* is typically found in organically enriched sediments where it may be present in high densities

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	- Sediment					(Dauvin and Gentil, 1989). Such areas can be prone to periodic oxygen deficiency and individual growth and survival is dependent upon the maintenance of a continuous balance between high energy input (food availability) and high metabolic costs which result from periodic anaerobic metabolism and regulation of oxygen uptake (Hylland et al. 1996). Experimental examination of the interactions between eutrophication and oxygen deficiency (2.4-3.5 mg O_2/l over a 93 day experimental period) revealed that *A. alba* became inefficient in its use of the available organic matter under prolonged conditions of hypoxia, as evidenced by a decreased growth rate (Hylland et al. 1996). As *A. alba* is able to shift from aerobic to anaerobic respiration, a short period of hypoxia is unlikely to have a significant effect upon the species. However, prolonged exposure to oxygen concentrations below 3 mg O_2/l may severely decrease growth and survival (Hylland et al. 1996). Rees and Dare (1993) reported *A. alba* to be sensitive to lowered oxygen concentrations arising from eutrophication off the Swedish west coast (Rosenberg and Loo, 1988; cited in Rees and Dare, 1993); lethal effects of low oxygen concentrations also noted by Weigelt and Rumohr (1986; cited in Rees and Dare, 1993) and Arntz and Rumohr (1986; cited in Rees and Dare, 1993) for the western Baltic, recovery of former densities taking some 1.5 years (Budd, 2007) Based on the above information, resistance is assessed as 'Low-Medium' and recovery as 'Very High' so that sensitivity is assessed as 'Low'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L -M(***)	H (***)	L- M (***)	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-	L (*)	H-VH (*)	L-M (*)	The Manila clam (*Tapes philippinarium*), which was introduced to Poole Harbour for aquaculture in 1998, has become a naturalised population on the intertidal mudflats, occurring at densities of 60 clams/m² in some locations within the harbour (Jensen et al. 2007; cited in Caldow et al. 2007). Densities of *Cerastoderma edule* and *A. tenuis* had increased since the introduction of the Manila clam.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		natives in translocated stock'				Caldow et al. (2007) concluded that within Poole harbour there was no evidence yet of species replacement by the Manila clam. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Abra* spp. are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. Based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as 'High-Very High' so that sensitivity is assessed as 'Medium'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This genus is not targeted by a commercial fishery and is therefore considered to be 'Not Sensitive'. Resistance is therefore considered to be 'High', recovery is assessed as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and	H (*)	VH (*)	NS (*)	Dredging for scallops and use of other mobile fishing gear may cause abrasion and displacement of *A. alba*. The effects of physical damage are considered in the physical disturbance theme.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		function through the effects of removal of target species on non-target species				This genus will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the genus is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed
	Introduction of hydrocarbons	Introduction of hydrocarbons	M (***)	VH (***)	L (***)	Information from MarLIN (Budd, 2007, references therein) Suchanek (1993) reviewed the effects of oil on bivalves. Sub-lethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates may increase at low concentrations and decrease at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. However, the *A. alba* population affected by the 1978 *Amoco Cadiz* benefited from the nutrient enrichment caused by the oil pollution. The biomass of the fine-sand community remained low in 1979, a year after the spill, owing to the decimation of the *Ampelisca* amphipod population, but the biomass then doubled as a result of an increase in *A. alba* abundance in 1980 and *A. alba* remained a dominant species over the 20 year duration over which recovery of the community was monitored (Dauvin, 1998). Intolerance has been assessed to be low as the *A. alba* population was apparently resilient to the presence of hydrocarbons in the subtidal sediments just two weeks after the wreck. The fact that *A. alba* occurs subtidally may mitigate the effects of oil pollution on the species, as it avoids a direct oiling. Recoverability has been assessed to be very high as the species is able to adapt its demographic strategy in order to benefit from the resulting nutrient enrichment (Dauvin and Gentil, 1989). Based on the above evidence, resistance to hydrocarbon contamination was assessed as 'Medium' (<25% decline) and recovery as 'Very High' (within six months following habitat recovery) so that sensitivity was assessed as Low'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of antifoulants	Introduction of antifoulants	H (***)	VH (***)	NS (***)	Information from MarLIN (Budd, 2007) *Abra alba* can live in polluted sediments (Dauvin, pers. comm.), for example, near Calais where high densities of *A. alba* were found in sediment containing 8 mg/g iron and 4 mg/g titanium (Dewarumez et al. 1976). The capacity of bivalves to accumulate heavy metals in their tissues, far in excess of environmental levels, is well known. Reactions to sub-lethal levels of heavy metals include siphon retraction, valve closure, inhibition of byssal thread production, disruption of burrowing behaviour, inhibition of respiration, inhibition of filtration rate, inhibition of protein synthesis and suppressed growth (see review by Aberkali and Trueman, 1985). Bryan (1984) states that Hg is the most toxic metal to bivalve molluscs while Cu, Cd and Zn seem to be most problematic in the field. In bivalve molluscs, Hg was reported to have the highest toxicity, mortalities occurring above 0.1-1 g/l after 4-14 days exposure (Crompton, 1997), toxicity decreasing from Hg > Cu and Cd > Zn > Pb and As > Cr (in bivalve larvae, Hg and Cu > Zn > Cd, Pb, As, and Ni > to Cr). Owing to evidence in the literature of sub-lethal effects and mortality of bivalves, intolerance of *A. alba* to heavy metal contamination has been assessed to be intermediate (Budd, 2007). Rygg (1985) classified the congener *A. nitida* as non-tolerant of Cu (absent from stations in Norwegian fjords where sediment Cu concentrations were >200 ppm (mg kg^{-1})). However, this species dominated harbour sediments in Ceuta, North Africa where 'very high' levels of organic matter (5-13% of sediment) and heavy metals were found (Guerra-Garcia and Garcia-Gomez, 2004). The high levels of organic matter may have reduced the bioavailability of Zn and Cu. However, Zn concentrations at stations where this species was found, ranged from 67- 207 ppm and Cu ranged from 40-209 ppm. Based on a sediment quality guideline of 100 mg kg^{-1} for Cu, the evidence from Guerra-Garcia and Garcia-Gomez (2004) indicates that the sediment quality guideline of 100 mg kg^{-1} would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	*Abra* spp. do not photosynthesise and are primarily deposit, rather than suspension feeders (although some suspension feeding may occur). The genus does not, therefore, directly require light and is therefore considered to be 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to				NA	Not relevant to SAC habitat features.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	species movement					

Table 1.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 1.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 1.3 Resistance Assessment Confidence Levels

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*** (1)	***	N/A
Deep Disturbance	*** (2)	***	*
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion			
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	** (1)	*	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (+5)	**	***
Decrease in oxygen levels - Water column	*** (+5)	**	***
Genetic impacts			
Introduction of non-native species			
Introduction of parasites/pathogens	Not Exposed		
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not Assessed. No Evidence.		
Introduction of hydrocarbons	*** (1)	**	N/A
Introduction of antifoulants	***		
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Budd, G. 2007. *Abra alba*. A bivalve mollusc. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 07/02/2012]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=2307.

Bergman, M.J.N. and van Santbrink, J.W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science 57: 1321-1331.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Caldow, R.W.G., Stillman, R.A., le V. dit Durell, S.E.A., West, A.D., McGrorty, S., Goss-Custard, J.D., Wood, P.J. and Humphreys, J. 2007. Benefits to shorebirds from invasion of a non-native shellfish. Proceedings of the Royal Society B 274: 1449-1455.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011-08.

Guerra-Garcia, J.M. and J. Garcia-Gomez, J.C. 2004. Soft bottom mollusc assemblages and pollution in a harbour with two opposing entrances. Estuarine, Coastal and Shelf Science 60: 273-283.

Rees, H.L. and Dare, P.J. 1993. Sources of mortality and associated life-cycle traits of selected benthic species: a review. Fisheries Research Data Report, Number 33.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

2. Species: *Angulus tenuis*

Species Description

- Taxonomy: Venerid bivalve;
- Information on environmental position: Infauna, buries to about 5-12 cm in the sand;
- Habitat: This species is found in fine sand from the middle of the shore to the shallow sublittoral;
- Body form: shell is thin and brittle;
- Length: Grows to about 2-3 cm in length;
- Feeding Type: Suspension feeder;
- Longevity: about 5 years (Fish and Fish, 1996); and
- Reproduction: The sexes are separate and breeding occurs during summer (Fish and Fish, 1996).

Recovery

Information from MarLIN (Carter, 2005).

This bivalve is a suspension feeder with a long siphon that extends above the sand when feeding and young flatfishes often feed on the tips of the siphon. However, the bivalve is not killed and the siphon can grow back again.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 2.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 2.2a and are combined, as in Table 2.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 2.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 2.2a).

Table 2.1 *Angulus tenuis* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	No evidence found. Based on environmental position, resistance to surface abrasion was assessed as 'High' (no significant effects on population) and recovery was therefore assessed as 'Very High' (no impact to recover from). This species is therefore categorised as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (*)	H-VH (*)	L (*)	No evidence found. Surface disturbance penetrating to a depth of 25mm was judged to miss most of the population which would be buried more deeply. Resistance was therefore assessed as 'Medium' (<25% mortality), and recovery as 'High-Very High' (based on Clarke and Tully, 2011, see below) so that the sensitivity of this species was assessed as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (***)	H-VH (***)	L (***)	A study of the effects of hydraulic dredging in Dundalk Bay, Ireland indicated that there was a short-lived effect (<4 months) of the fishery on *Angulus tenuis* and the target species *Cerastoderma edule*, which spatially overlapped (Clarke and Tully, 2011). The authors concluded that the dominant species in the benthic community, *A. tenuis*, *Macoma balthica*, *C. edule* and a number of polychaete species had low sensitivity (high resilience and high recoverability) to disturbance. Based on the above evidence resistance was assessed as 'Medium' and recovery as 'High-Very High', so that the sensitivity of this species is assessed as 'Low'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	No evidence found. Assessment based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	H-VH (*)	L(*)	No information found. Assessment based on deep disturbance due to greater pressure and penetration of vehicles into sediment.
	Extraction	Removal of	N (*)	M (*)	H (*)	No information found.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae				*Angulus tenuis* is predicted to have 'No' resistance to extraction, recovery was assessed as 'Medium' so that this species is considered to have 'High' sensitivity to sediment extraction.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	No information found. Venerid bivalves are typically able to relocate within the sediment in response to siltation. Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	M (*)	H (*)	No evidence found. As adults have limited to no horizontal mobility and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on a return to previous habitat conditions. Resistance is judged as 'None' with recovery as 'Medium' if original habitat conditions are re-instated, so that the sensitivity of this species is assessed as 'High'. If there were no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear is addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	boat/vehicle movements					
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N-L (*)	M-H (*)	M-H (*)	No information found. This species appears to be restricted to fine sands, an increase in coarse sediment fraction is considered to decrease habitat suitability for this species. Resistance is therefore assessed as 'None-Low' and recovery as 'Medium-High' following habitat recovery. Sensitivity is therefore assessed as 'Medium-High'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (***)	VH (***)	NS (***)	On intertidal sandflats, deposition of finer material (e.g. arising from hydrodynamic changes) will lead to increased dominance by species preferring finer sediments, such as *Angulus tenuis* (Elliott et al. 1998). Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	L-M (*)	M-H (*)	L-M (*)	No information found. Increased water flow rate may winnow fine sediments and at greater velocities may erode sediment and wash individuals out of the sediment. Aquaculture installations however are associated with reduced water flows. A decrease in water flow may reduce the availability of food that may be obtained from suspension feeding and may increase deposition of fine particles, this could support the development of a deposit feeding assemblage more typical of muddy sediments, decreasing suitability for *Angulus tenuis* through an increase in abundance of deposit feeding species and lower larval recruitment. Resistance is therefore assessed as 'Low-Medium' and recovery (following habitat restoration) as 'Medium-High'. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes in turbidity/ suspended	Increase in particulate matter (inorganic and	M (*)	H (*)	L (*)	No information found. *Angulus tenuis* does not require light and therefore the effects of increased turbidity on light attenuation

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment - Increased suspended sediment/ turbidity	organic)				are not directly relevant. An increase in turbidity may affect primary production in the water column and therefore reduce the availability of phytoplankton food. However, phytoplankton will also be transported through water exchange limiting effects unless in enclosed water bodies with limited flushing (that are not typical habitat). Increased seston concentrations may inhibit feeding where inorganic particle concentrations increase in the medium-long term, reducing feeding efficiency. Resistance is therefore assessed as 'Medium' and recovery is assessed as 'High, so that sensitivity is assessed as 'Low'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	*Angulus tenuis* does not require light and therefore the effects of decreased turbidity on light attenuation are not directly relevant. It is possible that decreased turbidity would increase primary production in the water column and the resultant increase in food availability may enhance growth and reproduction, but only if food was previously limiting. Resistance is therefore assessed as 'High, and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As this species is not a primary producer it is not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton may be utilised as food by this genus. This species is therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments			NEv	No information found. Not Assessed.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	M-H (*)	H-VH (*)	L-NS (*)	Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (Hartnoll, 1998). Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM (http://www.farmscale.org/), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters. Resistance to increased competition was assessed as 'Medium to High' (ranging from no lethal effect to mortality of <25% of population) and recovery as 'High-Very High' so that sensitivity was categorised as 'Low to Not Sensitive'. Increased clearance rates of suspended sediments by suspended bivalves may enhance local primary production through a reduction in turbidity, compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment			NEv	No evidence found. Not Assessed.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column			NEv	No evidence found. Not Assessed.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	M-H (*)	M (*)	No information found. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit/). Sediments where *Angulus tenuis* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. Based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as 'Medium-High' so that sensitivity is assessed as 'Medium'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This genus will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the genus is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services -				NA	Not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No information found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No information found. Not Assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Based on a Cu sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000), it is assumed, (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Angulus tenuis* do not photosynthesise and do not, therefore, directly require light and are therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to Annex I habitats and species.

Table 2.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 2.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 2.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	*** (1)	***	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	***(1)	*	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	Not assessed. No evidence found.		
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	Not assessed. No evidence found.		
Decrease in oxygen levels - Water column	Not assessed. No evidence found.		
Genetic impacts			
Introduction of non-native species	Not assessed. No evidence found.		
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not assessed. No evidence found.		
Introduction of hydrocarbons	Not assessed. No evidence found.		
Introduction of antifoulants	Not assessed. No evidence found.		
Prevention of light reaching seabed/features			
Barrier to species movement			

References

Carter, M. 2005. *Angulus tenuis*. Thin tellin. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 09/02/2012]. Available from: http://www.marlin.ac.uk/speciesinformation.php?speciesID=2524.

Clarke, S., Tully, O. 2011. BACI monitoring for the effects of hydraulic dredging for cockles on the intertidal benthic habitats of Dundalk Bay. Fisheries Science Service, Marine Institute. May 2011

Elliott, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D., Hemingway, K.L., 1998. Intertidal Sand and Mudflats and Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project). 151 Pages

Fish, J.D., Fish, S. 1996. A student's guide to the seashore. Second edition. Cambridge: Cambridge University Press

Hartnoll, R.G., 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland. [UK Marine SAC Project. Natura 2000 reports.]

Madsen, T., Samsoe-Petersen, L., Gustavson, K., Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

3. Species: *Bathyporeia* spp.

Species Description

- *Bathyporeia* is a genus of small active amphipod crustacea belonging to the Family Pontoporeiidae;
- Dispersal potential: 10-100m;
- Length: 3-8mm (MES Ltd, 2010);
- Life span: 1 year;
- Size: <6mm;
- Environmental position: burrowing infauna but can also move into the water column and swim freely; and
- Biotopes: This species has been recorded in a number of biotopes (see Table A below).

Habitat preferences (taken from biotope descriptions, JNCC, see Table A)

- Wave Exposure: Extremely exposed, Very Exposed, Exposed, moderately exposed, sheltered;
- Sediments: Medium to very fine sand with some silt;
- Tidal streams: Strong (3-6kn), Moderately strong (1-3kn), Weak (>1kn), Very Weak (negligible); and
- Zone: Mid shore, Lower shore, infralittoral (0-30m).

This genus has been identified as a characterising species in the following EUNIS habitats (see Table A) and JNCC equivalents. The habitat preferences listed above have been identified from the habitat descriptions of these biotopes (from the JNCC website, Connor et al. 2004)

Table A: *Bathyporeia* spp. have been recorded as a characterising species from the following EUNIS biotopes and JNCC equivalents

EUNIS (200410)	Marine Habitat Classification for Britain and Ireland Version 04.05
A5.233	SS.SSa.IFiSa.NCirBat
A5.222	SS.SSa.SSaVS.NcirMac
A2.2233	LS.LSa.MoSa.AmSco.Pon
A5.231	SS.SSa.IFiSa.IMoSa
A5.242	SS.SSa.IMuSa.FfabMag
A5.252	SS.SSa.CFiSa.ApriBatPo

Recovery

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 the 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 recovery quickly (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 3.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 3.2a and are combined, as in Table 3.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available, the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 3.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 3. 2a).

Table 3.1 *Bathyporeia* spp. Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (***)	NS (*)	As *Bathyporeia* spp. are infaunal and can also migrate to avoid disturbance they are considered to have 'High' resistance to surface abrasion and, taking into consideration the lack of impact, to have 'Very High' recovery rates, so this genus is assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	VH (***)	L (***)	No information found. Assessment based on deep disturbance as no information was found for this pressure. Shallow disturbance pressures are likely to lead to similar mortality as deep disturbance as *Bathyporeia* spp. occurs within the top 3cm of sediment.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (***)	VH (***)	L (***)	Bergman and Santbrink (2000) found that direct mortality of gammarid amphipods, following a single passage of a beam trawl (in silty sediments where penetration is greater) was 28%. Following experimental hydraulic dredging for razor clams there were no statistically significant differences in *Bathyporeia elegans* abundances between treatments after 1 or 40 days (Hall et al. 1990). Ferns et al. (2000) examined the effects of a tractor-towed cockle harvester on the benthic invertebrates and predators of intertidal plots of muddy and clean sand. Harvesting resulted in the loss of a significant proportion of the most common invertebrates from both areas. In the muddy sand, the population of a similar species, *B. pilosa* remained significantly depleted for more than 50 days, whilst the population in clean sand recovered more quickly. Rostron (1995) found that populations of *B. pilosa* exhibited greater fluctuations in numbers of individuals post-experimental dredging of sandflats with mechanical cockle dredge (well sorted fairly coarse sand, surface, sediment well drained and rippled as a result of wave activity). Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that *Bathyporeia* spp. experienced a reduction of 25% abundance in samples immediately after intense clam dredging, abundance recovered after 1 day (Constantino et al. 2008).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the evidence above it is considered that *Bathyporeia* spp. will have 'Medium' resistance (mortality <25%) to deep disturbance, their small size, infaunal position and mobility enabling a large proportion of the population to escape injury. Recovery is assessed as 'Very High' (within 6 months) and sensitivity is therefore categorised as 'Low'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	No information found. Assessment based on surface abrasion.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	VH (*)	L (*)	No information found. Assessment based on deep disturbance as vehicles exert greater compacting force and may penetrate sediment. Confidence has been assessed as lower as the sensitivity was extrapolated from a different pressure type.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N-L (*)	H-VH (*)	L-M (*)	Information from MarLIN (Budd and Curtis, 2007). *Bathyporeia pelagica* lives infaunally in the uppermost 3 cm of sandy substrata. The removal of the substratum would also remove the resident population and therefore intolerance has been assessed to be high. Re-population is likely to be rapid (Budd and Curtis, 2007). This species is considered vulnerable to dredging, but populations recover quickly (MES Ltd, 2010) This genus is assessed as having 'No-Low' (due to mobility) resistance to extraction, recovery is assessed as 'Very High- High' (following habitat recovery). Sensitivity is therefore categorised as 'Low to Medium'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat	M (***)	VH (***)	L (***)	Information from MarLIN (Budd and Curtis, 2007, references therein). Amphipod crustacea have efficient adaptations of body form to support a sand burrowing mode of life (Maurer et al. 1986). *Bathyporeia pelagica* would probably be unaffected by an additional covering of a sediment of a texture within its habitat preference (fine - medium sand, 0.125-0.5 mm median diameter, Wentworth scale), although there may be an energetic cost incurred by the additional burrowing activity required to attain a near-surface position for feeding and to swim. However, Maurer et al. (1986) observed curtailment of burrowing activity and reduced survivorship in another burrowing amphipod, *Parahaustorius longimerus* (Haustoriidae), when exposed to 'exotic' sediments with a greater silt/clay

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		quality)				content. Therefore, *B. pelagica* is likely to be more intolerant of smothering by both coarser and finer particles and viscous materials such as oil, through which burrowing is likely to be hindered. Consequently, the intolerance of *B. pelagica* to smothering has been assessed to be intermediate (Budd and Curtis, 2007). Resistance to siltation (addition of fine materials) is assessed as 'Medium' (mortality of <25% of population) and recovery (following habitat recovery) as 'Very High'. So that sensitivity is categorised as 'Low'. The effects of sediment composition are considered below (increased fine sediment proportion).
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	L-M (*)	H-VH (*)	L-M (*)	The habitat preferences of this genus are for medium to fine sands. The addition of coarse materials would alter habitat suitability and prevent feeding as photosynthesis of algae on the underlying sand grains would be prevented by shading. Resistance to smothering (resulting from the addition of coarse materials) is assessed as 'Low' (mortality of 27-75%) to reflect that individuals may not be able to escape from or feed after the addition of a layer of coarse materials. Recovery (following habitat recovery) is assessed as 'High-Very High (again reflecting the greater potential impact on the population). Sensitivity is therefore assessed as 'Low-Medium'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	L (*)	H-VH (*)	L-M (*)	Information from MarLIN (Budd and Curtis, 2007, references therein). This genus is found in medium-fine sands (see biotope information above), an increase in sediment coarseness to coarse sands or gravels would alter the ability of these amphipods to burrow into the sediment, reducing habitat suitability. *Bathyporeia pelagica*, avoided burrowing into substrata with particles >500µm median diameter (Khayrallah and Jones, 1978a; Budd and Curtis, 2007). This genus is assessed as having 'Low' resistance to this pressure and 'High-Very High' recovery following habitat rehabilitation, so that sensitivity is categorised as 'Low-Medium'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	L (*)	H-VH (*)	L-M (*)	No information found. This species occurs in areas of sand with some silt fraction (see biotope information above). An increase in silts would alter habitat suitability through changes in food availability (*Bathyporeia* spp. are sand-lickers, removing algae from sand grains). Where areas become muddy and sediments are more stable, bivalve populations may develop, out-competing *Bathyporeia* spp. for space. This genus is assessed as having 'Low' resistance to this pressure and 'High-Very High' recovery following habitat rehabilitation, so that sensitivity is categorised as 'Low-Medium'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	*Bathyporeia* spp. are found in areas with strong to very weak tidal streams, (6kn to negligible, see introduction), they are therefore considered resistant to changes in water flow and therefore 'not sensitive'. Accompanying changes in sediment characteristics following changes in water flow are described above. Resistance is therefore assessed as "High' and recovery as 'Very High', so that this genus is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd and Curtis, 2007, references therein). *Bathyporeia pelagica* is infaunal and is not likely to be affected by the light attenuating effects caused by an increase in turbidity. *B. pelagica* is an infaunal species whose feeding is not reliant upon a supply of suspended material, and it is unlikely that its swimming activity would be affected by an increase in the suspended matter in the water column, as it is a regular swimmer in the surf plankton, where the concentration of suspended particles would be expected to be higher (Fincham, 1970a). Furthermore, during the winter, when the species often extends its distribution into the mouths of estuaries, *B.*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	turbidity					*pelagica* may encounter concentrations of suspended sediment measurable in grams per litre (benchmark is mg/l) (Cole et al. 1999). However, in turn, as a result of increased suspended sediment, the quantity of material deposited on the substratum surface is likely to increase on the ebb tide. *B. pelagica* appears to have a habitat preference for substrata of fine to medium sand with a silt/clay content of <5% (Fish and Fish, 1978). Increased deposition of finer particles may result in changes of the sediment composition, certainly of the surface layers, and could have a smothering effect on the infaunal population (see smothering). However, the effects of accretion of material are addressed under siltation (Budd and Curtis, 2007). Based on the above evidence and their presence in areas subject to frequent disturbance where sediments are mobilised, *Bathyporeia* spp. are assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery is 'Very High'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	As *Bathyporeia* spp. are predominantly infaunal and are not suspension feeders they are assessed as 'Not Sensitive' to this pressure. Indirectly increased light penetration may have a beneficial effect by increasing the food availability to this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Organic enrichment - Water column	Eutrophication of water column	N (*)	H-VH (***)	L-M (*)	Information from MarLIN (Budd and Curtis, 2007, references therein). The sandy shore environment favoured by *Bathyporeia pelagica* has a characteristically low level of organic matter. As an epistrate feeder, *B. pelagica* feeds upon the film of diatoms and bacteria adhering to individual sand particles. Nutrient enrichment would enhance the growth of episammic diatoms and bacteria as nutrients are probably limiting. A flourishing population of bacteria would utilize oxygen for the oxidization of the resulting organic matter, possibly causing hypoxia. *B. pelagica* has been assessed to be intolerant of hypoxic conditions (see oxygenation below). Intolerance has been assessed as high because an increase in nutrient levels would probably result in the species being exposed to conditions outside its habitat preferences. Recovery has been assessed to be moderate owing to the length of time it may take to return to prior conditions. For instance the normal fauna of
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	N (*)	H-VH (***)	L-M (*)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						clean sandy beaches had only partially recovered after three years after the opening of a sewage works and resultant reduction in organic enrichment in the Firth of Forth (Read et al. 1983; Budd and Curtis, 2007). In sheltered conditions, increased nutrients may lead to the growth of ephemeral algae that may smother the sediment, however this is unlikely in the physically disturbed environment that *Bathyporeia* spp. favour. Low levels of enrichment may enhance food supply so that the impact would be beneficial to this species. However, as this species occurs in well-flushed sediments without an anoxic layer, this genus is likely to migrate to avoid areas where high levels of organic matter are leading to hypoxia and anoxia and the production of hydrogen sulphide. Resistance is therefore assessed as 'None' and recovery, following habitat rehabilitation, as 'Very High-High'. Sensitivity is therefore assessed as 'Low-Medium'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	No information found. This genus does not feed upon phytoplankton within the water column and are therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	N (***)	H-VH (***)	L-M (***)	Information from MarLIN (Budd and Curtis, 2007, references therein). Laboratory studies by Khayrallah (1977) on *Bathyporeia pilosa*, indicated that it has a relatively poor resistance to conditions of hypoxia in comparison to other interstitial animals. It was also susceptible to hydrogen sulphide, supporting the conclusion that aerated deposits are a fundamental requirement of *B. pilosa* and also probably *B. pelagica*. It is likely, therefore, that *B. pelagica* would be unable to endure hypoxic conditions for a week, that may result from smothering by impermeable/viscous materials, and intolerance has been assessed to be high (Budd and Curtis, 2007). Based on the above evidence, *Bathyporeia* spp. are assessed as having 'No' resistance to decreased oxygen layers, recovery, following habitat rehabilitation is assessed as 'High-Very High' so that sensitivity is assessed as 'Low-Medium'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	N (***)	H-VH (***)	L-M (***)	
Biological Pressure	Genetic impacts on	Presence/absence benchmark, the			NE	'Not Exposed'. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	wild populations and translocation of indigenous populations	presence of farmed and translocated species presents a potential risk to wild counterparts				
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L-M (*)	H-VH (*)	L-M (*)	No evidence found. Assessment based on smothering as the settlement of *Crassostrea gigas* or *Crepidula fornicata* would effectively lead to substratum smothering.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This genus is not targeted by a commercial fishery. Potential physical impacts from commercial fisheries are considered in the physical disturbance pressures above. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This genus will be sensitive to the removal of target species that occur in the same habitat, such as worms targeted by bait diggers, as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of				NA	Not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not Assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Based on a Cu sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000), it is assumed, (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. As this genus are not primary producers, have limited visual acuity and inhabit turbid, coastal waters and estuaries where light penetration may be limited, it is assessed as 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to this species.

Table 3.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 3.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 3.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***(4)	***	***
Deep Disturbance	***(4)	***	***
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***(1)	*	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***(1)	*	N/A
Decrease in oxygen levels - Water column	***(1)	*	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence found. Not assessed.		
Introduction of hydrocarbons	No evidence found. Not assessed.		
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Bergman, M.J.N. and van Santbrink, J.W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science 57: 1321-1331.

Budd , G. and Curtis, L. 2007. *Bathyporeia pelagica*. A sand digger shrimp. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 06/09/2012]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=2740.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Constantino, R., Gaspar, M.B., Tata-Regala, J., Carvalho, S., Cúrdia, J., Drago, T., Taborda, R. and Monteiro, C.C. 2008. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. Marine Environmental Research 67: 89-99.

Ferns, P.N., Rostron, D.M. and Siman, S.H.Y. 2000. Effects of mechanical cockle harvesting on intertidal communities. Journal of Applied Ecology 37: 464-474.

Hall, S.J., Basford, D.J. and Roberts, M.R. 1990. The impact of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community. Netherlands Journal of Sea Research 27: 119-125.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available at: http://www.genustraithandbook.org.uk/introduction.

Rostron, D.M. 1995. The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. Burry Inlet and Loughor Estuary Symposium, March 1995. Part 2. 111-117. Burry Inlet and Loughor Estuary Liaison Group.

4. Species: *Capitella capitata*

Species Description

- *Capitella capitata* is a fragile, sedentary polychaete worm growing to 40mm;
- *C. capitata* represents a complex (Grassle and Grassle, 1976) of up to 50 sibling species (Mendez et al. 1997). Species within the complex differ in size, reproductive strategy and larval characteristics (Pearson and Pearson, 1991; Mendez et al. 1997). Differentiation between species within the complex is difficult and therefore many studies do not identify which *Capitella capitata* species are considered - this means information may not be directly applicable (Riley and Bilewitch, 2009);
- Environmental position: abundant, head-down deposit-feeder restricted to the upper 2–3cm of the sediment (Madsen et al. 1997);
- Habitat: Occurs on mud/sandy mud/ muddy sand/ clean sand on the lower shore to sub-littoral. It may be found under pebbles or small stones, with the burrows at or near the surface of the sediment. Frequently found in polluted or disturbed areas, such as harbours, near sewage outfalls and sludge dumps and in sediments contaminated with oil (Riley and Bilewitch, 2009);
- Reproduction and fecundity: vary within the species complex (see below); and
- Longevity: 45 days to 2 years.

Recovery

Capitella capitata is a classic opportunist species possessing life history traits of rapid development, many reproductions per year, high recruitment and high death rates (Grassle and Grassle, 1974; McCall, 1977). Experimental studies using defaunated sediments have shown that on small scales *Capitella* can recolonise to background densities within 12 days (Grassle and Grassle, 1974; McCall, 1977).

In favorable conditions maturity can be reached in <3 months and growth rate is estimated to be 30 mm per year. Adult potential dispersal is up to 1 km. The species complex displays reproductive variability, planktonic larvae are able to colonise newly disturbed patches but after settlement the species can produce benthic larvae brooded within the adult tube to rapidly increase the population before displacement by more competitive species (Gray, 1979).

The spatial and temporal distribution of this species has been found to be highly variable (McCall, 1977), patchy disturbances that create areas devoid of competitors will support the presence of this species.

The high fecundity and rapid growth means that *Capitella* is likely to be resilient to dredging disturbance. This group of species is often one of the first re-colonizers after sediment mobilization (Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 4.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 4.2a and are combined, as in Table 4.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 4.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 4.2a).

Table 4.1 *Capitella capitata* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	L-M (*)	VH (***)	L (*)	Due to fragility and environmental position this species is likely to be vulnerable to shallow disturbance which will kill and damage individuals. No evidence was found in the literature for direct impacts of surface abrasion. *Capitella capitata* thrive in the absence of intraspecific competition as early colonizers to benthic habitat patches that have been disturbed or otherwise defaunated as a result of environmental stress (Grassle and Grassle, 1974; McCall, 1977). Experimental studies using defaunated sediments have shown that on small scales *Capitella* can recolonise to background densities within 12 days (Grassle and Grassle, 1974; McCall, 1977). Resistance is predicted to be 'Low to Medium' to direct exposure to activities that disturb the surface. Based on the above evidence resilience is predicted to be 'Very High'. Based on combined resistance and resilience categories, sensitivity is assessed as 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L-M (**)	VH (***)	L (**)	Due to fragility and environmental position this species is likely to be vulnerable to shallow disturbance which will kill and damage individuals. The species was assessed as 'vulnerable' to dredging disturbance in the Genus Trait Handbook (MES Ltd, 2010) with high recoverability. This species has been categorised through literature and expert review, as AMBI fisheries Group IV - a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Based on environmental position and the review, resistance has been assessed as 'Low to Medium' and Resilience as 'Very High'. This species sensitivity is therefore considered to be 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm)	L-M (**)	VH (***)	L (**)	Evidence from MarLIN Ls.LMx.Mx.CirCer In Burry Inlet, Wales, tractor towed cockle harvesting led to a reduction in density of some species but

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		disturbance				*Capitella capitata* had almost trebled its abundance within the 56 days in the clean sandy area (Ferns et al. 2000). Individuals exposed to activities that lead to deep disturbance are likely to be killed; however, the removal of competitors and predators is likely to enhance recruitment so that recovery is likely to be rapid. Resistance is therefore categorised as 'Low to Medium' and recovery as 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	L-M (***)	VH (***)	L (***)	Chandrasekara and Frid (1996; cited in Tyler-Walters and Arnold, 2008) found that along a pathway heavily used for five summer months (ca 50 individuals a day) some species including *Capitella capitata* reduced in abundance while others increased in abundance, probably due to rapid recruitment and growth of more opportunistic species, even though their population experienced mortality. Recovery took place within 5-6 months. Based on the above evidence and information from the above disturbance assessments, Resistance is assessed as 'Low to Medium' and recovery as 'Very High'. Sensitivity is therefore considered to be 'Low'. It should be noted that the intensity of trampling in this study was high and that at lower levels sensitivity would be lower.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	L-M (*)	VH (***)	L (*)	No information found. Sensitivity assessment is inferred from surface disturbance assessments.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	VH (***)	L (*)	This species is infaunal, extraction of the sediment would remove the population and resistance is considered to be 'None', however if suitable sediments remain, or habitat rehabilitation occurs through natural processes, recovery would be predicted to be 'Very High'.
	Siltation (addition of fine sediments,	Physical effects resulting from addition of fine sediments,	L (*)	VH (***)	L (*)	This species has been categorised through expert and literature review, as AMBI sedimentation Group IV – A second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	pseudofaeces, fish food)	pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)				fluctuation in sedimentation (Gittenberger and van Loon, 2011). Experimental relaying of mussels on intertidal fine sand sediments increased fine sediment proportions and led to colonisation by *Capitella capitata* (Ragnarsson and Rafaelli, 1999). The effects of siltation will depend on the amount and rate that particles are added. The species is sedentary and adults are judged unlikely to have any mechanism to escape from large inputs. A deep covering of sediment will prevent feeding. Where inputs are at low rates and similar to background sediments then adults may be able to extend tubes to reach the surface to feed. Resistance to siltation is judged to be low with regard to the rapid addition of silts to a depth of <5cm although recovery is predicted to be rapid. Sensitivity is therefore assessed as 'Low'. At lower levels of siltation, sensitivity will be likely to be lower.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	VH (***)	L (*)	Four months after the deposition of large quantities of *Ulva* that reduced oxygen levels, populations of *Capitella capitata* had recovered (Dauer, 1984) As adults are sedentary and require access to the sediment interface to feed, smothering will occur where the surface is completely covered by impermeable materials. If pockets of fine sediment accumulate within the coarse materials then these areas may be re-colonised, otherwise recovery will depend on the re-instatement of suitable habitat. Complete and permanent smothering would exclude this species through substrate change; recovery would depend on the return of previous habitat conditions. Resistance is judged as 'None' with recovery as 'Very High' if habitat conditions are re-instated. If there was no habitat recovery then sensitivity would be 'Very High'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Noise					
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (***)	NS (*)	No evidence found. Based on broad habitat preferences including for areas with boulders, increased sediment coarseness was not judged to completely reduce habitat suitability for this species. An increase of sediment coarseness to sand would not exclude this species, based on published habitat preferences, but may have population level effects as habitat suitability may be reduced. Recovery would depend on the return of previous habitat conditions. Resistance is judged as 'High' with recovery as 'Very High', so that this species is categorised as 'Not Sensitive'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (***)	VH (***)	NS (***)	Experimental relaying of mussels on intertidal fine sand sediments increased fine sediment proportions and led to colonisation by Capitella capitata- (Ragnarsson and Rafaelli, 1999). Experimental studies have shown that *Capitella capitata* have increased in abundance where there has been a 2-3cm layer of fine resuspended and re-settled sediment (McCall, 1977). Species sensitivity is assessed as 'Not Sensitive' as fine sediments provide suitable habitat. Siltation effects are discussed above, and organic enrichment and anoxia effects that may be associated with increased siltation are assessed below.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (***)	NS (*)	Increases in water flow above the critical erosion rate would re-suspend fine sediments and would wash-out the worms from their habitat. Increased sediment coarseness would reduce habitat suitability (as assessed above). Decreases in flow rate (which are more likely to occur through aquaculture infrastructure) may lead to increased deposition of fine sediments and organic matter that may enhance food supply.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Capitella are assessed as 'Not Sensitive to changes (decreases) in water flow rate as the species is typical of sheltered, depositional environments with lower water flows
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (***)	NS (*)	No evidence found. Where increased turbidity results from organic particles then subsequent deposition may enhance food supply favouring this species. Alternatively if turbidity results from an increase in suspended inorganic particles then energetic costs may be imposed on these species as feeding becomes less efficient, reducing growth rates and reproductive success. Lethal effects are considered unlikely given the occurrence of this species in estuaries where turbidity is frequently high from suspended organic and inorganic matter. Based on the above considerations, Resistance is categorised as 'High' and Recovery as 'Very High'. Reduction of light penetration from increased turbidity is assessed below in the 'shading pressure', increased siltation linked to increased supply of particles is considered above.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (***)	NS (*)	No evidence found. Decreased turbidity from a reduction in inorganic particles is not predicted to directly affect this species A reduction in suspended organic particles may reduce food supply impacting growth rates and reproduction, such effects are predicted to be sub-lethal. Resistance is predicted to be 'High' and recovery 'Very High' leading to an assessment of 'not sensitive'. Indirect effects of reduced turbidity such as an increase in predation from enhanced prey location by fish etc. are possible but not considered here.
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (***)	NS (***)	This species has been categorised through expert and literature review as AMBI Organic enrichment Group V - A first order opportunistic species, these are deposit feeders that proliferate in reduced sediments (Borja et al. 2000; validated by Gittenberger and van Loon, 2011). Dense *C. capitata* populations are frequently located in areas with greatly elevated organic content, even though eutrophic sediments are often anoxic and highly sulfidic (Tenore, 1977; Warren, 1977; Tenore and Chesney, 1985; Bridges et al. 1994) e.g. sewage enriched sediments in Kiel Bay (Gray, 1979).
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Benthic fauna underneath floating salmon farm cages in a Scottish sea loch showed marked changes in species number, diversity, faunal abundance and biomass in the region of the fish farm (Brown et al. 1987). Four 'zones' of effect identified: i) directly beneath and up to the edge of the cages there was an azoic zone, ii) from the edge of the cages out to 8m there was a highly enriched zone dominated by *Capitella capitella* and *Scolelepis fuliginosa*. Beneath lines growing mussels 1+ years in age, the benthic community was dominated by *C. capitata*, (Callier et al. 2007) A study undertaken by Haskoning (2006) to investigate the impact of fish farm deposition on maerl beds at three fish farms in Scotland (Shetland, Orkney and South Uist) found that evidence of gross organic enrichment was recorded up to 100m away from the cage edges. The organic enrichment was found to affect a number of different aspects of the benthic community. Many faunal groups were much more diverse at the reference sites than on maerl beds close to the fish farms. Marked reductions in species diversity of infaunal communities associated with the maerl were recorded around the fish farms in Shetland and Orkney. Organic enrichment effects on community structure were also noted around the fish farms in Shetland and South Uist. *Capitella capitata* increased greatly in abundance near the fish farms. Above evidence indicates that increased organic matter levels associated with aquaculture can favour this species, resistance is therefore considered to be 'High', resilience 'Very High' and the species is 'Not Sensitive'. It should be noted however that sensitivity is greater to gross organic enrichment levels within the spatial footprint of activities.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (***)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance was assessed as 'High' and resilience as 'Very High' so that this species is categorised as 'Not Sensitive'.
	Decrease in	Hypoxia/anoxia of	M (***)	VH (***)	L (***)	Dense *Capitella capitata* populations are frequently located in areas with greatly elevated organic

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	oxygen levels - Sediment	sediment				content, even though eutrophic sediments are often anoxic and highly sulfidic (Tenore, 1977; Warren, 1977; Tenore and Chesney, 1985; Bridges et al. 1994).
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	M (***)	VH (***)	L (***)	Following anoxia or, in conditions of moderate hypoxia, resistance is predicted to be 'Medium' and recovery 'Very High' providing a sensitivity assessment of 'Low'.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock	H (*)	VH (*)	NS (*)	No evidence found. *Crepidula fornicata* and *Crassostrea gigas* are the non-native species most likely to be introduced by aquaculture and become established in habitats in which this species is found. These may stabilise sediments and enhance food supply to this species by deposition of organic matter. *Capitella* is assessed as 'Not Sensitive' to this pressure, resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Potential impacts from commercial fisheries within this species' habitats are considered in the physical disturbance pressures above. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Removal of	Alteration of habitat	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Non-target species	character, e.g. the loss of structure and function through the effects of removal of target species on non-target species				worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	L-M (**)	VH (***)	L (***)	Mendez (2006) showed that the effects of exposing the deposit feeding polychaete *Capitella* to sediment spiked with environmentally relevant concentrations of teflubenzuron (another chemical used to control infestations of sea-lice) caused mortality in one species of *Capitella* and reduced the egestion rate of another. Based on the above information, resistance is therefore described as 'Low-Medium' and recovery as 'Very High' so that sensitivity is assessed as 'Low'.
	Introduction of hydrocarbons	Introduction of hydrocarbons	H (***)	VH (***)	NS (***)	Described by Hiscock et al. (2005) from Levell et al. (1989) as an extremely tolerant taxa, found in high abundances in the transitional zone along hydrocarbon contamination gradients surrounding oil platforms. After a major spill of fuel oil in West Virginia *Capitella* increased dramatically alongside large increases in *Polydora ligni* and *Prionospio* sp. (Sanders et al. 1972; cited in Gray 1979). Experimental studies adding oil to sediments have found that *C. capitata* increased in abundance initially although it was rarely found in samples prior to the experiment (Hyland, 1985). Based on the evidence above and the opportunistic life history traits exhibited by this species, resistance was assessed as 'High' and recovery as 'Very High' providing an assessment of 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of antifoulants	Introduction of antifoulants	H (***)	VH (***)	NS (***)	Tests of copper toxicity have been carried out on this species although comparison of results requires caution due to potential differences in the protocols used and the inherent problems in extrapolating laboratory results to the marine environment, as laboratory tests in clean water do not reflect lowered toxicity in the marine environment due to the buffering effects of carbon and sulphide which render copper non-labile (not bioavailable) and the influence of water pH, hardness, temperature and salinity etc. Laboratory tests carried out in water may not reflect sediment conditions where, again, copper toxicity and exposure is determined by a number of parameters including the degree to which it is adsorbed on to particles selected as food for deposit feeders. A 2-year microcosm experiment was undertaken to investigate the impact of copper on the benthic fauna of the lower Tyne Estuary (UK) by Hall and Frid (1995). During a 1-year simulated contamination period, 1 mg l^{-1} copper was supplied at 2-weekly 30% water changes, at the end of which the sediment concentrations of copper in contaminated microcosms reached 411 µg g^{-1}. Toxicity effects reduced populations of the four dominant taxa, including *Capitella capitata*. When copper dosage was ceased and clean water supplied, sediment copper concentrations fell by 50% in less than 4 days, but faunal recovery took up to 1 year, with the pattern varying between taxa. Since the copper leach rate was so rapid it is concluded that after remediation, contaminated sediments show rapid improvements in chemical concentrations, but faunal recovery may be delayed with experiments in microcosms showing faunal recovery taking up to a year. Rygg (1985) classified *Capitella capitata* as a highly tolerant species, common at the most copper polluted stations (copper > 200 mg Kg^{-1}) in Norwegian fjords. Based on a sediment quality guideline of 100 mg Kg^{-1}, the evidence from Rygg (1985) indicates that the sediment quality guideline of 100 mg Kg^{-1} would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited it is assessed as 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Barrier to species movement				NA	Not relevant to Annex I habitats and species.

Table 4.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 4.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 4.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	**(1)	**	N/A
Deep Disturbance	**(1)	**	N/A
Trampling - Access by foot	***(1)	**	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	***(1)	**	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	***	***	***

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Organic enrichment of sediments	***	***	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***	**	***
Decrease in oxygen levels - Water column	***	**	***
Genetic impacts			
Introduction of non-native species	Not assessed. No evidence found.		
Introduction of parasites/pathogens			
Removal of Target Species			
Removal of Non-target species			
Ecosystem Services - Loss of biomass			
Introduction of medicines	**(1)	***	N/A
Introduction of hydrocarbons	***(3)	**	**
Introduction of antifoulants	** (1)	**	N/A
Prevention of light reaching seabed/features			
Barrier to species movement			

References

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40: 1100-1114.

Bridges, T.S., Levin, L.A., Cabrera, D. and Plaia, G. 1994. Effects of sediment amended with sewage, algae, or hydrocarbons on growth and reproduction in two opportunistic polychaetes. Journal of Experimental Marine Biology and Ecology 77: 99-119.

Brown, J.R., Gowen, R.J. and McLusky, D.S. 1987. The effect of salmon farming on the benthos of a Scottish sea loch. Journal of Experimental Marine Biology and Ecology 109: 39-51.

Callier, M.D., McKindsey, C.W. and Desrosiers, G. 2007. Multi-scale spatial variations in benthic sediment geochemistry and macrofaunal communities under a suspended mussel culture. Marine Ecology Progress Series 348: 103-115.

Dauer, D.M. 1984. High resilience to disturbance of an estuarine polychaete community. Bulletin of Marine Science 34: 170-174.

Ferns, P.N., Rostron, D.M. and Siman, H.Y. 2000. Effects of mechanical cockle harvesting on intertidal communities. Journal of Applied Ecology 37: 464-474.

Gittenberger, A. and van Loon, W.M.G.M. 2011 Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08.

Grassle, J.F. and Grassle, J.P. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. Marine Research 32: 253-284.

Grassle, J.F. and Grassle, J.P. 1976. Sibling species in the marine pollution indicator (*Capitella*) (Polychaeta). Science 192: 567-569.

Gray, J.S. 1979. Pollution-induced changes in populations. Philosophical Transcriptions of the Royal Society London. Series B 286: 545-561.

Hall. J.A. and Frid, C.L.J. 1995. Responses of estuarine benthic macrofauna in copper-contaminated sediments to remediation of habitat quality. Marine Pollution Bulletin 30: 694-700.

Haskoning UK Ltd. 2006. Investigation into the impact of marine fish farm deposition on maerl beds. Scottish Natural Heritage Commissioned Report No. 213 (ROAME No. AHLA10020348).

Hiscock, K., Langmead, O., Warwick, R. and Smith, A. 2005. Identification of seabed indicator species to support implementation of the EU Habitats and Water Framework Directives. Second edition. Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Plymouth: Marine Biological Association. JNCC Contract F90-01-705. 77 pp.

Hyland, J.K. Hoffman, E.J. and Phelps, D.K. 1985. Differential responses of two nearshore infaunal assemblages to experimental petroleum additions. Journal of Marine Research 43: 365-396.

Levell, D., Rostron, D. and Dixon, I.M.T. 1989. Sediment macrobenthic communities from oil ports to offshore oilfields. In: Dicks, B. (Ed.) Ecological impacts of the oil industry, pp. 97- 134. London: Wiley.

Madsen, S.D., Forbes, T.F. and Forbes, V.E. 1997. Particle mixing by the polychaete *Capitella* species I: Coupling fate and effect of a particle-bound organic contaminant (fluoranthene) in a marine sediment. Marine Ecology Progress Series 147: 129-142.

McCall, P.L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. Marine Research 35: 221-266.

Mendez, N. 2006. Effects of teflubenzuron on sediment processing by members of the *Capitella* species complex. Environmental Pollution 139: 118-124.

Mendez, N., Romero, J. and Flos, J. 1997. Population dynamics and production of the polychaete *Capitella capitata* in the littoral zone of Barcelona (Spain, NW Meditterannean). Journal of Experimental Marine Biology and Ecology 218: 263-284.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Pearson, M., Pearson, T.H., 1991. Variation in populations of *Capitella capitata* (Fabricius, 1780) (Polychaeta) from the West coast of Scotland. Ophelia Supplement 5: 363-370.

Ragnarsson, S.A. and Rafaelli, D. 1999. Effects of the mussel *Mytilis edulis* L. on the invertebrate fauna of sediments. Journal of Experimental Marine Biology and Ecology 241: 31-43.

Riley, K. and Bilewitch, J. 2009. *Capitella capitata*. Gallery worm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 09/02/2012]. Available from:
http://www.marlin.ac.uk/speciesfullreview.php?speciesID=2875.

Rygg, B.1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

Tenore, K.R. 1977. Growth of *Capitella capitata* cultured on various levels of detrit.us derlved from different sources. Limnology and Oceanography 22: 936-941.

Tenore, K.R. and Chesney Jr., E.J. 1985. The effects of interaction of rate of food supply and population density on the bioenergetics of the opportunistic polychaete, *Capitella capitata* (type I). Limnology and Oceanography 30: 1188-1195.

Tyler-Walters, H. and Arnold, C. 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth [Contract no. FC 73-03-327].

Warren, L.M. 1977. The ecology of *Capitella capitata* in British waters. Journal of the Marine Biological Association of the United Kingdom 57: 151-159.

5. Species: *Cerastoderma edule*

Species Description

- Common name: Cockle;
- Size: 3-38 mm. Growth rates of *Cerastoderma edule* vary with age, year, season, geographical location, tidal height, temperature regime, food availability, population density and interspecific competition (Tyler-Walters, 2007);
- Environmental Position: Infauna;
- Feeding: Active suspension feeder which typically feeds on phytoplankton, zooplankton and organic particulate matter;
- Longevity: *Cerastoderma edule* may live for up to 9 years or more in some habitats but 2-4 years is normal;
- Body type: The shell is solid, thick, equivalve, globular and broadly oval in outline; up to 5 cm long but usually less;
- Inhabits the surface of sediments, burrowing to a depth of no more than 5 cm;
- Habitat: Inhabits the surface layer of sediments, burrowing to a depth of no more than 5 cm. Found on clean sand, muddy sand, mud or muddy gravel from the middle to lower intertidal, sometimes subtidally. Usually live at salinities between 15 -35 psu but can tolerate salinities as low as 10 psu; and
- Often abundant in estuaries and sheltered bays, and population densities of 10,000 per m^2 have been recorded (Tyler-Walters, 2007).

Recovery

Recovery is dependant on recruitment of spat or migration (active or passive) from the surrounding substratum. Coffen-Smout and Rees (1999) reported that cockles could be distributed by flood and ebb tides, but especially flood tides (by rolling around the surface) up to 0.45 m on neap tides or between 94 m and 164 m on spring tides and could colonize cleared areas at a rate of 2.2-12 individuals/m^2 /14 days. It seems likely therefore that the population could recover within a year, however, given the sporadic nature of recruitment in *C. edule*, recovery may be more protracted.

Recoverability: *Cerastoderma* has a life span of 6-10 years (although most live for 3-4 years) and reaches sexual maturity between 1 and 2 years. Cockles generally spawn over the summer and fertilization is external. Males may release about 15 million sperm per second while females release about 1900 eggs per second. Gamete viability is short and fertilization is reduced 50% in 2 hrs; no fertilization occurs after 4-8 hrs. Settlement and recruitment are sporadic, varying in time and location, which has a significant impact on the dynamics of *Cerastoderma* populations and can influence recoverability after aggregate extraction (http://www.genustraithandbook.org.uk/genus/cerastoderma).

André and Lindegarth (1995) noted that fertilization efficiency was dependent on sperm concentration so that at high water flow rates fertilisation was only likely between close individuals. However, this may be compensated for by high population densities and synchronous spawning of a large proportion of the population.

Recruitment-related information from MarLIN (Tyler-Walters, 2007, references therein).

Settlement and subsequent recruitment has a significant impact on the dynamics of *C. edule* populations, in many but not all circumstances (Olaffsson et al. 1994). Settlement and recruitment is sporadic and varies with geographic location, year, season, reproductive condition of the adults and climatic variation. Factors reported to affect recruitment include:

- Geographical location (Ducrotoy et al. 1991; Olaffsson et al. 1994);
- Annual variation in climate. Ducrotoy et al. (1991) reported the variation in annual recruitment between years for several sites in Europe, and noted a correlation between good recruitment and a previous severe winter (presumably due to high adult mortality, reduced population density of adults and reduced numbers of infaunal predators), in many but not all cases;
- Good recruitment was also observed after heavy storm surges reduced the adult population (Ducrotoy et al. 1991);
- Post-settlement erosion and surface sediment erosion by currents and storms. Juveniles may be transported by currents until 2 mm in size and high densities of juveniles may be swept away by winter storms resulting in subsequent patterns of adult distribution (Olaffsson et al. 1994);
- Post-settlement mortalities of 60-96% have been reported, resulting from intra- and inter-specific mortality and predation (Sanchez-Salazar et al. 1987a; Montaudouin and Bachelet, 1996; André et al. 1993; Guillou and Tartu, 1994);
- Adult suspension feeders, including adult cockles, may reduce settlement by ingestion of settling larvae and juveniles or smothering by sediment displaced in burrowing and feeding (Montaudouin and Bachelet, 1996). Therefore, recruitment may be dependent on adult population density (André et al. 1993). André et al. (1993) observed that adults inhaled 75% of larvae at 380 adults/m^2, which were also ingested. However, Montaudouin and Bachelet (1996) noted that adults that inhaled juveniles, rejected them and closed their siphons but that rejected juveniles usually died;
- Predation (see distribution) (Dame, 1996; Sanchez-Salazar et al. 1987a); and
- Guillou and Tartu (1994) noted that spat also suffered from mortality in their first year in the spring following their settlement, even through food was available, probably due to exhausted energy reserves (after winter) and spring predation from shore crabs.

Ducrotoy et al. (1991; Figure 14) identified 'crisis', 'recovery', 'upholding' and 'decline' phases in the dynamics of *C. edule* populations. Each phase is characterised by:

- 'Crisis': a few age classes and successive spawnings and maximal growth due to low density;
- 'Recovery': single high density recruitment to first year class (breeding stocks may be synchronised by severe temperatures);
- 'Upholding': several age classes, higher densities of older age classes, seasonal recruitment, and low growth rate; and
- 'Decline': reducing abundance, adult mortality or unsuccessful recruitment due to climatic factors, lower food levels, competition or parasitic infection.

Ducrotoy et al. (1991) suggested that increased growth rate indicated instability. Any population may exhibit these characteristics at different times or location (Tyler-Walters, 2007).

Coffen-Smout and Rees (1999) noted that cleared areas of sediment could be recolonized by 2.2 -12 cockles /m² / 14 days.

The annual recruitment of some bivalves, including *C. edule*, *Mya arenaria* and *Macoma balthica* are characterised by substantial year to year variability. The consequence of this variability in the early benthic stages explains most of the subsequent between year variability in numerical abundance, biomass and production of these species (Beukema and Dekker, 2005 and references therein).

Variability in recruitment is not fully understood but factors that may play a role include climate changes, variability in post-larvae predation (e.g. by shrimp and shore crabs), effects of intensive bottom-disturbing fisheries (e.g. for cockles) and/or changes in sediment composition (through the loss of enriching faeces and pseudofaeces) (Beukema and Dekker, 2005).

A substantial part of bivalve recruitment variability appears to be climate related (Beukema and Dekker, 2005 and references therein) and for some species, including *C. edule* and *M. balthica*, better recruitment has been observed after cold winters compared to mild winters. The mechanism behind the influence of winter severity on recruitment success is only partly known, and most studies are limited to *M. balthica* in which low egg production after mild winters (Honkoop et al. 1998) appears to play only a minor role (Beukema et al. 1998). Instead, survival during the first few months of life appears to be the decisive factor for recruitment success (Beukema and Dekker, 2005).

Beukema and Dekker (2005) investigated possible causes of frequent recruitment failure in bivalves in the Wadden Sea by comparing long term data sets of annual abundance of spat of *C. edule*, *M. arenaria* and *M. balthica* in a tidal flat area in the western most part of the Wadden Sea. Recruitment success of all three species declines significantly over the period analysed (1973-2002), particularly at sampling sites characterised by low intertidal levels and sandy sediments. In these areas, there was a high biomass of the shrimp *Crangon crangon*, a predator of bivalve post-larvae and annual recruitment of the three bivalve species was negatively related to shrimp biomass at the time of settlement. The only areas where no decline in bivalve recruitment was found were high intertidal flats which had low shrimp biomass. The timing of the changes in recruitment of the three bivalve species coincided with the start of the change in climate regime (1988) as opposed to the start of major sediment changes (1990). As such, the authors concluded that recruitment trends in the Wadden Sea were governed primary by natural processes, and in-particular predation pressure at early benthic stages, which in turn appeared to be largely governed by the warming climate. This theory was supported by the fact that the recent decline of bivalve recruitment (and their shoreward shift to higher and muddier tidal flats) was not restricted to the western half of the Dutch Wadden Sea and that such geographically large scale events pointed to climate-related factors as opposed to local man-induced factors (i.e. fisheries).

Investigating the mechanism underlying enhanced recruitment of bivalve species including *C. edule* after severe winters, Strasser and Gunther (2001) found no evidence that high bivalve recruitment after severe winters is caused by enhanced larval supply; total and peak abundance of bivalve larvae studied, including *C. edule*, were 3-6 times lower after the severe winter than after the mild winter. The larval supply of a key predator *Carcinus maenas* was lower after the severe winter, supporting the theory that reduced epibenthic predation is an important factor in high bivalve recruitment after severe winters.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 5.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 5.2a and are combined, as in Table 5.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 5.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 5.2a).

Table 5.1 *Cerastoderma edule* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	M (*)	H-VH (*)	L (*)	The assessment of sensitivity to surface abrasion is based on that for trampling. Cockles live close to the surface and hence abrasion at the surface is likely to damage a proportion of the population, with damage depending on the force exerted. Surface abrasion is considered to remove <25% of the population, with recovery taking place within <2 years through recruitment of juveniles and within 6 months through adult migration. Resistance is therefore assessed as 'Medium' and recovery as 'High-Very High' so that sensitivity is therefore assessed as 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L (***)	VH-M (*)	L-M (*)	Based on evidence below, shallow disturbance from fishing gears etc. leads to cockle damage, displacement and removal. This species has been categorised through expert judgement and literature review as AMBI fisheries Group IV - a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Information from MarLIN (Tyler-Walters, 2007, references therein). With respect to displacement, cockles are capable of burrowing rapidly into the substratum and >50% burrowed into the substratum within 1 hour in experimental trials (Coffen-Smout and Rees, 1999), although this rate was inhibited by prior disturbance. Brock (1979) reported that 80% began to burrow within 60 min and 50% had successfully burrowed into sediment within 60 min. He also noted that young cockles could burrow quickly, and were nearly buried within 5 min. Disturbance and displacement may also reduce the growth rates (Orton, 1926) or interfere with the reproductive cycle (Hummel and Bogaards, 1989). Cockles on the surface of the sediment, are at an increased risk of predation, depending on the time of day, light, and tide. However, populations of cockles are probably moved, buried or displaced naturally by storms and once exposed can burrow relatively quickly into

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						suitable sediment, and therefore are probably adapted to being displaced. Reduction in the local population density may enable good recruitment in following years, dependent on larval supply (Tyler-Walters, 2007). This assessment is based on the evidence presented below in deep disturbance due to the overlap in activities and impacts.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	L (***)	VH-M (***)	L-M (***)	Information from MarLIN (Tyler-Walters, 2007, references therein). *Mechanical dredging* Cockles are often damaged during mechanical harvesting, e.g. 5-15% were damaged by tractor dredging (Cotter et al. 1997) and ca 20% were too damaged to be processed after hydraulic dredging (Pickett, 1973). In the intertidal, mechanical cockle harvesting in muddy sand reduced the abundance of *C. edule* by ca 34%. Populations of *C. edule* had not recovered their original abundance after 174 days (Ferns et al. 2000). Hall and Harding (1997) examined the effects of hydraulic and tractor dredging of *C. edule* on macrobenthic communities. They concluded that although significant mortality of *C. edule* and other infauna occurred, recovery was rapid and the overall effects on populations was low. Hall and Harding (1997) found that abundance had returned to control levels within about 56 days and Moore (1991) also suggested that recovery was rapid. Tractor dredging leaves visible tracks in the sediment, which can act as lines for erosion and accelerate erosion of the sediment (Moore, 1991; Gubbay and Knapman, 1999). In most cases subsequent settlement was good especially in areas of previously high population density; however, Franklin and Pickett (1978) noted that subsequent spat survival was markedly reduced. Cotter et al. (1997) reported appreciable loss of spat and juveniles, partly due to increased predation of exposed juveniles. Pickett (1973) also noted reduced survivability of 1-2 year old cockles after hydraulic dredging (Tyler-Walters, 2007). Rostron (1995) carried out experimental dredging of sandflats with mechanical cockle dredge. Two distinct sites were sampled; Site A: poorly sorted fine sand with small pools and *Arenicola marina* casts

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						with some algal growth, and Site B: well sorted fairly coarse sand, surface sediment well drained and rippled as a result of wave activity. At both sites *C. edule* reduced after dredging but recovery was rapid at Site B (no difference between control and experimental plots after 14 days), whilst at Site A significant reduction in numbers compared with the control were still apparent up to six months post-dredging. Information from MarLIN (Tyler-Walters, 2007, references therein). *Simulated fisheries impact* Coffen-Smout (1998) studied simulated fisheries impacts *on C. edule* and reported that the cockle shell withstood between 12.9 and 171.4 newtons (N) of force depending on shell size and position of load (a 1 kg weight exerts about 10 N). *Bait digging* Jackson and James (1979) pointed out that bait digging disturbs sediment to a depth of 30-40 cm and probably buries many cockles below 10cm and surface exposure of others that are then taken by predators. They suggested that bait digging was involved in the decline in the cockle fishery on the north Norfolk Coast in the 1950s and 60s. Fowler (1999) cites reports of 90% mortality of cockles in areas affected by bait digging, recolonization occurring three months after bait digging, although the cockle population structure was still different from undisturbed areas. *Recovery* Time of year of exploitation will influence recovery and avoiding seasonal spawning or larval settlement periods is likely to reduce the time taken for recovery (Gubbay and Knapman, 1999). Cockle beds have been mechanically fished for decades but several beds are closed from time to time depending on settlement and recruitment to the population, which is sporadic. Recovery may take less than a year in years of good recruitment but longer in bad years (Tyler-Walters, 2007). Hand-raking for cockles was shown not to influence the re-burial rate of cockles in Strangford Lough, Northern Ireland (McLaughlin et al. 2007).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above evidence resistance to deep disturbance was assessed as 'Low', (mortality of 25-75% of populations, although this will be mediated by the type of disturbance and whether cockles are being harvested. Recovery will be influenced by a range of factors as outlined in the introduction section. Small patches are likely to be in-filled by adult cockle movement, large patches will recover through larval recruitment, which again is subject to many factors, and may be improved by the removal of adult cockles. Recovery is therefore assessed as a range from 'Very-High' (within 6 months as described by Hall and Harding, 1997, although population structure may be different), to medium (within 3-5 years) to take account of recruitment variability and return of normal age structure. Sensitivity is therefore categorised as ranging from 'Low to Medium'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	L (***)	VH-H (***)	L-M (***)	Rossi et al. (2007) conducted experimental trampling on a mudflat (5 people, 3-5 hours, twice a month between March and September). Mobile fauna were not affected; however, abundance of adult *C. edule* were sharply reduced, probably due to the trampling directly killing or burying the animals, resulting in asphyxia. However, no effect was observed on small (<12 mm) individuals of *C. edule*. The authors suggested that this was because the experiment was conducted in the reproductive season for these species and hence there were juveniles present in the water column to replace individuals displaced by trampling. Resistance to trampling was assessed as 'Low' (mortality of 25-75%) and recovery as 'Very High' to 'High' (as small individuals were unaffected and these will contribute to recovery) so that sensitivity was assessed as 'low to medium'.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	L (*)	VH-M (***)	L-M (*)	No information found. Due to the greater weight of vehicles and the potential for sub-surface penetration and damage this assessment was based on deep disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	VH-M (***)	L-H (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). Loss of the substratum will also remove the resident population of *C. edule*. Hall and Harding (1997) found that *C. edule* abundance had returned to control levels within about 56 days after significant mortality due to suction dredging, and Moore (1991) also suggested that recovery was rapid. *Cerastoderma edule* as an infaunal species is assessed as having no resistance to extraction, recovery

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						is assessed as 'Very High' to 'Medium', infilling of local cleared areas is likely to be rapid where sediments are mobile and adult migration replaces lost individuals, however large scale impacts may take longer to recover from and recruitment can be episodic.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	M (***)	VH (***)	L (***)	This species has been categorised through expert judgement and literature review as AMBI sedimentation Group II – species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Information from MarLIN (Tyler-Walters, 2007, references therein). *Cerastoderma edule* has short siphons and needs to keep in contact with the surface of the sediment. Richardson et al. (1993(b)) reported that they burrow quickly to the surface if covered by 2 cm of sediment (under laboratory or field conditions) when emersed (45% of cockles emerged onto the surface in light and 60% in darkness). In light the cockles quickly re-burrow, however, in darkness they move across the substratum, partly to increase the distance between neighbours. Richardson et al. (1993b) suggested that surface movement in darkness, perhaps accompanied by passive movement if rolled by flood and ebb tides might be a response to avoiding areas of disturbed sediment. Jackson and James (1979) reported that few *C. edule* buried to 10 cm in sediment were able to burrow to the surface whereas most buried to a depth of 5 cm could reach the surface. In another experiment, *C. edule* buried 10cm in sandy substrate was able to burrow near to the surface, but still suffered 83% mortality in 6 days, whereas in muddy substrates all cockles died between 3 and 6 days. Experimental bait digging resulted in significant mortality in dug areas rather than undug areas (48% mortality in 9 days to a maximum of 85% after 11 days) probably due to smothering (Jackson and James, 1979). Smaller individuals were more likely to die than larger ones. Therefore, cockles are probably of intermediate intolerance to smothering by 5 cm of sediment although smaller individuals may be more intolerant. No information on smothering and spat was found. In years of good recruitment recovery may occur within a year; however, recruitment is sporadic and may take longer in 'bad' years. Cockles are assessed as having 'Medium' resistance to siltation, (this would be 'Low' where siltation in a single event buried the cockles to 10cm) and recovery is assessed as Very High, due to lack of impact, a more conservative assessment of recovery would still categorise sensitivity as 'Low'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	VH-M (***)	L-M (*)	Smothering by an impermeable layer would prevent *C. edule* extending siphons to the surface to respire and feed, killing the population. Resistance is therefore assessed as 'None' and recovery (following habitat recovery) is assessed as 'Very High' to 'Medium' (depending on whether recovery is via adult migration or recruitment of juveniles which may be episodic). Sensitivity is therefore categorised as 'Low to High'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual - Boat/ vehicle movements				NS	Not sensitive.
	Visual - Foot/ traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N (*)	VH-M (***)	L-H (*)	No information found. Based on habitat preferences increased sediment coarseness (greater than sand particle sizes, leading to a re-classification of the habitat type) would exclude this species. Resistance is therefore assessed as 'None' and recovery (following habitat recovery) is assessed as 'Very High to Medium' (depending on whether recovery is via adult migration or recruitment of juveniles which may be episodic). Sensitivity is therefore categorised as 'Low to High'.
	Changes in sediment composition - Increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (***)	NS (*)	Based on the presence of *C. edule* in mud biotopes (LS.LMu.MEst.HedMac; Connor et al. 2004) resistance to increased fine sediment is assessed as 'High' and recovery as 'Very High', so that this species is considered to be 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	M (*)	VH (*)	L (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). The hydrodynamic regime strongly influences the sediment structure, oxygenation, food supply and recruitment. Increasing water flow may remove adult cockles from the sediment surface and carry them to unfavourable substratum or deep water, where they may be lost from the population. Coffen-Smout and Rees (1999) reported that cockles could be distributed up to 0.45 m on neap tides or between 94 m and 164 m on spring tides. Newly settled spat and juveniles (<4.8 mm) are capable of bysso-pelagic dispersal. Therefore, water flow rates probably affect the distribution and dispersal of juveniles and adults. *Cerastoderma edule* prefers muddy-sand to sandy-mud substrates. Decreasing water flow rate may increase siltation and favour muddy substrates that are unsuitable for *C. edule*. Boyden and Russell (1972) suggested that lack of tidal flow may exclude *C. edule* possibly due to reduced food availability as suggested by Brock (1979). Therefore, decreased water flow rates may exclude *C. edule* from the affected area. Based on the above information decreases in flow rate (which are more likely to occur through aquaculture infrastructure) may lead to increased deposition of fine sediments and organic matter that may enhance food supply. *Cerastoderma edule* occur in muddy sands in areas that are sheltered and where fine sediments are deposited. Some resistance to reductions in water flows is therefore suggested and resistance is assessed as 'Medium' and recovery as 'Very High' where this occurs through adult migration. Sensitivity is therefore assessed as 'Low'. Sensitivity to water flow changes that substantially alter habitat character will be high (see changes in sediment composition above).
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). Increasing total particulate concentrations have been shown to decrease clearance rates and increase pseudofaeces production (Navarro et al. 1992; Navarro and Widdows, 1997). Filtration rates increased with particulate concentration until 300 mg/l at which concentration filtration rates abruptly declined. Pseudofaeces production was triggered by concentrations of total particulate matter of 1.5 mg/l (Navarro et al. 1992) or 4.8 mg/l (Navarro and Widdows, 1997). However, the absorption efficiency remained independent of particulate concentration over a large range but reduced at concentrations above 250 mg/l (Navarro and Widdows, 1997). Navarro and Widdows (1997) concluded that *C. edule*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						was well adapted to living in turbid environments such as intertidal mudflats. Increased siltation and suspended sediment concentration results in increased pseudofaeces production and concomitant loss of energy and carbon as mucus. Therefore, *C. edule* probably has a low intolerance to increased suspended sediment. Increasing turbidity may reduce phytoplankton productivity and hence decrease food availability, however *C. edule* is capable of ingesting organic seston and is adapted to life in sedimentary and estuarine conditions where turbidity is high (Navarro and Widdows, 1997). Therefore, *C. edule* is probably tolerant to changes in turbidity (Tyler-Walters, 2007). Obligate suspension feeders such as *C. edule* are most likely to be adversely affected by an increase in suspended sediment. The feeding and respiration structures risk becoming clogged thus potentially impairing growth and reproduction (Grant and Thorpe, 1991; Navarro and Widdows, 1997). Clearance rate depends on seston concentration and composition; clearance rates are reduced at increased TPM concentrations (Prins et al. 1991; Iglesias et al. 1996). Based on the above evidence *C. edule* is assessed as having 'High' resistance to increased turbiditiy (effects are considered to be sub-lethal' and recovery is assessed as 'Very High' , this species is therefore considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	A decrease in turbidity and hence increased light penetration may result in increased phytoplankton production and hence increased food availability for suspension feeders, including *C. edule.* Therefore, reduced turbidity may be beneficial. In areas of high suspended sediment, a decrease may result in improved condition and recruitment due to a reduction in the clogging of filtration apparatus of suspension feeders and an increase in the relative proportion of organic particulates. However, a decrease in suspended organic particles in some areas may reduce food availability resulting in lower growth or reduced energy for reproduction. *Cerastoderma edule* was assessed as having 'High' resistance to decreased turbidity and 'Very High' recovery, so that this species was assessed as 'Not Sensitivie'. However, long-term decreases from competition by cultivated bivalves may have population level effects. See removal of primary

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						production, below.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). Changes in the nutrient concentrations (e.g. nitrogen and phosphates) are likely to have indirect rather than direct affects on *C. edule*. Increased levels of nutrients at low level may increase phytoplankton productivity and increase food availability for *C. edule*. However, higher nutrient inputs are associated with eutrophication, resulting in increased oxygen consumption and decreased oxygen concentration. Rosenberg and Loo (1988) suggested that the mass mortalities of *C. edule* observed in Laholm Bay, western Sweden during the 1980s was correlated with increased nutrient levels, and associated decrease in oxygen levels during the this period (see oxygenation below). However, no direct causal link was established. It is likely that increased nutrient levels leading to eutrophication may contribute indirectly to mass mortalities in *C. edule* populations (Tyler-Walters, 2007). As *C. edule are* not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton and algal detritus may be utilised as food by this genus. This species is therefore considered to be 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (**)	VH (**)	NS (**)	This species has been categorised through expert judgement and literature review as AMBI Group III - a 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). They are surface deposit-feeding species (Borja et al. 2000; validated by Gittenberger and van Loon, 2011). Where high levels of organic enrichment occur, bacterial demand may lead to decreases in oxygen (as assessed below). Based on the reviews by Borja et al. (2000) and Gittenberger and van Loon (2011), *Cerastoderma edule* are considered to have 'High' resistance to increased organic matter and subsequently, 'Very High' recovery. This species is therefore considered to be 'Not Sensitive'.
	Increased removal of primary	Removal of primary production above background rates by	M-H (*)	VH-M (*)	L-NS (*)	Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (cited from Hartnoll, 1998). Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	production - Phytoplankton	filter feeding bivalves				(http://www.farmscale.org/), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters. Resistance to increased competition was assessed as medium to high (ranging from no lethal effect to mortality of <25% of population) and recovery as very high to medium, so that sensitivity was categorised as 'low to not sensitive'. Increased clearance rates of suspended sediments by suspended bivalves may enhance local primary production compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	L (***)	H-VH (*)	L-M (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). Rosenberg et al. (1991) reported 100% mortality of *C. edule* exposed to 0.5-1.0ml/l oxygen for 43 days and 98% mortality after 32 days. *Cerastoderma edule* migrated to the surface of the sediment in response to decreased oxygen concentrations. Theede et al. (1969) reported 50% mortality after 4.25 days at 1.5 mg/l oxygen. Theede et al. (1969) also noted that *C. edule* only survived 4 days exposure to 0.0-6.1 cm³/l of hydrogen sulphide, which is associated with anoxic conditions. This suggests that *C. edule* could survive several days of anoxia but it is likely that continued exposure to 2 mg/l oxygen for a week would be lethal (Tyler-Walters, 2007). Fifty percent (LT50) of cockles in anoxic seawater died after 3.5 days (Babarro and de Zwaan, 2001) The anoxic survival time of *C. edule* from two different ecosystems and differing anoxia tolerances was studied in static (closed) and flow-through systems. The antibiotics chloramphenicol, penicillin and polymyxin were added, and molybdate (specific inhibitor of the process of sulfate reduction). Median mortality times were 2.7 and 2.9 days for *Cerastoderma* for static and flow-through incubations, respectively. Addition of chloramphenicol increased strongly survival time in both systems with corresponding values of 6.4 and 6.5 days for *Cerastoderma*. Overall the results indicate that proliferation of anaerobic pathogenic bacteria, associated with the bivalves, is a main cause of death besides lack of oxygen. Bacterial damage is probably caused by injury of the tissues of the clams and not by the release of noxious compounds to the medium (de Zwaan et al. 2002). Based on the evidence above *Cerastoderma edule* is assessed as having 'Low' sensitivity to episodes
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L (***)	H-VH (*)	L-M (*)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						of hypoxia (resistance is assessed as Low' and recovery as 'High- Very High'), although sensitivity to prolonged hypoxia and anoxia would be considered to be greater.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	H-VH (*)	M (*)	The Manila clam (*Tapes philippinarium*), which was introduced to Poole Harbour for aquaculture in 1998, has become a naturalised population on the intertidal mudflats (occurring at densities of 60 clams/m^2 in some locations within the harbour (Jensen et al. 2007; cited in Caldow et al. 2007). Densities of *C. edule* and *Abra tenuis* had increased since the introduction of the Manila clam. Caldow et al. (2007) concluded that within Poole harbour there was no evidence yet of species replacement by the Manila clam. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Cerastoderma edule* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. No evidence was found, but based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as 'High-Very High' so that sensitivity is assessed as 'Medium'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		L (*)	H (*)	M (*)	*Cerastoderma edule* may be targeted for extraction using mechanical methods (e.g. tractor dredges or hydraulic suction dredging) or by large numbers of fishers using hand rakes. Removal of *C. edule* (cockles) by targeted fishery may result in an altered community and reduced extent of the *C. edule* and polychaetes in littoral muddy sand biotope. The physical effects of harvesting on this species are addressed in the Physical Disturbance sections. In general fishing practices will be efficient at removing this species, resistance is therefore assessed as 'Low' (removal is not considered to be total as smaller individuals may escape), recovery is assessed as 'High' based on evidence presented in the physical disturbance assessment, so that sensitivity is assessed as 'Medium'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services -				NA	Not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No information found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	L (***)	H-VH (*)	L-M (*)	Information from MarLIN (Tyler-Walters, 2007, references therein). Savari et al. (1991(a)) stated there was a concentration related reduction in scope for growth of *C. edule* with increasing concentration of hydrocarbons in the water column. McLusky (1982) examined the fauna of the intertidal mudflats at Kinneil in the Forth estuary that received petroleum, chemical and domestic effluents. Spatfall of *C. edule* occurred in 1976 but the abundance declined steadily between 1976 and 1980. *Cerastoderma edule*, together with many other species, was excluded from sediment within 1.5 km of effluent discharges. Between 1.5-2.25 km the abundance of fauna, including *C. edule* increased markedly (McLusky, 1983). Large numbers of moribund and dead marine animals, including *C. edule*, were washed ashore after the Sea Empress oil spill, however no commercial stocks were affected (SEEEC, 1998) (Tyler-Walters, 2007). Based on the above evidence *C. edule* was assessed as having 'Low' resistance to hydrocarbon pollution, recovery was assessed as 'High-Very High' following habitat recovery and sensitivity is considered to be 'Low-Medium'
	Introduction of antifoulants	Introduction of antifoulants			NEv	Information from MarLIN (Tyler-Walters, 2007, references therein). Studies of *C. edule* populations from polluted and un-contaminated sites in Southampton Water showed that tissue heavy metal concentrations were lower in summer than winter/spring, tissue heavy metal concentrations decreased with size of the cockle, and that cockles in sediments contaminated with metals and hydrocarbons had lower life expectancies, growth rates and body condition index (Savari et al. 1991a; 1991b). Bryan and Gibbs (1983) report that *C. edule* takes up heavy metals mainly from solution rather than from sediment. They concluded that the toxic body load for Cu in *C. edule* was ca. 250 µg/g tissue (Tyler-Walters, 2007). No evidence was found to support assessment at the benchmark.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited it is assessed as 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to SAC habitat features.

Table 5.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 5.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 5.3 Resistance Assessment Confidence Levels

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*** (5+)	***	***
Deep Disturbance	*** (5+)	***	***
Trampling - Access by foot	***(1)	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***	**	**
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment of sediments	**(2)	**	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***	***	***
Decrease in oxygen levels - Water column	***	*	***
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens	Not Exposed.		
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass	Not Assessed		
Introduction of medicines	No evidence. Not assessed.		
Introduction of hydrocarbons	***	*	N/A
Introduction of antifoulants	No evidence. Not Assessed.		
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Andre, C. and Lindegarth, M. 1995. Fertilization efficiency and gamete viability of a sessile, freespawning bivalve, *Cerastoderma edule*. Ophelia 43: 215-227.

Babarro, J.M.F. and de Zwaan, A. 2001. Factors involved in the (near) anoxic survival time of *Cerastoderma edule*: associated bacteria vs. endogenous fuel. Comparative Biochemistry and Physiology C-Toxicology and Pharmacology 128: 325-337.

Beukema, J.J. and Dekker, R. 2005. Decline of recruitment success in cockles and other bivalves in the Wadden Sea: possible role of climate change, predation on postlarvae and fisheries. Marine Ecology Progress Series 287: 149-167.

Boyden, C.R. and Russel, P.J.C. 1972. The distribution and habitat range of the brackish water cockle (*Cardium* (*Cerastoderma*) *edule*) in the British Isles. Journal of Animal Ecology 41: 719-734.

Brock, V. 1979. Habitat selection of two congeneric bivalves, *Cardium edule* and *C. glaucum* in sympatric and allopatric populations. Marine Biology 54: 149-156.

Caldow, R.W.G., Stillman, R.A., le V. dit Durell, S.E.A., West, A.D., McGrorty, S., Goss-Custard, J.D., Wood, P.J. and Humphreys, J. 2007. Benefits to shorebirds from invasion of a non-native shellfish. Proceedings of the Royal Society B 274: 1449-1455.

Coffen-Smout, S.S. and Rees, E.I.S. 1999. Burrowing behaviour and dispersion of cockles *Cerastoderma edule* L. following simulated fishing disturbance. Fisheries Research 40(1): 65-72.

de Zwaan, A., Babarro, J.M., Monari, M. and Cattani, O. 2002. Anoxic survival potential of bivalves: (arte)facts. Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology 131: 615-624.

Fauchald, J. and Jumars, P.A. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology: an Annual Review 17: 193-284.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common marine macrozoobenthos species in The Netherlands, their characteristics and sensitivities to environmental pressures. GiMaRIS 2011.08.

Grant, J. and Thorpe, B. 1991. Effects of suspended sediments on growth, respiration, and excretion of the soft shell clam (*Mya arenaria*). Canadian Journal of Fisheries and Aquatic Sciences 48: 1285-1292.

Hall, S.J. and Harding, M.J.C. 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. Journal of Applied Ecology 34: 497-517.

Hartnoll, R.G. 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland [UK Marine SAC Project. Natura 2000 reports].

Iglesias, J.I.P., Urrutia, M.B., Navarro, E., Alvarez-Jorna, P., Larretxea, X., Bougrier, S. and Heral, M. 1996. Variability of feeding processes in the cockle *Cerastoderma edule* (L.) in response to changes in seston concentration and composition. Journal of Experimental Marine Biology and Ecology 197: 121-143.

McLaughlin, E., Portig, A. and Johnson, M.P. 2007. Can traditional harvesting methods for cockles be accommodated in a Special Area of Conservation? ICES Journal of Marine Science 64: 309-317.

Navarro, J.M. and Widdows, J. 1997. Feeding physiology of Cerastoderma edule in response to a wide range of seston concentrations. Marine Ecology Progress Series 152: 175-186.

Prins, T.C., Smaal, A.C. and Pouwer, A.J. 1991. Selective ingestion of phytoplankton by the bivalves *Mytilus edulis* L. and *Cerastoderma edule* (L.). Hydrobiological Bulletin 25: 93-100.

Rossi, F., Forster, R.M., Montserrat, F., Ponti, M., Terlizzi, A., Ysebaert, T. and Middelburg, J.J. 2007. Human trampling as short-term disturbance on intertidal mudflats: effects on macrofauna biodiversity and population dynamics of bivalves. Marine Biology 151: 2077-2090.

Rostron, D.M. 1995. The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. p111-117. In Burry Inlet and Loughor Estuary Symposium, March 1995. Part 2. Burry Inlet and Loughor Estuary Liaison Group.

Strasser, M. and Günther, C.P. 2001. Larval supply of predator and prey: temporal mismatch between crabs and bivalves after a severe winter in the Wadden Sea. Journal of Sea Research 46: 57–67.

Tyler-Walters, H. 2007. *Cerastoderma edule*. Common cockle. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 09/02/2012]. Available from: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=2924.

6. Species: *Fabulina fabula*

Species Description

- Taxonomy: *Fabulina fabula* is a venerid bivalve;
- Length: About 2cm in length;
- Habitat: This species burrows in fine to medium sand and silty sand on the lower shore and in the shallow sublittoral; and
- Mobility: Can re-burrow rapidly and lives up to a depth of 10cm.

Recovery

Information from MarLIN (Rayment, 2008, references therein).

The life history characteristics of *Fabulina fabula* contribute to its strong powers of recoverability. *F. fabula* spawns at least once a year and has a protracted breeding period (Salzwedel, 1979). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson et al. 1994). Timing of spawning and settlement suggests that the larval phase lasts at least a month (Salzwedel, 1979), and therefore the species has high dispersal potential. However, post settlement development is not particularly rapid and the species may take 2 or more years to mature, particularly in colder waters at the limit of its range (Muus, 1973).

Bosselmann (1988) concluded that *F. fabula* was among a group of species with high potential for dense settlement in the German Bight as larvae were found in large numbers in the water column and the prolonged reproductive period enabled rapid settling following environmental change. Bosselmann (1991) conducted colonization experiments in an offshore subtidal region of the German Bight. Sediment containers exposed in April were heavily settled by *F. fabula* in July. Spat had grown to a length of 3.2 mm after 1 year, suggesting that maturity would not be reached until the second summer after colonization. The author proposed that relatively slow growing species, such as *Fabulina fabula*, were not well adapted to opportunistic colonization of new sediments. This conclusion was supported by colonization experiments conducted by Diaz-Castaneda et al. (1989) in Dunkerque harbour. Defaunated sediments were colonized by *F. fabula* at the end of the successional sequence. It was suggested that *F. fabula* is an equilibrium species with a long life span for which successful spatfall is not an annual event. This does not make the species a particularly effective colonizer relative to opportunists like polychaete worms, but, due its low death rate, ensures that the species is persistent once established.

The experimental data suggest that *F. fabula* would colonize available sediments in the year following environmental perturbation, but that a breeding population may take 2 or more years to establish. It is expected that full recovery would occur within 5 years (Rayment, 2008).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 6.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 6.2a and are combined, as in Table 6.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 6.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 6. 2a).

Table 6.1 *Fabulina fabula* Sensitivity Assessment

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	Based on environmental position resistance is assessed as 'High' (no mortality), based on exposure to abrasion at the surface only, recovery is assessed as 'Very High' (no impact to recover from), so that sensitivity is categorised as 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M-H (*)	M-VH (*)	L-NS (*)	This species has been categorised through expert and literature review as AMBI fisheries Group II - Species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly (Gittenberger and van Loon, 2011). This species is considered to have 'Medium-High' resistance to shallow sediment disturbance based on environmental position (buried to 10cm depth), and due to their small size (a proportion of the population is predicted to escape by either being missed by gear or pushed aside by the pressure wave caused by passage of gear (Gilkinson et al. 1998). Recovery is assessed as 'High-Very High' (based on annual spawning and low impact, sensitivity is therefore assessed as 'Low-Not Sensitive'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M-H (*)	M-VH(*)	L-NS (*)	Assessment based on shallow disturbance.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Assessment based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	H (*)	VH (*)	NS (*)	Assessment based on surface disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M-H (*)	M-H (*)	Information from MarLIN (Rayment, 2008). *Fabulina fabula* lives infaunally in sandy sediments. Removal of the substratum would also remove the entire population of the species and so intolerance is assessed as high. Recoverability is recorded as high (Rayment, 2008). *F. fabula* are predicted to have 'No' resistance to extraction, recovery was assessed as 'Medium-High'

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						so that this species is considered to have 'Medium-High' sensitivity to sediment extraction.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	This species has been categorised through expert judgement and literature review as AMBI sedimentation Group II – Species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Information from MarLIN (Rayment, 2008, references therein). *Fabulina fabula* is a shallow burrower in sandy sediments and require their inhalant siphon to be above the sediment surface for feeding and respiration. Smothering with 5 cm of sediment would temporarily halt feeding and respiration and require the species to relocate to its preferred depth. *F. fabula* is an active burrower (Salzwedel, 1979) and would be expected to relocate with no mortality. However, growth and reproduction may be compromised. Growth and reproduction would return to normal following relocation (Rayment, 2008). Venerid bivalves are typically able to relocate within the sediment in response to siltation. Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	M-H (*)	M-H (*)	No evidence found. As adults have limited to no horizontal mobility and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on a return to previous habitat conditions. Resistance is judged as 'None' with recovery as 'High' if original habitat conditions are re-instated, so that the sensitivity of this species is assessed as 'Medium-High'. If there were no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N-L (*)	M-H (*)	M-H (*)	No information found. This species appears to be restricted to fine sands, an increase in coarse sediment fraction is considered to decrease habitat suitability for this species. Resistance is therefore assessed as 'None-Low' and recovery as 'Medium- High' following habitat recovery. Sensitivity is therefore assessed as 'Medium-High'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	L-M (*)	M-H (*)	L (*)	Information from MarLIN (Rayment, 2008, references therein). An increased deposition of fine suspended sediment (Hiscock, 1983), changing the sediment characteristics of the habitat in which the species lives. Over the course of a year, it is likely that species which favour stable, fine sediment communities would proliferate at the expense of species such as *Fabulina fabula* which are tolerant of more dynamic environments (Rayment, 2008). Increased deposition of fine particles could support the development of a deposit feeding assemblage more typical of muddy sediments, decreasing suitability for *F. fabula* through an increase in deposit feeders and lower larval recruitment. Resistance is therefore assessed as 'Low-Medium' and recovery (following habitat restoration) as 'Medium-High'. Sensitivity is therefore assessed as 'Low'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	M (*)	H (*)	L (*)	Information from MarLIN (Rayment, 2008, references therein). Increased water flow - *Fabulina fabula* typically occurs in areas of 'moderately strong' water flow (Salzwedel, 1979; Diaz-Castaneda et al. 1989). An increase in water flow to 'very strong' flow for one year would change the sediment characteristics in which the species lives, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). This would result in erosion of the preferred habitat. Additionally, the increased water flow rate may interfere with feeding and respiration. It is likely that some mortality would result. Recoverability is recorded as high.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Decreased water flow - Decreased water movement would result in increased deposition of fine suspended sediment (Hiscock, 1983), changing the sediment characteristics of the habitat in which the species lives. Over the course of a year, it is likely that species which favour stable, fine sediment communities would proliferate at the expense of species such as *F. fabula* which are tolerant of more dynamic environments. Some mortality would therefore be expected. Recoverability is assessed as high (Rayment, 2008). Increased water flow rate may winnow fine sediments and at greater velocities may erode sediment and wash individuals out of the sediment. Aquaculture installations, however, are associated with reduced water flows. A decrease in water flow may reduce the availability of food that may be obtained from suspension feeding and may increase deposition of fine particles, this could support the development of a deposit feeding assemblage more typical of muddy sediments, decreasing suitability for *F. fabula* through an increase in deposit feeding and lower larval recruitment. Resistance is therefore assessed as 'Low-Medium' and recovery (following habitat restoration) as 'Medium-High'. Sensitivity is therefore assessed as 'Low'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Rayment, 2008, references therein). Levels of suspended sediment are likely to be most relevant to feeding. *Fabulina fabula* is known to practice two alternative modes of feeding – suspension feeding and deposit feeding (Salzwedel, 1979). The alternative feeding methods are likely to make the species insensitive to changes in suspended sediment. If the level of suspended sediment becomes so high as to risk clogging the feeding structures, *F. fabula* could presumably switch to deposit feeding. Furthermore, an increase in suspended sediment is likely to increase the rate of siltation and therefore the food available to deposit feeders. *F. fabula* is therefore assessed as 'tolerant' with the potential for growth and reproduction to be enhanced by the increased food supply. *F. fabula* does not require light and therefore the effects of increased turbidity on light attenuation are not directly relevant. An increase in turbidity may reduce the availability of phytoplankton food. However, phytoplankton will also immigrate from distant areas and so the effect may be decreased. If the turbidity increase only persists for a year, decreased food availability would probably only affect

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						growth and fecundity. As soon as light levels return to normal, primary production will increase and hence recoverability is recorded as very high (Rayment, 2008). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High', so that this species is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Rayment, 2008). A decrease in suspended sediment is likely to decrease the availability of food for both suspension and deposit feeding. The reduction in food availability may result in less energy available for growth and reproduction by *Fabulina fabula*. However, an arbitrary benchmark change of 100 mg/l for 1 month would not be expected to result in mortality. When suspended sediment returns to original levels, growth and reproduction should quickly return to normal. *F. fabula* does not require light and therefore the effects of decreased turbidity on light attenuation are not directly relevant. It is possible that decreased turbidity would increase primary production in the water column and by microphytobenthos. The resultant increase in food availability may enhance growth and reproduction in *F. fabula*, but only if food was previously limiting (Rayment, 2008). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	M (*)	H (*)	L (*)	Information from MarLIN (Rayment, 2008, references therein). At low levels of nutrient enrichment, an increase in phytoplankton and benthic diatoms may increase food availability for *Fabulina fabula*, thus enhancing growth and reproductive potential. However, increased levels of nutrient (beyond the carrying capacity of the environment) may result in eutrophication, algal blooms and concomitant reductions in oxygen concentrations (e.g. Rosenberg and Loo, 1988). It is likely therefore that a dramatic increase in nutrient levels would cause some mortality of *F. fabula* (Rayment, 2008). Eutrophication levels associated with aquaculture and fishing activites are generally considered to be negligible (see Introduction Sections Table II.2 and II.9.).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above information (for enhancement rather than gross enrichment) resistance is assessed as 'High' and recovery is assessed as 'High'. The sensitivity of this species is therefore assessed as 'Low'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	N-L (***)	M (*)	M-H (*)	This species has been categorised by Borja et al. (2000) as AMBI Group I - species very sensitive to organic enrichment and present under unpolluted conditions (initial state). The conclusion of this review was supported by a later assessment (Gittenberger and van Loon, 2011). Based on the above information resistance to organic enrichment is assessed as 'None-Low', recovery is assessed as 'Medium' (as recruitment is not annual and the age structure of the population will take some years to recover). The sensitivity of this species is therefore assessed as 'Medium-High'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	M-H (*)	VH-M (*)	L-NS (*)	Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (Hartnoll, 1998). Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM (http://www.farmscale.org), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters. Resistance to increased competition was assessed as 'Medium to High' (ranging from no lethal effect to mortality of <25% of population) and recovery as 'Very High to Medium', so that sensitivity was categorised as 'Low to Not Sensitive'. Increased clearance rates of suspended sediments by suspended bivalves may enhance local primary production through a reduction in turbidity, compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	M-H (***)	H-VH (***)	NS-L (***)	Information from MarLIN (Rayment, 2008, references therein). *Fabulina fabula* is an aerobic organism and therefore will be intolerant to some degree to lack of oxygen. Inferences may be drawn from the effects on other species. Jorgensen (1980) recorded the effects of low oxygen levels on benthic fauna in a Danish fjord. At dissolved oxygen concentrations of 0.2-1.0mg/l the bivalves, *Cerastoderma edule* and *Mya arenaria*, suffered mortality between 2 and 7 days. Rosenberg and Loo (1988) reported mass mortalities of *M. arenaria* and *C. edule* in Sweden, following a eutrophication event which resulted in low oxygen concentrations over several years (often

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						<1ml O_2/l). Hence with exposure to oxygen levels of 2mg/l for one week it is expected that some mortality of *F. fabula* would occur However, Niermann et al. (1990) reported that *F. fabula* in a fine sand community in the German Bight area exposed to regular seasonal hypoxia, remained abundant during a period of hypoxia (1-3mg/O_2/dm^3), and decreased slightly in abundance on resumption of normoxia (Rayment, 2008). Based on the above information, resistance is assessed as 'Medium-High' as some lethal effects would be expected but these levels may be relatively low (as suggested by Niermann et al. 1990). Recovery is assessed as 'High-Very High' and sensitivity is therefore assessed as 'Not Sensitive-Low'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	M-H (***)	H-VH (***)	NS-L (***)	Assessment based on the information presented for 'Decrease in oxygen levels-sediment'.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	M-H (*)	M (*)	No information found. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Fabulina fabula* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. Based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as 'High-Very High' so that sensitivity is assessed as 'Medium'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Information from MarLIN (Rayment, 2008, references therein). *Fabulina fabula* is not a targeted species. The species is potentially at risk from fishing activities on sandy substrata, e.g. beam trawling for flatfish, and extraction of sand by the aggregate industry (Eno, 1991; Rayment, 2008). As this species is not targeted by a commercial fishery, resistance is assessed as 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem				NA	Not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Services - Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	L-M (***)	M (***)	L-M (*)	Information from MarLIN (Rayment, 2008, references therein). In general, the effect of oil on bivalves is an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Conan (1982) investigated the long term effects of the Amoco Cadiz oil spill at St Efflam beach in France. *Fabulina fabula* (studied as *Tellina fabula*) started to disappear from the intertidal zone a few months after the spill and from then on was restricted to subtidal levels. In the following 2 years, recruitment of *Fabulina fabula* was very much reduced. The majority of the *Fabulina fabula* population lives subtidally and would therefore avoid the impact of an oil spill. Recoverability would be delayed by the persistence of oil in sediments, as was demonstrated by the inhibition of recruitment (Rayment, 2008). From the above evidence the presence of a subtidal population of *F. fabulina* following the oil spill was interpreted as demonstrating 'Low-Medium' resistance to this pressure (some lethal effects following spill) and 'Medium' recovery (following habitat recovery). Sensitivity was therefore assessed as 'Low-Medium'.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Information from MarLIN (Rayment 2008, references therein). Copper is widely used as an antifoulant. Although no direct evidence was found relating to *Fabulina fabula* inferences may be drawn from studies of a closely related species. Stirling (1975) investigated the effect of exposure to Cu on *Tellina tenuis*. The 96 hour LC50 for Cu was 1000µg/l. Exposure to Cu concentrations of 250µg/l and above inhibited burrowing behaviour and would presumably result in greater vulnerability to predators. Following replacement of Cu solutions with clean seawater, *T. tenuis* showed little recovery of burrowing ability, either because residual Cu in the sand acted as a deterrent

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						or previous exposure had a deleterious metabolic effect. The lethal and sublethal effects of Cu exposure on *T. tenuis* suggest that *F. fabula* would also be affected. Recoverability would be partially dependent on the persistence time of heavy metals in the sediments (Rayment, 2008). Based on a copper sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000), it is assumed, (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Fabulina fabula* does not photosynthesise and do not, therefore, directly require light and are therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to SAC habitat features.

Table 6.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 6.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 6.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	***(2)	Not clear.	***

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***(2)	*	*
Decrease in oxygen levels - Water column	***(2)	*	*
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence found. Not assessed.		
Introduction of hydrocarbons	*** (1)	*	N/A
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40: 1100-1114.

Gilkinson, K.D., Gordon Jr., D.C., MacIsaac, K.G., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C. and Vassb, W.P. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada. ICES Journal of Marine Science 62(5): 925-947.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS Report No 2011.08.

Hartnoll, R.G. 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland [UK Marine SAC Project. Natura 2000 reports].

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

Rayment, W. 2008. *Fabulina fabula*. Bean-like tellin. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 09/02/2012]. Available from: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3329.

7. Species: *Glycera* sp.

Species Description

- Infaunal polychaete worms;
- Mobile, free-living predators on invertebrates and also exploiting detritus in the sediment (MES Ltd, 2010);
- Habitat: in sand and muddy-sand;
- Longevity: 5 years for *Glycera rouxi* (Buchanan and Warwick, 1974), 3-5 years for *Glycera* sp. (BIOTIC:PML);
- Reproduction: pelagic and later benthic stage, epitoky (Strathman, 1987; Shanks, 2001; cited in Carson and Hentschel, 2006), *Glycera* are monotelic having a single breeding period towards the end of their life (Klawe and Dickie, 1952);
- Recorded as having high dispersal potential; and
- Moderate mobility within sediment and can, however, re-burrow after disturbance (MES Ltd, 2010).

Table A: *Glycera lapidum* has been recorded as a characterising species from the following EUNIS biotopes and JNCC equivalents

EUNIS (version 2004)	Marine Habitat Classification Britain/Ireland (v0405)
A5.123	S.SCS.ICS.MoeVen
A5.125	SS.SCS.ICS.Glap
A5.132	SS.SCS.CCS.MedLumVen
A5.133	SS.SCS.CCS.Pkef
A5.135	SS.SCS.CCS.Blan
A5.141	SS.SCS.OCS.GlapThyAmy
A5.251	SS.SSa.CFiSa.EpusOborApri

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Wave exposure: very exposed, exposed, moderately exposed, sheltered
- Tidal streams: strong (3-6kn) moderately strong (1-3kn), weak (<1kn)
- Substratum: gravel with coarse to medium sand, medium to coarse sand and gravelly sand, medium to coarse sand with some gravel or shell, and a fine sand or mud fraction, Coarse sands and gravel, stone or shell, and occasionally silt, medium to fine sand.

Table B: *Glycera tridactyla* has been recorded as a characterising species from the following EUNIS biotopes and JNCC equivalents

EUNIS (version 2004)	Marine Habitat Classification Britain/Ireland (v0405)
A5.373	SS.SMu.OMu.StyPse

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Wave exposure: Very sheltered
- Tidal streams: Weak (>1 kn)

- Substratum: Mud with terrigenous debris
- Zone: Circalittoral
- Depth Band: 50-100 m

Recovery

Glycera has a relatively long life-span of 5 years. Reproductive maturity occurs at 3 years. Large numbers of as many as 3-10 million eggs of about 0.15 mm diameter are released by female worms on the surface of the sediment in April and are fertilised externally by the males. The larvae are planktotrophic and spend 11-30 days in the water column, settling mainly in May. This genus has a high potential rate of recolonisation of sediments, but the relatively slow growth-rate and long-life span suggests that recovery of biomass following initial recolonisation by post-larvae is likely to take several years. Recoverability is assessed as intermediate (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 7.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 7.2a and are combined, as in Table 7.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 7.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 7.2a).

Table 7.1 *Glycera* sp. Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	No evidence found. *Glycera alba* are generally tolerant to disturbances (Trannum et al. 2006). The infaunal life habit of this species was considered to protect against surface abrasion. Resistance was therefore assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L-M (***)	M-H (***)	L-M (***)	*Glycera alba* has been categorised through expert judgement and literature review as AMBI fisheries Group III - A second-order opportunistic species, which is sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). *Glycera lapidum* has been categorised through expert judgement and literature review as AMBI fisheries Group III - A second-order opportunistic species, which is sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Based on the evidence presented above resistance is categorised as 'Low to Medium' .Where the spatial footprint of the impact is small , recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery is assessed as 'Medium-High. The sensitivity of this species is therefore considered to range from 'Low-Medium'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	L-M (*)	M-H (*)	L-M (*)	*Glycera lapidum* is present in the biotope SS.SCS.ICS.Glap which is an impoverished biotope type subject to sediment destabilisation by wave action (Connor et al. 2004). The assessment is based on the presence of species of this genus in disturbed sediments and the information in shallow disturbance. Resistance is categorised as 'Low to Medium' .Where the spatial

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						footprint of the impact is small , recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery is assessed as 'Medium-High. The sensitivity of this species is therefore considered to range from 'Low-Medium'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	No evidence found. Assessment is based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	L-M (*)	M-H(*)	L-M (*)	Assessment based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M-H (*)	M (*)	Extraction of the sediment will remove the population of this infaunal species from an area, so resistance is categorised as "None'. Based on life history traits and the mobility of adults, recovery is assessed as 'Medium-High', sensitivity is categorised as 'Medium'. Recovery will require that either the sediments that are left are suitable or that infilling with suitable sediments occurs.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	*Glycera alba* has been categorised through expert judgement and literature review as AMBI sedimentation Group II – Species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). *Glycera lapidum* has been categorised through expert judgement and literature review as AMBI sedimentation Group II – Species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Based on the mobility and burrowing habitat of this species but also considering the GiMARIS review (Gittenberger and van Loon, 2011) resistance for this species is assessed as 'Medium' and recovery as 'High', providing a sensitivity assessment of 'Low'.
	Smothering	Physical effects	H (*)	VH (*)	NS (*)	Smothering with coarse materials may prevent *Glycera* sp. reaching the surface. As the worm inhabits

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	(addition of materials biological or non-biological to the surface)	resulting from addition of coarse materials				burrows, is mobile and hunts infaunally resistance was considered to be 'High' as individuals may be relatively unaffected by surface smothering. Recovery was therefore assessed as 'Very High'. This genus is therefore considered to be 'Not Sensitive'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	*Glycera alba* prefers sediments with a median grain size of 50 to 250 µm (very fine sand to fine sand) but is also found in coarser sediments (up to 500 µm). The species tends to prefer sediments with a mud content of 10-20% (Degraer et al. 2006). This genus occurs in mixed sediments and therefore is considered to have some tolerance to increases in coarse sand fractions. The wide sediment preferences (see introduction) suggest species within this genus would be able to tolerate an increase in coarse sediments within the habitat envelope (but possibly with population impacts). However, a transition to a fully coarse sediment type is likely to negatively impact this species as the habitat becomes sub-optimal. Based on this information resistance is assessed as 'High' and recovery as 'Very High', therefore the species is considered to be 'Not Sensitive'.
	Changes in	Fine sediment	H (*)	VH (*)	NS (*)	Based on published habitat preferences (JNCC biotope descriptions; Connor et al. 2004), the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment composition – increased fine sediment proportion	fraction increases				occurrence of *G. tridactyla* in very fine sands, muddy sands and muds is taken to indicate that this species is tolerant to increased in fine sediment fraction. Based on habitat preferences, resistance is assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	This genus is found in areas with strong tidal streams where sediments are mobile (Roche et al. 2007) and in extremely sheltered areas (Connor et al. 2004). Resistance is assessed as 'High' and recovery as 'Very High'. Therefore, this genus was judged to be 'Not Sensitive' to either increases or decreases in water flow.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	No evidence found. Increased turbidity and seston are not predicted to directly affect this genus which is predatory and lives in burrows in sediments. Resistance is therefore assessed as 'High' and recovery as 'Very High', the genus is therefore considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	No evidence found. Decreased turbidity from a reduction in inorganic particles is not predicted to directly affect this genus which is predatory and lives in burrows in sediments. Indirect effects of reduced turbidity such as an increase in predation from enhanced prey location by fish etc are possible but not considered here. Based on environmental position, resistance is assessed as 'High' and recovery as 'Very High' so that this species was considered to be 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (**)	As *Glycera species* are not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton and algal detritus may be utilised as food by this genus.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						This species is therefore considered to be 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	*Glycera alba* has been categorised by (Borja et al. 2000) as a Group IV species. However, a later review by Gittenberger and van Loon (2011) classified this species as 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 situa- tions). *Glycera lapidum* has been categorised through expert judgement and literature review as AMBI Group III - Species tolerant to excess organic matter enrichment. This species may occur under normal conditions, but populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids (Borja et al. 2000; validated by Gittenberger and van Loon, 2011). Based on the reviews by Gittenberger and van Loon (2011), this genus is considered to have 'High' resistance to increased organic matter and subsequently, 'Very High' recovery. This genus is therefore considered to be 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	This species is primarily a predator of invertebrates and is not considered to be sensitive to increased removal of phytoplankton. Resistance is therefore considered to be 'High' and recovery as 'Very High'. This genus is therefore considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (***)	VH (***)	NS (***)	*Glycera alba* has been found to be able to tolerate periods of anoxia resulting from inputs of organic rich material from a wood pulp and paper mill in Loch Eil (Scotland) (Blackstock et al. 1982). Little evidence was found for tolerance of hypoxia and anoxia. Based on the above information resistance was assessed as 'High' and recovery as 'Very High' so that this genus is considered to be 'Not Sensitive'
	Decrease in	Hypoxia/anoxia water	H (***)	VH (***)	NS (***)	*Glycera alba* has been found to be able to tolerate periods of anoxia resulting from inputs of organic

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	oxygen levels - Water column	column				rich material from a wood pulp and paper mill in Loch Eil (Scotland) (Blackstock et al. 1982). Little evidence was found for tolerance of hypoxia and anoxia. Based on the above information resistance was assessed as 'High' and recovery as 'Very High' so that this genus is considered to be 'Not Sensitive'
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NA	Not assessed.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock	H (*)	VH (*)	NS (*)	Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Glycera* spp. are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. The assessment was based on the smothering pressure and evidence presented for that assessment as this was considered to be relevant to habitat colonisation by *Crepidula fornicata* and *Crassostrea gigas*.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of parasites/ pathogens				NA	Not assessed.
	Removal of Target Species		H (*)	VH (*)	NS (*)	This species is not targeted by a commercial fishery. Resistance is considered to be 'High' and recovery as 'Very High'. Therefore this genus is considered to be 'Not Sensitive'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat, resistance is considered to be 'High' and recovery as 'Very High'. The genus is therefore assessed as 'Not Sensitive'.
	Ecosystem Services - Loss of biomass				NA	Not assessed.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	H (***)	VH (***)	NS (***)	Described by Hiscock et al. (2004; 2005, from Levell et al. 1989) as a very tolerant taxa, found in enhanced abundances in the transitional zone along hydrocarbon contamination gradients surrounding oil platforms. Based on the above information, resistance was assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Introduction of antifoulants	Introduction of antifoulants			NA	Rygg (1985) classified *G. roux* as non-tolerant of Cu (absent from stations in Norwegian fjords where sediment copper concentrations were > 200 mg/kg).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Rygg (1985) classified *G. alba* as a highly tolerant species, common at the most Cu polluted stations (Cu > 200 mg/kg). As the evidence for copper tolerance appears to vary between species, no assessment was made. No evidence was found regarding sensitivity to Zinc.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited, resistance is therefore considered to be 'High' and recovery as 'Very High'. The genus is assessed as 'Not Sensitive'.
	Barrier to species movement				NA	Not assessed.

Table 7.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 7.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 7.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*** (1)	Not clear	N/A
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*** (1)	Not clear	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	***(1)	Not clear	N/A

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (1)	*	N/A
Decrease in oxygen levels - Water column	*** (1)	*	N/A
Genetic impacts			
Introduction of non-native species			
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass	Not relevant.		
Introduction of medicines	No evidence.		
Introduction of hydrocarbons	*** (1)	*	N/A
Introduction of antifoulants	Not assessed.		
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement	Not relevant.		

References

Blackstock, J., Barnes, M. and Barnes, H. 1982. The loch eil project: biochemical composition of the polychaetes, *Glycera alba* (Muller), from Loch Eil. Journal of Experimental Marine Biology and Ecology 57: 85-92.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Buchanan, J.B. and Warwick, R.M. 1974. An estimate of benthic macrofaunal production in the offshore mud of the Northumberland Coast. Journal of the Marine Biological Association of the United Kingdom 54: 197-222.

Carson, H.S. and Hentschel, B.T. 2006. Estimating the dispersal potential of polychaete species in the Southern California Bight: implications for designing marine reserves. Marine Ecology Progress Series 316: 105-113.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Degraer S., Wittoeck, J., Appeltans, W., Cooreman, K., Deprez, T., Hillewaert, H., Hostens, K., Mees, J., Vanden Berghe, E. and Vincx, M. 2006. The macrobenthos atlas of the Belgian part of the North Sea. Belgian Science Policy. D/2005/1191/3. ISBN 90-810081-6-1. 164 pp.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08.

Hiscock, K., Langmead, O. and Warwick, R. 2004. Identification of seabed indicator species from time-series and other studies to support implementation of the EU Habitats and Water Framework Directives. Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Plymouth: Marine Biological Association. JNCC Contract F90-01-705. 109 pp.

Hiscock, K., Langmead, O., Warwick, R. and Smith, A. 2005. Identification of seabed indicator species to support implementation of the EU Habitats and Water Framework Directives. Second edition. Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Plymouth: Marine Biological Association. JNCC Contract F90-01-705. 77 pp.

Klawe, W.L. and Dickie, L.M. 1957. Biology of the bloodworm, Glycera dibranchiata Ehlers, and its relation to the bloodworm fishery of the Maritime Provinces. Fisheries Research Board of Canada. Bull. 115: 37p.

Levell, D., Rostron, D. and Dixon, I.M.T. 1989. Sediment macrobenthic communities from oil ports to offshore oilfields. In: Dicks, B. (Ed.) Ecological impacts of the oil industry, pp. 97-134. London: Wiley.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Roche, C., Lyons, D.O., Franco, J.F. and O'Connor, B. 2007. Benthic surveys of sandbanks in the Irish Sea. Irish Wildlife Manuals, No. 29. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

Trannum, H.C., Pettersen, A. and Brakstad, F. 2006. Field trial at Sleipner Vest Alfa Nord: Effects of drilling activities on benthic communities. APN-411.3041.2.

8. Species: *Hediste diversicolor*

Species Description

- Common name: harbour ragworm;
- Taxonomy: Polychaete worm from the *Nereid* family;
- Environmental Position: Infaunal, inhabiting deep semi-permanent burrows (up to 15cm deep, Zwarts and Eselink, 1989);
- Feeding: Omnivorous and exhibits a diversity of feeding modes; carnivorous, scavenging, filter feeding on suspended particles and deposit-feeding on materials in and on the surface layers of the sediment (Barnes, 1994);
- Reproduction: Benthic larvae;
- Longevity: age at maturity is variable from 1-3 years, the species spawn once and then die;
- Mobility: Burrower, swimmer, crawler (BIOTIC, Aberson et al. 2011);
- Habitat: muddy sediments in brackish waters and estuaries, *Hediste diversicolor* characteristically inhabits littoral mudflats predominantly of clay (particles <4 µm), silt (4-63 µm) and to a lesser extent very fine sand (63-125 µm) (Jones et al. 2000);
- Targeted by bait digging; and
- Ecosystem Services: Important prey species of fish and birds (Scaps, 2002; Rosa et al. 2008), acts as an ecosystem engineer altering sediment properties through bioturbatory activities (Widdows et al. 2009).

Recovery

Information from MarLIN (Budd, 2008)
Adults can migrate by crawling or swimming (Aberson et al. 2011). Disturbed sediments may be rapidly recolonised by adult and post-larvae *Hediste diversicolor* through swimming, burrowing or bedload transport (Shull, 1997). Pelagic larvae may be dispersed widely, Davey and George (1986) found evidence that larvae of *H. diversicolor* were tidally dispersed within the Tamar Estuary over a distance of 3 km. Recruitment will depend on habitat suitability and will be moderated by larval supply which will vary temporally. Recovery of this species would be influenced by the length of time it would take for the potential habitat to return to a suitable state for recolonization by adult and juvenile specimens from adjacent habitats, and the establishment of a breeding population. This may take between one and three years, as populations differ in reaching maturity (Dales, 1950; Mettam et al. 1982; Olive and Garwood, 1981), from the time that the habitat again becomes suitable for the species.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 8.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure/interaction rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 8.2a and are combined, as in Table 8.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 8.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 8.2a).

Table 8.1 *Hediste diversicolor* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	*Hediste diversicolor* have a fragile hydrostatic skeleton, and are therefore vulnerable to damage by physical abrasion, however their environmental position as burrowing infauna should provide a high degree of protection from activities that lead to surface abrasion only. Resistance is therefore assessed as 'High'. *Hediste diversicolor* is an active burrower, swimmer and crawler and recovery of populations would take place through larval recruitment and, in the short-term, active migration. As the population has 'High' resistance, recovery is assessed as 'Very High' (little impact to recover from) and this species is therefore considered to be 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L-M (**)	M-VH (**)	L-M (**)	This species has been categorised through expert and literature review as AMBI fisheries Group III - a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Information from MarLIN (Budd, 2008) The body *of Hediste diversicolor* may be physically damaged by mechanical interference as it has a fragile hydrostatic skeleton. Mechanical interference within the substratum, such as that caused by the dropping and dragging of an anchor or fishing gear, could physically damage ragworms within the path of the anchor and cause their displacement. Physical injury and displacement would hinder the ability of a ragworm to burrow rapidly back into the sediment to seek refuge from predation. Regeneration of the lost body is often observed (M. Kendall, pers. comm.) however it is likely that some individuals may die. Recovery is dependent on the reproductive success and dispersion of the remaining population and colonization by adults from unaffected areas. Based on the evidence presented above resistance is categorised as 'Low to Medium' .Where the spatial footprint of the impact is small , recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						is assessed as 'Medium-High'. The sensitivity of this species is therefore considered to range from 'Low-Medium'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	N-L (***)	M-VH (***)	L-H (***)	The effects of a pipeline construction on benthic invertebrates were investigated using a Before/After impact protocol at Clonakilty Bay, West Cork, Ireland. Benthic invertebrates were sampled once before the excavation and at one, two, three and six months after the completion of the work. Invertebrate samples were dominated *by Hediste diversicolor*, *Scrobicularia plana* and *Tubifex* spp. An impact was obvious in the construction site in that no live invertebrates were found at one month after disturbance, but there followed a gradual recolonisation by *H. diversicolor*. At six months after the disturbance there was no significant difference in the mean number of total individuals (of all species) per core sample amongst all study sites, but the apparent recovery in the impacted area was due to two taxa only, *H. diversicolor* and *Tubifex* spp. Information from MarLIN (Budd, 2008) Hand and mechanical digging operating at a level to achieve a 50% reduction in *Arenicola marina*, caused a significant reduction in many of the common species, including *Hediste diversicolor*. A total of 1.9 g of other benthic animals were removed for every 1 g of *Arenicola marina*. The evidence suggests that deep disturbance will remove all, or most, of the population, so that resistance was assessed as 'None to Low' (removal of >75% of individuals). Where the spatial footprint of the impact is small, recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery is assessed as medium-high. The sensitivity of this species is therefore considered to range from 'Low-High'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (**)	NS (*)	A study of trampling (sites trampled 2 times a month for 8 months by 5 researchers) found no impacts on *Hediste diversicolor* abundances although the sample size was limited (Rossi et al. 2007). Resistance was therefore assessed as 'High' and recovery as 'Very High' so that this specie sis considered to be 'Not Sensitive'.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	H (**)	L (*)	No evidence found. The greater weight of vehicles is predicted to lead to compaction of sediment, crushing some worms within burrows.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Resistance is therefore assessed as "Medium' and recovery as 'High to Very High' so that this species is considered to have "Low' sensitivity.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M-VH (**)	L-H(*)	Removal of substrate would remove infaunal populations including *Hediste diversicolor*. Depending on the scale of extraction recovery would require sediment infilling and would occur through migration or larval supply. Information from MarLIN (Budd, 2008) *Hediste diversicolor* is infaunal and is reliant upon a muddy/sandy sediment in which to burrow. Physical removal of the substratum e.g. as a result of channel dredging activities would remove with it the entire associated population of *Hediste diversicolor*. Resistance is categorised as 'None' and recovery as 'Very High' so that sensitivity is assessed as low. Where the spatial footprint of the impact is small, recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery is assessed as 'medium-high'. The sensitivity of this species is therefore considered to range from 'Low-High'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (***)	NS (***)	This species has been categorised through expert and literature review as AMBI sedimentation Group II – Species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Field experiments where 10cm of sediment were placed on intertidal sediments to investigate the effects of beneficial use of dredged materials found that abundance of *Hediste diversicolor* had returned to ambient levels within 1 week (Bolam et al. 2004). Information from MarLIN Smith (1955) noted that when a population of *Hediste diversicolor* was covered with several inches of sand, the worms burrowed through the additional material and showed no adverse reaction. *Hediste diversicolor* are infaunal and display plasticity in their feeding methods (McLusky and Elliott, 1981; Nielsen et al. 1995). They are primarily deposit feeders but are able to switch to suspension feeding when conditions allow. They are therefore unlikely to be adversely affected by changes in siltation as

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						they would be able to employ the feeding method most appropriate for the environmental conditions. An increase in suspended sediment would result in an increased rate of siltation and therefore an increased food supply for deposit feeders. The species may therefore increase in abundance if food had been previously limiting. Based on the experimental evidence rather than the review (Gittenberger and van Loon, 2011) resistance is assessed as 'High' and recovery as 'Very High' so that the species is categorised as 'Not Sensitive',
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	L (*)	M-VH (**)	L-M (*)	Information from MarLIN (Budd, 2008) *Hediste diversicolor* inhabits depositional environments. It is capable of burrowing to depths of up to 0.3 m and reworking sub-surface modifications of its burrow through fine clays and sand. Smith (1955) found no appreciable difference in the population of a *Hediste diversicolor* colony which had been covered by several inches of sand through which the worms tunnelled. It would not be adversely affected by smothering with additional fine sediments. Smothering with impermeable materials would prevent *Hediste diversicolor* clearing the burrow to the sediment surface and prevent feeding. Larvae are more intolerant than adults as they are still acquiring the physical ability to burrow (see larval sensitivity). Based on this evidence, resistance to the addition of coarse materials is assessed as 'Low' and recovery as 'Medium- Very High' where habitat conditions are restored. If the spatial footprint of the impact is small, recovery will be through water transport and active migration within sediments and could be 'Very High' (within 6 months), however, for broadscale effects, recovery is assessed as 'Medium-High'. The sensitivity of this species is therefore considered to range from 'Low-Medium'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual - Boat/				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	vehicle movements					
	Visual - Foot/ traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N (*)	M-H (**)	M-H (*)	Rapid recovery (1 week) to ambient abundance levels was demonstrated from short-term increases in sand content in manipulation experiments where material was placed on intertidal mudflat (Bolam et al. 2004). The creation and maintenance of burrow structures requires the cohesive properties of mud and fine sand sediments - a permanent increase in the proportion of coarse sediment through changes in hydrodynamics would prevent the construction of these and hence *Hediste diversicolor* is judged to be an obligate inhabitant of fine sediment habitats- an increase in coarse sediments would therefore render the habitat unsuitable for this species. Based on these habitat assumptions, this species is judged to have no resistance to increased sediment coarseness and populations will not recover until the habitat is re-instated to original condition. Resistance is therefore assessed as 'None' and recovery as 'Medium-High' where impacts occur over a wide area. Sensitivity is therefore assessed as 'Medium-High'. The experiment by Bolam et al. (2004) indicated however that where changes are fleeting and the population is exposed to little impact, recovery will be very rapid.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	As this species is restricted to fine sediments it is considered to have 'High' resistance to the addition of further fine sediment particles and therefore recovery is assessed as 'Very High' (little or no impact to recover from). This species is therefore considered to be 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures	H (*)	VH (**)	NS (*)	Information from MarLIN (Budd, 2008) *Hediste diversicolor* characteristically inhabits littoral mudflats where the type, direction and speed of the currents control sediment deposition within an area. A change in two categories in water flow rate from weak and negligible to moderately strong and strong would entrain and maintain particles in

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		placed in the water column				suspension and erode the mud. The scouring and consequent redistribution of components of the substratum would alter the extent of suitable habitat available to populations of *H. diversicolor*. Recovery of this species would be influenced by the length of time it would take for the potential habitat to return to a suitable state for recolonization by adult and juvenile specimens from adjacent habitats, and the establishment of a breeding population. This may take between one and three years, as populations differ in reaching maturity (Dales, 1950; Mettam et al. 1982; Olive and Garwood, 1981), from the time that the habitat again becomes suited to the species. Decreases in flow rate may lead to increased deposition of fine sediments and organic matter that may enhance food supply. *H. diversicolor* are assessed as not sensitive to changes in water flow rate that do not alter sediment characteristics due to the protection afforded by the burrowing life habitat. Changes in water flow may alter sediment types and lead to siltation (see relevant pressures above for assessments).
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	Information from MarLIN (Budd, 2008) An increase in turbidity may affect primary production in the water column and therefore reduce the availability of diatom food, both for suspension feeders and deposit feeders. In addition, primary production by the microphytobenthos on the sediment surface may be reduced, further decreasing food availability for deposit feeders. However, primary production is probably not a major source of nutrient input into systems in which *Hediste diversicolor* occur and, furthermore, phytoplankton will also immigrate from distant areas so the effect may be decreased. *Hediste diversicolor* characteristically inhabits estuaries where turbidity is typically higher than other coastal waters. Changes in the turbidity may influence the abundance of phytoplankton available as a food source that may be attained through filter feeding. However, *Hediste diversicolor* utilizes various other feeding mechanisms and, the likely effects of a change in turbidity are limited (Budd, 2008). Based on this information *H. diversicolor* is considered to have 'High' resistance to increases in suspended sediment and hence 'Very High' recovery, leading to an assessment of 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	Information from MarLIN (Budd, 2008) A decrease in turbidity will mean more light is available for photosynthesis by macroalgae, phytoplankton in the water column and microphytobenthos on the sediment surface. This would increase the primary production in the biotope and *Hediste diversicolor* may react to the proliferation of phytoplankton by switching to suspension feeding. A decrease in the suspended sediment would result in decreased food availability for suspension feeders. It would also result in a decreased rate of deposition on the substratum surface and therefore a reduction in food availability for deposit feeders. This would be likely to impair growth and reproduction. *Hediste diversicolor* display plasticity in their feeding methods (McLusky and Elliott, 1981; Nielsen et al. 1995) and therefore are adapted to utilizing whatever food source is available (Budd, 2008) Based on this information *H. diversicolor* is assessed as 'Not Sensitive' to a reduction in turbidity as resistance is considered to be 'High' and recovery as 'Very High'.
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (**)	NS (**)	Information from MarLIN (Budd, 2008) Nutrient enrichment favours the growth of opportunistic green macro-algae blooms which can cause declines in some species and increases in others (Raffaelli, 2000). Evidence (Beukema, 1989; Reise et al. 1989; Jensen, 1992) suggested a doubling in the abundance of *Hediste diversicolor* in the Dutch Wadden Sea, accompanied by a more frequent occurrence of algal blooms that were attributed to marine eutrophication. Algae may be utilized by *Hediste diversicolor* in its omnivorous diet, so some effects of nutrient enrichment may be beneficial to this species. Based on this information *H. diversicolor* is assessed as 'Not Sensitive' to eutrophication. It should be noted that nutrient enrichment may be indirectly beneficial to this species as the food supply may be enhanced. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (**)	VH (**)	NS (**)	This species has been categorised through expert and literature review as 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). They are surface deposit-feeding species, as tubicolous spionids (Borja et al. 2000; validated by Gittenberger and van Loon, 2011).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Hediste diversicolor (as *Nereis diversicolor)* was identified as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski, 1975; cited in Gray, 1979) Based on the evidence above *H. diversicolor* is considered to have 'High' resistance and 'Very High' recovery to an increase in organic matter in sediments and the species is therefore considered to be 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (**)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. *H. diversicolor* are omnivorous and use a range of feeding strategies so they are not dependent on primary production by phytoplankton as a food supply. This species is therefore considered to have 'High' resistance and 'Very High' recovery to reduced phytoplankton abundance so that the species is considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (***)	VH (**)	NS (**)	Evidence from MarLIN (Budd, 2008) The littoral muds and muddy sands which *Hediste diversicolor* inhabits tend to have lower oxygen levels than other sediments. *Hediste diversicolor* are noted by Diaz and Rosenberg (1995) as resistant to severe hypoxia. The successful survival of *H. diversicolor* under prolonged hypoxia was confirmed by the resistance experiments of Vismann (1990), which resulted in a mortality of only 15% during a 22 day exposure of *Hediste diversicolor* at 10% oxygen (ca. 2.8 mg O_2 per litre). *Hediste diversicolor* is active at the sediment/water interface where hydrogen sulphide concentrations increase during periods of hypoxia. Vismann (1990), also demonstrated that the high tolerance of *Hediste diversicolor* to hypoxia in the presence of sulphide is enabled by elevated sulphide oxidation activity in the blood. *Hediste diversicolor* may also exhibit a behavioural response to hypoxia by leaving the sediment (Vismann, 1990) which is enhanced in the presence of sulphide. After 10 days of hypoxia (10% oxygen saturation) with sulphide (172-187 µmM) only 35% of *Hediste diversicolor* had left the sediment compared to 100% of *Nereis virens*. Laboratory experiments in the absence of sediments, found that *Hediste diversicolor* could survive hypoxia for more than 5 days and that it had a higher tolerance to hypoxia than *Nereis virens*, *Nereis succinea* and *Nereis pelagica* (Theede, 1973; Dries and
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	H (***)	VH (**)	NS (**)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Theede, 1974; Theede et al. 1973). Based on the evidence above *H. diversicolor* is assessed as 'Not Sensitive' to episodes of hypoxia (resistance is assessed as "High' and recovery as 'Very High'), although sensitivity to prolonged anoxia would be considered to be higher.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	M-VH (**)	L-M (*)	Evidence from MarLIN *Hediste diversicolor* is parasitized by the coccidian, *Coelotropha durchoni*, but apparently does not suffer mortality (Porchet-Hennere and Dugimont, 1992). Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit/). Sediments where *H. diversicolor* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. This assessment is based on the smothering pressure (see above). However, it should be noted that, once established, removal of these species may not be possible and recovery may therefore not occur. Sensitivity would therefore be greater.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target		L (*)	M-VH (**)	L-M (*)	This species is targeted by bait diggers (Anon, 1999; Fowler, 1999). However, very little information was found concerning the effect of this extraction and it is not possible to assess biotope intolerance

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Species					further than saying that a proportion of the species population would be removed. (Information from MarLIN). Information from MarLIN (Budd, 2008) *Hediste diversicolor*, a characteristic species of saltmarsh, may be used as bait by anglers and are often sold commercially. They are harvested using a fork to turn over the substrata and collected (note this information is not specific to saltmarsh). *Hediste diversicolor* is also used as a food source in aquaculture (Scaps, 2002). Populations of *Hediste diversicolor* are dominated by females, males may constitute up to 40% of the population but several reports suggest that the proportion of males is frequently lower (< 20%) (see Clay, 1967c). The sexes are externally indistinguishable except when approaching maturation and during spawning (see reproduction and adult general biology). Consequently extraction e.g. by bait digging, of 50% of the specimens from within an area is likely to remove more females than males. A reduction in the female proportion of the population prior to spawning could reduce recruitment to the population. The mechanical action of the digging, even if the worms were not actually taken, may also cause some damage to the bodies. Recovery is dependent on the reproductive success and survival of the remaining population and colonization by adults from unaffected areas. Targeted harvesting may be very efficient at removing this species, resistance to this pressure is therefore assessed as 'Low' (25-75% of population removed). Recovery rates and mechanisms will depend on the size of the area impacted. Where small-scale disturbance and removal has occurred rapid recovery may take place through water transport and migration from adjacent, un-impacted areas. However, following broadscale disturbances, the establishment of a mature population may take up to three years. Recovery is therefore assessed as 'Medium-Very High'. The sensitivity of this species is therefore considered to be 'Low-Medium'
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of	H (*)	VH (*)	NS (*)	*Hediste diversicolor* may be extracted, exposed or damaged during commercial fishing activities targeting other species such as cockle (*Cerastoderma edule*) as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		target species on non-target species				removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.	N-L (***)	M-H (**)	M-H (**)	The anti-parasite compound Ivermectin is highly toxic to benthic polychaetes and crustaceans (Black, 1998; Collier and Pinn, 1998; Grant and Briggs, 1998; cited in Wilding and Hughes, 2010). For example, Collier and Pinn (1998; summarised in Rayment, 2008) showed that the polychaete *Hediste diversicolor* was particularly susceptible to Invermectin, exhibiting 100% mortality within 14 days when exposed to 8 mg/m² of Ivermectin in a microcosm. Based on this assessment *H. diversicolor* is assessed as having 'No to Low' resistance and 'Medium to High' recovery, resulting in a sensitivity assessment of 'Medium to High'
	Introduction of hydrocarbons	Introduction of hydrocarbons	N-L (***)	M-H (**)	M-H (**)	Information from MarLIN (Budd, 2008) The 1969 West Falmouth (America) spill of Grade 2 diesel fuel documents the effects of hydrocarbons in a sheltered habitat (Suchanek, 1993). The entire benthic fauna including *Hediste diversicolor* was eradicated immediately following the spill and remobilization of oil that continued for a period > 1 year after the spill, contributed to much greater impact upon the habitat than that caused by the initial spill. Effects are likely to be prolonged as hydrocarbons incorporated within the sediment by bioturbation will remain for a long time owing to slow degradation under anoxic conditions. Oil covering the surface and within the sediment will prevent oxygen transport to the infauna and promote anoxia as the infauna utilize oxygen during respiration. Although *Hediste diversicolor* is tolerant of hypoxia and periods of anoxia, a prolonged absence of oxygen will result in the death of it and other infauna. McLusky (1982) found that petrochemical effluents released from a point source to an estuarine intertidal mudflat, caused severe pollution in the immediate vicinity. Beyond 500 m distance the effluent contributed to an enrichment of the fauna in terms of abundance and biomass similar to that reported by Pearson and Rosenberg (1978) for organic pollution, and *Hediste diversicolor* was found amongst an impoverished fauna at 250 m from the discharge.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on this assessment *H. diversicolor* is assessed as having 'None to Low' resistance and 'Medium to High' recovery, resulting in a sensitivity assessment of 'Medium to High'
	Introduction of antifoulants	Introduction of antifoulants	H (***)	VH (*)	NS (*)	A number of experimental studies have been undertaken to determine the sensitivity of this species to copper and zinc (ingredients within antifoulants). Field surveys have found that exposed populations can develop copper tolerance. In the highy contaminated Fal Estuary *Hediste diversicolor* has been found to live in sediments containing 4000 ppm (mg Kg^{-1} copper) and high levels of zinc (Bryan and Gibbs, 1983). *H. diversicolor* have also been found to live in areas with high levels of zinc (Bryan and Hummerstone, 1971). Based on a sediment quality guideline of 100 mg Kg^{-1} for Copper, the evidence from Bryan and Gibbs (1983) suggests that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited it is assessed as 'Not Sensitive'. Resistance is therefore categorised as 'High' and recovery as 'Very High', so that this species is considered to be 'Not Sensitive'.
	Barrier to species movement				NA	Not relevant to this species.

Table 8.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 8.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 8.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	**(1)	Not known	N/A
Deep Disturbance	***(1)	***	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***(5)	**	***
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion			
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	***(7)	***	***

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment of sediments	***(7)	***	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***(4)	**	***
Decrease in oxygen levels - Water column	***(4)	**	***
Genetic impacts			
Introduction of non-native species	***(1)	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species			
Ecosystem Services - Loss of biomass			
Introduction of medicines	***(1)	**	N/A
Introduction of hydrocarbons	***(3)	**	***
Introduction of antifoulants	*** (2)	*	N/A
Prevention of light reaching seabed/features	No evidence. Not assessed.		
Barrier to species movement	*	N/A	N/A
Barrier to species movement			

References

Aberson, M.J.R., Bolam, S.G. and Hughes, R.G. 2011. The dispersal and colonisation behaviour of the marine polychaete Nereis diversicolor in south-east England. Hydrobiologia 672(1): 3.

Barnes, R.S.K. 1994. The brackish-water fauna of northwestern Europe. Cambridge: Cambridge University Press.

Bolam, S.G., Whomersley, P. and Schratzberger, M. 2004. Macrofaunal recolonization on intertidal mudflats: effect of sediment organic and sand content. Journal of Experimental Marine Biology and Ecology 306: 157-180.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecologi- cal quality of soft-bottom benthos within European estuarine and coastal environ- ments. Marine Pollution Bulletin 40(12): 1100-1114.

Bryan, G.W. and Hummerstone, L.G. 1971. Adaptations of the polychaete *Nereis diversicolor* to estuarine sediments containing high concentrations of heavy metals. I. General observations and adaptation to copper. Journal of the Marine Biological Association of the United Kingdom 51: 845-863.

Bryan, G.W. and Gibbs, P.E. 1983. Heavy metals in the Fal estuary, Cornwall: A study of long term contamination by mining waste and its effects on estuarine organisms. Occasional Publications. Marine Biological Association of the United Kingdom (2) 112p.

Budd, G. 2008. *Hediste diversicolor*. Ragworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 20/09/2012]. Available from:
http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3470.

Dales, R.P. 1950. The reproduction and larval development of *Nereis diversicolor* O. F. Müller. Journal of the Marine Biological Association of the United Kingdom 29: 321-360.

Gittenberger, A. and van Loon, W.M.G.M. 2011 Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08.

Gray, J.S. 1979. Pollution-induced changes in populations.Philosophycal Transactions of the Royal Society of London, Series B 286: 545-561.

Jones, L.A., Hiscock, K. and Connor, D.W. 2000. Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. Joint Nature Conservation Committee, Peterborough (UK Marine SACs Project report).

Mettam, C., Santhanam, V. and Havard, M.C.S. 1982. The oogenic cycle of *Nereis diversicolor* under natural conditions. Journal of the Marine Biological Association of the United Kingdom 62: 637-645.

Olive, P.J.W. and Garwood, P.R. 1981. Gametogenic cycle and population structures of *Nereis* (*Hediste*) *diversicolor* and *Nereis* (*Nereis*) *pelagica* from North-East England. Journal of the Marine Biological Association of the United Kingdom 61: 193-213.

Rosa, S., Granadeiro, J.P., Vinagre, C., Franca, S., Cabral, H.N. and Palmeirim, J.M. 2008. Impact of predation on the polychaete *Hediste diversicolor* in estuarine intertidal flats. Estuarine, Coastal and Shelf Science 78: 655-664.

Rossi, F., Forster, R.M., Montserrat, F., Ponti, M., Terlizzi, A., Ysebaert, T. and Middelburg, J.J. 2007. Human trampling as short term disturbance on intertidal mudflats: effects of macrofauna biodiversity and population dynamics of bivalves. Marine Biology 151: 2077-2090.

Scaps, P. 2002. A review of the biology, ecology and potential use of the common ragworm *Hediste diversicolor* (O.F. Müller) (Annelida: Polychaeta). Hydrobiologia 470: 203-218.

Widdows, J., Brinsley, M.D. and Pope, N.D. 2009. Effect of *Nereis diversicolor* density on the erodability of estuarine sediment. Marine Ecological Progress Series 378: 135-143.

Zwarts, L. and Eselink, P. 1989. Versatility of male curlews (*Numeniius arquata*) preying upon *Nereis diversicolor*: deploying contrasting capture modes dependent on prey availability. Marine Ecology Progress Series 56: 255-269.

9. Species: *Lanice conchilega*

Species Description

- Taxonomy: Terebellid polychaete;
- Length: Up to 30cm long;
- Inhabits a tube made out of sand grains and shell fragments that projects 1-4cm above the sediment surface and can be up to 65cm long;
- Size: 25-30cm;
- Mobility: Burrower;
- Feeding type: Feeds on detritus and switches between suspension and deposit feeding modes (Buhr, 1976);
- Longevity: 1-2 years (Beukema et al. 1978), 3 years (Feral, 1989); and
- Ecological function: this species can form dense aggregations. These reefs trap sediment and support a number of commensal species. This heterogeneity increases diversity.

Recovery

Information taken from MarLIN (Ager, 2008, references therein).

Lanice conchilega spends up to 60 days in the plankton and could disperse over a wide area. Heuers and Jaklin (1999) found that areas with adult worms or artificial tubes were settled and areas without these structures were not. 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. Recoverability is, therefore, probably quicker in areas that already have a population of *L. conchilega* but will occur in suitable substratum within only a few years even in the absence of existing populations (Ager, 2008).

Information from Calloway et al. (2010, references therein).

The resilience *of Lanice conchilega* aggregations depends on the ability of larval and post-larval organisms to settle in areas where aggregations of tubes suffered some form of disturbance and were decimated or eradicated.

The small-scale distributional patterns of *L. conchilega* did not suggest much redistribution over time and given its sessile life style, this species may not be prone to prolific post-larval migration. However, in two of the three areas disturbed by cultivation of Manila clams measurable re-colonization took place after one or two years. The results tally with other descriptions of *L. conchilega's* re-colonization strategy, which appears to start with few adults migrating into an area (Zuhlke, 2001; Strasser and Pieloth, 2001). These relatively low numbers of post-larval immigrants provide a holdfast for juveniles and initiate a period of accelerated colonization. Also, juveniles may recolonize an area by adhering to hard substratum such as shells of dead bivalves, rather than attaching to tubes of adult conspecifics (Herlyn et al. 2008). If the environmental conditions are favourable, juveniles simply settle directly into the sediment (Strasser and Pieloth, 2001).

The duration of recovery, i.e. the elasticity, appears to range between one and four years (Heuers et al. 1998; Beukema, 1990; Zühlke, 2001; Calloway et al. 2010).

Water transport of adults, intact in tubes, has been observed after storms and this represents a potential colonisation mechanism. The tube itself can be rapidly repaired or rebuilt following damage (Nicolaidou, 2003).

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Lanice (Sand-mason) is a medium-large polychaete worm belonging to the Family Terebellidae. It reaches a length of 25-30cm and forms a characteristic tube of sand-grains ending at the head end in a tuft of sandy filaments that project from the surface of the sediment. The genus can be found in a wide range of sediments from coarse sand to sandy muds. The tube is U-shaped and allows water to be drawn through for gas exchange. The worm feeds on particulate matter on the sediment surface captured by a crown of tentacles. *Lanice* is capable of movement only within the tube, and is vulnerable to dredging and to deposition of material mobilised by the dredging process.

Lanice lives for about 1 year at which point reproduction occurs between April-June. The female releases around 160,000 eggs (about 0.18mm diameter) and these are fertilised at the sediment surface. The larvae spends about 8 weeks in a planktotrophic phase during which time a proto-tube develops before the post-larva sinks to the seabed. It has a capacity to disperse over considerable distances and can be found in dense communities. The relatively short life-span suggests that restoration of the biomass is achieved within 1 year following initial recolonisation by the juveniles. This genus has a high recoverability (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 9.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 9.2a and are combined, as in Table 9.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 9.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 9. 2a).

Table 9.1 *Lanice conchilega* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	*Lanice conchilega* inhabit tough, flexible tubes which afford some protection from surface abrasion. Tubes can be rapidly repaired and therefore this species is considered to have High' resistance to a single event of surface abrasion. Recovery is therefore assessed as 'Very High' (no, or very limited, effect to recover from). This species is therefore assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M-H (***)	H-VH (***)	NS-L (***)	Rabaut et al. (2008) studied fisheries impacts at the species level in temperate sandy bottom areas. A controlled field manipulation experiment was designed focusing on areas with high densities of *Lanice conchilega* (i.e. *L. conchilega* reefs). A treatment zone was exposed to a one-off experimental trawling and the impact on and recovery of the associated fauna was investigated for a period of 9 days post-impact. Community analysis showed a clear impact followed by a relatively quick recovery. The passage of a single beam trawl did not significantly alter the density of *L. conchilega*. Rabaut et al. (2009) 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 24 h, 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. This species has been categorised through literature and expert review, as AMBI fisheries Group IV - a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Information from MarLIN (Ager, 2008, references therein).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Lanice conchilega inhabits a permanent tube and is likely to be damaged by any activity that penetrates the sediment. Ferns et al. (2000) investigated the effect of mechanical cockle harvesting. The tubes of *L. conchilega* were damaged but this damage was seen to be repaired. An intolerance of intermediate has therefore been recorded. A recoverability of very high has been recorded. This assessment is for minor abrasion or disturbance, major abrasion, or disturbance would be similar to substratum removal (Ager, 2008). Based on the above evidence, *L. conchilega* is considered to have 'Medium-High' resistance to a single event of shallow disturbance and 'High-Vey High' recovery. The sensitivity of this specie is therefore assessed as 'Not Sensitive-Low'. Repeated disturbances will lead to greater effects.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M-H (***)	H-VH (***)	NS-L (***)	Based on shallow disturbance as evidence and assessment are also relevant to this pressure.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M-H (*)	H-VH (*)	NS-L (*)	Based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N-L (*)	M-H (***)	M-H (*)	Information from MarLIN (Ager, 2008, references therein). Displacement of *Lanice conchilega* would lead to increased risk of predation from flatfish (Ansell, 1995). Yonow (1989) observed *L. conchilega* re-establishing tubes immediately after removal from the sediment into a suitable sediment in the laboratory. Intolerance has therefore been recorded as intermediate (Ager, 2008). The removal of sediment will remove most or all this infaunal species population within the footprint of extraction, hence resistance to extraction is assessed as 'None'-Low'. Recovery following defaunation (where suitable habitat remains) has been observed to take three years on intertidal sand flats (and to occur in areas where no adults remain). In that study the recovery time was attributed to a decline in the wider meta-population (Strasser and Pieloth, 2001). Recovery is therefore assessed as 'Medium-

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						High'. Recovery will be influenced by the spatial scale of impact. Where small areas are impacted water transport of adults may reduce recovery times. The sensitivity of this species is therefore assessed as 'Medium-High'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (*)	NS (*)	This species has been categorised through expert and literature review, as AMBI sedimentation Group IV – a second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). This species dominated areas of Manila clam cultivation where protective netting had led to an increase in sedimentation (Spencer et al. 1996) and in areas where oysters were cultivated and sedimentation increased (Sylvand, 1995). Information from MarLIN (Ager, 2008) *Lanice conchilega* lives in the sediment and uses sand grains and shell fragments to make a tube that rises several centimetres above the sediment surface. It is therefore, unlikely that silt will smother the worm. It is also likely that *L. conchilega* will be able to move up through the extra sediment, therefore intolerance has been recorded as low. However, smothering by impermeable material is likely to result in anoxic conditions and have a greater impact. (Ager, 2008). Dense aggregations on *L. conchilega* trap sediment suggesting that this species has some tolerance to siltation by fine particles. The occurrence of this species in sandy habitats that are relatively dynamic suggests that water action will also remove deposits of fine sediments, reducing the impact of this pressure (although see increase in fine sediments and changes in water flow). Resistance based on these considerations and the above evidence, is therefore assessed as 'High' to both episodic and chronic siltation. Recovery is therefore assessed as 'Very High' and this species is assessed as 'Not Sensitive'.
	Smothering (addition of	Physical effects resulting from	N-L (*)	M-H (*)	M-H (*)	Information from MarLIN (Ager, 2008). *Lanice conchilega* lives in the sediment and uses sand grains and shell fragments to make a tube that

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	materials biological or non-biological to the surface)	addition of coarse materials				rises several centimetres above the sediment surface. It is therefore, unlikely that silt will smother the worm. It is also likely that *L. conchilega* will be able to move up through the extra sediment, therefore intolerance has been recorded as low. However, smothering by impermeable material is likely to result in anoxic conditions and have a greater impact (Ager, 2008). Other anthropogenic activities have been found to affect *L. conchilega* through increased input of particles into the system. Sludge disposal of dredged material in the Weser estuary, for example, caused a strong decline in *L. conchilega* densities (Witt et al. 2004). Resistance is judged as 'None' with recovery as 'Medium-High' if original habitat conditions are re-instated, so that the sensitivity of this species is assessed as 'Medium-High'. If there were no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed. This feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	*Lanice conchilega* occurs in mixed sediments and some increase in sediment coarseness is likely to be tolerated. However, the removal of a large proportion of fine sediment content, e.g. through winnowing, is likely to reduce habitat suitability for this species (see changes in fine sediment composition). Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (***)	VH (***)	NS (***)	Dense aggregations of *Lanice conchilega* facilitate the deposition of fine materials as the tubes reduce the velocity of flow. Some increase in fine sediment fraction is therefore likely to be tolerated. *L. conchilega* are recorded from a variety of sediments. *L. conchilega* have dominated areas where fine particles are deposited due to cultivation of oysters (Sylvand, 1995). Degraer et al. (2006) report that *L. conchilega* displays a preference for fine to medium-grained sediments (100 to 500µm) with a relatively high mud content (10 to 40%). An increase in fine sediment proportion is considered to be tolerated by this species (unless it exceeds habitat preference thresholds, i.e. change to a pure mud sediment). Resistance is therefore assessed as 'High' and recovery, consequently, as 'Very High'. This species is therefore assessed as 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2008). A decrease in water flow will lead to deposition of finer sediments and the possibility of reduced food supply. Changes in water flow rate are likely to change the distribution and extent of the population due to changes in the preferred substratum of *Lanice conchilega*. Therefore, an intolerance of intermediate has been recorded (Ager, 2008). Suspension feeders such as *L. conchilega* tend to dominate more exposed shores and coarser sediments where food supply may be limited but constant and with their abundance determined by the supply of particulate organic material and plankton in the water (Brown, 1983; McLachlan, 1983; Peterson, 1991; cited in Elliott, 1998). However, dense and more stable aggregations of *L. conchilega* seem more likely to form under more sheltered conditions (Hertweck, 1995; Callaway et al. 2010). Increases in water flow that remove fine sediment are considered unlikely to affect this species, or to be beneficial through increasing food supply. However, aquaculture installations are more likely to result in reduced water flows which may lead to the deposition of fine sediments (see siltation pressure above). On more exposed shores this may enhance juvenile recruitment. The dominance of *L. conchilega* in sheltered areas beneath Manila clam lays (Spencer et al. 1996) and oyster cultivation areas indicate that resistance is 'High and recovery is 'Very High' so that this species is assessed as 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2008). *Lanice conchilega* is a deposit and/ or suspension feeder and unless the feeding crown is clogged is unlikely to be troubled by an increase in suspended sediment and tolerant has, therefore, been recorded. *L. conchilega* is found in estuarine regions which experience high levels of turbidity. An increase in turbidity would lead to reduced light penetration of the water column. *L. conchilega* is not light dependent, therefore, tolerant has been recorded for this pressure (Ager, 2008). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2008, references therein). A decrease in suspended sediment may mean a reduction in the amount of available food for *Lanice conchilega*; however, the protruding part of the tube affects the near bottom flow rate which can lead to an increase in sediment re-suspension (Jones and Jago, 1993). In any case, any adverse affect will lead to a loss of condition rather than mortality. Therefore, an intolerance of low has been recorded. *L. conchilega* is not affected by light availability therefore tolerant has been recorded for this pressure (Ager, 2008). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As *Lanice* sp. are not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton and algal detritus may be utilised as food by this genus. This species is therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (*)	VH (*)	NS (*)	This species has been categorised by Borja et al. (2000) 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). This assessment was reviewed by Gittenberger and van Loon (2011) and changed 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).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	Ropert and Goulletquer (2000) who studied the trophic competition between *Lanice conchilega* and cultivated oysters, obtained worm clearance rates ranging from 0.073 to 0.108 l h^{-1} ind^{-1} and retention efficiencies starting above 4µm. *Crassostrea gigas* and *L. conchilega* could be competitors, but Dubois et al. (2007) have demonstrated that these suspension-feeding species had a different diet. The dominance of *L.conchilega* beneath oyster cultivation trestles (Sylvand, 1995) and in Manila clam lays (Spencer et al. 1996), indicate that this species is not outcompeted by cultivated bivalves. Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	L (***)	M-H (*)	M (*)	Niermann et al. (1990; cited in Rayment, 2008) reported that the abundance of *Lanice conchilega*, in a fine sand community in the German Bight area exposed to regular seasonal hypoxia, was significantly reduced during a period of hypoxia (1-3mg/O_2/dm^3) (evidence specific to EUNIS biotope A5.242). Based on the above information, resistance was assessed as 'Low' and recovery as 'Medium-High', Sensitivity was therefore assessed as 'Medium.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L (***)	M-H (*)	M (*)	Niermann et al. (1990; cited in Rayment, 2008) reported that the abundance of *Lanice conchilega*, in a fine sand community in the German Bight area exposed to regular seasonal hypoxia, was significantly reduced during a period of hypoxia (1-3mg/O_2/dm^3) (evidence specific to EUNIS biotope A5.242). Based on the above information, resistance was assessed as 'Low' and recovery as 'Medium-High', Sensitivity was therefore assessed as 'Medium'.
Biological Pressure	Genetic impacts on wild populations and	Presence/absence benchmark, the presence of farmed and translocated species presents a			NE	Not Exposed. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	translocation of indigenous populations	potential risk to wild counterparts				
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	N-L (*)	M-H (*)	M-H (*)	No evidence found. Assessment based on smothering as the settlement of *Crassostrea gigas* or *Crepidula fornicata* would effectively lead to substratum smothering.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This genus will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the genus is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated			NEv	No evidence found. Not Assessed.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		with aquaculture.				
	Introduction of hydrocarbons	Introduction of hydrocarbons	L-M (***)	VH (***)	L (***)	Information from MarLIN (Ager, 2008) Soft sediment communities and especially infaunal polychaetes are particularly affected by oil pollution (Suchanek, 1993). A 20 year study investigating community effects after the Amoco Cadiz oil spill of 1978 (Dauvin, 2000) found that a population of *Lanice conchilega* was established between 1978-84 but disappeared after 1985 (Ager, 2008). From the above evidence the establishment of a population of *L. conchilega* following the oil spill was interpreted as demonstrating 'Low-Medium' resistance to this pressure (some lethal effects following spill) and 'Very High' recovery. Sensitivity was therefore assessed as 'Low'.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Based on a Cu sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000), it is assumed, (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Lanice conchilega* does not photosynthesise and do not, therefore, directly require light and are therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to Annex I habitats and species.

Table 9.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 9.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 9.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***(4)	***	***
Deep Disturbance	***(4)	***	***
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***(4)	***	***
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*** (1)	***	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (1)	*	N/A
Decrease in oxygen levels - Water column	*** (1)	*	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence found. Not assessed.		
Introduction of hydrocarbons	*** (1)	*	N/A
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Ager, O. 2008. *Lanice conchilega*. Sand mason. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 30/08/2012]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=3633.

Beukema, J.J., Debruin, W. and Jansen, J.J.M. 1978. Biomass and species richness of macrobenthic animals living on tidal flats of the Dutch Wadden Sea - Long-term changes during a period with mild winters. Netherlands Journal of Sea Research 12: 58-77.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40: 1100-1114.

Buhr, K.J. 1976. Suspension-feeding and assimilation efficiency in *Lanice conchilega* (Polychaeta). Marine Biology 38: 373-383.

Callaway, R., Desroy, N., Dubois, S.F., Fournier, J., Frost, M., Godet, L., Hendrick, V.J. and Rabaut, M. 2010. Ephemeral Bio-engineers or Reef-building Polychaetes: How Stable are Aggregations of the Tube Worm *Lanice conchilega*. Integrative and Comparative Biology 50(2): 237-250.

Degraer, S., Wittoeck, J., Appeltans, W., Cooreman, K., Deprez, T., Hillewaert, H., Hostens, K., Mees, J., Vanden Berghe, E. and Vincx, M. 2006. The macrobenthos atlas of the Belgian part of the North Sea. Belgian Science Policy. 164 pp.

Dubois, S., Barille, L. and Retiere, C. 2003. Efficiency in the paticle retention and clearance rate in the polychaete *Sabellaria alveolata* L. C. R. Biologies 326: 413-421.

Dubois, S., Orvain, F., Marin-Léal J. C., Ropert, M. and Lefebvre, S. 2007. Small-scale spatial variability of food partitioning between cultivated oysters and associated suspension feeding species, as revealed by stable isotope analysis. Marine Ecology Progress Series 336: 151-160.

Elliott, M. 1998. Summary of effects of commercial fisheries on estuarine ecosystems: a European perspective. Unpublished report to SCOR working group 105, Halifax NS, March 1998. p57.

Feral, P. 1989. Influence des populations de *Lanice conchilega* (Pallas) (Annelida, Polychaeta) sur la sedimentation sableuse intertidale de deux plages bas-nomandes (France). Bulletin de la Societe Geologique de France 8: 1193-1200.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS Report No 2011.08.

Hertweck, G. 1995. Verteilung charakteristischer Sedimentkorper und der Benthossiedlungen im Ruckseitenwatt der Insel Spiekeroog, sudliche Nordsee Wattkartierung 1988-92. Senck marit 26: 81-94.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Nicolaidou, A. 2003. Observations on the re-establishment and tube construction by adults of the polychaete *Lanice conchilega*. Journal of the Marine Biological Association of the United Kingdom 83: 1223-1224.

Rabaut, M., Braeckman, U., Hendrickx, F., Vincx, M. and Degraer, S. 2008. Experimental beam-trawling in *Lanice conchilega* reefs: Impact on the associated fauna. Fisheries Research 90: 209-216.

Rabaut, M., Vincx, M., Hendrickx, F. and Degraer, S. 2009. The resistance of *Lanice conchilega* reefs to physical disturbance. In: Rabaut, M. (Ed.) *Lanice conchilega*, fisheries and marine conservation: Towards an ecosystem approach to marine management. pp. 79-90.

Rayment, W.J. 2008. Venerid bivalves in circalittoral coarse sand or gravel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth, Marine Biological Association of the UK. Available from:
http://www.marlin.ac.uk/habitatsbasicinfo.php?habitatid=63&code=1997.

Ropert, M. and Goulletquer, P. 2000. Comparative physiological energetics of two suspension feeders: polychaete annelid *Lanice conchilega* (Pallas 1766) and Pacific cupped oyster *Crassostrea gigas* (Thunberg 1795). Aquaculture 181: 171-189.

Spencer, B.E., Kaiser, M.J. and Edwards D.B. 1996. The effect of Manila clam cultivation on an intertidal benthic community: The early cultivation phase. Aquaculture Research 27: 261-276.

Strasser, M. and Pieloth, U. 2001. Recolonization pattern of the polychaetes *Lanice conchilega* on an intertidal sand flat following the severe winter of 1995/96. Helgoland Marine Research 55: 176-181.

Sylvand, B. 1995. The Baie des Veys (Western Littoral of the Bay of Seine, English Channel) 1972–1973 - Structure and Long-Term Evolution of a Soft-Bottom Intertidal Benthic Ecosystem under Estuarine Influence. PhD Thesis, Universite de Caen, 409 pp.

Witt, J., Schroeder, A., Knust, R. and Arntz, W.E. 2004. The impact of harbour sludge disposal on benthic macrofauna communities in the Weser estuary. Helgoland Marine Research 58: 117-128.

10. Species: *Lumbrineris latreilli*

Species Description

- Taxonomy: Polychaete worm;
- Feeding method: Because of its jaws, *Lumbrineris latreilli* is recorded as a predator, similar to most other lumbrinerids (Fauchald and Jumars, 1979);
- Length: 50-300 mm (Hayward and Ryland, 1995); and
- Habitat: The species shows a preference for muddy fine sand, but is also recorded from coarse sand, gravel, among algae and sea grass and in black mud under stones (Hartmann-Schröder, 1971; Hayward and Ryland, 1990). In sand, mud, shell fragments, gravel, and mixtures of these, under stones, amongst algae and sea grass (*Posidonia* and *Zostera*) from the intertidal zone to a depth of about 4800 m (World Register of Marine Species; cited in Holtmann et al. 1996).

Recovery

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Lumbrineris latreilli probably has a non-pelagic development (Woolf, 1973; Fauchald and Jumars, 1979). It is a medium-large eunicid polychaete belonging to the Family Lumbrineridae. It is a free-living burrowing genus that reaches 10-40 cm in length and lives in a mucus-lined burrow in gravel, muddy sand, mud and shelly substrata. It feeds on living and dead animals in the sediment and has very low mobility. It is vulnerable to the direct effects of dredging and to the deposition of sediments mobilised during the dredging process.

Lumbrineris lives for about 3-5 years and reproduces once at the end of this time. The reproductive season is from June-August. There are about 500 eggs per brood. Each egg is about 0.3 mm in diameter and the eggs are released as egg masses that are fertilised externally at the sediment surface. There is no dispersal phase and growth takes place over a period of 3-5 years, so this genus is assessed as of low recoverability following disturbance by dredging (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 10.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report).

The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 10.2a and are combined, as in Table 10.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 10.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 10.2a).

Table 10.1 *Lumbrineris latreilli* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	No evidence found. As this species is found free-living within the sediment it is considered to be protected from surface abrasion. Based on environmental position this species is assessed as having 'High' resistance to surface abrasion and therefore recovery (based on little or no impact) is assessed as 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	H (*)	VH (*)	NS (*)	This species was characterised as AMBI Fisheries Review Group III - Species insensitive to fisheries in which the bottom is disturbed. Their populations do not show a significant decline or increase (Gittenberger and van Loon, 2011). Based on the above review, this species is assessed as having 'High' resistance to shallow disturbance and therefore recovery (based on little or no impact) is assessed as 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	H (*)	VH (*)	NS (*)	Assessment based on the Gittenberger and van Loon (2011) review (see shallow disturbance).
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Assessment based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	H (*)	VH (*)	NS (*)	Assessment based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/	N (*)	L (*)	VH (*)	Extraction of the sediment will remove most of the population so that resistance is categorised as 'none'. Recovery will be limited by the low mobility and low dispersal potential of this species and the relatively long period to reach sexual maturity and breed (3-5 years). Recovery is therefore assessed as low, so that sensitivity is categorised as 'Very High'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		macroalgae				
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (***)	NS (***)	This species was characterised as AMBI Sedimentation Group III - Species insensitive to higher amounts of sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Based on the above evidence, resistance to siltation was assessed as 'High' and recovery (based on little effect) was 'Very High', this species is therefore considered to be 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	L (*)	M (*)	M (*)	Smothering with coarse materials is likely to prevent *Lumbrineris* sp. reaching the surface to spawn. As the species is considered to have low mobility (MES Ltd, 2010) resistance was considered to be 'Low' as individuals are unlikely to escape surface smothering. Recovery was assessed as 'Medium'. This genus is therefore considered to be 'Medium'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	Based on published habitat preferences (see introduction) which indicate that this species occurs on a wide range of habitat types, resistance is considered to be 'High' and recovery as 'Very High'. This

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	composition - Increased coarseness					species is assessed as 'Not Sensitive' to increases in coarse sediment fraction.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	Based on published habitat preferences (see introduction) which indicate that this species occurs on a wide range of habitat types, resistance is considered to be 'High' and recovery as 'Very High'. This species is assessed as 'Not Sensitive' to increases in fine sediment fraction.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	JNCC record a biotope within which this species occurs (SS.SCS.CCS.MedLumVen as occurring within weak (>1 kn) to moderately strong (1-3 kn) tidal streams. This species also occurs in a wide range of sediment types indicating that it is tolerant to a range of hydrodynamic regimes as these are a strong determiner of sediment type. Localised scour from structures may remove sediments (see extraction pressure) but in general this species is not considered sensitive to changes in water flow based on habitat preferences. Resistance is therefore assessed as 'High' and recovery as 'Very High' leading to an assessment of 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (***)	VH (***)	NS (***)	*Lumbrineris latreilli* live completely buried within the sediment and are protected from the resulting physical changes (decrease in light penetration and increased scour). Such changes may lead to decreased production within the system (phytoplankton or microphytobenthos) altering food supply but this may be compensated by increased deposition of organic materials. An increase in the supply of organic materials is likely to benefit this species, density of *L. latreilli* has increased in response to particulate organic matter (Harmelin-Vivien, 2009) *Lumbrineris latreilli* is assessed as 'not sensitive' to this pressure as it was considered to be beneficial to this species. Resistance is therefore assessed as 'High' and recovery as 'Very High' leading to an assessment of 'Not Sensitive'.
	Changes in turbidity/ suspended	Decrease in particulate matter (inorganic and	H (*)	VH (*)	NS (*)	No evidence found. Decreased turbidity from a reduction in inorganic particles is not predicted to directly effect this species. A reduction in suspended organic particles may indirectly reduce food supply impacting growth rates and reproduction, such effects are predicted to be sub-lethal.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment - Decreased suspended sediment/ turbidity	organic)				Resistance is predicted to be 'High and recovery 'Very High' leading to an assessment of 'Not Sensitive'. Indirect effects of reduced turbidity such as an increase in predation from enhanced prey location by fish etc are possible but not considered here.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	Eutrophication is not predicted to directly impact this species, increased nutrient levels may stimulate primary production and lead to deposition of more organic matter benefiting this species. Resistance is therefore considered to be 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive' to this pressure.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	The addition of particulate organic matter has led to increased density of *L. latreilli* (Harmelin-Vivien, 2009). Increases in organic matter that stimulate bacterial production resulting in hypoxia/anoxia are assessed in the 'decreased oxygen' pressure below. This species was 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 and van Loon, 2011). *Lumbrineris latreilli* is assessed as 'Not Sensitive' to this pressure as it was considered to be beneficial to this species. Resistance is therefore considered to be 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive' to this pressure.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance is therefore considered to be 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive' to this pressure.
	Decrease in	Hypoxia/anoxia of	M (***)	M-H (*)	L (*)	The congener *L. longifolia* was one of the most persistent species in hypoxic conditions experienced off

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	oxygen levels - Sediment	sediment				the coast of North Korea (Lim et al. 2006). As the oxygen level decreases Rabalais et al. (2001) observed that hypoxic conditions in the North Coast of the gulf of Mexico (oxygen concentrations from 1.5 to 1 mg/L (1 to 0.7 ml L^{-1}) led to the emergence of *Lumbrineris* sp. from the substrate these then lie motionless on the surface. Based on the information above and the presence of this species in anoxic muds beneath stones (see Introduction) resistance was assessed as 'Medium' and recovery as 'Medium-High'. Sensitivity was therefore considered to be 'Low".
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	M (***)	M-H (*)	L (*)	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock	H (*)	VH (*)	NS (*)	No evidence found. The most likely species that would colonise the habitats in which this species is found are the Pacific oyster, *Crassostrea gigas* and the slipper limpet, *Crepidula fornicata.* The burrowing lifestyle of this species and broad habitat tolerances (see introduction) may confer some protection from changes to the sediment. Based on these consideratons, resistance is assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Potential impacts from commercial fisheries within this species/habitat are considered in the physical disturbance pressures above.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Resistance is considered to be 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment, resistance is therefore assessed as 'High' and recovery as 'Very High' and the species is assessed as 'Not Sensitive'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No Evidence found. Not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	L (***)	L (*)	M (*)	The Braer oil spill in Shetland in 1993 provided an opportunity to identify species that increased or declined in abundance where oiling occurred. Severe weather conditions meant that oil was incorporated into sediments. Kingston et al. (1995) noted that the congener *L. gracilis* (from Hiscock et al. 2004) declined at oiled sites. Based on the above evidence, resistance was assessed as 'Low' and recovery as 'Medium'. Sensitivity is therefore assessed as 'Medium'.
	Introduction of antifoulants	Introduction of antifoulants	L (***)	L (*)	M (*)	Rygg (1985) classified *Lumbrineris* spp. species as non-tolerant of Cu (species only occasionally found at stations in Norwegian fjords where Cu concentrations were > 200 ppm (mg kg^{-1})). Based on the above evidence sensitivity was assessed as 'Low' and recovery as 'Medium'. Sensitivity is therefore assessed as 'Medium'.
Physical Pressures	Prevention of light reaching	Shading from aquaculture	H (*)	VH (*)	NS (*)	As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited, resistance is assessed as 'High' and recovery as

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	seabed/ features	structures, cages, trestles, longlines				'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Barrier to species movement				NA	Not assessed.

Table 10.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 10.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 10.3 Resistance Assessment Confidence Levels

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***	Not clear	Not clear
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*** (1)	*	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	***	*	*

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (1)	*	N/A
Decrease in oxygen levels - Water column	***(1)	*	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not Assessed. No Evidence.		
Introduction of hydrocarbons	***(1)	*	N/A
Introduction of antifoulants	***(1)	*	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Fauchald, K. and Jumars, P.A. 1979. The diet of worms: a study of polychaete feeding guilds. In: Barnes, M. (Ed.) Oceanography and Marine Biology: an annual review 17: 193-284.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011-08.

Harmelin–Vivien, M.L., Bănaru, D., Dierking, J., Hermand, R., Letourneur, Y. and Salen–Picard, C. 2009. Lin- king benthic biodiversity to the functioning of coastal ecosystems subjected to river runoff (NW Mediterranean). Animal Biodiversity and Conservation 32(2): 135-145.

Hartmann-Schröder, G. 1971. Annelida, Borstenwürmer, Polychaeta. Tierwelt Deutschlands 58: 1-594.

Hayward, P.J. and Ryland, J.S. 1990. The marine fauna of the British Isles and North-West Europe: 1. Introduction and protozoans to arthropods. Clarendon Press: Oxford, 1-627 pp.

Hayward, P.J. and Ryland, J.S. 1995. Handbook of the marine fauna of North-West Europe. Publisher: Oxford: Oxford University Press.

Hiscock, K., Langmead, O. and Warwick, R. 2004. Identification of seabed indicator species from time-series and other studies to support implementation of the EU Habitats and Water Framework Directives. Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association. Plymouth: Marine Biological Association. JNCC Contract F90-01-705. 109 pp.

Holtmann, S.E., Groenewold, A., Schrader, K.H.M., Asjes, J., Craeymeersch, J.A., Duineveld, G.C.A., van Bostelen, A.J. and van der Meer, J. 1996. Atlas of the zoobenthos of the Dutch continental shelf. Ministry of Transport, Public Works and Water Management: Rijswijk, The Netherlands. ISBN 90-369-4301-9. 243 pp.

Kingston, P.F., Dixon, I.M.T., Hamilton, S. and Moore, D.C. 1995. The impact of the Braer oil spill on the macrobenthic infauna of the sediments off the Shetland Islands. Marine Pollution Bulletin 30: 445-459.

Lim, H.S., Diaz, R.J., Hong, J.S. and Schaffner, L.C. 2006. Hypoxia and benthic community recovery in Korean coastal waters. Marine Pollution Bulletin 52: 1517-1526.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Rabalais, N.N., Harper Jr., D.E. and Turner, R.E. 2001. Responses of nekton and demersal and benthic fauna to decreasing oxygen concentrations, In: Rabalais, N.N. and Turner, R.E (Eds.) Coastal and estuarine studies: 3637 coastal hypoxia consequences for living resources and ecosystems, American Geophysical Union, Washington, D.C., 115–128.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

11. Species: *Nephtys cirrosa*

Species Description

- Common name: White catworm;
- Length: Up to 10cm;
- Infaunal;
- Mobility: Active worm able to swim, crawl and burrow; and
- Feeding type: Predator and scavenger (BIOTIC).

Nephtys cirrosa has been recorded as a characterising species from a range of EUNIS biotopes (Table A).

Table A: Biotopes with which *Nephtys cirrosa* is commonly associated

EUNIS (version 200410)	Marine Habitat Classification for Britain and Ireland Version 04.05
A2.231	LS.LSa.FiSa.Po
A2.2312	LS.LSa.FiSa.Po.Aten
A2.2313	LS.LSa.FiSa.Po.Ncir
A5.222	SS.SSa.SSaVS.NcirMac
A5.23	SS.SSa.IFiSa
A5.231	SS.SSa.IFiSa.IMoSa
A5.233	SS.SSa.IFiSa.NcirBat
A5.241	SS.SSaIMuSa.EcorEns

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Wave exposure: Exposed, moderately exposed, sheltered, very sheltered, extremely sheltered;
- Tidal streams: Strong (3-6kn), moderately strong (1-3kn), weak (>1kn), very weak (negligible);
- Substratum: Medium sand, fine sand, very fine sand, slightly muddy sand; and
- Other features: Surface veneer of mud may be present at slack water (SS.SSa.SSaVS.NcirMac).

Recovery

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Nephtys is a genus of medium-sized polychaete worms belonging to the Family Nephtyidae (catworms). It is a free-living worm that reaches 10cm in length and lives burrowed in sands and muddy sands, where it is a carnivore feeding on small invertebrates. It is capable of swimming as well as crawling and burrowing. It is likely to be vulnerable to dredging but can probably accommodate limited sediment deposition from the dredging process.

Nephtys is a relatively long-lived polychaete with a life-span of 6 to possibly as much as 9 years. It matures at 1year 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 are fertilised externally and 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 likely to have a high recoverability following disturbance (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 11.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 11.2a and are combined, as in Table 11.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 11.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 11. 2a).

Table 11.1 *Nephtys cirrosa* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	Based on environmental position, the presence of this species within highly mobile sediments (Connor et al. 2004) and the evidence presented below in shallow and deep disturbance. Resistance is categorised as 'High', due to lack of effects, resilience is also categorised as 'Very High' therefore this species is assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	VH (***)	L (***)	Shallow disturbance will result in the surface disturbance effects outlined above. Additionally, Tuck et al. (1998) assessed the effects of trawling disturbance in a previously unfished sheltered Scottish sea loch consisting of a fine muddy habitat. The polychaete *Nephtys cirrosa* was identified as a sensitive species. Information from MarLIN (Budd, 2008, references therein). Ferns et al. (2000) recorded significant losses of common infaunal polychaetes from areas of muddy sand worked with a tractor-towed cockle harvester. For instance, 31% of the polychaete *Scoloplos armiger* (initial density of 120 per m^2) were removed (Budd, 2008). This species is categorised as AMBI- Fisheries Review Group II - Species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly (Gittenberger and van Loon, 2011). Based on the above evidence, shallow disturbance was considered to impact a proportion of the population, however the infaunal position of this species and its presence in mobile sediments subject to frequent natural disturbance were considered to support an assessment of 'Medium' resistance. Based on evidence presented below (deep disturbance) the high mobility of this species and the presence of a population to provide recruits, recovery was assessed as 'High' to 'Very High'. The sensitivity of this species was, therefore, assessed as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm)	M (***)	H-VH (***)	L (***)	Following experimental hydraulic dredging for razor clams there were no statistically significant different differences in *Nephtys cirrosa* abundances between treatments after 1 or 40 days (Hall et al. 1990).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		disturbance				Experiments in shallow wave disturbed areas using a toothed, clam dredge found that some polychaete taxa without external protection and with a carnivorous feeding mode were enhanced by fishing. *Nephtys* sp. were one of these: large increases in abundance in samples were detected post dredging and persisting over 90 days. The passage of the dredge across the sediment floor will have killed or injured 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. The persistence of disturbance will benefit these, increasing their abundance (Frid et al. 2000) and potentially changing the trophic structure of the benthic communities. Based on the above evidence, deep disturbance was considered to impact a proportion of the population; however, the infaunal position of this species and its presence in mobile sediments subject to frequent natural disturbance were considered to indicate 'Medium' resistance. Based on the high mobility of this species and the presence of a population to provide recruits, recovery was assessed as 'High' to 'Very High'. The sensitivity of this species was therefore assessed as 'Low'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Assessment based on surface abrasion.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	VH (**)	L (*)	No evidence found. The greater weight of vehicles is predicted to lead to compaction of sediment crushing some worms within burrows. Resistance is therefore assessed as "Medium' and recovery as 'Very High' resulting in a "Low' sensitivity assessment.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	H (*)	L (*)	Three years after intensive aggregate extraction of 30 years duration had ceased, abundances of juvenile and adults *Nephtys cirrosa* had greatly increased (Mouleaert and Hostens, 2007). Removal of substrate would remove infaunal populations including *N. cirrosa.* Depending on the scale of extraction, recovery would require sediment infilling and would occur through migration or larval supply. Resistance is categorised as 'None' and recovery as 'High' so that sensitivity is assessed as Low.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (***)	NS (***)	Information from MarLIN (Budd, 2008, references therein). *Nephtys* species are highly mobile within the sediment. Vader (1964) observed that *N. hombergii* relocated throughout the tidal cycle and is unlikely to be affected by smothering with a sediment consistent with that of the habitat (Budd, 2008). Allen and Moore (1987) found that *N. cirrosa* was the only errant polychaete strongly associated with unstable sediments. This species is categorised as AMBI Sedimentation review Group IV - Second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). Based on the above evidence, resistance to siltation was assessed as 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive'. Siltation may lead to habitat changes where sediments become finer (see changes in sediment composition below), however in the sandy areas where this species is found water transport may rapidly remove fine sediments reducing effects.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	H (*)	VH (*)	NS (*)	*Nephtys* are one of the few polychaetes that are able to live in shifting sand and can penetrate and move through sand very efficiently (Truman and Ansell, 1969; cited from Tyler-Walters et al. 2005). The mobility of this species suggests that in areas of localised smothering the species will be able to move though the sand to escape an impermeable surface layer. The addition of a surface layer of coarse materials may however reduce habitat suitability. Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Noise					
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	M (*)	H (**)	L (*)	The coarsest sediments that this species occurs in are medium sands, an increase in the coarse fraction greater than this sediment type would be considered likely to impact this species. An increase of sediment coarseness to greater particle size than sand would exclude this species, recovery would depend on the return of previous habitat conditions. Resistance is judged as 'None' with recovery as 'Very High' if habitat conditions are re-instated, If there was no habitat recovery then sensitivity would be 'Very High'. Overall sensitivity of this species is assessed as "Low'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	This species is found in a range of sediment types and is present in areas where a surface layer of mud may be deposited on slack tides (see Introduction). An increase in fine sediment proportion is therefore considered to be tolerated by this species (unless it exceeds habitat preference thresholds, i.e. change to a pure mud sediment). Resistance is therefore assessed as 'High' and recovery, consequently, as 'Very High'. This species is therefore assessed as 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	M (*)	VH (*)	L (*)	*Nephtys* are one of the few polychaetes that are able to live in shifting sand and can penetrate and move through sand very efficiently (Truman and Ansell, 1969; cited from Tyler-Walters et al. 2005). Allen and Moore (1987) found correlations between community structure and the prevailing physical conditions including shore stability for both individual organisms and guilds. *N. cirrosa* was the only errant polychaete strongly associated with unstable sediments (from Elliott et al. 1998). This species is found in habitats that occur in a range of tidal stream strength (see Introduction Sections). This species is therefore unlikely to be sensitive to changes in water flow that do not alter the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						sediment type. Decreases in flow rate (which are more likely to occur through aquaculture infrastructure) may lead to increased deposition of fine sediments and organic matter. *N. cirrosa* occur in sandy muds in some sheltered areas / where fine sediments may be temporarily deposited. Some resistance to reductions in water flows is therefore suggested and resistance is assessed as 'Medium' and recovery as 'Very High' where this occurs through adult migration. Sensitivity is therefore assessed as 'Low'. Sensitivity to water flow changes that substantially alter habitat character will be higher (see changes in sediment composition above).
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	As an infaunal predator an increase in turbidity is considered unlikely to affect this species. Resistance is therefore categorised as 'High' so that recovery is 'Very High' and the species is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	As this species is primarily predatory, decreased turbidity will not lead to a reduction in food supply. Resistance is therefore assessed as 'High', recovery as 'Very High'; the species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	This species does not feed on phytoplankton or algae and therefore an increase in plant nutrients is considered unlikely to negatively impact this species. Indirect eutrophication effects such as de-oxygenation following algal blooms are considered below. Resistance to eutrophication is therefore assessed as 'High' and recovery as 'Very High', so that this

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						species is assessed as 'Not Sensitive'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (*)	VH (*)	NS (*)	The congener *Nephtys hombergi* are tolerant of nutrient enrichment (Pearson and Rosenberg, 1978). This species is categorised 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 and van Loon, 2011). Based on this information, resistance is assessed as 'High', recovery as 'Very High', so that this species is assessed as 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	This species is primarily a predator of invertebrates and is not considered to be sensitive to increased removal of phytoplankton. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd, 2008, references therein). *Nephtys hombergii* was found to be particularly tolerant of severe hypoxia and hydrogen sulphide (Alheit, 1978; Arndt and Schiedek, 1997; Budd, 2008). Based on evidence from the congener *N. hombergii* resistance is assessed as 'High', recovery as 'Very High' and hence sensitivity is assessed as 'Not Sensitive'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	H (*)	VH (*)	NS (*)	Resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
Biological Pressure	Genetic impacts on wild populations and	Presence/absence benchmark, the presence of farmed and translocated species presents a			NE	Not Exposed. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	translocation of indigenous populations	potential risk to wild counterparts				
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	H (*)	M (*)	No evidence found. The sand habitats in which this species occurs may be too dynamic for invasive species to become established. If conditions allowed *Crepidula fornicata* and *Crassostrea gigas* to colonise, the subsequent sediment stabilisation, enhanced siltation and accumulation of pseudofaeces may render habitats unsuitable for this species (see changes in sediment composition above). Based on occurrence in biogenic habitats (maerl beds) the species may have some resistance to smothering effects. Based on these considerations *Nephtys cirrosa* is categorised as having 'Low' resistance to habitat changes induced by non-native bivalves, following habitat rehabilitation recovery is assessed as 'High', sensitivity is therefore assessed as 'Medium'. However, removal of invasive species is unlikely and sensitivity will therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		L (*)	M-H (*)	M (*)	Information from MarLIN (Budd, 2008, references therein). *Nephtys* species are used by anglers as bait and the biotope may be subjected to bait digging. Jackson and James (1979) observed that bait digging disturbs sediment to a depth of 30-40cm (Budd, 2008). Based on *N. hombergii* resistance has been assessed as 'Low' and recovery as 'Medium-High' sensitivity is therefore assessed as 'Medium'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Ecosystem Services - Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Based on a Cu sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000) it is assumed (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Nephtys cirrosa* does not photosynthesise and does not, therefore, directly require light and is therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not assessed.

Table 11.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 11.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 11.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***(5)	***	**
Deep Disturbance	***(5)	***	**
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***	***	***
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*	N/A	N/A
Decrease in oxygen levels - Water column	*	N/A	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence. Not assessed.		
Introduction of hydrocarbons	No evidence. Not assessed.		
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Allen, J.A. and Moore, J.J. 1987. Invertebrate macrofauna as potential indicators of sandy beach instability. Estuarine, Coastal and Shelf Sciene 24: 109-125.

BIOTIC website: http://www.marlin.ac.uk/biotic/browse.php?sp=4414.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Budd, G.C. 2008. Dense *Lanice conchilega* in tide-swept lower shore sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 22/03/2013]. Available from: http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=195&code.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Elliott, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. and Hemingway K.L. 1998. Intertidal Sand and Mudflats and Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs.151 pp.

Frid, C.L.J. and Clark, R.A. 2000. Long term changes in North Sea benthos: discerning the role of fisheries. In: Kaiser, M.J. and de Groot, S.J. (Eds.) Effects of fishing on non-target species and habitats. Oxford, Blackwells Scientific.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS Report No 2011-08.

Hall, S.J., Basford, D.J. and Roberts, M.R. 1990. The impact of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community. Netherlands Journal of Sea Research 27: 119-125.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Moulaert, I. and Hostens, K. 2007. Post-extraction evolution of a macrobenthic community on the intensively extracted Kwintebank site in the Belgian part of the North Sea. C.M. - International Council for the Exploration of the Sea, CM 2007(A:12). ICES: Copenhagen. 13 pp.

Pearson, T. and Rosenberg, R. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology. An Annual Review 16: 229-311.

Tuck, I., Hall, S.J., Roberston, M., Armstrong, E. and Basford, D. 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. Marine Ecology Progress Series 162: 227-242.

Tyler-Walters, H., Marshall, C., Hiscock, K., Hill, J.M., Budd, G.C., Rayment, W.J. and Jackson, A. 2005. Description, temporal variation, sensitivity and monitoring of important marine biotopes in Wales. Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth.

Veale, L.O., Hill, A.S. and Brand, A.R. 2000. An in situ study of predator aggregations on scallop (*Pecten maximus* (L.)) dredge discards using a static time-lapse camera system. Journal of Experimental Marine Biology and Ecology 255: 111-121.

World Register of Marine Species (WoRMS) website: http://www.marinespecies.org.

12. Species: *Nephtys hombergii*

Species Description

- Taxonomy: phyllodocid polychaete (Fauchald and Bellan, 2012);
- Habitat: intertidal/subtidal, from medium sand to soft mud (Rainer 1991);
- Length: maximum 150mm (Rainer, 1991);
- Longevity: 7 years (Rainer, 1991);
- Feeding: mobile carnivore (Faunchald and Jumars, 1979) at low densities, at higher densities populations may deposit feed or graze on microphytobenthos (Rainer, 1991, references therein);
- Reproduction: Pelagic larvae (Strathman, 1987; Grantham et al. 2003; cited in Carson and Hentschel, 2006); and
- Environmental Position: *Nephtys hombergii* creates a maze of temporary burrows in the sediment, marked only by a mucilage lining. These tunnels are located 5 to 15 cm beneath the surface (BIOTIC; Linke, 1939; Holme, 1949).

Recovery

Nephtys is a relatively long-lived polychaete with a life-span of 6 to possibly as much as 9 years. It matures at 1year 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 are fertilised externally and 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 recoverability following disturbance (Marine Macrofauna Genus Traits Handbook - MES Ltd, 2010).

Dittman et al. (1999) observed that *N. hombergii* was amongst the macrofauna that colonized experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment.

Recoverability will depend on the scale of the pressure and the intensity and the presence of adults and spawning populations in the vicinity. Where the species is extirpated from relatively small areas recovery will take place through adult migration due to the mobility of this species. Severe perturbations that remove the species from larger areas will require habitat recovery and a larval supply for re-establishment to occur.

Based on this information recoverability (resilience) for this species is generally assessed below as ‘high’ as, following cessation of activities, population recovery is likely to be complete within two years. Where the population has high resistance to an activity, recovery is likely to be very high as there is little or no detectable impact to recover from. These assessments are also based on the premise that the habitat is suitable for this species, i.e. that there has been no permanent alteration.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 12.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure/interaction rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 12.2a and are combined, as in Table 12.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 12.2a).

Table 12.1 *Nephtys hombergii* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (**)	NS (*)	Information from MarLIN (Budd and Hughes, 2005, references therein) *Nephtys hombergii* excavates no permanent burrow, but continually changes course in the sediment in the hunt for food, so that a maze of temporary burrows is made, marked only by a mucilage lining. These tunnels are located 5 to 15 cm beneath the surface (Linke, 1939; Holme, 1949). The sampling technique of Vader (1964) showed that the worm can move very quickly through the substratum, downwards on the ebb tide and up again on the flood tide (Clay, 1967). *Nephtys hombergii* is also capable of swimming short distances with an undulatory movement. Based on information on environmental position, resistance is categorised as 'High', due to lack of effects, resilience is also categorised as 'Very 'High' and the species is 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	VH (*)	L (*)	This species has been categorised through expert and literature review as AMBI fisheries Group II - Species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly (Gittenberger and van Loon, 2011). Experimental trawling has been shown to decrease the abundance of *Nephtys* compared with a control area (Kaiser et al. 1998). Information from MarLIN (Budd and Hughes, 2005) *Nephtys hombergii* lives in sediment between a depth of 5-15 cm and is therefore protected from most sources of abrasion and physical disturbance caused by surface action. However, it is likely to be damaged by any activity (e.g. anchors, or scallop dredging) that penetrates the sediment. Based on this information resistance has been categorised as 'Medium' and recovery has been assessed to be 'Very High', as re-population would occur initially relatively rapidly via adult migration and later by larval recruitment. Sensitivity is therefore assessed as Medium and recovery as Very High, so that overall sensitivity is assessed as 'Low'.
	Deep	Direct impact from	M (***)	VH (***)	L (***)	Rostron (1995; cited in Gubbay, 1999) undertook experimental dredging of sandflats with a mechanical

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Disturbance	deep (>25mm) disturbance				cockle dredger. The distribution of *Nephtys hombergii* was disturbed by dredging with recovery after six months. Information from MarLIN (Budd and Hughes, 2005, references therein) Ferns et al. (2000) recorded significant losses of common 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. Recovery of *Nephtys hombergii* has been assessed to be very high as re-population would occur initially relatively rapidly via adult migration and later by larval recruitment. Deep disturbance has the potential to directly kill and expose members of the population to scavengers. Resistance is assessed as 'Medium' and recovery via adult migration and larval recruitment as 'Very High', sensitivity is assessed as 'Low'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (**)	NS (*)	No evidence found. Assessment is based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	VH (**)	L (*)	No evidence found. The greater weight of vehicles is predicted to lead to compaction of sediment crushing some worms within burrows. Resistance is therefore assessed as "Medium' and recovery as 'Very High' resulting in a "Low' sensitivity assessment.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	H (**)	L (*)	Removal of substrate would remove infaunal populations including *Nephtys hombergii*. Depending on the scale of extraction, recovery would require sediment infilling and would occur through migration or larval supply. Resistance is categorised as 'None' and recovery as 'High' so that sensitivity is assessed as Low.
	Siltation (addition of fine	Physical effects resulting from addition of fine	H (**)	VH (**)	NS (**)	This species has been categorised through expert judgement and literature review as AMBI sedimentation Group II – Species sensitive to high sedimentation. They prefer to live in areas with some sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediments, pseudofaeces, fish food)	sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)				and van Loon, 2011). The sampling technique of Vader (1964) showed that the worm can move very quickly through the substratum, downwards on the ebb tide and up again on the flood tide (Clay, 1967f; cited from BIOTIC). Information from MarLIN (Budd and Hughes, 2005, references therein) *Nephtys hombergii* is an active polychaete that uses its eversible proboscis to dig rapidly through the sediment. Vader (1964) observed that the worm relocates throughout the tidal cycle. It is unlikely therefore, that *Nephtys hombergii* would be adversely affected by additional sediment of a texture consistent with that of the habitat. Based on the mobility and burrowing habitat of this species but also considering the GiMARIS review (Gittenberger and van Loon, 2011) we have assessed resistance for this species as 'Medium' and recovery as 'High', providing a sensitivity assessment of 'Low'
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd and Hughes, 2005) It is likely that viscous or impermeable materials would prevent the polychaete coming to the surface to seek food, but as it hunts infaunally and is mobile and therefore may be able to travel sufficient distance beneath impermeable materials in avoidance and therefore may survive for a period of one month. Based on this evidence resistance is assessed as 'High' although this is dependent on the spatial scale of smothering, and recovery (following habitat re-instatement) as 'Very High'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this species does not occur in the water column except as larval forms.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	movements					
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N (*)	H (**)	M (*)	The coarsest sediments that this species occurs in are medium sands, an increase in the coarse fraction past this sediment type would be considered likely to impact this species. An increase of sediment coarseness to greater particle size than sand would exclude this species, recovery would depend on the return of previous habitat conditions. Resistance is judged as 'None' with recovery as 'High' if habitat conditions are re-instated, If there was no habitat recovery then sensitivity would be 'Very High'. Overall sensitivity of this species is considered to be' Medium'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	Based on habitat preferences increased fine sediment proportion is not considered to constrain this species. Hence the assessment is 'Not Sensitive' Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (***)	VH (**)	NS (**)	The sampling technique of Vader (1964) showed that the worm can move very quickly through the substratum, downwards on the ebb tide and up again on the flood tide (Clay, 1967; cited from BIOTIC). Information from MarLIN (Budd and Hughes, 2005) *Nephtys hombergii* lives within the sediment but may surface during periods of immersion to hunt on the surface where it would experience surface currents, but its size and growth form mean that it would not protrude above the substratum and therefore is unlikely to be swept away. Furthermore, if the polychaete finds conditions intolerable at the surface it may cease to emerge and only hunt infaunal prey. The locations where *Nephtys hombergii* is typically found have low rates of water flow, which favour the deposition of finer sediments. Although *Nephtys hombergii* may inhabit a variety of substrata, it is reported to occur in highest densities in muddier sediments (see adult distribution) and consequently other species of *Nephtyidae*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						e.g. *Nephtys cirrosa*, that favour coarser cleaner sands may become dominant in the habitat. *Nephtys hombergii* may suffer reduced viability as a result of changes in its habitat and competition. Recolonisation of the substratum would occur via adult migration and larval settlement. Based on this information and siltation assessment *N. hombergii* is assessed to have 'High' resistance to decreases in water flow that lead to increased deposition (the effect most likely to arise from aquaculture facilities), recovery is assessed as 'Very High' and this species is considered to be 'Not Sensitive'. For sensitivity to changes in water flow that lead to increased sediment coarseness see above.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	As an infaunal predator an increase in turbidity is considered unlikely to effect this species, at high densities some individuals may feed on microphytobenthos which may be reduced under conditions of decreased light penetration but this is not considered to have population level effects. Resistance is therefore categorised as 'High' so that recovery is 'Very High' and the species is 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (**)	NS (*)	Information from MarLIN (Budd and Hughes, 2005) *Nephtys hombergii* lives infaunally between a depth of 5 and 15 cm where light is not transmitted. A decrease in turbidity is unlikely to have a detectable effect on the viability of the species. As this species is primarily predatory decreased turbidity will not lead to a reduction in food supply. At high densities individuals may feed on microphytobenthos and increased light penetration may increase production allowing the population to increase where food supply is limiting. Resistance is therefore assessed as 'High', recovery as 'Very High'; the species is categorised as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (**)	NS (*)	This species has been categorised through expert judgement and literature review 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; validated by Gittenberger and van Loon, 2011).
	Organic	Increased organic	H (***)	VH (**)	NS (**)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	enrichment of sediments - Sedimentation	matter input to sediments				Information from MarLIN (Budd and Hughes, 2005, references therein) *Nephtys hombergii* is unlikely to be directly affected by nutrient enrichment as growth is not dependent on nutrient availability. However, symptoms of eutrophication (when nutrient input may exceeds the assimilative capacity of the environment) include hypoxia, to which *Nephtys hombergii* may be intolerant over long episodes (see oxygenation below) but has been found tolerant over short episodes. Dittman et al. (1999) observed that *Nephtys hombergii* was amongst the macrofauna that colonized experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment. Based on this information, resistance is assessed as 'High', recovery as 'Very High', so that this species is considered to be 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	This species is primarily a predator of invertebrates and is not considered to be sensitive. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (***)	VH (***)	NS (***)	*Nephtys hombergii*, are noted by Diaz and Rosenberg (1995) as resistant to severe hypoxia. Information from MarLIN (Budd and Hughes, 2005) *Nephtys hombergii* is a free-living, burrowing predator in marine sediments in which it has to survive periods of severe hypoxia and sulphide exposure, while at the same time maintaining agility in order to feed on other invertebrates. *Nephtys hombergii* has adapted to such conditions by utilising several strategies. Arndt and Schiedek (1997) found *Nephtys hombergii* to have a remarkably high content of phosphagen (phosphoglycocyamine), which is the primary energy source during periods of environmental stress. With increasing hypoxia, energy is also provided via anaerobic glycolysis, with strombine as the main end-product. Energy production via the succinate pathway becomes important only under severe hypoxia, suggesting a biphasic response to low oxygen conditions which probably is related to the polychaete's mode of life. The presence of sulphide resulted in a higher anaerobic energy flux and a more pronounced energy production via glycolysis than in anoxia alone. Nevertheless, after sulphide exposure under anaerobic conditions of <24 h, Arndt and Schiedek (1997) observed *Nephtys*
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	H (***)	VH (***)	NS (***)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						hombergii to recover completely. Although *Nephtys hombergii* appears to be well adapted to a habitat with short-term fluctuations in oxygen and appearance of hydrogen sulphide, its high energy demand as a predator renders it likely to limit its survival in an environment with longer lasting anoxia and concomitant sulphide exposure. For instance, Fallesen and Jørgensen (1991) recorded *Nephtys hombergii* in localities in Århus Bay, Denmark, where oxygen concentrations were permanently or regularly low, but in the late summer of 1982 a severe oxygen deficiency killed populations of *Nephtys* species (*Nephtys hombergii* and *Nephtys ciliata*) in the lower part of the bay. However, *Nephtys hombergii* recolonized the affected area by the end of autumn the same year. Alheit (1978) reported a LC50 at 8°C of 23 days for *Nephtys hombergii* maintained under anaerobic conditions. Based on the above information *N. hombergii* is categorised as having 'High' resistance and 'Very High' recovery and is therefore considered to be 'Not Sensitive'.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	H (*)	VH (*)	NS (*)	No evidence found. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Nephtys hombergii* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. This assessment is based on the smothering pressure (see above). However, it should be noted that, once established, removal of these species may not be possible and recovery may therefore not occur. From any population effects.
	Introduction of parasites/				NE	Not Exposed. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	pathogens					
	Removal of Target Species		L (**)	M-H (*)	M (*)	*Nephtys* species are considered very vulnerable to bait digging as it is possible for local populations to be dug out (UK Marine SACs information). Resistance has been assessed as 'Low' and Recovery as 'Medium to High', so that overall sensitivity is considered to be 'Medium'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	N (***)	H (***)	M (***)	Conan (1982; cited in Rayment, 2008) investigated the long term effects of the Amoco Cadiz oil spill at St Efflam beach in France. Polychaetes, however, including *Nephtys hombergii*, *cirratulids* and *capitellids* were largely unaffected. Information from MarLIN (Budd and Hughes, 2005, references therein) The 1969 West Falmouth Spill of Grade 2 diesel fuel, documented by Sanders (1978), illustrates the effects of hydrocarbons in a sheltered habitat with a soft mud/sand substrata (Suchanek, 1993). The entire benthic fauna was eradicated immediately following the spill and remobilization of oil that continued for a period >1 year after the spill contributed to much greater impact upon the habitat than that caused by the initial spill. Effects are likely to be prolonged as hydrocarbons incorporated within

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						the sediment by bioturbation will remain for a long time owing to slow degradation under anoxic conditions. Oil covering the surface and within the sediment would prevent oxygen transport to the infauna and promote anoxia as the infauna utilise oxygen during respiration. Although *Nephtys hombergii* is relatively tolerant of hypoxia and periods of anoxia (see oxygenation), a prolonged absence of oxygen would probably result in the death of it and other infauna. McLusky (1982) found that petrochemical effluents, including organic solvents and ammonium salts, released from a point source to an estuarine intertidal mudflat of the Forth Estuary, Scotland, caused severe pollution in the immediate vicinity. Beyond 500 m distance the effluent contributed to an enrichment of the fauna in terms of abundance and biomass similar to that reported by Pearson and Rosenberg (1978) for organic pollution; *Nephtys hombergii* was found in the area with maximum abundance of species and highest total biomass at 500 m from the discharge. Resistance has been assessed as 'None' as it seems likely that significant hydrocarbon contamination would kill affected populations of the species. On return to prior conditions recovery has been assessed to be 'High as recolonization is likely via adult migration and larval settlement, overall sensitivity is considered to be 'Medium'.
	Introduction of antifoulants	Introduction of antifoulants	H (**)	VH (**)	NS (*)	Experimental studies using individuals from copper contaminated and normal areas (metal levels 18 and 2120 ppm Cu normal and contaminated areas, respectively, and 305 and 483 ppm Zn normal and contaminated areas found that the lethal concentration to copper was as follows: 96h Cu LC50= 0.7 and 0.25 ppm tolerant and non- tolerant animals, respectively respectively (Bryan, 1976; cited from Bat, 2005). Based on a sediment quality guideline of 100 mg Kg^{-1} for Copper, the evidence from Bryan (1976) suggests that concentrations up to and below this level would protect this species (as tolerant forms are found where copper levels are much greater than this). Resistance is therefore assessed as 'High' and recovery as 'Very High'. This species is therefore considered to be 'Not Sensitive'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching	Shading from aquaculture	H (*)	VH (*)	NS (*)	Information from MarLIN (Budd and Hughes, 2005) *Nephtys hombergii* lives infaunally between a depth of 5 and 15 cm where light is not transmitted. An

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	seabed/ features	structures, cages, trestles, longlines				increase in turbidity is unlikely to have a detectable effect on the viability of the species. At high densities some individuals may feed on microphytobenthos which may be reduced under conditions of decreased light penetration but this is not considered to have population level effects. Resistance is therefore categorised as 'High' so that recovery is 'Very High' and the species is 'Not Sensitive'.
	Barrier to species movement				NA	Not relevant to Annex I habitats and species.

Table 12.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 12.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 12.3 Confidence Levels for Resistance Assessments

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***(1 and 1 review report)	N/A (not clear for review)	N/A
Deep Disturbance	*** (2)	***	***
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	**	*	*
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion			
Changes to water flow	***(1)	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended	*	N/A	N/A

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
sediment - Decreased			
Organic enrichment - Water column	***(1+1 review report)	Not clear from reviews.	***
Organic enrichment of sediments	***(1+1 review report)	Not clear from reviews.	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***(>5)	**	***
Decrease in oxygen levels - Water column	***(>5)	**	***
Genetic impacts	Not exposed.		
Introduction of non-native species	*		
Introduction of parasites/pathogens	Not exposed.		
Removal of Target Species	** (1)	**	N/A
Removal of Non-target species			
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence found. Not Assessed.		
Introduction of hydrocarbons	***(3)	**	***
Introduction of antifoulants	** (1)	*	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Bat, L. 2005. A review of sediment toxicity bioassays using the amphipods and polychaetes. Turkish Journal of Fisheries and Aquatic Sciences 5: 119-139.

BIOTIC website: http://www.marlin.ac.uk/biotic/browse.php?sp=4414.

Bryan, G.W. 1976. Heavy metal contamination in the sea. In: Johnston, R. (Ed.) Marine Pollution. London Academic Press. London: 185-302.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40: 1100-1114.

Budd, G. and Hughes, J. 2005. *Nephtys hombergii*. A catworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 06/02/2012]. Available from: http://www.marlin.ac.uk/reproduction.php?speciesID=3897.

Budd, G.C. 2008. Dense *Lanice conchilega* in tide-swept lower shore sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 20/09/2012]. Available from: http://www.marlin.ac.uk/habitatecology.php?habitatid=195&code.

Carson, H.S. and Hentschel, H.T. 2006. Estimating the dispersal potential of polychaete species in the Southern California Bight: implications for designing marine reserves, Marine Ecology Progress Series 316: 105-113.

Dittmann, S. and Villbrandt, M. 1999. Size frequency, distribution and colour variation of Carcinus maenas in Spiekeroog Backbarrier System. In: Dittman, S. (Ed.) The Wadden Sea ecosystem, pp.163-173. Germany: Springer-Verlag.

Fauchald, J. and Jumars, P.A. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology: an Annual Review 17: 193-284.

Fauchald, K. and Bellan, G. 2012. *Nephtys hombergii* Savigny in Lamarck, 1818. In: Read, G. and Fauchald, K. (Eds.) World Polychaeta database. Accessed through: World Register of Marine Species at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=130359.

Gittenberger, A. and van Loon, W.M.G.M., 2011 Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08.

Gubbay, S. 1999. A review of the potential effects of fisheries within UK European marine sites. English Nature (UK Marine SACs Project), 120p.

Holme, N.A. 1949. The fauna of sand and mud banks near the mouth of the Exe Estuary. Journal of the Marine Biological Association of the United Kingdom 28: 189-237.

Kaiser, M.J., Edwards, D.B., Armstrong, P.J., Radford, K., Lough, N.E.L., Flatt, R.P. and Jones, H.D. 1998. Changes in megafaunal benthic communities in different habitats after trawling disturbance. ICES Journal of Marine Science 55: 353–361.

Linke, O. 1939. Die Biota des Jadebusenwatts. Helgolander Wissenschaftliche Meeresuntersuchungen 1: 201-348.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Rainer, S.F. 1991. Distribution, growth and production of *Nephtys hombergii* and *N. assimilis* (Polychaeta: Nephtyidae) in benthic communities of the North Sea. Bulleting of Marine Science 48: 330-345.

Rayment, W.J. 2008. *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 20/09/2012]. Available from: http://www.marlin.ac.uk/habitatsbasicinfo.php?habitatid=142&code.

13. Species: *Owenia fusiformis*

Species Description

- Length: Up to 10cm;
- Inhabits a long flexible tube made of sand grains up to 30cm;
- Long-planktonic larval stage; and
- Feeding type: Deposit and suspension feeder (Dales, 1957).

Recovery

Information from MarLIN (Neal and Avant, 2008).

Owenia fusiformis has high individual fecundity and high population density. Larval life is long and there is often free exchange of larvae between populations. Spatfall is usually very dense, growth rapid and in optimal conditions, and *O. fusiformis* can reproduce in its first year. Recoverability of this species is likely to be high but variable in rate because wind driven currents and adult fecundity will determine larval supply to defaunated areas (Neal and Avant, 2008).

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Owenia is an infaunal polychaete widespread around the British and the Irish coasts in fine clean sand, muddy sand and sandy mud substrata, from the eulittoral to the bathyal zone. The solely recognised species of this genus, *O. fusiformis*, can reach 10cm in length with a tube of up to 30cm. The maximum recorded density is circa 4,500 individuals per m^2. The worm is fragile and this species can be considered vulnerable to aggregates extraction.

This polychaete has a life span of up to 4 years in British waters and a polymodal population structure in classes since mortality rates increase gradually with age. Sexual maturity is size dependent and is achieved between 3 and 6cm length. A female can mature up to 70,000 oocytes from September to April that are spawned in May. The duration of the larval stage is 10-30 days, with a potential dispersal of >10km and settlement densities varying from 4,000 to 15,000 juveniles per m^2. Recoverability potential after dredging disturbance is high (MES Ltd. 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 13.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 13.2a and are combined, as in Table 13.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 13.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 13. 2a).

Table 13.1 *Owenia fusiformis* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	Based on species traits (environmental position and ability to retract into a protective tube and regenerate damaged portions), adults of *Owenia fusiformis* were judged to have 'High' resistance to surface abrasion, the lack of effect means that recovery is judged as 'Very High' and hence this species is assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	H-VH (***)	L (*)	This species has been categorised through literature and expert review, as AMBI fisheries Group II - Species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly (Gittenberger and van Loon, 2011). Bergman and Hup (1992) found no change in the total density of *Owenia fusiformis* following experimental beam trawling. Based on the environmental position of adults, experimental trawling and the review *O. fusiformis* was judged to have 'Medium-High' resistance to shallow disturbance. Recovery would occur from reproduction within the remaining population and would be expected to take place within 6 months- 2 years so that Recovery is assessed as 'Very High- High'. Sensitivity is therefore categorised as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (***)	H-VH (***)	L (*)	Assessment based on shallow disturbance.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Assessment based on surface abrasion.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	H-VH (*)	L (*)	No information found. As vehicle access is likely to damage sediments the assessment is based on shallow disturbance.
	Extraction	Removal of Structural components of	N (*)	H (*)	M (*)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* is an infaunal organism and removal of the substratum is likely to also remove adults. Therefore an intolerance of high has been recorded. Due to high fecundity and the prevalence

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		habitat e.g. sediment/ habitat/biogenic reef/ macroalgae				of allochthonous larval supply (Barnay et al. 2003), recovery of a population is likely to occur in less than a year (Neal and Avant, 2008). This species is infaunal, extraction of the sediment would remove the population and resistance is assessed as 'None', however if suitable sediments remain, recovery would be predicted to be 'High' so that sensitivity assessed as 'Medium'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (***)	NS (***)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* in the intertidal and shallow subtidal are likely to be buried as a result of wave action disturbing sediments but can work their way back up to the surface in the flexible tube (Wells et al. 1981). *O. fusiformis* also occurs in areas where dredging spoil is deposited (Dauvin and Gillet, 1991). However, juveniles cannot construct tubes in sediments with a grain size <63µm. Therefore, if a lot of clay and silt was deposited around a population of *O. fusiformis* recruits will not be able to construct tubes, juvenile mortality will be high, and an intolerance of intermediate has been recorded (Neal and Avant, 2008). This species has been categorised through expert and literature review, as AMBI sedimentation Group III - Species insensitive to higher amounts of sedimentation, but don't easily recover from strong fluctuations in sedimentation (Gittenberger and van Loon, 2011). Based on the above evidence, resistance to siltation was assessed as 'High' and recovery (based on little effect) was 'Very High', this species is therefore assessed as 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N-L (*)	H (*)	M (*)	No evidence found. As adults have limited to no horizontal mobility and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on a return to previous habitat conditions. Based on the above considerations resistance is assessed as 'None-Low' and recovery as 'High', sensitivity is therefore assessed as 'Medium".
	Collision risk	Presence of significant collision			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		risk, e.g. access by boat				
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	L-M (*)	H (*)	L-M (*)	*Owenia fusiformis* can be found in fine to coarse sediments (150 to 500µm) the species only reaches a high relative occurrence in the finer sediments. Sediment has to contain mud to be suitable *for O. fusiformis*. The highest relative occurrence is reached in sediments with a mud content of 10 to 40%. *O. fusiformis* does not occur in sediments with a mud content exceeding 40% (Degraer et al. 2006). This species is considered to have some resistance to increased sediment coarseness where high proportions of fine sediment fractions remain. Removal of fine sediments (for example by winnowing or changes in water flow) will reduce habitat suitability for this species and remove tube-building materials. Resistance is therefore assessed as 'Low to Medium' and recovery (following habitat recovery) is assessed as 'High'. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	M (*)	H-VH (*)	L (*)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* in the intertidal and shallow subtidal are likely to be buried as a result of wave action disturbing sediments but can work their way back up to the surface in the flexible tube (Wells et al. 1981). *O. fusiformis* also occurs in areas where dredging spoil is deposited (Dauvin and Gillet, 1991). However, juveniles cannot construct tubes in sediments with a grain size <63 µm. Therefore, if a lot of clay and silt was deposited around a population of *O. fusiformis* recruits will not be able to construct tubes, juvenile mortality will be high, and an intolerance of intermediate has been recorded (Neal and Avant, 2008). *O. fusiformis* can be found in fine to coarse sediments (150 to 500µm) the species only reaches a high

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						relative occurrence in the finer sediments. Sediment has to contain mud to be suitable for *O. fusiformis*. The highest relative occurrence is reached in sediments with a mud content of 10 to 40%. *O. fusiformis* does not occur in sediments with a mud content exceeding 40% (Degraer et al. 2006). An increase in sediments below fine sand size (<63µm) will decrease availability of material for tube construction, adults have already constructed tubes and these would be unaffected by a short-term change (e.g. the deposition of fine silts that were then removed by wave action and water flow). However, a significant change in sediment composition in the long-term (e.g. following changes in water flow) will decrease habitat suitability for juveniles, so that populations will not be replaced. Resistance is therefore assessed as 'Medium' (as some fine sediment increase (up to 40%) will be tolerated) and recovery (following habitat recovery) is assessed as 'High-Very High'. Sensitivity is therefore assessed as 'Low".
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	M (*)	H-VH (*)	L (*)	Information from MarLIN (Neal and Avant, 2008, references therein). Increase in water flow rate will most likely cause winnowing of the sediment, exposing tubes of *Owenia fusiformis*. However, *O. fusiformis* is found in front of river outlets in the Mediterranean and can be subject to a wide range of water velocities. The tubes of *O. fusiformis* can stabilize the sediment and reduce water movement related stresses on the benthos (Somaschini, 1993). *O. fusiformis* is probably tolerant to changes in water flow rate. A decrease in water flow rate is likely to cause an increase in siltation; however, *O. fusiformis* can migrate up through the sediment in their flexible tube (Wells et al. 1981). However, deposition of sediment with grain sizes <63µm is likely to cause high mortality amongst recruits which cannot construct tubes in this sort of sediment. An intolerance of intermediate has been recorded to account for recruitment failure in silts and clays (Neal and Avant, 2008). Aquaculture installations can reduce water flow which may lead to deposition of fine materials. Although this species is considered to have high tolerance for temporary siltation, decreases in water flow that result in chronic and permanent deposition of fine sediments are considered likely to reduce habitat suitability for this species. Resistance is therefore assessed as 'Medium' and recovery as 'High-Very High' (following habitat recovery). Sensitivity is therefore assessed as 'Low'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Neal and Avant, 2008, references therein) *Owenia fusiformis* occurs in front of river outlets (Somaschini, 1993) and in areas where dredging spoil is dumped (Dauvin and Gillet, 1991), and therefore is probably tolerant of an increase in suspended sediment. *O. fusiformis* feeds on suspended organic matter. Therefore an increase in the concentration of phytoplankton and particulate organic matter is likely to be of benefit to *O. fusiformis*, and tolerant has been recorded (Neal and Avant, 2008). Based on the above assessment, resistance is judged to be 'High' and recovery 'Very High', so that this species is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* is a suspension feeder and deposit feeder (Rouse and Pleijel, 2001) but is not reliant on suspended sediment as such and is probably tolerant of a decrease in suspended sediment (Neal and Avant, 2008). Based on the above assessment, resistance is judged to be 'High' and recovery 'Very High', so that this species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	Information from MarLIN (Neal and Avant, 2008). Increases in nutrient levels are likely to increase phytoplankton productivity, which would benefit *Owenia fusiformis* populations. Therefore tolerant has been recorded (Neal and Avant, 2008). As this species is not a primary producer it is not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton may be utilised as food by this genus. This species is therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	This species has been categorised by Borja et al. (2000) 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). This assessment was supported by Gittenberger and van Loon (2011).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Similarly, Simboura and Zenetos (2002) classified *Owenia fusiformis* as Ecological Group 2 for the BENTIX index: '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 above evidence, this species is considered to have 'High' resistance to organic enrichment and 'Very High' recovery. This species is therefore assessed as 'Not Sensitive'' to this pressure.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	M-H (*)	H-VH (*)	L-NS (*)	Resistance to increased competition was assessed as 'Medium to High' (ranging from no lethal effect to mortality <25% of population) and recovery as 'High to Very High', so that sensitivity was categorised as 'Low to Not Sensitive'. Increased clearance rates of suspended sediments by suspended bivalves may enhance local primary production compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	L (***)	H (*)	M (*)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* is very tolerant of anoxia and can tolerate anaerobic conditions for up to 21 days by becoming quiescent (Dales, 1958) and therefore is tolerant to changes in oxygenation (Neal and Avant, 2008). Niermann et al. (1990; cited in Rayment, 2008) reported that in a fine sand community in the German Bight area exposed to regular seasonal hypoxia, *O. fusiformis* were reduced in abundance significantly by the hypoxia (Rayment, 2008). Based on the field observations rather than laboratory experiments *Owenia fusiformis* is considered to have 'Low' resistance to episodic hypoxia and 'High' recovery. Sensitivity is therefore considered to be 'Medium'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L (***)	H (*)	M (*)	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	populations					
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	N-L (*)	H (*)	M (*)	No evidence found. Assessment based on smothering as the settlement of *Crassostrea gigas* or *Crepidula fornicata* would effectively lead to substratum smothering.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This genus will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the genus is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not assessed, not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No Evidence. Not assessed
	Introduction of hydrocarbons	Introduction of hydrocarbons	L-M (*)	H (*)	L-M (*)	Information from MarLIN (Neal and Avant, 2008, references therein). A few *Owenia fusiformis* were recorded in the subtidal sediments of the Pembrokeshire coast after the

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Sea Empress oil spill but whether densities had increased, decreased or remained the same was not recorded (Rutt et al. 1998). An intolerance to oil cannot be assessed for *O. fusiformis* on the basis of other polychaetes as some are tolerant to oil and others highly intolerant (Kingston et al. 1997; Neal and Avant, 2008). From the above evidence the presence of a population of *O. fusiformis* following the oil spill was interpreted as demonstrating 'Low-Medium' resistance to this pressure (some lethal effects following spill) and 'High' recovery (following habitat recovery). Sensitivity was therefore assessed as 'Low-Medium'.
	Introduction of antifoulants	Introduction of antifoulants	H (***)	VH (***)	NS (***)	Information from MarLIN (Neal and Avant, 2008, references therein). *Owenia fusiformis* from the south coast of England were found to have loadings of 1335µg Cu per gram bodyweight and 784µg Zn per gram bodyweight. The metals were bound in spherules within the cells of the gut (Gibbs et al. 2000). No mention was made of any ill effects of these concentrations of metal within the body and it is presumed that *O. fusiformis* is tolerant of heavy metal contamination (Neal and Avant, 2008). Gibbs et al. (2000) explained the wide range of Cu and Zn concentrations seen in *O. fusiformis* as most likely the result of the ability of these animals to switch between a filter feeding and a detritus-feeding diet. The greater the reliance on deposit feeding by an individual the higher its uptake of heavy metals was from the sediments. Based on the above evidence *O. fusiformis* are considered to have 'High' resistance to Zn and Cu based antifoulants. Recovery is therefore assessed as 'Very High' and this species is assessed as 'Not Sensitive'.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Owenia fusiformis* do not photosynthesise and do not, therefore, directly require light and are therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to				NA	Not assessed.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	species movement					

Table 13.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 13.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 13.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*** (2)	***	*
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*** (3)	**	***
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*** (3)	Not clear from papers	***

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	*** (1)	**	N/A
Decrease in oxygen levels - Water column	*** (1)	**	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No Evidence. Not assessed.		
Introduction of hydrocarbons	*	N/A	N/A
Introduction of antifoulants	***(1)	*	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beamtrawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science: Journal du conseil 49(1): 5-11.

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40: 1100-1114.

Dales, R.P. 1957. The feeding mechanism and structure of the gut of *Owenia fusiformis* Delle Chiaje. Journal of the Marine Biological Association of the United Kingdom 36: 81-89.

Degraer, S., Wittoeck, J., Appeltans, W., Cooreman, K., Deprez, T., Hillewaert, H., Hostens, K., Mees, J., Vanden Bergh, W. and Vincx, M. 2006. The macrobenthos atlas of the Belgian part of the North Sea. Belgian Science Policy. D/2005/1191/3. ISBN 90-810081-6-1. 163 pp.

Gibbs, P.E., Burt, G.R., Pascoe, P.L., Llewellyn, C.A. and Ryan, K.P. 2000. Zinc, copper and chlorophyll-derivatives in the polychaete *Owenia fusiformis*. Journal of the Marine Biological Association of the United Kingdom 80: 235-248.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS Report No 2011.08.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available from: http://www.genustraithandbook.org.uk/introduction.

Neal, K. and Avant, P. 2008. *Owenia fusiformis*. A tubeworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 12/02/2013]. Available from:
http://www.marlin.ac.uk/speciesfullreview.php?speciesID=4001.

Rayment, W.J. 2008. *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 26/03/2013]. Available from: http://www.marlin.ac.uk/habitatsbasicinfo.php?habitatid=142&code.

Simboura, N. and Zenetos, A. 2002. Benthic indicators to use in Ecological Quality classification of Mediterranean soft bottom marine ecosystems, including a new Biotic Index. Mediterranean Marine Science 3/2: 77-111.

14. Species: *Phaxas pellucidus*

Synonyms: *Cultellus pellucidus* (Neish, 2008); *Solen pygmaeus*

Species Description

- Taxonomy: bivalve mollusc from the family Pharidae;
- Length: up to 40 m long;
- Feeding type: suspension feeder;
- Habitat: mixed fine substrata (Hayward and Ryland, 1995); and
- Biotopes: this species characterises the biotopes listed below in Table A.

This species has been identified as a characterising species in the following EUNIS habitats (see Table A) and JNCC equivalents. The habitat preferences listed below have been identified from the habitats descriptions of these biotopes (from the JNCC website; Connor et al. 2004).

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Tidal streams: strong (3-6 kn)-very weak (negligible);
- Wave exposure: moderately exposed, sheltered, very sheltered;
- Sediment: mixed sediment with stones and shells, muddy sand and gravel, sandy mud, fine to very fine sand with a silt fraction, mud with a significant fine to very fine sand fraction; and
- Infralittoral, Circalittora (10-100 m).

Table A: *Phaxas pellucidus* has been recorded as a characterising species from the following EUNIS biotopes and JNCC equivalents

EUNIS (version 2004)	Marine Habitat Classification Britain/Ireland (v0405)
A5.24	SS.SSa.IMuSa
A5.242	SS.SSa.IMuSa.FfabMag
A5.35	SS.SMu.CSaMu
A5.44	SS.SMx.CMx
A5.334	SS.SMu.ISaMu.MelMagThy
A5.353	SS.SMu.CSaMu.AfilNten
A5.352	SS.SMu.CSaMu.ThyNten
A5.355	SS.SMu.CSaMu.LkorPpel
A5.443	SS.SMx.CMx.MysThyMx

Recovery

The recovery potential of this species 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, 2008).

Other members of the *Pharidae,* the razor shells, are long-lived and reach sexual maturity after 3-5 years. This species 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) suggest that wide spatial dissemination is possible for this species). Recovery of a population from significant mortalities (loss of 25-75% of the population) is considered likely to be 'Medium' (3-5 years).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 14.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 14.2a and are combined, as in Table 14.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 14.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 14.2a).

Table 14.1 *Phaxas pellucidus* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	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. Resistance is assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L (***)	M (*)	M (*)	Ball et al. (2000) found that *Phaxas pellucidus* were present at a site protected from fishing but absent from adjacent *Nephrops* trawling grounds, indicating that this species may be sensitive to fishing impacts. *Phaxas pellucidus* is considered to be sensitive towards disturbance (Zucco et al. 2006). Resistance is considered to be 'Low' based on the evidence presented above and in the deep disturbance assessment (below). Population recovery (based on longevity) was considered to be 'Medium' (3-5 years). Sensitivity was therefore considered to be 'Medium'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	L (***)	M (*)	M (*)	Bergman and Santbrink (2000) experimentally tested the direct mortality caused by a single pass of a beam trawl. This species was sensitive to disturbance with mean direct mortality in silty sediments (where penetration is deeper) of 27% and 29% after a pass of 12 m and 4 m beam trawls (with tickler chains). This evidence is supported by observations by Duineveld et al. (2007) who found greater abundances of *P. pelucidus* and other fragile bivalves, in areas where fishing was excluded. Based on this evidence resistance is assessed as 'Low' (mortality of 25-75%), recovery was assessed as "Medium", sensitivity was therefore considered to be 'Medium'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing			NE	Not exposed. Subtidal feature not accessible.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access			NE	Not exposed. Subtidal feature not accessible.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M (*)	H (*)	No information found. This species was considered to have 'No' resistance to the removal of sediments. Recovery was considered to be 'Medium'; sensitivity was therefore assessed as 'High'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (***)	VH (***)	NS (***)	Rees et al. (1992) from JNCC biotope descriptions (Connor et al. 2004) suggests this species can become dominant in areas where dredge spoil is dumped. This species is therefore assessed as 'Not Sensitive' to siltation. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	L (*)	M (*)	M (*)	No evidence found. As adults are sedentary and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on the return of previous habitat conditions. Resistance is therefore considered to be 'Low' and recovery (following removal of coarse material or burial through overburden) would be predicted to be 'Medium'. Sensitivity is assessed as 'Medium'.
	Collision risk	Presence of significant collision			NE	Not exposed, this feature does not occur in the water column.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		risk, e.g. access by boat				
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	This species is found in a wide range of habitats (see Introduction Section) with mixed sediments, including those without a silt or clay fraction. The species is therefore considered to have 'High' resistance to an increased coarse sediment fraction. Resistance is therefore considered to be 'Very High' so that this species is considered to be 'Not Sensitive'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	This species is found in a wide range of habitats (see Introduction Section) with mixed sediments, including muddy sands and gravels. This species is therefore considered to have 'High' resistance to an increased fine sediment fraction. Resistance is therefore considered to be 'Very High' so that this species is considered to be 'Not Sensitive'. This species would be expected to have greater sensitivity however, to a transition to a pure mud sediment type as this species is not found in this habitat type.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	*Phaxas pellucidus* is found in areas with strong to very weak tidal streams, (6 knots to negligible, see Introduction). They are considered resistant to changes in water flow and therefore 'Not Sensitive'. Accompanying changes in sediment characteristics following changes in water flow are described above.
	Changes in	Increase in	H (*)	VH (*)	NS (*)	No information found. The dominance of this species in areas subject to dredge soil dumping and

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	turbidity/ suspended sediment - Increased suspended sediment/ turbidity	particulate matter (inorganic and organic)				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. Resistance is therefore considered to be 'High' and recovery as 'Very High', so that this species is considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	No information found. Decreased turbidity through, for example, increased suspension feeding by bivalves may remove organic particles and phytoplankton (see below) and decrease the food supply to this species. However, such effects may be offset by increased primary production. In well flushed areas water recharge may supply adequate food to this species. Resistance is therefore assessed as 'High' with recovery categorised as 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As *Phaxas pellucidus* is not a primary producer it is not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton and algal detritus may be utilised as food by this genus. This species is therefore considered to be 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	L-M (*)	M (*)	L (*)	No information found. Organic enrichment of sediments can lead to community replacement by deposit feeders. The bioturbating activities of these species can lead to re-suspension of sediment and inhibit the feeding activities of suspension feeders leading to their exclusion (Rhoads and Young, 1970). As a suspension feeder this species is considered to have 'Low-Medium' resistance to organic enrichment and 'Medium' recovery. Sensitivity is therefore considered to be 'Low '.
	Increased removal of primary	Removal of primary production above background rates by	M-H (*)	VH-H (*)	L-NS (*)	Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (cited in Hartnoll, 1998). Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	production - Phytoplankton	filter feeding bivalves				(http://www.farmscale.org), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters. Resistance to increased competition was assessed as 'Medium to High' (ranging from no lethal effect to mortality of <25% of population) and recovery as 'Very High to High', so that sensitivity was categorised as 'Low to Not Sensitive'. Increased clearance rates of suspended sediments by suspension feeding bivalves may enhance local primary production compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment			NEv	No evidence found. Not Assessed.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column			NEv	No evidence found. Not Assessed.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in	L (*)	M-H (*)	M (*)	Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Phaxas pellucidus* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		translocated stock'				established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. This may impose significant economic costs to the aquaculture industry. In shallow bays where the slipper limpet has been introduced in France, it can completely smother the sediment creating beds with several thousand individuals per m^2. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them. Based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as ''Medium-High' so that sensitivity is assessed as 'Medium'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	This species is not targeted by a commercial fishery. Potential impacts from commercial fisheries within this species/habitat are considered in the physical disturbance pressures above. Resistance is assessed as 'High' and recovery as 'Very High' and overall as 'Not Sensitive'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat, resistance is assessed as 'High' and recovery as 'Very High' and overall as 'Not Sensitive'.
	Ecosystem Services -				NA	Not assessed, not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Loss of biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not Assessed.
	Introduction of antifoulants	Introduction of antifoulants			NEv	No evidence found. Not Assessed.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited, resistance is assessed as 'High' and recovery as 'Very High' and overall as 'Not Sensitive'.
	Barrier to species movement				NA	Not assessed.

Table 14.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 14.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 14.3 Table Confidence Levels

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*** (2)	***	***
Deep Disturbance	*** (2)	***	***
Trampling - Access by foot	Not Exposed.		
Trampling - Access by vehicle	Not Exposed.		
Extraction	*	N/A	N/A
Siltation	*** (1)	*	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	*	N/A	N/A

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	No Evidence. Not Assessed.		
Decrease in oxygen levels - Water column	No Evidence. Not Assessed.		
Genetic impacts			
Introduction of non-native species	*		
Introduction of parasites/pathogens			
Removal of Target Species	*		
Removal of Non-target species	*		
Ecosystem Services - Loss of biomass	Not Assessed.		
Introduction of medicines	No Evidence. Not Assessed.		
Introduction of hydrocarbons	No Evidence. Not Assessed.		
Introduction of antifoulants	No Evidence. Not Assessed.		
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Ball, B.J., Fox, G. and Munday, B.W. 2000. Long and short-term consequences of a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. ICES Journal of Marine Science 57: 1315-1320.

Bergman, M.J.N. and van Santbrink, J.W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science 57: 1321-1331.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K. O. and Reker, J.B. 2004. The marine habitat classififation for Britain and Ireland. Peterborough, JNCC.

Duineveld, G.C.A., Bergman, M.J.N. and Lavaleye, M.S.S. 2007. Effects of an area closed to fisheries on the composition of the benthic fauna in the southern North Sea. ICES Journal of Marine Science 64: 899-908.

Hartnoll, R.G. 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland [UK Marine SAC Project. Natura 2000 reports].

Hayward, P.J. and Ryland, J.S. 1995. Handbook of the marine fauna of North-West Europe. Publisher: Oxford: Oxford University Press.

Lebour, M. 1938. Notes on the breeding of some lamellibranchs from Plymouth and their larvae. Journal of the Marine Biological Association of the United Kingdom 23: 119-144.

Neish, A. 2008. *Phaxas pellucidus*. A razor shell. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 12/09/2012]. Available from:
http://www.marlin.ac.uk/speciesinformation.php?speciesID=4088.

Rees, H.L., Rowlatt, S.M. and Limpenny, D.S. 1992. Benthic studies at dredged material disposal sites in Liverpool Bay. Aquatic Environment Monitoring Report. Number 28. MAFF.

Rhoads, D.C. and Young, D.K. 1970. The influences of deposit feeding organisms on sediment stability and community trophic structure. Journal of Marine Research 28: 156-178.

Tillin, H.M. 2008 Assessing habitat Quality; Developing the Tools for Management. University of Liverpool. Unpublished PhD thesis.

Zucco, C., Wende, W., Merck, T., Köchling, I. and Köppel, J. 2006. Ecological Research on Offshore Wind Farms: International Exchange of Experiences - Part B. Federal Agency for Nature Conservation. 804 46 001, 290pp.

15. Species: *Pygospio elegans*

Species Description

- Sedentary, tube living, spionid polychaete (Avant, 2005);
- Tubes project above the surface and at high densities may form a mat of tubes altering sediment properties and the composition of the macroinvertebrate assemblage composition (Bolam, 2003);
- Suspension/deposit feeder;
- Pelagic larvae (Leppakoski, 1972; cited in Gray, 1979);
- Length: Up to 15 mm long (Avant, 2005); and
- Habitat: Found on sandy shores and mud flats and mud that has collected in crevices (Avant, 2005).

Recovery

This species exhibits a number of reproductive strategies (poecilogony). Larvae may develop directly, ingesting nurse eggs while brooded in capsules within the parental tube or they may hatch early to feed in the plankton before settling. This is an annual species reaching sexual maturity within a year (Bolam, 2004; BIOTIC) with two main spawning periods leading to high larval availability at certain times (Bolam, 1999). The species is classified as an 'opportunist' readily able to recolonise defaunated sediments (Grassle, 1974; McCall, 1977) so, where conditions are suitable populations may rapidly recover. Experimental defaunation studies have shown an increase in *P. elegans*, higher than background abundances within 2 months, reaching maximum abundance within 100 days (Colen et al. 2008).

Recovery will depend on the lack of stronger competitors and the supply of larvae and hence the season of disturbance will moderate recovery time. In general recovery is predicted to occur within 6 months. However, patches are short-lived and where conditions are stable the species is likely to be replaced by competitive dominants, particularly bivalves such as cockles, *Macoma balthica* or *Tellina tenuis*.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 15.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report).

The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 15.2a and are combined, as in Table 15.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 15.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 15.2a).

Table 15.1 *Pygospio elegans* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	L-M (*)	VH (***)	L (*)	Due to environmental position and lack of mobility *Pygospio elegans* is exposed to surface abrasion which it is unable to escape. No evidence was found in the literature for direct impacts of surface abrasion: resistance is predicted to be ''Low to Medium' to direct exposure to surface disturbance'. Recovery will depend on the lack of stronger competitors and the supply of larvae and hence the season of disturbance will moderate recovery time. In general recovery is predicted to occur within 6 months. Recovery from superficial damage may be rapid. Like other polychaetes and molluscs *P. elegans* may suffer from predation by fish and birds on exposed parts of the body and can rapidly repair this (repair takes between 9-12 days (Lindsay et al. 2007). Based on 'Low to Medium' resistance and 'Very High' recovery, sensitivity is assessed as ''Low'.'
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L (**)	VH (***)	L (**)	This species has been categorised through expert and literature review as AMBI fisheries Group IV - Second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Due to environmental position and lack of mobility *Pygospio elegans* is exposed to shallow disturbance which it is unable to escape. No evidence was found in the literature for direct impacts of shallow disturbance: resistance is predicted to be 'Low' to direct exposure.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Recovery will depend on the lack of stronger competitors and the supply of larvae and hence the season of disturbance will moderate recovery time. In general recovery is predicted to occur within 6 months. Based on 'Low' resistance and 'Very High' recovery, sensitivity is assessed as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	N (***)	H (***)	M (***)	The evidence for the response of *Pygospio elegans* to deep disturbance comes from cockle dredging studies. Ferns et al. (2000) found that tractor-towed cockle harvesting, removed 83% of *P. elegans* (initial density 1850 per m^2). In muddy sand habitats, *P. elegans* had not recovered their original abundance after 174 days (Ferns et al. 2000). These results are supported by work by Moore (1991) who also found that cockle dredging can result in reduced densities of some polychaete species, including *P. elegans*. Rostron (1995; cited in Gubbay, 1999) undertook experimental dredging of sandflats with a mechanical cockle dredger, including a site comprised of stable, poorly sorted fine sands with small pools and *Arenicola marina* casts with some algal growths. At this site, post-dredging, there was a decreased number of *P. elegans* with no recovery to pre-dredging numbers after six months. The resistance of *P. elegans* to deep disturbance is predicted to be 'None' (based on Ferns et al. 2000), individuals would suffer direct mortality, damage and exposure to predators. Recovery is predicted to be 'High' based on opportunistic life-style; recovery is considered to take longer from deep disturbance than shallow disturbance as the initial impact on the population is greater. Sensitivity is therefore assessed as 'Medium'.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	L-M (*)	VH (**)	L (*)	No evidence found. Assessment based on surface disturbance (above).
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	L-M (*)	VH (**)	L (*)	No evidence found. Assessment based on surface disturbance (above).
	Extraction	Removal of Structural components of	N (*)	H-VH (***)	L-M (*)	This species is infaunal, extraction of the sediment would remove the population and resistance is considered to be 'None', however if suitable sediments remain recovery would be predicted to be 'High-Very High'', so that sensitivity is ''Low-Medium''.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		habitat e.g. sediment/ habitat/biogenic reef/ macroalgae				
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	L (***)	H-VH (***)	L (***)	This species has been categorised through expert and literature review as AMBI sedimentation Group IV – A second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). At low levels of siltation the high bioturbatory nature of mudflat organisms will decrease sensitivity to effects (Elliott et al. 1998). The characterising species *Pygospio elegan*s is limited by high sedimentation rates (Nugues et al. 1996) and the species does not appear to be well adapted to oyster culture areas where there are high rates of accumulation of faeces and pseudo faeces (Sornin et al. 1983; Deslous-Paoli et al. 1992; Mitchell, 2006; Bouchet and Sauriau, 2008). *P. elegans* is known to decline in areas following re-deposition of very fine particulate matter (Rhoads and Young, 1971; Brenchley, 1981). Experimental relaying of mussels on intertdal fine sands led to the absence of *P. elegans* compared to adjacent control plots. The increase in fine sediment fraction from increased sediment deposition and biodeposition alongside possible organic enrichment and decline in sediment oxygen levels was thought to account for this (Ragnarsson and Rafaelli, 1999). *P. elegans* occurs on stable and sheltered shores (Allen and Moore, 1987) and theoretically should be able to withstand low amounts of siltation, however the species does stabilise sediments through the presence of tubes and is absent from areas colonised by bivalves which destabilise sediments. Literature evidence suggests that the species is sensitive to high amounts of siltation, resistance to high levels of siltation is therefore categorised as 'None' and recovery (where siltation ceases as 'Very High', however where high siltation rates persist this species is not predicted to recover. Overall sensitivity is considered to be 'Low'.
	Smothering	Physical effects	N (***)	H-VH	L-M (***)	Simenstad and Fresh (1995; cited in Kaiser and Beadman, 2002) reported that the application of gravel

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	(addition of materials biological or non-biological to the surface)	resulting from addition of coarse materials		(***)		to intertidal sediments resulted in a shift from a polychaete to a bivalve and nemertean dominated community, but emphasised that changes are likely to be site-specific. Addition of mussels to intertidal fine sands was shown, experimentally, to alter sediment characteristics resulting in the absence of *Pygospio elegans* compared with unaffected, adjacent control areas (Ragnarsson and Rafaelli, 1999). Based on the evidence outlined above and the sedentary nature of this species, the resistance of *P. elegans* to the addition of coarse material is assessed as 'None', recovery (following habitat rehabilitation) is predicted to be 'High-Very High'', leading to a sensitivity assessment of 'Low'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	N (*)	H-VH (***)	L-M (*)	Based on the habitat preferences of this species (for fine sediments such as sand and mud) increased sediment coarseness is likely to render sediments unsuitable for this species. Resistance is assessed as 'None' and recovery (following habitat recovery) as 'High-Very High'. Overall sensitivity is considered to be 'Low-Medium'.
	Changes in sediment composition –	Fine sediment fraction increases	H (**)	VH (***)	NS (**)	Based on habitat preferences an increase in fine sediment proportion is likely to favour this species. Where fine settlements settle in rock crevices etc. this species may become established (MarLIN). Empirical evidence supporting this view is provided by Bolam (1999) where experimental manipulation

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	increased fine sediment proportion					of sediments by implanting macroalgae mats led to increased fine sediment fractions (with associated increased organic and water content) which led to the establishment of *Pygospio elegans*. Based on this information *P. elegans* is assessed as 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	N-L (*)	H-VH (***)	L-M (*)	This species is sensitive to sediment de-stabilisation and hence increases in water flow that led to erosion of the sediment are considered likely to remove this species. However, the species do engineer sediments (via tube creation to stabilise sediments). Decreases in water flow will increase sediment deposition and the species is likely to be sensitive to this (see siltation pressure above). *P. elegans* is therefore likely to have 'No to Low' resistance to changes in water flow although the species will recovery rapidly when habitat conditions regain suitability, sensitivity is assessed as 'Low'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (***)	NS (*)	No evidence found. Where increased turbidity results from organic particles then subsequent deposition may enhance food supply favouring this species. Alternatively if turbidity results from an increase in suspended inorganic particles then energetic costs may be imposed on these species as feeding becomes less efficient reducing growth rates and reproductive success. Lethal effects are considered unlikely given the occurrence of this species in coastal areas where turbidity is frequently high from suspended organic and inorganic matter. Resistance is therefore categorised as High and Recovery as 'Very High'. Reduction of light penetration from increased turbidity is assessed below in the 'shading pressure', increased siltation linked to increased supply of particles is considered above).
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (***)	NS (*)	No evidence found. Decreased turbidity from a reduction in inorganic particles is not predicted to directly effect this species A reduction in suspended organic particles may reduce food supply impacting growth rates and reproduction, such effects are predicted to be sub-lethal. Resistance is predicted to be high and recovery ''Very High'' leading to an assessment of 'not sensitive'. Indirect effects of reduced turbidity such as an increase in predation from enhanced prey location by fish etc are possible but not considered here.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (***)	NS (*)	This species has been categorised through expert and literature review as 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; validated by Gittenberger and van Loon, 2011). This assessment is supported by experimental field studies carried out by Bolam (1999), establishment of macroalgal mats led to an increase in organic matter and reducing conditions and favoured the establishment of populations of P*ygospio elegans*. In the sewage enriched sediments of Kiel Bay, *P. elegans* is the numerical dominant. Studies have also identified *P. elegans* as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski, 1975; cited in Gray, 1979). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High, so that this species is considered to be 'Not Sensitive'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (***)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Sensitivity is assessed as 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	M (**)	VH (***)	L (**)	In experiments establishment of macroalgal mats led to reducing conditions which favoured the establishment of populations of *Pygospio elegans* (Bolam, 1999). This indicates this species is tolerant of low oxygen levels, more specific information on tolerances was not found, resistance is described as 'Medium' and recovery as 'Very High', so that sensitivity is assessed as 'Low'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	M (**)	VH (***)	L (**)	
Biological Pressure	Genetic impacts on wild populations and	Presence/absence benchmark, the presence of farmed and translocated species presents a			NE	Not Exposed. This feature is not farmed or translocated.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	translocation of indigenous populations	potential risk to wild counterparts				
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	VH (*)	M (*)	No evidence found. Eight invasive species are recorded in Ireland (Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *Pygospio elegns* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). These may lead to smothering effects as described above. The slipper limpet can be introduced via aquaculture (although licence requirements will include measures to control the spread of this established non-native species by avoidance of spat material from areas that are known to have slipper limpet present). They may settle on stones in substrates and hard surfaces such as bivalve shells or form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. Dense aggregations of slipper limpet trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Based on the slipper limpet, resistance to non-native species is assessed as 'Low' and recovery as Very High' so that sensitivity is assessed as 'Low'. However, recovery requires removal of slipper limpet and this is unlikely to be possible, sensitivity may therefore be higher based on no recovery.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore considered to be 'High' and recovery, 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	The intertidal mudflat and sandflat habitats where this species are found may be targeted for bait digging, cockle fishing or removal of other bivalves. Extraction of bivalve competitors which destabilise sediments may favour *Pygospio elegans* as an early recoloniser. This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not Assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS(*)	No evidence found. Bryan and Gibbs (1983) found that *Pygospio elegans* appear to have adapted to the very high concentrations of copper and zinc in Restronguet Creek in the highly contaminated Fal estuary and the larvae are subjected to widely fluctuating conditions of salinity and relatively high metal concentrations. Based on a sediment quality guideline of 100 mg Kg^{-1}, the evidence from Bryan and Gibbs (1983) suggests that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited it is assessed as 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to Annex I habitats and species.

Table 15.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 15.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 15.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	**	*	*
Deep Disturbance	***(3)	***	***
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	***(8+)	***	*
Smothering	***(2)	*	
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment - Water column	***(4)	**	***
Organic enrichment of sediments	***(4)	**	***
Increased removal of primary production - Phytoplankton			
Decrease in oxygen levels - Sediment	***(1)	*	N/A
Decrease in oxygen levels - Water column	***(1)	*	N/A
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not Assessed. No evidence found.		
Introduction of hydrocarbons	Not Assessed. No evidence found.		
Introduction of antifoulants	** (1)	**	N/A
Prevention of light reaching seabed/ features	*	N/A	N/A
Barrier to species movement			

References

Allen, J.A. and J.J. Moore. 1987. Invertebrate macrofauna as potential indicators of sandy beach instability. Estuarine, Coastal and Shelf Science 24: 109-125.

Avant, P. 2005. *Pygospio elegans*. A bristleworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 16/02/2012]. Available from: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4227.

Bolam, S.G. 1999. An investigation into the processes responsible for the generation of the spatial pattern of the spionid polychaete *Pygospio elegans* Claparede. PhD Thesis, Napier University.

Bolam, S.G. 2003. Dense aggregations of *Pygospio elegans* (Claparede): effect on macrofaunal community structure and sediments. Journal of Sea Research 49: 171-185.

Bolam, S.G. 2004. Population structure and reproductive biology of *Pygospio elegans* (Polychaeta: Spionidae) on an intertidal sandflat, Firth of Forth, Scotland. Invertebrate Biology 123: 260-268.

Bouchet, V.M.P. and Sauriau, P-G. 2008. Influence of oyster culture practices and environmental conditions on the ecological status of intertidal mudflats in the Pertuis Charentais (SW France: A multi-index approach. Marine Pollution Bulletin 56: 1898-1912.

Brenchley, G.A. 1982. Mechanisms of spatial competition in marine soft-bottom communities. Journal of Experimental Marine Biology and Ecology 60: 17-33.

Bryan, G.W. and Gibbs, P.E. 1983. Heavy metals in the Fal estuary, Cornwall: A study of long term contamination by mining waste and its effects on estuarine organisms. Occasional Publications. Marine Biological Association of the United Kingdom 2, 112p.

Colen, C.V., Monserrat, F., Vincx, M., Herman, P.M.J. and Ysebaert, T. 2008. macrobenthic recovery from hypoxia in an estuarine tidal mudflat. Marine Ecology Progress Series 372: 31-42.

Deslous-Paoli, J. M., Lannou, A.-M., Geairon, P., Bougrier, S., Raillard, O. and Héral, M. 1992. Effects of the feeding behaviour of *Crassostrea gigas* (Bivalve Molluscs) on biosedimentation of natural particulate matter. Hydrobiologia 231: 85-91.

Elliot, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. and Hemingway, K.L. 1998. Intertidal sand and mudflats and subtidal mobile sandbanks (Vol. II). An overview of dynamic and sensitivity for conservation management of marine SACs. Prepared by the Scottish Association for Marine Science for the UK Marine SACs Project.

Ferns, P.N., Rostron, D.M. and Siman, H.Y. 2000. Effects of cockle harvesting on intertidal communities. Journal of Applied Ecology 37: 464-474.

Gittenberger, A. and van Loon, W.M.G.M. 2011 Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08.

Grassle, J.F. and Grassle, J.P. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. Journal of Marine Research 32: 253-284.

Gray, J.S. 1979. Pollution-induced changes in populations. Philosophical Transcriptions of the Royal Society London, Series B 286: 545-561.

Gubbay, S. 1999. A review of the potential effects of fisheries within UK European marine sites. English Nature (UK Marine SACs Project). 120p.

Kaiser, M.J. and Beadman. H.A. 2002. Scoping study of the carrying capacity for bivalve cultivation in the coastal waters of Great Britain.

Lindsay, S.M., Jackson, J.L. and He, S.Q. 2007. Anterior regeneration in the spionid polychaetes *Dipolydora quadrilobata* and *Pygospio elegans*. Marine Biology 150: 1161-1172.

McCall, P.L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. Journal of Marine Research 35: 221-226.

Mitchell, I.M. 2006. In situ biodeposition rates of Pacific oysters (*Crassostrea gigas*) on a marine farm in Southern Tasmania (Australia). Aquaculture 257: 194-203.

Moore, J. 1991. Studies on the Impact of Hydraulic Cockle Dredging on Intertidal Sediment Flat Communities. A report to the Nature Conservancy Council from the Field Studies Council Research Centre, Pembroke, Wales, FSC/RC/4/91.

Nugues, M.M., Kaiser, M.J., Spencer, B.E. and Edwards, D.B. 1996. Benthic community changes associated with intertidal oyster cultivation. Aquaculture Research 27: 913-924.

Ragnarsson, S.A. and Rafaelli, D. 1999. Effects of the mussel *Mytilis edulis* L. on the invertebrate fauna of sediments. Journal of Experimental Marine Biology and Ecology 241: 31-43.

Rhoads, D.C. and Young, D.K. 1970. The influences of deposit feeding organisms on sediment stability and community trophic structure. Journal of Marine Research 28: 156-178.

Sornin, J.M., Feuillet, M., Héral, M. and Deslous-Paoli, J.M. 1983. Effet des biodépôts de l'huître *Crassostrea gigas* (Thunberg) sur l'accumulation de matières organiques dans les parcs du bassin de Marennes-Oléron. Journal of Molluscan Studies Suppt. 12A: 185-197.

16. Species: *Scoloplos armiger*

Species Description

Information from MarLIN (Ballerstedt, 2005).

- *Scoloplos armiger* is red to bright orange-pink in colour;
- *Scoloplos armiger* has a sharply pointed, cone-shaped head and 200 or more body segments;
- The posterior has 2 long cirri;
- Prominent red blood vessels run along the length of the body;
- Mobility/Movement: Burrower;
- Feeding: subsurface deposit feeder (Jumars and Fauchald, 1979);
- Environmental position: Infaunal;
- Habit: free-living, muddy sands to coarse clean sands (BIOTIC);
- Size: Medium (11-20 cm);
- Adult dispersal potential: 100-1000 m;
- Kruse and Reise (2003) showed that populations in the intertidal with holo- benthic development are reproductively isolated from subtidal ones with pelagic larvae;
- Intertidal *S. armiger* hatch from egg cocoons and directly enter the sediment below the surface (Gibbs, 1968); and
- Widely distributed in NW Europe and Britain on lower shore and in sublittoral.

Recovery

The adult worm has a life-span of about 4 years and reaches maturity at 2 years. The sexes are separate and as many as 100-5000 eggs of about 0.25 mm are fertilised externally between February-April. The eggs are attached to the seabed in a gelatinous mass and emerge after 3 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 Ltd, 2010).

Breeding occurs in early spring and is synchronized with spring tides. There also exist reports of a second breeding period. In some habitats the larvae probably have a benthic development and in other places a short planktonic stage. *Scoloplos armiger* is a fast growing species, breeding for the first time in its second year and living for about four years.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 16.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 16.2a and are combined, as in Table 16.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 16.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 16.2a).

Table 16.1 *Scoloplos armiger* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	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 millimeters below the sediment surface, adults may retreat to 10 cm 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 recovery is judged as 'Very High' and hence this species is assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (*)	H (*)	L (*)	In the muddy habitats in which this species is found, fishing gears such as beam trawls may penetrate to >3 cm, hence beam trawl evidence has been assessed below in deep disturbance. This species has been categorised as AMBI Fisheries Review Group II - Species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly (Gittenberger and van Loon, 2011). Based on the environmental position of adults and the review *S. armiger* was judged to have 'Medium' resistance to shallow disturbance (surface disturbance would lead to mortality of <25% of population). Recovery would occur from migration and reproduction within the remaining population and would be expected to take place within 2 years so that Recovery is assessed as 'high'. Sensitivity is therefore categorised as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	L-M (***)	M-H (*)	L-M (*)	Bergman and Hup (1992) found that worm species (including *S. armiger*) showed no change in total density after trawling. The effect of commercial digging for worms and clams on the infaunal benthic communities of mudflats in Maine, USA was investigated using experimentally dug plots and comparing the infaunal populations with those of undisturbed control plots (Brown and Wilson, 1997). The results showed that the density

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						of a congener *S. fragilis* was not affected by the digging. Conversely, Tuck et al. (1998) assessed the effects of extensive and repeated trawl disturbance over 18 months followed by 18 months recovery in an area which has been closed to fishing for over 25 years. *Scoloplos armiger* was identified as a sensitive species. Rostron (1995) undertook experimental dredging of sandflats with a mechanical cockle dredger, including a site comprised of stable, poorly sorted fine sands with small pools and *Arenica marina* casts with some algal growths. At this site, post-dredging *S. armiger* had disappeared from some dredged plots. Ferns et al. (2000) used a tractor-towed cockle harvester, to extract cockles from intertidal plots of muddy sand and clean sand, to investigate the effects on non-target organisms. 31% of the population of *S. armiger* (initial density of 120 per m^2) were removed. Populations of *S. armiger* remained significantly depleted in the area of muddy sand for more than 50 days after harvesting. Ball et al. (2000) found that species including *S. armiger* showed a significant decrease in abundance of between 56-27% after 16 months of otter trawling at a previously unfished Scottish sea loch.. Bergman and Santbrink (2000) found that the direct mortality of *S. armiger* from a single passage of a beam trawl in silty grounds was 18% of population. The degree of impact will be influenced by the type of activity causing the deep disturbance and the frequency and intensity of the activity. Experimental findings above that showed little or no impact are acknowledged, taking these and other findings into account resistance to deep disturbance is assessed as 'Low-Medium' (25-75%- <25% mortality) and recovery is assessed as 'Medium-High' based on inward migration and local reproduction of this species. Sensitivity is therefore categorised as 'Low-Medium'.
	Trampling - Access by foot	Direct damage caused by foot	H (*)	VH (*)	NS (*)	Chandrasekara and Frid (1996; cited in Tyler-Walters and Arnold, 2008) found that along a pathway heavily used for five summer months (ca. 50 individuals day^{-1}), *S. armiger* reduced in abundance.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		access, e.g. crushing				Recovery took place within 5-6 months. As the trampling evidence referred to repeated heavy disturbance the assessment for trampling is based on shallow disturbance as a more realistic scenario. Frequent and intense episodes of would be predicted to lead to a greater impact on this species.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	H (*)	L (*)	No information found. As vehicle access is likely to damage sediments the assessment is based on shallow abrasion.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M (*)	H (*)	No information found. Removal of substrate would remove infaunal populations, including *S. armiger*. Depending on the scale of extraction, recovery would require sediment infilling and would occur through transport or migration of adults or juveniles. Intertidal populations of this species have a benthic developmental stage so that recovery will require that local populations remain; however, this species is widely distributed. Resistance to sediment extraction is assessed as 'None' recovery is assessed as 'Medium' based on low dispersal potential; sensitivity is therefore assessed as 'High'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	Evidence from MarLIN Ls.LMx.Mx.CirCer (Marshall, 2008, references therein). Maurer et al. (1986) studied the effects of dredged material on the vertical migration and mortality of four species of benthic invertebrates (including two polychaetes) and reported that the intolerance of species to smothering was influenced by the nature of the sediment. They predicted that some individuals of both the polychaete species studied (*Nereis succinea* and *S. fragilis*) would be capable of vertical migration through 0.9 m of sediment if that sediment was indigenous to their usual habitat (Marshall, 2008). The species has been categorised through expert judgement and literature review, as AMBI sedimentation review Group IV - Second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the evidence from the congener and the review, *S. armiger* is assessed as having 'High' resistance to siltation, so that recovery is also assessed as 'Very High', the species is therefore categorised as 'Not Sensitive' to this pressure.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	H (*)	VH (*)	NS (*)	No information found. As the worms roam through a burrow system down to 15 cm depth and are not found on the surface (Kruse et al. 2004) resistance to smothering was assessed as 'High' and recovery, based on no effect, was assessed as 'Very High', so that this species was assessed as 'Not Sensitive'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	No information found. This species is a burrower and changes in sediment composition that alter the grade of sediment this species must move through can affect the suitability of the habitat. Based on habitat preferences, changes in sediment composition that removed all the silt fraction from muddy sands to leave a clean sand would not be considered to impact this species. However, an increase in coarse composition to gravels would be expected to negatively impact this burrowing species. This species is assessed as not sensitive to a change in sediment to a sand, but any further increased coarseness would lead to impacts.
	Changes in	Fine sediment	H (*)	VH (*)	NS (*)	No information found. Based on habitat preferences (see feature description) this species would not be

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment composition – increased fine sediment proportion	fraction increases				sensitive to the addition of fine materials to a sand that result in a muddy sand habitat. However, where sand was winnowed away, or silts were deposited to leave a mud sediment then this species is likely to be impacted. This species is assessed as 'Not Sensitive' to the addition of silts to a sand sediment but a habitat change to a mud sediment would be considered to render the habitat unsuitable for this species.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	No information found. Based on the environmental position of this species as a subsurface burrower, resistance is assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	No information found. Based on the environmental position of this species as a subsurface burrower, resistance is assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	No information found. Based on the environmental position of this species as a subsurface burrower, resistance is assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (***)	NS (***)	Identified as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski, 1975; cited in Gray, 1979). This species has been categorised as AMBI Group III by Borja et al. (2000) - 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). They are surface deposit-feeding species, as tubicolous spionids. However, a later review has characterised this species as 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. They tend to be surface deposit-feeding species (Borja et al. 2000; Gittenberger and van Loon, 2011). Resistance is assessed as 'High' and recovery as 'Very High' so that the species is assessed as 'Not Sensitive'. Although organic enrichment may enhance food supply to this species and be beneficial, associated increases in sediment sulphides and a decrease in oxygen may be detrimental (see below).
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (***)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance was assessed as 'High' and recovery as 'Very High' so that this species is considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	L (***)	H (***)	M (***)	*Scoloplos armiger* has been described as being present in low oxygen areas and as a dominant species in the recolonization of previously anoxic areas (Pearson and Rosenberg, 1978). Intertidal *S. armiger* are, in contrast to subtidal specimens, subject to hypoxia when tidal flats are without oxygenated seawater during low tide (Kruse et al. 2004). Tolerance against hypoxia and sulfide is low (Kruse et al. 2004), and worms may ascend into the oxic layer during low tide (Schoettler and Grieshaber, 1988). The available evidence is contradictory, based on Kruse et al. (2004) resistance to hypoxia is assessed as 'Low' and based on Pearson and Rosenberg (1978) supported by evidence of this species opportunistic life-history traits recovery is assessed as 'High'. Sensitivity is therefore considered to be
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L (***)	H (***)	M (***)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						'Medium'.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	L (*)	H (*)	M (*)	No information found. The sand habitats in which this species occurs may be too dynamic for invasive species to become established. If conditions allowed *Crepidula fornicata* and *Crassostrea gigas* to colonise, the subsequent sediment stabilisation, enhanced siltation and accumulation of pseudofaeces may lead to increased sediment sulphides which could be detrimental to this species. Resistance is therefore assessed as 'Low' and recovery as 'High', so that sensitivity was assessed as 'Medium'. Sensitivity will be greater where removal of non-natives is impossible.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		L (**)	M- H (***)	M (**)	Although this species is not targeted by a commercial fishery, evidence from intertidal experimental exclusion indicates that abundance of *S. armiger* is higher where the lugworm *A. marina* is present due to beneficial habitat modifications (Volkenborn and Reise, 2004). Removal of this species by bait collectors could therefore negatively impact this species. Resistance is assessed as 'Low' and recovery as 'Medium- High'. Sensitivity is therefore considered to be 'Medium'.
	Removal of Non-target	Alteration of habitat character, e.g. the	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	species	loss of structure and function through the effects of removal of target species on non-target species				As the species is not dependent on other species to provide or maintain habitat, resistance is assessed as 'High' and recovery as 'Very High'. Overall, sensitivity is assessed as 'Not Sensitive'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No information found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No information found. Not Assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Rygg (1985) classified *Scoloplos armiger* as a highly tolerant species, common at the most Copper polluted stations in a Norwegian fjord (Cu > 200 mg Kg^{-1}). Based on a sediment quality guideline of 100 mg kg^{-1} for Copper, the evidence from Rygg (1985) indicates that the sediment quality guideline of 100 mg kg^{-1} would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Copper may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. As this species lives buried below the sediment surface and is not dependent on light, resistance was assessed as 'High' and recovery as 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Barrier to species movement				NA	Not Assessed.

Table 16.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 16.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 16.3 Confidence Levels for Resistance Assessments

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	***(5+)	***	**
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk	Not Relevant.		
Underwater Noise	Not Relevant.		
Visual - Boat/vehicle	Not Relevant.		
Visual - Foot/traffic	Not Relevant.		
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Organic enrichment - Water column	***(1)	N/A	N/A
Organic enrichment of sediments	***(1)	N/A	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***	***	N/A
Decrease in oxygen levels - Water column	***	***	N/A
Genetic impacts	Not Relevant.		
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens	Not Relevant.		
Removal of Target Species	Not relevant.		
Removal of Non-target species	Not Relevant.		
Ecosystem Services - Loss of biomass	Not Relevant.		
Introduction of medicines	No Evidence. Not Assessed.		
Introduction of hydrocarbons	No Evidence. Not Assessed.		
Introduction of antifoulants	*** (1)	**	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement	Not Relevant.		

References

Ball, B., Munday, B. and Tuck, I. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. In: Kaiser, M.J. and de Groot, S.J. (Eds.) Effects of fishing on non-target species and habitats, pp 69-82. Oxford: Blackwell Science.

Ballerstedt, S. 2005. *Scoloplos* (*Scoloplos*) *armiger*. A bristleworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 31/08/2012]. Available from: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4307.

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beamtrawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science: Journal du conseil 49(1): 5-11.

Bergman, M.J.N. and van Santbrink, J.W. 2000. Mortality in megafaunal benthic populations caused by trawl fisheries on the Dutch continental shelf in the North Sea in 1994. ICES Journal of Marine Science 57: 1321-1331.

BIOTIC website: http://www.marlin.ac.uk/biotic/browse.php?sp=6020 [cited: 21/09/12].

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Brown, B. and Wilson, W.H. 1997. The role of commercial digging of mudflats as an agent for change of infaunal intertidal populations. Journal of Experimental Marine Biology and Ecology 218: 49-61.

Ferns, P.N., Rostron, D.M. and Siman, H.Y. 2000. Effects of mechanical cockle harvesting on intertidal communities. Journal of Applied Ecology 3: 464-474.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011-08.

Gibbs, P.E. 1968. Observations on the population of *Scoloplos armiger* at Whitstable. Journal of the Marine Biological Association of the United Kingdom 48: 225-254.

Gray, J.S. 1979. Pollution induced changes in populations. Philosophical Transactions of the Royal Society B 286: 545-561.

Jumars, P.A. and Fauchald, K. 1979. The diet of the worms: a study of polychaete feeding guilds. Oceanography and Marine Biology - An Annual Review 17: 193-284.

Kruse, I. and Reise, K. 2003. Reproductive isolation between intertidal and subtidal *Scoloplos armiger* (Polychaeta, Orbiniidae) indicates sibling species in the North Sea. Marine Biology 143: 511-17.

Kruse, I., Strasser, M. and Thiermann, F. 2004. The role of ecological divergence in speciation between intertidal and subtidal *Scoloplos armiger* (Polychaeta, Orbiniidae). Journal of Sea Research 51: 53-62.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Marshall, C.E. 2008. Cirratulids and *Cerastoderma edule* in littoral mixed sediment. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 03/09/2012]. Available from: http://www.marlin.ac.uk/habitatbenchmarks.php?habitatid=372&code.

Pearson, T.H. and Rosenberg, R. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology - An Annual Review 16: 229-311.

Reise, K. and Ax, P. 1979. A meiofaunal "thiobios" limited to theanaerobic sulfide system of marine sand does not exist. Marine Biology 54: 225-237.

Rostron, D.M. 1995. The effects of mechanised cockle harvesting on the invertebrate fauna of Llanrhidian sands. P111-117. In Burry Inlet and Loughor Estuary Symposium, March 1995. Part 2. Burry Inlet and Loughor Estuary Liaison Group.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

Schoettler, U. and Grieshaber, M. 1988 Adaptation of the polychaete worm *Scoloplos armiger* to hypoxic conditions. Marine Biology 99: 215-222.

Tuck, I., Hall, S.J., Roberston, M., Armstrong, E. and Basford, D. 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. Marine Ecology Progress Series 162: 227-242.

Tyler-Walters, H. and Arnold, C. 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN) [Contract no. FC 73-03-327]. Plymouth, Marine Biological Association of the UK.

Volkenborn, N. and Reise, K. 2006. Lugworm exclusion experiment: responses by deposit feeding worms to biogenic habitat transformation. Journal of Experimental Marine Biology and Ecology 330: 169-179.

17. Species: *Spio* spp.

Species Description (from BIOTIC)

- Feeding type: Able to switch between deposit and suspension feeding (Fauchald and Jumars, 1979);
- Habitat: Tubicolous infauna, found in a range of sediment types (see below);
- Mobility: Sedentary;
- Longevity: 1 year;
- Reproduction: 2 spawning episodes a year; and
- Dispersal: Planktotrophic larvae.

This genus has been identified as a characterising species in the following EUNIS habitats (see Table A and B) and JNCC equivalents. The habitat preferences listed below have been identified from the habitats descriptions of these biotopes (from the JNCC website; Connor et al. 2004)

Table A: Biotopes with which *Spio filicornis* commonly associated

EUNIS (version 2004)	Marine Habitat Classification Britain/Ireland (v0405)
A2.23	LS.LSa.FiSa
A2.231	LS.LSa.FiSa.Po
A2.2312	LS.LSa.FiSa.Po.Aten
A5.123	SS.SCS.ICS.MoeVen
A5.233	SS.SSa.IFiSa.NcirBat
A5.234	SS.SSa.IFiSa.TbAmPo
A5.24	SS.SSa.IMuSa
A5.242	SS.SSa.IMuSa.FfabMag
A5.355	SS.SMu.CSaMu.LkorPpel

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Wave exposure: Moderately exposed, sheltered, very sheltered, extremely sheltered;
- Tidal streams: Moderately strong (1-3kn), weak (1>kn), very weak (negligible); and
- Sediment: Medium and fine sand, very fine sand, medium to coarse sand and gravelly sand, medium to very fine muddy sand, fine to very fine sand with a silt fraction, muddy sand.

Table B: Biotopes with which *Spio martinensis is* commonly associated

EUNIS (version 2004)	Marine Habitat Classification Britain/Ireland (v0405)
A2.2311	LS.LSa.FiSa.Po.Pful
A2.2313	LS.LSa.FiSa.Po.Ncir
A5.125	SS.SCS.ICS.Glap
A5.233	SS.SSa.IFiSa.NcirBat
A5.24	SS.SSa.IMuSa
A5.242	SS.SSa.IMuSa.FfabMag
A5.355	SS.SMu.CSaMu.LkorPpel

Habitat Preferences (from JNCC Marine Habitat Classification Britain/Ireland 0405; Connor et al. 2004)

- Wave exposure: Very exposed, exposed, moderately exposed, sheltered, very sheltered, extremely sheltered;
- Tidal streams: Strong (3-6kn), moderately strong (1-3kn), weak (1-3kn), very weak (negligible); and
- Sediment: medium to coarse sand with some gravel, medium and fine sand, very fine sand, fine to very fine sand with a silt fraction, sandy mud.

Recovery

Information from MarLIN – *Spio filicornis* (Ager, 2007)

Spio filicornis is a highly opportunistic polychaete with a short life span (Diaz-Castaneda et al. 1989). It reproduces throughout the year and reportedly thrives in regularly disturbed environments (Kröncke, 1990; Niermann et al. 1990). It reaches maturity quickly, and has good local recruitment since eggs and larvae are retained within an egg mass. Therefore, recoverability has been recorded as very high. There is no pelagic larval stage, suggesting that where the population is removed, recovery may take longer. However, adults and juveniles may recruit to an area due to bedload transport and recoverability is likely to be high (Ager, 2007).

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Spio is a short-lived genus with a life-span of about 1year. Sexual maturity is achieved at 2-3 months. The sexes are separate and approximately 250 eggs of 0.13-0.15mm are fertilised externally during two reproductive periods (April-June and August-September). The embryos are brooded in the tube and then released as lecithotrophic larvae that spend about 4 weeks in the plankton. The dispersal potential is high and the relatively short generation time and rapid growth rate suggests that restoration of the biomass is achieved soon after settlement. This genus has a high recoverability (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 17.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 17.2a and are combined, as in Table 17.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 17.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 17.2a).

Table 17.1 *Spio* spp. Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	M (*)	VH (***)	L (*)	The environmental position of this species and fragility suggest that surface abrasion will result in damage and mortality to a proportion of the population within the spatial footprint. Resistance is therefore assessed as 'Medium'. Based on evidence presented below for surface disturbance, recovery is assessed as 'Very High'. The sensitivity of this genus is therefore assessed as 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	M (***)	VH (***)	L (***)	Information from MarLIN – *Spio filicornis* (Ager, 2007, references therein) *Spio filicornis* is a soft bodied organism that exposes its palps at the surface while feeding. It lives infaunally in sandy sediment and any physical disturbance that penetrates the sediment, for example dredging or dragging an anchor, would lead to physical damage of *S. filicornis*. However, adult worms can burrow up to 10cm down and may escape the disturbance. Juveniles can only burrow up to 2cm into the sediment and are likely to be affected. However, individuals are likely to pass through a passing scallop dredge due to their small size. Bergman and Hup (1992) reported that the total density of spionids actually increased with increased fishing disturbance presumably due to their ability to colonize newly exposed substratum. Hall et al. (1990) investigated the impact of hydraulic dredging for razor clams. They reported that any effects only persist for a short time, with the community restored after approximately 40 days in stormy conditions. The population density of *S. filicornis* was slightly reduced in the dredged site relative to the control site but its abundance had increased over that of the control site after 40 days. However, the control site showed a similar level of variation in abundance. An intolerance of intermediate has therefore been recorded. Recoverability has been recorded as very high (Ager, 2007). This species has been categorised through literature and expert review, as AMBI fisheries Group IV - a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above information resistance was assessed as 'Medium' (mortality of <25% of population in direct footprint, recovery was assessed as 'Very High'. Sensitivity was therefore assessed as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (***)	VH (***)	L (***)	Assessment based on shallow disturbance.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	M (*)	VH (***)	L (*)	Assessment based on surface disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	VH (***)	L (*)	Assessment based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	H-VH (*)	L-M (*)	Information from MarLIN – *Spio filicornis* (Ager, 2007) *Spio filicornis* lives in the sediment and a loss of substratum would cause a loss of population. Therefore, an intolerance of high has been recorded. Recoverability has been recorded as high (Ager, 2007). This species is infaunal, extraction of the sediment would remove the population and resistance is assessed as 'None', however if suitable sediments remain, or habitat rehabilitation occurs through natural processes, recovery would be predicted to be 'High-Very High' (modified by the spatial scale of impact and presence of nearby population to provide colonists due to lack of pelagic stage). Sensitivity is therefore assessed as 'Low-Medium'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat	H (*)	VH (*)	NS (*)	Information from MarLIN – *Spio filicornis* (Ager, 2007) *Spio filicornis* lives in the sediment and uses sediment grains to make its tube. It is likely that *S. filicornis* will be able to move up through any extra sediment, therefore intolerance, has been recorded as low. Recoverability will probably be very high (see additional information below). However, smothering by impermeable material is likely to result in anoxic conditions and have a greater impact (Ager, 2007). This species was characterised as AMBI Sedimentation Group IV - Second-order opportunistic species,

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		quality)				insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive').
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	H (***)	M (*)	No evidence found. As adults are sedentary and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on the return of previous habitat conditions. Resistance is judged as 'None' with recovery as 'High' if original habitat conditions are re-instated, so that the sensitivity of this genus is assessed as 'Medium'. If there was no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual - Boat/ vehicle movements				NS	Not sensitive.
	Visual - Foot/ traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition -	Coarse sediment fraction increases	L-M (*)	H-VH (*)	L-M (*)	No information found. This genus is found in coarse sands and gravelly sands, therefore the species is considered to have some tolerance to the addition of a coarse fraction or the removal of some of the fine sediment fraction e.g. the addition of gravel to sands. However, a significant increase in the coarse

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Increased coarseness					sediment fraction e.g. a change to gravel sediments would be considered to reduce habitat suitability for this species. Resistance is therefore assessed as 'Low-Medium' and recovery as 'High-Very High' following habitat recovery. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	L-M (*)	H-VH (*)	L-M (*)	No information found. This genus is found in muddy sands, therefore the genus is considered to have some tolerance to an increase in fine sediment fractions. However, a change to a fine sediment is considered to decrease habitat suitability for this species. Resistance is therefore assessed as 'Low-Medium' and recovery as 'High-Very High' following habitat recovery. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (*)	VH (*)	NS (*)	Information from MarLIN – *Spio filicornis* (Ager, 2007) A change in water flow rate will change sediment characteristics. Increased water flow will increase deposits of coarser sediments. Changes in water flow are likely to change the distribution and extent of the population due to changes in the preferred substratum of *Spio filicornis*. Therefore, intolerance has been recorded as intermediate. A recoverability of very high has been recorded. A change in water flow rate will change sediment characteristics. A decrease in water flow rate will lead to deposits of finer sediments. The distribution and extent of the population is likely to alter due to changes in the preferred substratum of *S. filicornis*. Therefore, an intolerance of intermediate has been recorded. A recoverability of very high has been recorded (Ager, 2007). This genus has been recorded as characterising a number of biotope types (see Introduction Tables A and B) wave exposure and tidal streams where these biotopes develop vary from exposed to very sheltered and from strong to very weak. Based on this information this genus is assessed as 'Not Sensitive' to changes in water flow. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Changes in turbidity/ suspended	Increase in particulate matter (inorganic and	H (*)	VH (*)	NS (*)	Information from MarLIN – *Spio filicornis* (Ager, 2007) *Spio filicornis* lives in the sediment and is unlikely to be perturbed by an increase in suspended sediment. There may be an increase in the amount of food avaliable therefore, tolerant has been

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment - Increased suspended sediment/ turbidity	organic)				recorded (Ager, 2007). *S. filicornis* is found in estuarine regions which experience high levels of turbidity. An increase in turbidity will lead to reduced light penetration of the water column. *S. filicornis* is not affected by light availability, therefore, tolerant has been recorded (Ager, 2007). Based on the above information, resistance is assessed as 'High' and recovery as 'Very High' so that this specie sis assessed as 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN – *Spio filicornis* (Ager, 2007) *Spio filicornis* is a surface deposit feeder and relies on a supply of nutrients at the sediment surface. A decrease in suspended sediment is likely to lead to a reduction in the amount of available food. A reduction in food availability may impair growth and reproduction but is unlikely to cause mortality. Intolerance has, therefore, been recorded as low. *Spio filicornis* is not affected by light availability, therefore, tolerant has been recorded (Ager, 2007). Based on the above information resistance is assessed as 'High' and recovery as 'Very High'. This genus is therefore assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As *Spio* spp. are not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton may be utilised as food by this genus. This species is therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	Information from MarLIN – *Spio filicornis* (Ager, 2007, references therein) *Spio filicornis* is often found in environments subject to high levels of nutrients, for example, it was found in areas of the Firth of Forth exposed to high levels of sewage pollution (Read et al. 1983). *S. filicornis* is also found in nutrient poor areas (Diaz-Castaneda et al. 1989). Therefore, an intolerance of low has been recorded. A recoverability of very high has been recorded (Ager, 2007). This species was characterised as AMBI Group III - Species tolerant to excess organic matter

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids (Borja et al. 2000; Gittenberger and van Loon, 2011). Based on the above information, this genus was assessed as having 'High' resistance and, consequently, 'Very High' recovery. This genus is therefore assessed as 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (***)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance was assessed as 'High' and resilience as 'Very High' so that this species is categorised as 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment			NEv	No evidence found. Not assessed.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column			NEv	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native	Cultivation of a non-native species and/or	H (*)	VH (*)	NS (*)	No evidence found. *Crepidula fornicata* and *Crassostrea gigas* are the non-native species most likely to be introduced by aquaculture and become established in habitats in which this species is found. These

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	species	potential for introduction of non-natives in translocated stock'				may stabilise sediments and enhance food supply to this species by deposition of organic matter. *Spio* spp. are assessed as 'Not Sensitive' to this pressure, resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Potential impacts from commercial fisheries within this species' habitats are considered in the physical disturbance pressures above. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species, that occur in the same habitat (such as worms targeted by bait diggers), as assessed through the disturbance pressure themes above. As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to Annex I species and habitat features.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	H (***)	VH (***)	NS (***)	Information from MarLIN – *Spio filicornis* (Ager, 2007) Diaz-Castaneda et al. (1989) looked at colonization of defaunated and polluted sediments in Dunkerque harbour. The sediment was polluted with both heavy metals and oil. *Capitella capitata* was generally the first polychaete to colonize the polluted sediment. *Spio filicornis* took between 7 weeks

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						and 3 months to appear in the sediment suggesting it is tolerant of oil pollution. Intolerance has therefore been recorded as low. A recoverability of very high has been recorded (Ager, 2007). Based on the above information, resistance was assessed as 'High' and recovery as 'Very High'. This genus was therefore assessed as 'Not Sensitive'.
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	Based on a Cu sediment quality guideline of 100 mg kg^{-1} (Madsen et al. 2000) it is assumed (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Spio* spp. do not photosynthesise and do not, therefore, directly require light and are therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to Annex I species and habitat features.

Table 17.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 17.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 17.3 Resistance Assessment Confidence Levels

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***	***	***
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment - Water column	*	N/A	N/A
Organic enrichment of sediments	***(3)	**	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	Not assessed. No evidence.		
Decrease in oxygen levels - Water column	Not assessed. No evidence.		
Genetic impacts			
Introduction of non-native species			
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not assessed. No evidence.		
Introduction of hydrocarbons	***(1)	*	N/A
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Ager, O. 2007. *Spio filicornis*. A bristleworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 02/03/2013] http://www.marlin.ac.uk/speciesfullreview.php?speciesID=4354.

BIOTIC website: http://www.marlin.ac.uk/biotic/browse.php?sp=6020 [cited: 21/09/12].

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.

Fauchald, J. and Jumars, P.A. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology: an Annual Review 17: 193-284.

Gittenberger, A. and van Loon, W.M.G.M. 2011 Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011-08.

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

18. Species: *Spiophanes bombyx*

Synonyms: *Spio bombyx; Spiophanes verilli*

Species Description

- Fragile polychaete worm from the family Spionidae;
- Species inhabitats solid tube built of sand grains that protrudes slightly above the surface (Degraer et al. 2006);
- Length: 5-6 cm;
- Habitat: Reaches a high relative occurrence in almost all sediment types. A relative occurrence of >40% is reached in sediments with a median grain size of 100 to 550 μm and with a mud content of 0 to 90% (Degraer et al. 2006);
- Although the species has been found in a variety of sediment types, its density distribution suggests a distinct preference for fine sandy substrates (Holtmann et al. 1996);
- Feeding type: Deposit feeder (Wildish and Peer, 1981), filter feeder (Eleftheriou and Basford, 1989), interface grazer and suspension feeder (Dauer et al. 1981); and
- Environmental Position: Infaunal, shallowly buried, with feeding palps exposed at surface.

This species has been identified as a characterising species in the following EUNIS habitats (see Table A) and JNCC equivalents. The habitat preferences listed below have been identified from the habitats descriptions of these biotopes (from the JNCC website; Connor et al. 2004)

Table A: *Spiophanes bombyx* has been recorded as a characterising species from the following EUNIS biotopes and JNCC equivalents

EUNIS (version 200410)	Marine Habitat Classification Britain/Ireland 0405
A5.14	SS.SCS.CCS
A5.5331	SS.SMp.SSgr.Zmar
A5.24	SS.SSa.IMuSa
A5.26	SS.SSa.CMuSa
A2.231	LS.LSa.FiSa.Po
A5.233	SS.SSa.IFiSa.NcirBat
A5.137	SS.SCS.ICS.SLan
A5.242	SS.SSa.IMuSa.FfabMag
A5.241	SS.SSa.IMuSa.EcorEns
A5.331	SS.SMu.ISaMu.NhomMac
A5.261	SS.SSa.CMuSa.AalbNuc
A5.13	SS.SCS.ICS
A5.23	SS.SSa.IFiSa
A5.25	SS.SSa.CFiSa
A2.23	LS.LSa.FiSa
A5.44	SS.SMx.CMx
A2.2313	LS.LSa.FiSa.Po.Ncir
A5.133	SS.SCS.ICS.MoeVen
A5.244	SS.SSa.IMuSa.SsubNhom
A5.135	SS.SCS.ICS.Glap
A5.234	SS.SSa.IFiSa.TbAmPo
A5.335	SS.SMu.ISaMu.AmpPlon

EUNIS (version 200410)	Marine Habitat Classification Britain/Ireland 0405
A5.142	SS.SCS.CCS.MedLumVen
A5.151	SS.SCS.CCS.MedLumVen
A5.5213	SS.SMp.KSwSS.LsacR.Sa
A5.251	SS.SSa.CFiSa.EpusOborApri
A5.252	SS.SSa.CFiSa.ApriBatPo
A5.355	SS.SMu.CSaMu.LkorPpel
A5.443	SS.SMx.CMx.MysThyMx

Recovery

Information from MarLIN (BIOTIC, references therein).

Spiophanes bombyx is regarded as a typical 'r' selective species with a short life span, high dispersal potential and high reproductive rate (Kröencke, 1980; Niermann et al. 1990). It is often found at the early successional stages of variable, unstable habitats that it is quick to colonize following perturbation (Pearson and Rosenberg, 1978). Its larval dispersal phase may allow the species to colonise remote habitats.

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Spiophanes has a life-span of 1 year at which time it reaches sexual maturity. The sexes are separate and there is one reproductive phase which occurs from March-October. About 30-40 eggs of 0.3mm diameter are produced by each female and after external fertilisation these develop into planktotrophic larvae that spend about 6 weeks in the plankton. The fecundity is relatively low, but the dispersal potential is high and the growth rate is fast after settlement of the post-larvae (MES Ltd, 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 18.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 18.2a and are combined, as in Table 18.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as ‘Not Assessed’ (NA) in the matrix.

For a limited number of pressures the assessment ‘No Evidence’ (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 18.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 18.2a).

Table 18.1 *Spiophanes bombyx* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	M (*)	VH (***)	L (*)	Information from MarLIN (Ager, 2009) If *S. bombyx* is displaced from the substratum it is likely that it could burrow back into the sediment. It would, however, be more susceptible to predation. Surface abrasion would be predicted to damage and perhaps kill a small proportion of the population (<25%), tubes would be damaged and require repairing which may also result in energetic costs for individuals. Resistance is therefore assessed as 'Medium' and recovery as 'Very High' so that sensitivity is assessed as 'Low'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	L (***)	VH (***)	L (***)	Information from MarLIN (Ager, 2009, references therein) *Spiophanes bombyx* is a soft bodied organism that exposes its palps at the surface while feeding. It lives infaunally in sandy sediment and any physical disturbance that penetrates the sediment, for example dredging or dragging an anchor, would lead to physical damage of *S. bombyx*. Bergman and Hup (1992) reported a 40-60% decrease in the total density of *S. bombyx* after 3 trawling events. Therefore, an intolerance of intermediate has been recorded. Hall et al. (1990) investigated the impact of hydraulic dredging for razor clams. They reported that any effects only persist for a short time, with the community restored after approximately 40 days. Similarly, Jennings and Kaiser (1995) suggested that the top few centimetres of the sediment were usually occupied by opportunistic species, such as spionids, capitellid polychaetes and amphipods, which were able to recolonize disturbed areas quickly. They further suggested that this surface community would probably recover within 6-12 months. Therefore, a recoverability of very high has been recorded (see additional information below) (Ager, 2009). Bergman and Hup (1992) carried out a pre and post experimental investigation using a 12 m beam trawl. The area was trawled three times over 2 days and samples taken up to 2 weeks after trawling. Some benthic species showed a 10-65% reduction in density after trawling the area three times. There was a significant lowering of densities (40-60%) of echinoderms *Asterias rubens* and small *Echinocardium cordatum*, and of polychaete worms *Lanice conchilega* and *S. bombyx*.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Gilkinson et al. (2005) carried out a hydraulic clam dredging experiment, designed to mimic offshore commercial dredging practices, at a depth of approximately 70 m on a sandy seabed on Banquereau, on the Scotian Shelf, eastern Canada. The experiment was designed to study the separate and combined effects of dredging through three treatment boxes (Dredging Only, Dredging and Discarding, Discarding Only) and two spatially separated reference boxes. Recovery trajectories of target and non-target species were followed for 2 years. Following initial declines in abundance and biomass of most taxa immediately after dredging, there were marked increases in abundance of polychaetes and amphipods after 1 year. Two years after dredging, abundances of opportunistic species were generally elevated by ≫100% relative to pre-dredging levels. Two years after dredging, average taxonomic distinctness had decreased (i.e. taxonomic relatedness between species had increased) due, in part, to increased numbers of species of certain polychaetes and amphipods, while communities had become numerically dominated (50-70%) by *S. bombyx*. This species has been categorised through expert judgement and literature review as AMBI fisheries Group IV - Second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger and van Loon, 2011). Based on this evidence resistance was assessed as ‘Low’ (mortality 25-75%) and recovery was assessed as ‘Very High’ (within 6 months). Sensitivity was therefore considered to be ‘Low’.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	N-L (***)	VH (*)	L (***)	Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that deposit feeding polychaetes were more impacted than carnivorous species. Dredging resulted in reductions of >90% of *S. bombyx* immediately post dredging compared with before impact samples and the population reduction persisting for 90 days (although results may be confounded by storm events within the monitoring period which caused sediment mobility). Based on the above evidence resistance was assessed as ‘None to Low’ and recovery as ‘Very High’, so that sensitivity was assessed as ‘Low’.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	M (*)	VH (***)	L (*)	Assessment based on surface abrasion.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	L (*)	VH (*)	L (*)	Assessment based on shallow disturbance.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	VH (*)	L (*)	This species is infaunal and has restricted mobility. Extraction of the sediment would remove the population of this shallow burying species. Resistance has therefore been assessed as 'None'. As this species is an early coloniser of disturbed sediments, recovery has been recorded as 'Very High' (following habitat recovery). Sensitivity is therefore categorised as 'Low'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2009) *Spiophanes bombyx* lives in the sediment and uses sediment grains to make its tube. It is likely that *S. bombyx* will be able to move up through any extra sediment. Therefore, intolerance has been recorded as low. However, smothering by impermeable material is likely to result in anoxic conditions and have a greater impact (Ager, 2009). The species has been categorised through expert judgement and literature review, as AMBI sedimentation review Group IV - Second-order opportunistic species, insensitive to higher amounts of sedimentation. Although it is sensitive to strong fluctuations in sedimentation, populations recover relatively quickly and even benefit. This causes population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger and van Loon, 2011). Based on the information above, resistance to siltation was assessed as 'High' and recovery as 'Very High', this species was therefore assessed as 'Not Sensitive'.
	Smothering (addition of materials biological or	Physical effects resulting from addition of coarse materials	N (*)	VH (*)	L (*)	Based on the evidence outlined above and the sedentary nature of this species, the resistance of *S. bombyx* to the addition of coarse material is assessed as 'None'. Recovery (following habitat rehabilitation) is predicted to be 'Very High'', leading to a sensitivity assessment of 'Low'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	non-biological to the surface)					
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed. Adults of this species do not occur in the water column.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual-boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	M (*)	VH (*)	L (*)	This species is found in a range of sediment types (see Introduction) as long as sand is available to construct tubes this species is considered to have some resistance to increased proportions of coarse fractions. Resistance is therefore assessed as 'Medium', recovery as 'Very High' and sensitivity as 'Low'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	M (*)	VH (*)	L (*)	This species is found in a range of sediment types (see Introduction) as long as sand is available to construct tubes this species is considered to have some resistance to increased proportions of coarse fractions. Resistance is therefore assessed as 'Medium', recovery as 'Very High' and sensitivity as 'Low'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2009, references therein) A change in water flow rate will change sediment characteristics. A decrease in water flow rate will increase the deposit of finer sediments. The preferred substratum of *S. bombyx* is finer sands, therefore, a change in the sediment characteristics may lead to an increase in the distribution and extent of the population.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		column				Increases in water flow above the critical erosion rate would resuspend fine sediments and would wash-out the worms from their habitat. Increased sediment coarseness would reduce habitat suitability (as assessed above). Changes to flow rate below this benchmark may lead to changes in behaviour. Most spionid polychaetes switch from deposit feeding to suspension feeding as current velocity and the supply of suspended food particles increases. Flume tank experiments have demonstrated that increased flow led to improved growth rates for other spionid species due to enhanced food supply (Hentschel, 2004; cited in Ager, 2009). Increased water flow rates may therefore favour this species while decreased flow rates may impose energetic costs through the reduction of food availability (which may be offset by increased deposition of organic matter). The resistance of this species is therefore judged to be 'High' to changes in water flow that do not alter sediment characteristics and recovery is judged to be 'Very High'. This species is therefore considered to be 'Not Sensitive'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Information from MarLIN (Ager, 2009) *Spiophanes bombyx* is found in estuarine regions which experience high levels of turbidity. An increase in turbidity will lead to reduced light penetration of the water column. *Spiophanes bombyx* is not affected by light availability. *Spiophanes bombyx* lives in the sediment and is unlikely to be perturbed by an increase in suspended sediment (Ager, 2009). Increased suspended sediment levels may enhance food supply to this species but, as these effects are considered beneficial, resistance is assessed as 'High' and recovery as 'Very High'./Overall sensitivity is assessed as 'Not Sensitive'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (***)	NS (*)	Information from MarLIN (Ager, 2009) *Spiophanes bombyx* is a surface deposit feeder and relies on a supply of nutrients at the sediment surface. A decrease in suspended sediment is likely to lead to a reduction in the amount of available food. A reduction in food availability may impair growth and reproduction but is unlikely to cause mortality (Ager, 2009). Laboratory experiments indicated that this species did not feed very often when there were no suspended particles and faecal production was much lower (Dauer et al. 1981). A reduction in suspended organic particles may reduce food supply impacting growth rates and reproduction; such effects are predicted to be sub-lethal. Resistance is predicted to be High' and recovery 'Very High' leading to an assessment of 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (***)	NS (***)	Organic enrichment beneath oyster cultivation trestles, mussel cultivation sites and fish cages has led to community replacement/dominance by Spionid polychaetes in mudflats, that characterise disturbed areas enriched in organic matter (Pearson and Rosenberg, 1978; Samuelson, 2001; see Bouchet and Sauriau, 2008 for references for activities). Information from MarLIN (Ager, 2009, references therein). Moderate nutrient levels may be beneficial to *S. bombyx* but increased nutrient enrichment may result in a community dominated by opportunist species (e.g. capitellids followed by spionids). This results in an increase of abundance but a decrease in species richness eventually leading to abiotic, anoxic sediments (Pearson and Rosenberg, 1978). Intolerance has therefore been recorded as low. A recoverability of high has been recorded (Ager, 2009). This species has been characterised as 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). They tend to be surface deposit-feeding species (Borja et al. 2000; Gittenberger and van Loon, 2011). Based on field observations and the AMBI review, this species was considered to have 'High'
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						resistance to organic enrichment and 'Very High' recovery, so that this species was assessed as 'Not Sensitive'.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (***)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance was assessed as High and resilience as 'Very High, this species is therefore considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	L (***)	VH (***)	L (***)	Information from MarLIN (Ager, 2009, references therein). Nierman et al. (1990) reported changes in a fine sand community for the German Bight in an area with regular seasonal hypoxia. In 1983, oxygen levels were exceptionally low (<3mg O_2/l) in large areas and <1mg O_2/l in some areas. Species richness decreased by 30-50% and overall biomass fell. *Spiophanes bombyx* was found in small numbers at some, but not all areas, during the period of hypoxia. Once oxygen levels returned to normal *S. bombyx* increased in abundance. The benchmark is for 2mg O_2/l for 1 week. The evidence suggests that at least some *S. bombyx* would survive hypoxic conditions. Therefore, intolerance has been recorded as intermediate. A recoverability of high has been recorded (see additional information below). Based on the evidence outlined above, resistance to decreased oxygen levels was assessed as 'Low' (mortality of 25-75%) and recovery as 'Very High' based on life history traits. Sensitivity was therefore categorised as 'Low'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	L (***)	VH (***)	L (***)	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of	Cultivation of a non-	L (*)	VH (*)	L (*)	No evidence found. Eight invasive species are recorded in Ireland (Invasive species Ireland

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	non-native species	native species and/or potential for introduction of non-natives in translocated stock				management toolkit; http://invasivespeciesireland.com/toolkit). Sediments where *S. bombyx* are found could be colonised by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). Sediment stabilisation and organic enrichment by the addition of faeces and pseudofaeces may benefit this species but sediment changes and smothering effects may be detrimental for this species. Resistance was therefore assessed as 'Low' and recovery as 'Very High', sensitivity is therefore considered to be 'Low'. However, it should be noted that, once established, removal of these species may not be possible and recovery may therefore not occur and therefore sensitivity may be considered to be higher.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	This species will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. *Spiophanes bombyx* is not the subject of a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	As the species is not dependent on other species to provide or maintain habitat, resistance is assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical	Introduction of	Introduction of			NEv	Information from MarLIN (Ager, 2009, references therein).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Pressures	Medicines	medicines associated with aquaculture.				No information was found directly relating to the effects of synthetic chemicals on *S. bombyx* . However, there is evidence from other polychaete species. Collier and Pinn (1998) investigated the effect on the benthos of ivermectin, treatment for infestations of sea-lice on farmed salmonids. The ragworm *Hediste diversicolor* exhibited 100% mortality after 14 days when exposed to 8mg/m^2 of Ivermectin in a microcosm. The blow lug, *Arenicola marina*, was also intolerant of Ivermectin through ingestion of contaminated sediment (Thain et al. 1998; cited in Collier and Pinn 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. The high mortality rate of polychaetes due to exposure to Ivermectin suggests a high intolerance to synthetic chemicals. Therefore, an intolerance of high has been recorded at a very low level of confidence. Recoverability has been recorded as high (see additional information below) (Ager, 2009).
	Introduction of hydrocarbons	Introduction of hydrocarbons	M (***)	VH (***)	L (***)	Information from MarLIN (Ager, 2009, references therein). Generally soft sediment inhabitants, especially infaunal polychaetes, are particularly affected by oil pollution (Suchanek, 1993). Jacobs (1980) investigated the effects of the Amoco Cadiz oil spill in 1978. The numbers of spionid polychaetes decreased after the spill. Capitellid polychaetes recovered very quickly, spionids took slightly longer but did recover quickly. Intolerance has, therefore, been recorded as intermediate. A recoverability of high has been recorded (see additional information below) (Ager, 2009). Based on the evidence above, resistance is assessed as 'Medium' and recovery as 'Very High' so that sensitivity was assessed as 'Medium'.
	Introduction of antifoulants	Introduction of antifoulants			NEv	No Evidence Found. Not Assessed.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines			NA	Not Assessed.
	Barrier to species movement		H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						and estuaries where light penetration may be limited, resistance is therefore assessed as 'High' and recovery as 'Very High'. Overall sensitivity is assessed as 'Not Sensitive'.
	Barrier to species movement				NA	Not relevant.

Table 18.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 18.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 18.3 Confidence Levels for Resistance Assessments

	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	***		
Deep Disturbance	***		
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk	Not exposed.		
Underwater Noise	Not sensitive.		
Visual - Boat/vehicle	Not sensitive.		
Visual - Foot/traffic	Not sensitve.		
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	***(3)	***	***

	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Organic enrichment of sediments	***(3)	***	***
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	***(1)	N/A	N/A
Decrease in oxygen levels - Water column	***(1)	N/A	N/A
Genetic impacts	Not Exposed.		
Introduction of non-native species			
Introduction of parasites/pathogens	Not Exposed.		
Removal of Target Species	Not Sensitive.		
Removal of Non-target species	Not Sensitive.		
Ecosystem Services - Loss of biomass	Not Assessed.		
Introduction of medicines			
Introduction of hydrocarbons	***		
Introduction of antifoulants			
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement	Not Assessed.		

References

Ager, O. 2009. *Spiophanes bombyx*. A bristleworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 10/09/2012]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=4356.

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beam trawling on macrofauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science 49: 5-11.

BIOTIC website: http://www.marlin.ac.uk/biotic/browse.php?sp=4411 [cited 21/09/12].

Borja, A., Franco, J. and Perez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Bouchet, V.M.P. and Sauriau, P-G. 2008. Influence of oyster culture practices and environmental conditions on the ecological status of intertidal mudflats in the Pertuis Charentais (SW France): A multi-index approach. Marine Pollution Bulletin 56: 1898-1912.

Dauer, D.M., Maybury, C.A. and Ewing, R.M. 1981. Feeding behavior and general ecology of several spionid polychaetes from the Chesapeake Bay. Journal of Experimental Marine Biology and Ecology 54(1): 21-38.

Degraer, S., Wittoeck, J., Appeltans, W., Cooreman, K., Deprez, T., Hillewaert, H., Hostens, K., Mees, J., Vanden Berghe, E. and Vincx, M. 2006. The macrobenthos atlas of the Belgian part of the North Sea. Belgian Science Policy. D/2005/1191/3. ISBN 90-810081-6-1. 164 pp.

Eleftheriou, A. and Basford, D.J. 1989. The macrobenthic infauna of the offshore northern North Sea. Journal of the Marine Biological Association of the United Kingdom 69(1): 123-143.

Gilkinson, K.D., Gordon Jr., D.C., MacIsaac, K.G., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C. and Vassb, W.P. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada. ICES Journal of Marine Science 62(5): 925-947.

Gittenberger, A. and van Loon, W.M.G.M. 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011-08.

Holtmann, S.E., Groenewold, A., Schrader, K.H.M., Asjes, J., Craeymeersch, J.A., Duineveld, G.C.A., van Bostelen, A.J. and van der Meer, J. 1996. Atlas of the zoobenthos of the Dutch continental shelf. Ministry of Transport, Public Works and Water Management: Rijswijk, The Netherlands. ISBN 90-369-4301-9. 243 pp.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Wildish, D.J. and Peer, D. 1981. Tidal current speed and production of benthic macrofauna in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 40 (Suppl. 1): 309-321.

19. Species: *Thracia phaseolina* (*Thracia papyracea*)

Species Description

- Habitat: Found in sand, muddy sand and sandy gravel from very low in the intertidal zone to about 55m;
- Feeding type: Suspension feeder;
- Size: Up to 38mm in length; and
- Fragility: Shell fragile (Allen, 1961).

Recovery

Information from Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010).

Thracia is a relatively long-lived bivalve with an estimated life-span of 12 years. There is little information on the reproductive biology of this species. It is hermaphrodite breeding from June-September. It is not possible to estimate the dispersal potential, but the genus is long-lived and slow-growing and probably has a relatively low recoverability following disturbance (MES, Ltd 2010).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 19.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 19.2a and are combined, as in Table 19.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as ‘Not Assessed’ (NA) in the matrix.

For a limited number of pressures the assessment ‘No Evidence’ (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 19.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 19. 2a).

Table 19.1 *Thracia papyracea* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	Assessment based on surface disturbance, this specie is relatively deeply buried and siphons are protected within the sediment. Resistance is therefore assessed as 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	H (*)	VH (*)	NS (*)	Assessment based on surface disturbance, this species is relatively deeply buried and siphons are protected within the sediment. Resistance is therefore assessed as 'High' and recovery as 'Very High'. This species is therefore assessed as 'Not Sensitive'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	H (*)	VH (*)	NS (*)	Rumohr and Kujawski (2000) examined historical datasets (1902-1912) with 1986 survey records and did not find any changes in the abundance of *Thracia phaseolina* that could be attributed to fishing, although this may be due to the fact that the species was, and is, fairly uncommon. Investigations after experimental beam trawling (three times in 2 days) on fine to medium sand sediments found no differences in abundance of the less common bivalves (including *Thracia* sp.) (Bergman and Hup, 1992). Based on the above information, resistance to deep disturbance was assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'. It is acknowledged that detecting changes in abundance of less common species may be problematic in experimental trials.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	H (*)	VH (*)	NS (*)	Assessment based on deep disturbance.
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	H (*)	VH (*)	NS (*)	Assessment based on deep disturbance.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	M (*)	M (*)	No information found. Resistance is judged as 'None' with recovery assessed as 'Medium' if original habitat conditions are re-instated, so that the sensitivity of this species is assessed as 'Medium'. If there were no habitat recovery then sensitivity would be greater.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	No information found, bivalves are typically able to relocate within the sediment in response to siltation. Resistance is therefore assessed as 'High' and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	M (*)	M (*)	No evidence found. As adults have limited to no horizontal mobility and require access to the sediment surface to feed, smothering will occur where the surface is completely covered by materials. Complete and permanent smothering would exclude this species through substrate change, recovery would depend on a return to previous habitat conditions. Resistance is judged as 'None' with recovery assessed as 'Medium' if original habitat conditions are re-instated, so that the sensitivity of this species is assessed as 'Medium'. If there were no habitat recovery then sensitivity would be greater.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Visual - Boat/ vehicle movements				NS	Not sensitive.
	Visual - Foot/ traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	L-M (*)	M-H (*)	L-M (*)	No information found. This species is found in sandy gravels, therefore the species is considered to have some tolerance to the addition of a coarse fraction or the removal of some of the fine sediment fraction e.g. the addition of gravel to sands. However, a significant increase in the coarse sediment fraction e.g. a change to gravel sediments would be considered to reduce habitat suitability for this species. Resistance is therefore assessed as 'Low-Medium' and recovery as 'Medium-High' following habitat recovery. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes in sediment composition – increased fine sediment proportion	Fine sediment fraction increases	L-M (*)	M-H (*)	L-M (*)	No information found. This species is found in muddy sands, therefore the species is considered to have some tolerance to an increase in fine sediment fractions. However a change to a fine sediment is considered to decrease habitat suitability for this species. Resistance is therefore assessed as 'Low-Medium' and recovery as 'Medium-High' following habitat recovery. Sensitivity is therefore assessed as 'Low-Medium'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	L-M (*)	M-H (*)	L-M (*)	No information found. Increased water flow rate may winnow fine sediments and at greater velocities may erode sediment and wash individuals out of the sediment. Aquaculture installations however are associated with reduced water flows. A decrease in water flow may reduce the availability of food that can be obtained from suspension feeding and may increase deposition of fine particles, this could support the development of a deposit feeding assemblage more typical of muddy sediments, decreasing suitability for *Thracia phaseolina* through an increase in sediment disturbing deposit feeding and lower larval recruitment. Resistance is therefore assessed as 'Low-Medium' and recovery (following habitat restoration) as 'Medium-High'. Sensitivity is therefore assessed as 'Low-Medium'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	M (*)	M-H (*)	L (*)	No information found. *Thracia phaseolina* does not require light and therefore the effects of increased turbidity on light attenuation are not directly relevant. An increase in turbidity may affect primary production in the water column and therefore reduce the availability of phytoplankton food. However, phytoplankton will also be transported through water exchange limiting effects unless in enclosed water bodies with limited flushing (that are not typical habitat). Increased seston concentrations may inhibit feeding where inorganic particle concentrations increase in the medium-long term, reducing feeding efficiency. Resistance is therefore assessed as 'Medium' and recovery is assessed as 'Medium-High, so that sensitivity is assessed as 'Low'.
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	*Thracia phaseolina* does not require light and therefore the effects of decreased turbidity on light attenuation are not directly relevant. It is possible that decreased turbidity would increase primary production in the water column and the resultant increase in food availability may enhance growth and reproduction, but only if food was previously limiting. Resistance is therefore assessed as 'High, and recovery as 'Very High' so that this species is assessed as 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	As *Thracia phaseolina* are not primary producers they are not considered sensitive to an increase in plant nutrients in the water column. Phytoplankton may be utilised as food by this genus. This species is therefore assessed as 'Not Sensitive' to this pressure. Resistance is therefore assessed as 'High' and recovery as 'Very High'. The development of algal blooms may lead to de-oxygenation pressures and these are considered below.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	L-M (***)	M (*)	L-M (*)	*Thracia papyracea* were classed by Simboura and Zenetos (2002) as Ecological Group 1 (GI). This group includes species which are sensitive to disturbance in general. These species correspond to the k-strategy species, with relatively long life, slow growth and high biomass (Gray, 1979). Also species indifferent to disturbance, always present in low densities with non-significant variations with time are included in this group, as they cannot be considered as tolerant by any degree.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above assessment *Thracia* sp. are assessed as having 'Low-Medium' resistance, 'Medium' recovery.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	M-H (*)	H-VH (*)	NS-L (*)	Any change in the balance of filter feeders, in enclosed situations, could affect water clarity and the supply of particulate food to wild populations of bivalves (Hartnoll, 1998). Carrying capacity models for shellfish production have been developed for system specific analyses e.g. FARM (http://www.farmscale.org), the SMILE project for Northern Ireland Loughs (http://www.longline.co.uk/site/smile.pdf) and MUSSEL models to estimate production of cultured bivalves and to ensure adequate food supply and avoid or minimise ecological impacts. In areas that are well flushed, water exchange should recharge waters. Resistance to increased competition was assessed as 'Medium to High' (ranging from no lethal effect to mortality of <25% of population) and recovery as 'Very High to High', so that sensitivity was categorised as 'Low to Not Sensitive'. Increased clearance rates of suspended sediments by suspension feeding bivalves may enhance local primary production compensating for increased competition.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment			NEv	No evidence found. Not Assessed.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column			NEv	
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock	N (*)	M (*)	M (*)	No evidence found. Assessment based on smothering as the settlement of *Crassostrea gigas* or *Crepidula fornicata* would effectively lead to substratum smothering.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	This genus will be sensitive to the removal of target species that occur in the same habitat, as assessed through the disturbance pressure themes above. As the genus is not assessed as dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Ecosystem Services - Loss of biomass				NA	Not relevant to this species.
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not Assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not Assessed.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Introduction of antifoulants	Introduction of antifoulants	H (*)	VH (*)	NS (*)	No evidence found. Based on a Cu sediment quality guideline of 100mg kg^{-1} (Madsen et al. 2000), it is assumed (without evidence) that concentrations up to and below this level would protect this species. Resistance is therefore assessed as 'High' and recovery as 'Very High'. Higher levels of Cu may reduce populations although a higher level threshold cannot be given based on current evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No information found. *Thracia phaseolina* does not photosynthesise and does not, therefore, directly require light and is therefore assessed as 'Not Sensitive' to this pressure. Resistance was assessed as 'High' and recovery as 'Very High'.
	Barrier to species movement				NA	Not relevant to SAC habitat features.

Table 19.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 19.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 19.3 Confidence Levels for Resistance Assessments

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	*	N/A	N/A
Deep Disturbance	*	N/A	N/A
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	*	N/A	N/A
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*	N/A	N/A

Pressure	Quality of Information Sources	Applicability of Evidence	Degree of Concordance
Organic enrichment of sediments	*** (1)	*	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	Not Assessed. No Evidence.		
Decrease in oxygen levels - Water column	Not Assessed. No Evidence.		
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens			
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	Not Assessed. No Evidence.		
Introduction of hydrocarbons	Not Assessed. No Evidence.		
Introduction of antifoulants	*	N/A	N/A
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Allen, J.A. 1961. The British species of *Thracia* (Eulamellibranchia). Journal of the Marine Biological Association of the United Kingdom 41: 723-73.

Bergman, M.J.N. and Hup, M. 1992. Direct effects of beam trawling on macro- fauna in a sandy sediment in the southern North Sea. ICES Journal of Marine Science 49: 5-11.

Gray, J.S. 1979. Pollution-induced changes in populations. Philosophical Transcriptions of the Royal Society London, Series B 286: 545-561.

Hartnoll, R.G. 1998. Volume VIII. Circalittoral faunal turf biotopes: An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Sciences, Oban, Scotland [UK Marine SAC Project. Natura 2000 reports].

Madsen, T., Samsoe-Petersen, L., Gustavson, K. and Rasmussen, D. 2000. Ecotoxicological assessment of antifouling biocides and non-biocidal antifouling paints; environmental project 531. Miljostyrelsen, Danish EPA, DHI Water and Environment: Copenhagen.

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Rumohr, H. and Kujawski, T. 2000. The impact of trawl fishery on the epifauna of the southern North Sea. ICES Journal of Marine Science 57: 1389-1394.

Simboura, N. and Zenetos, A. 2002. Benthic indicators to use in Ecological Quality classification of Mediterranean soft bottom marine ecosystems, including a new Biotic Index. Mediterranean Marine Science 3/2: 77-111.

20. Species: *Tubificoides* sp.

Species Description

- Taxonomy: Oligochaete worms of the family Tubificidae, (congeners previously known as Tubifex);
- Environmental Position: Infaunal, freeliving in anoxic sediment without contact with the surface or in mucilaginous tubes connecting to surface;
- Habitat: Muddy and sandy sediments;
- Length: May grow up to 5cm;
- Longevity: 2 years;
- Reproduction: fertilisation is internal, young are hatched from egg masses (cocoons); and
- Mobility: limited, burrowing.

Recovery

The longevity of *Tubificoides* is two years at which point the worm is sexually mature. It is hermaphrodite and reproduces throughout the year. Fertilisation is internal and the larvae are hatched after about 15 days in a cocoon. The worm can form dense communities, but the dispersal potential is very low. The Marine Macrofauna Genus Traits Handbook (MES Ltd, 2010) suggests this genus has a low recoverability. However the species exhibits many of the traits of opportunistic species. The Marine Life Information Network (MarLIN) have researched the sensitivity of a biotope characterised by *Tubificoides benedii* and state that 'the community most likely reaches maturity within one year of space becoming available. In an experimental study investigating recovery of a range of species characteristically found in this biotope after copper contamination, Hall and Frid (1995) found that recovery took up to a year. However, Hall and Frid (1998) found that colonization by many of the polychaetes associated with this biotope did not vary significantly with season although recruitment of *T. benedii* did vary significantly with season (Hiscock, 2008).

In general there was little information found on this genus but, taking into consideration the information above, this review considers that the recoverability of this species is generally 'high', so that recovery from defaunation is suggested to take place within two years.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table 20.1 (below) forms an accompanying database to the Sensitivity Matrix (Appendix E), showing the information that was used in each assessment.

The table shows the resistance and resilience scores for the sensitivity assessment against each pressure and the confidence of the assessment associated with these. The evidence column outlines and summarises the information used to create the sensitivity assessments for the sensitivity matrix (and the accompanying resistance and resilience matrices). Although the sensitivity assessment process is pressure rather than activity led, we have recorded any information related to specific fishing metiers or aquaculture activities as this was considered useful to inform the Appropriate Assessment process.

The first part of this report outlines the methodology used and the assessment scales for resistance and resilience and the combination of these to assess sensitivity (see Tables 2, 3 and 4, main report). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the quality of information used (assessed as Low (*), Medium (**) and High (***)). These scores are explained further in Table 20.2a and are combined, as in Table 20.2b (below), to assess confidence in the sensitivity assessment. In some cases the scores were assessed as a range to either create a precautionary assessment where evidence was lacking or to incorporate a range of evidence which indicated different responses.

For some pressures the evidence base may not be considered to be developed sufficiently enough for assessments to be made of sensitivity, or it was not possible to develop benchmarks for the pressure or the features were judged not to be sensitive to the pressure e.g. visual disturbance. These assessments are marked as 'Not Assessed' (NA) in the matrix.

For a limited number of pressures the assessment 'No Evidence' (NEv) is recorded. This indicates that we were unable to locate information regarding the feature on which to base decisions and it was not considered possible or relevant to base assessments on expert judgement or similar features.

The recovery scores are largely informed by the evidence presented in this introductory text, as recovery is likely to occur through similar mechanisms in response to different pressures, in many cases. Where available the recovery assessment is informed by pressure specific evidence and this is described in the evidence sections. The confidence in the resistance score was considered more likely to be pressure specific and the confidence in this score is assessed in further detail in Table 20.3 accompanying the evidence table. This table assesses the information available, the degree to which this evidence is applicable and the degree to which different sources agree (these categories are described further in Table 20.2a).

Table 20.1 *Tubificoides* sp. Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	H (*)	VH (*)	NS (*)	*T. benedii* can live buried up to 10cm deep. Based on environmental position, resistance is categorised as 'High', due to lack of effects, resilience is also categorised as 'Very High' and the species is 'Not Sensitive'.
	Shallow Disturbance	Direct impact from surface (to 25mm) disturbance	H (*)	VH (**)	NS (*)	Experimental use of a clam dredge assessing the effects of two passes of an oyster dredge that removed the sediment to a depth of between 15-20 cm did not significantly affect *Tubifcoides benedii* (Southern Science, 1992). Based on the information above and that *Tubificoides* sp. are likely to be buried deeper than 25mm; resistance to shallow disturbance is described as 'High and recovery is assessed as 'Very High'. Combined sensitivity is therefore 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	M (**)	H (**)	L (**)	The effects of a pipeline construction on benthic invertebrates were investigated using a Before/After impact protocol at Clonakilty Bay, West Cork, Ireland (Rees, 1978; cited in Hiscock et al. 2002). Benthic invertebrates were sampled once before the excavation and at one, two, three and six months after the completion of the work. Analysis was designed to compare natural variation over time within control sites with the variation that occurred in the disturbed site from before to after construction. Invertebrate samples were dominated by *Hediste diversicolor*, *Scrobicularia plana* and *Tubifex* spp. An impact was obvious in the construction site in that no live invertebrates were found at one month after disturbance, but there followed a gradual recolonization. Six months after the disturbance there was no significant difference in the mean number of total individuals (of all species) per core sample amongst all study sites, but the apparent recovery in the impacted area was due to two taxa only, *Hediste diversicolor* and *Tubifex* spp. Experimental use of a clam dredge assessing the effects of two passes of an oyster dredge that removed the sediment to a depth of between 15-20 cm did not significantly affect *Tubifcoides benedii* (Southern Science, 1992).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Based on the above information, resistance was assessed as 'Medium' and recovery as 'High' so that sensitivity was assessed as 'Low'; this assessment is precautionary taking into account evidence for trampling (see below). The evidence from Southern Science (1992) suggests that resistance may be higher and the species may be relatively insensitive to sediment disturbance.
	Trampling - Access by foot	Direct damage caused by foot access, e.g. crushing	M (*)	H (*)	L (*)	Experimental studies on crab-tiling impacts have found that densities of *Tubificoides benedii* and *T. pseudogaster* were higher in non-trampled plots (Sheehan et al. 2010), indicating that these oligochaetes have some sensitivity to trampling. Based on the above information, resistance was assessed as 'Medium' and recovery as 'High' so that sensitivity was assessed as 'Low'
	Trampling - Access by vehicle	Direct damage, caused by vehicle access	M (*)	H (*)	L (*)	No evidence found. Assessment based on trampling disturbance by foot.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/biogenic reef/ macroalgae	N (*)	H (*)	M (*)	This species is infaunal, extraction of the sediment would remove the population and resistance is considered to be 'None'; however, if suitable sediments remain recovery would be predicted to be 'High', so that sensitivity is assessed as 'Medium'.
	Siltation (addition of fine sediments, pseudofaeces, fish food)	Physical effects resulting from addition of fine sediments, pseudofaeces, fish food, (chemical effects assessed as change in habitat quality)	H (*)	VH (*)	NS (*)	*Tubificoides* live relatively deeply buried and can tolerate periods of low oxygen that may occur following the deposition of a fine layer of sediment. In addition, the presence of this species in areas of high siltation such as estuaries indicates that this species is likely to have a high tolerance to siltation events, hence the assessment of 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Smothering (addition of	Physical effects resulting from	M (*)	H (*)	L (*)	The addition of a coarse layer of impermeable material would lead to local defaunation of sediments. However where there are gaps within the overlying material some infauna would service and if

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	materials biological or non-biological to the surface)	addition of coarse materials				sediment collected in pockets on the material some species would colonise. *Tubificoides benedii* are abundant in mussel beds (mussel relaying may be the source of smothering) which has been attributed to their tolerance of organically rich deoxygenated sediment (Commito and Boncavage, 1989). Their reproductive strategy also overcomes the problem of ingestion by mussel filtration due to the production of non-larval benthic offspring from cocoons (Hunter and Arthur, 1978). Resistance is characterised as 'Medium' to reflect population reduction following the addition of a coarse layer. Recovery is assessed as 'High' and sensitivity is therefore considered to be 'Low'.
	Collision risk	Presence of significant collision risk, e.g. access by boat			NE	Not exposed, this feature does not occur in the water column. Collision of benthic features with fishing gear are addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual- boat/vehicle movements				NS	Not sensitive.
	Visual – foot/traffic				NS	Not sensitive.
Change in Habitat	Changes to sediment composition - Increased coarseness	Coarse sediment fraction increases	H (*)	VH (*)	NS (*)	Based on the EUNIS habitat classification, *Tubificoides* spp. are found in a range of sediments from muds to mixed sediments indicating that increased sediment coarseness would not exclude this species as long as some areas of fine sediment remain to provide habitat to this infaunal species. Based on habitat preferences *Tubificoides* is assessed as having 'High' resistance to this pressure and consequently 'Very High' recovery. This species is therefore considered to be 'Not Sensitive'.
	Changes in sediment composition – increased fine	Fine sediment fraction increases	H (*)	VH (*)	NS (*)	This species is found in fine sediments so additional fine sediment would not alter suitability of habitat. Siltation pressures are assessed separately. Based on habitat preferences *Tubificoides* is assessed as having 'High' resistance to this pressure and

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	sediment proportion					consequently 'Very High' recovery. This species is therefore considered to be 'Not Sensitive'.
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	H (***)	VH (***)	NS (***)	Flume experiments have shown that *Tubificoides benedii* and *T. pseudogaster* were unaffected by changes in water flow that mobilised sediments, they avoided suspension by burrowing deeper into sediments (Zuhlke and Reise, 1994). As this species can live relatively deeply buried and in depositional environments with low water flows (based on habitat preferences) it is considered to be not sensitive to decreases in water flow. Resistance is therefore assessed as 'High' , recovery as 'Very High' and hence the genus is categorised as 'Not Sensitive'
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Based on environmental position and the occurrence of this genus in turbid coastal/estuarine areas, resistance is assessed as 'High' and recovery as 'Very High', so that sensitivity is categorised as 'Not Sensitive'
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/ turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	Due to environmental position buried within sediment, this species is not predicted to be sensitive to decreases in turbidity. Resistance is therefore considered to be 'High' and recovery as 'Very High'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Organic enrichment - Water column	Eutrophication of water column	H (***)	VH (***)	NS (***)	Eutrophic tidal flats and polluted coastal sites are the predominant habitat of the marine oligochaete *Tubificoides benedii*. The worms live in dense populations in these stressed habitats which are often characterized by high levels of hydrogen sulfide. This indicates that they have a high capacity to tolerate anoxic (and sulfidic) conditions. Respiration rates of *T. benedii* measured at various oxygen concentrations showed that aerobic respiration is maintained even at very low oxygen concentrations (Giere et al. 1999). *T. benedii* are abundant in mussel beds (mussel relaying may be the source of smothering) which has been attributed to their tolerance of organically rich deoxygenated sediment (Commito and Boncavage, 1989). *Tubificoides benedii* have also been found in elevated abundances in areas of organic enrichment around fish farms (Haskoning, 2006). Based on this information *Tubificoides* sp. resistance to organic enrichment is assessed as 'High' and recovery as 'Very High', and the genus is therefore categorized as 'Not Sensitive'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (***)	VH (***)	NS (***)	
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	Increased removal of primary production is not predicted to directly affect this species. Removal of primary production due to suspended bivalve culture may have positive effects increasing the supply of food (via pseudofaeces) to the sediment. Resistance is assessed as 'High' and recovery as 'Very High' and this species is therefore considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (***)	VH (***)	NS (***)	Eutrophic tidal flats and polluted coastal sites are the predominant habitat of the marine oligochaete *Tubificoides benedii*. The worms live in dense populations in these stressed habitats which are often characterized by high levels of hydrogen sulfide. This indicates that they have a high capacity to tolerate anoxic (and sulfidic) conditions. Respiration rates of *T. benedii* measured at various oxygen concentrations showed that aerobic respiration is maintained even at very low oxygen concentrations (Giere et al. 1999). *T. benedii* are abundant in mussel which has been attributed to their tolerance of organically rich, deoxygenated sediment (Commito and Boncavage, 1989). Morphological and ecophysiological adaptations allow the worms to exist at toxic concentrations of Suphides (Dubilier et al. 1995). Based on this evidence, this genus is judged to have 'High' resistance and 'Very High' recovery to this pressure. This species is therefore considered to be 'Not Sensitive'.
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	H (***)	VH (***)	NS (***)	

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	Presence/absence benchmark, the presence of farmed and translocated species presents a potential risk to wild counterparts			NE	Not Exposed. This feature is not farmed or translocated.
	Introduction of non-native species	Cultivation of a non-native species and/or potential for introduction of non-natives in translocated stock'	H (*)	VH (*)	NS (*)	No evidence found. *Crepidula fornicata* and *Crassostrea gigas* are the non-native species most likely to be introduced by aquaculture and become established in habitats in which this species is found. These may stabilise sediments and enhance food supply to this species by deposition of organic matter. *Tubificoides* sp. assessed as 'Not Sensitive' to this pressure, resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Not Sensitive. This species is not targeted by a commercial fishery. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Removal of Non-target species	Alteration of habitat character, e.g. the loss of structure and function through the effects of removal of target species on non-target species	H (*)	VH (*)	NS (*)	As the species is not dependent on other species to provide or maintain habitat the assessment to removal of these target and other non-target species is 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'. *Tubificoides* spp. can burrow relatively deeply and hence are protected from the physical impacts of many types of fishing gear (see physical disturbance pressures above).
	Ecosystem Services - Loss of				NA	Not relevant to this species.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	biomass					
Chemical Pressures	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence found. Not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons			NEv	No evidence found. Not assessed.
	Introduction of antifoulants	Introduction of antifoulants	H (**)	VH (**)	NS	A 2-year microcosm experiment was undertaken to investigate the impact of copper on the benthic fauna of the lower Tyne Estuary (UK) by Hall and Frid (1995). During a 1-year simulated contamination period, 1 mg l^{-1} copper was supplied at 2-weekly 30% water changes, at the end of which the sediment concentrations of copper in contaminated microcosms reached 411 µg g^{-1}. Toxicity effects reduced populations of the four dominant taxa including Tubificoides spp.). When copper dosage was ceased and clean water supplied, sediment copper concentrations fell by 50% in less than 4 days, but faunal recovery took up to 1 year, with the pattern varying between taxa. Since the copper leach rate was so rapid it is concluded that after remediation, contaminated sediments show rapid improvements in chemical concentrations, but faunal recovery may be delayed with experiments in microcosms showing faunal recovery taking up to a year. Rygg (1985) classified *Tubificoides* spp. as highly tolerant species, common at the most copper polluted stations (>200 mg Kg^{-1}) in Norwegian fjords. Based on the above evidence *Tubificoides* would not be sensitive to copper levels within a sediment quality guideline of 100 mg Kg^{-1}. *Tubificoides* may tolerate higher levels but an upper threshold could not be determined from the available evidence.
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	H (*)	VH (*)	NS (*)	No evidence found. As this species is not a primary producer, has limited visual acuity and inhabits turbid, coastal waters and estuaries where light penetration may be limited it is assessed as 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Barrier to species movement				NA	Not relevant to SAC habitat features.

Table 20.2a Guide to Confidence Levels

Confidence Level	Quality of Information Source	Applicability of Evidence	Degree of Concordance
High	*** 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 arising from fishing and aquaculture activities, acting on the same type of feature in Ireland, UK	*** Agree on the direction and magnitude of impact
Medium	** 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	* Based on expert judgement	* Assessment based on proxies for pressures e.g. natural disturbance events in other areas	* Do not agree on concordance or magnitude

Table 20.2b Sensitivity Assessment Confidence Levels

Recovery	Resistance		
	Low	Medium	High
Low	Low = *	Low = *	Low = *
Medium	Low = *	Medium = **	Medium = **
High	Low = *	Medium = **	High = ***

Table 20.3 Table Confidence Levels for Resistance Assessments

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	N/A	N/A
Shallow Disturbance	**	**	N/A (1 paper)
Deep Disturbance	**	*	N/A (1 paper)
Trampling - Access by foot	*	N/A	N/A
Trampling - Access by vehicle	*	N/A	N/A
Extraction	*	N/A	N/A
Siltation	*	N/A	N/A
Smothering	*	N/A	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	N/A	N/A
Changes to sediment composition - Increased fine sediment proportion	*	N/A	N/A
Changes to water flow	***(1)	* (based on flume experiments)	N/A (1 paper)
Changes in turbidity/suspended sediment	*	N/A	N/A
Changes in turbidity/suspended	*	N/A	N/A

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
sediment - Decreased			
Organic enrichment - Water column	***(3)	***	***
Organic enrichment of sediments	*** (3)	***	***
Increased removal of primary production - Phytoplankton			
Decrease in oxygen levels - Sediment	***(3)	***	***
Decrease in oxygen levels - Water column	***(3)	***	***
Genetic impacts			
Introduction of non-native species	*	N/A	N/A
Introduction of parasites/pathogens	*	N/A	N/A
Removal of Target Species	*	N/A	N/A
Removal of Non-target species	*	N/A	N/A
Ecosystem Services - Loss of biomass			
Introduction of medicines	No evidence. Not assessed.		
Introduction of hydrocarbons	No evidence. Not Assessed.		
Introduction of antifoulants	**		
Prevention of light reaching seabed/features	*	N/A	N/A
Barrier to species movement			

References

Commito, J.A. and Boncavage, E.M. 1989. Suspension-feeders and co-existing infauna: an enhancement example. Journal of Experimental Marine Biology and Ecology 125: 33-42.

Dubilier, N., Giere, O. and Grieshaber, M.K. 1995. Morphological and ecophysiological adaptations of the marine oligochaete Tubificoides benedii to Sulfidic sediments. Integrative and Comparative Biology 35: 163-173.

Giere, O., Preusse, J-H. and Dubilier, N. 1999. *Tubificoides benedii* (Tubificidae, Oligochaeta) - a pioneer in hypoxic and sulfidic environmental. An overview of adaptive pathways. Hydrobiologia 406: 235-241

Hall, J.A. and Frid, C.L.J. 1998. Colonisation patterns of adult macrobenthos in a polluted North Sea Estuary. Aquatic Ecology 31: 333-340.

Hall, J.A. and Frid, C.L.J. 1995 Responses of estuarine benthic macrofauna in copper-contaminated sediments to remediation of habitat quality. Marine Pollution Bulletin 30: 694-700.

Haskoning UK Ltd. 2006. Investigation into the impact of marine fish farm deposition on maerl beds. Scottish Natural Heritage Commissioned Report No. 213 (ROAME No. AHLA10020348).

Hiscock, K., Tyler-Walters, H. and Jones, H. 2002. High Level Environmental Screening Study for Offshore Wind Farm Developments – Marine Habitats and Species Project. Report from the Marine

Biological Association to the Department of Trade and Industry New and Renewable Energy Programme (AEA Technology, Environment Contract: W/35/00632/00/00).

Hiscock, K. 2008. *Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom [cited 04/01/2013].

Hunter, J. and Arthur, D.R. 1978. Some aspects of the ecology of *Peloscolex benedeni* Udekem (Oligochaeta: Tubificidae) in the Thames Estuary. Estuarine, Coastal and Shelf Science 6: 197-208.

Lewis, L. 2002. A study of the impact of a pipeline construction on estuarine benthic invertebrate communities. Estuarine, Coastal and Shelf Science 55: 213-221

MES Ltd. 2010. Marine Macrofauna traits handbook, Marine Ecological Surveys Ltd. Available on-line at: http://www.genustraithandbook.org.uk/introduction.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Marine Ecology Progress Series 25: 83-89.

Sheehan, E., Coleman, R.A., Thompson, R.C. and Attrill, M.J. 2010. Crab-tiling reduced the diversity of estuarine infauna. Marine Ecolology Progress Series 411: 137-148.

Southern Science. 1992. An experimental study on the impact of clam dredging on soft sediment macro invertebrates. Report to English Nature.

Zühlke, R. and Reise, K. 1994. Response of macrofauna to drifting tidal sediments. Helgoländer Meeresuntersuchungen 48(2-3): 277-289.

ABP Marine Environmental Research Ltd (ABPmer)
Quayside Suite, Medina Chambers, Town Quay, Southampton SO14 2AQ

T +44 (0)23 80 711840
F +44 (0)23 80 711841
E enquiries@abpmer.co.uk

www.abpmer.co.uk

Creating sustainable solutions for the marine environment